Feasibility Analysis on Electric Energy Saving Methods

An Interactive Qualifying Project Report

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Abstract

This project addresses the feasibility of two basic methods for saving electric energy. The goal of the works is to determine the viability of motion detector and remote controller of air-conditioner to reserve electric energy. After calculation and analysis, it was learned that for building with good thermally insulation, the intermittent on/off operation on air-conditioner could result in about 50% reduction on the consumption of electric energy; similarly, installation of motion sensor in places demanding for great electric lighting would assist people in saving electric cost in less than 3 years. In conclusion, the paybacks of both of the methods are desirable, which indicates the worthiness of investment on these two means of saving electric energy.

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Chapter 1 Executive Summary

1.1 Introduction

Nowadays in America, approximately 39% of the total national energy is used to generate electricity. For example, it cost about 24000 dollars per year for LED lighting in Atwater Kent. [1] If this cost is reduced, the savings may benefit students and staffs through scholarships and new equipments. The high demand of electric energy also causes problems of energy waste and pollution. When electricity usage reaches the peak, power companies need to obtain electricity from backup power plants. However these backup plants are often old and inefficient, which could result in a higher cost of electricity. For these reasons, a better way for energy management is to reduce the utility of electricity. However, there are no many efficient ways for people to reduce the consumption of electric energy, and people's awareness for saving energy is not very strong. Therefore, it is important to find a way to automatically turn off electronic that are not in use. The following report provides methods of reducing cost involve installing motion sensors and installing air-condition control system both in home and school.

1.2 Background

In the past, there have been a number of groups that have done their IQP focusing on energy saving issues. In 2010, a group performed a project on "Atwater Kent Energy Audit and Solar Energy" which covers similar topics to what is being proposed in this paper. [2] While the pervious project was focused on the installing a photovoltaic system on the roof of Atwater Kent to reduce energy use, this project builds off the idea of energy reduction and provides two simple and widely applicable ways to solve the problem.

One method of reduction cost involves installing motion sensor lights in the proper locations to lessen the amount of energy use. The cost of indoor motion sensor lights range from around $20 to $50 and it would reduce the lighting energy costs up to 60 %. If Atwater Kent replaces incandescent lights with motion sensor lights, electricity cost would save roughly 14400 dollar per year. If motion sensor lights are use in home, it would save up to 400 dollar per year.

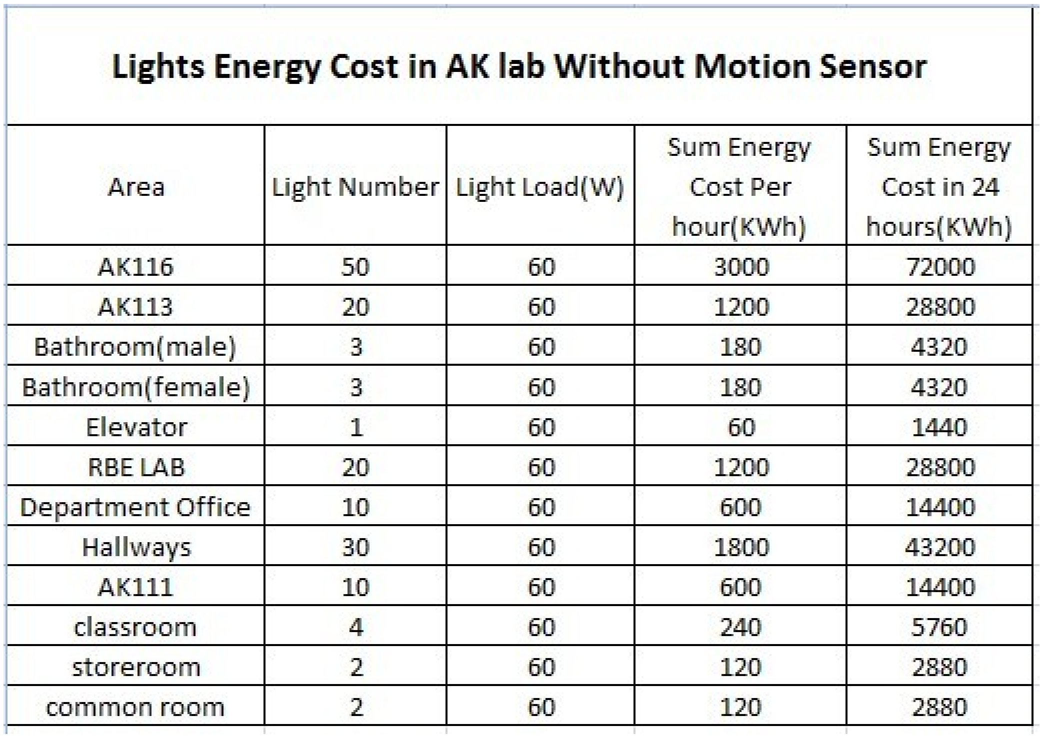
The other method involves installing air-condition control system that turns on-off for every 15 minutes to reduce the amount of energy use. By intermittent using of air-conditioning on very hot days or when there is high demand for electricity, the electrify cost would save up to 50%.

1.3 Project Statement

The purpose of this project was to reduce the amount of money spent on electric energy both in school and home. In order to achieve this goal, energy consumption must be lowered. This project explored two solutions to reduce the amount of power used and social attitudes towards these solutions are also collected.

1.4 Methods

To calculate the lighting energy use in Atwater Kent we determined the power use of the 60W fluorescent light bulbs. The breakdown of lighting energy consumption in Atwater Kent can be seen below in Table 1.1.



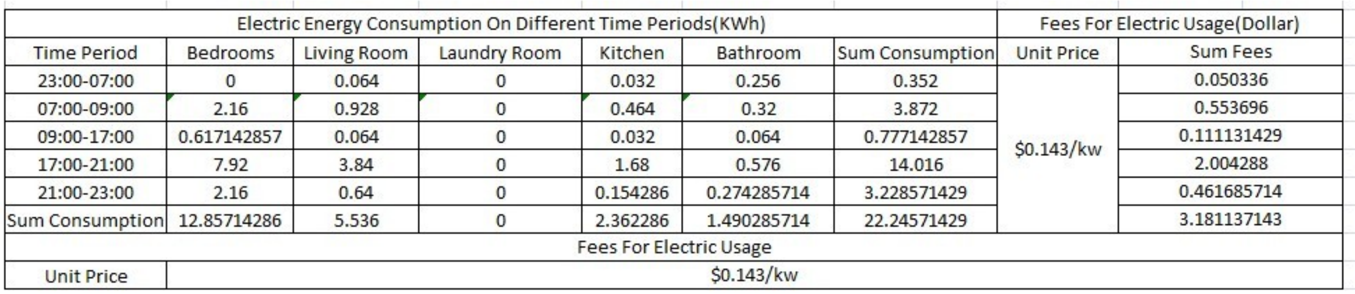
Lights Energy Cost in AK lab Without Motion Sensor

Area	Light Number	Light Load(W)	Sum Energy Cost Per hour(KWh)	Sum Energy Cost in 24 hours(KWh)
AK116	50	60	3000	72000
AK113	20	60	1200	28800
Bathroom(male)	3	60	180	4320
Bathroom(female)	3	60	180	4320
Elevator	1	60	60	1440
RBE LAB	20	60	1200	28800
Department Office	10	60	600	14400
Hallways	30	60	1800	43200
AK111	10	60	600	14400
classroom	4	60	240	5760
storeroom	2	60	120	2880
common room	2	60	120	2880

Table1.1-Energy consumption of Atwater Kent without motion sensor on kWh per day basis

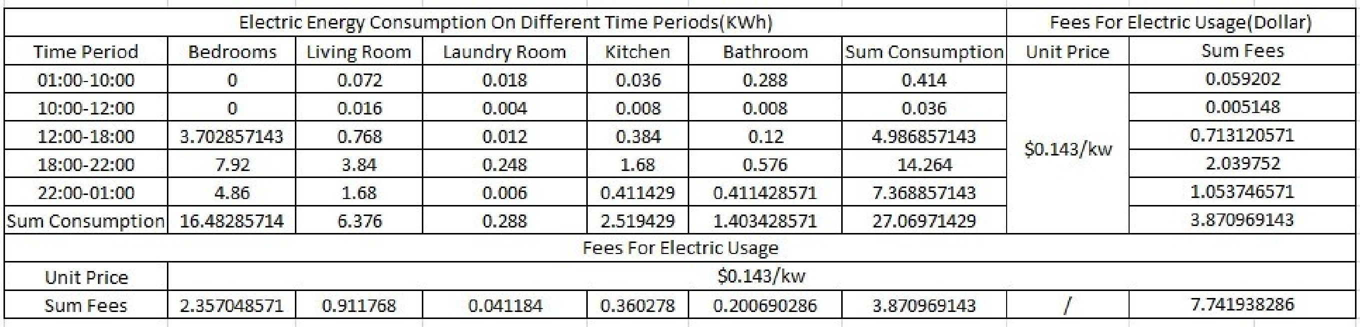
By calculating the total lighting energy consumption of Atwater Kent, the group was able to determine how much of an impact in school would installing motion sensors have. The result could be seen in Chapter 2 Table 2.1.

To calculate the electric energy use in a 3 bedrooms apartment we determined the power use of the 60W fluorescent light bulbs. The breakdown of electric energy consumption can be seen below in Table 1.2 and Table 1.3. Table 1.2 shows the electric energy consumption on weekdays, and Table 1.3 shows the electric energy consumption on weekends.



Electric Energy Consumption On Different Time Periods(KWh)							Fees For Electric Usage(Dollar)	
Time Period	Bedrooms	Living Room	Laundry Room	Kitchen	Bathroom	Sum Consumption	Unit Price	Sum Fees
23:00-07:00	0	0.064	0	0.032	0.256	0.352	$0.143/kw	0.050336
07:00-09:00	2.16	0.928	0	0.464	0.32	3.872		0.553696
09:00-17:00	0.617142857	0.064	0	0.032	0.064	0.777142857		0.111131429
17:00-21:00	7.92	3.84	0	1.68	0.576	14.016		2.004288
21:00-23:00	2.16	0.64	0	0.154286	0.274285714	3.228571429		0.461685714
Sum Consumption	12.85714286	5.536	0	2.362286	1.490285714	22.24571429		3.181137143
Fees For Electric Usage								
Unit Price	$0.143/kw							

Table1.2-Energy consumption of apartment on weekdays on kWh per day basis



Electric Energy Consumption On Different Time Periods(KWh)							Fees For Electric Usage(Dollar)	
Time Period	Bedrooms	Living Room	Laundry Room	Kitchen	Bathroom	Sum Consumption	Unit Price	Sum Fees
01:00-10:00	0	0.072	0.018	0.036	0.288	0.414	$0.143/kw	0.059202
10:00-12:00	0	0.016	0.004	0.008	0.008	0.036		0.005148
12:00-18:00	3.702857143	0.768	0.012	0.384	0.12	4.986857143		0.713120571
18:00-22:00	7.92	3.84	0.248	1.68	0.576	14.264		2.039752
22:00-01:00	4.86	1.68	0.006	0.411429	0.411428571	7.368857143		1.053746571
Sum Consumption	16.48285714	6.376	0.288	2.519429	1.403428571	27.06971429		3.870969143
Fees For Electric Usage								
Unit Price	$0.143/kw							
Sum Fees	2.357048571	0.911768	0.041184	0.360278	0.200690286	3.870969143	/	7.741938286

Table1.3-Energy consumption of apartment on weekends on kWh per day basis

By calculating the total electric energy consumption of a three bedroom apartment, the group was able to determine how much of an impact in home would installing motion sensors have. The result could be seen in Chapter 2 Table 2.2 and Table 2.3.

A survey is made to understand social attitude towards motion sensors both in school and home. The main target of the survey is the undergraduate on campus. In the survey, the following questions are asked:

(1) Does the student know there are motion sensors in school?

(2) Does he or she think the motion sensor is a good way to save energy?

(3) Does the student willing to install the motion sensor in his or her apartment?

(4) Where would the student install motion sensor?

The questioner is shown in Appendix and the analysis based on responses is shown in Chapter 2. This survey helped us understand the social concern of installing motion sensors.

Chapter 2: Background

2.1 Introduction

Electricity is an important part in our daily life. It lights up our home, runs appliances, powers our phones and computers. Some electricity are generate from renewable energy, like solar, wind and hydro. These types of energy can be restored or renewed. But lots of electricity are generate from energy that are not being replenished. Fossil fuels took millions of years to create, and there are limit amount of fossil source. That means once they are gone they cannot be used again. So it is important to save energy as much as we can. However, most people do not think much about electricity until they received a high electricity bill or face a power outage. In 2011, Electricity consumption totaled nearly 3865 Billion Kilowatt-hours. U.S electricity use in 2011 was more than 13 times greater than electricity use in 1950[3]. In hot summer days, as the demand for electricity increasing, the cost to utility is also rising dramatically. (Shown in Figure 2.1.1: temperature and electricity consumption)

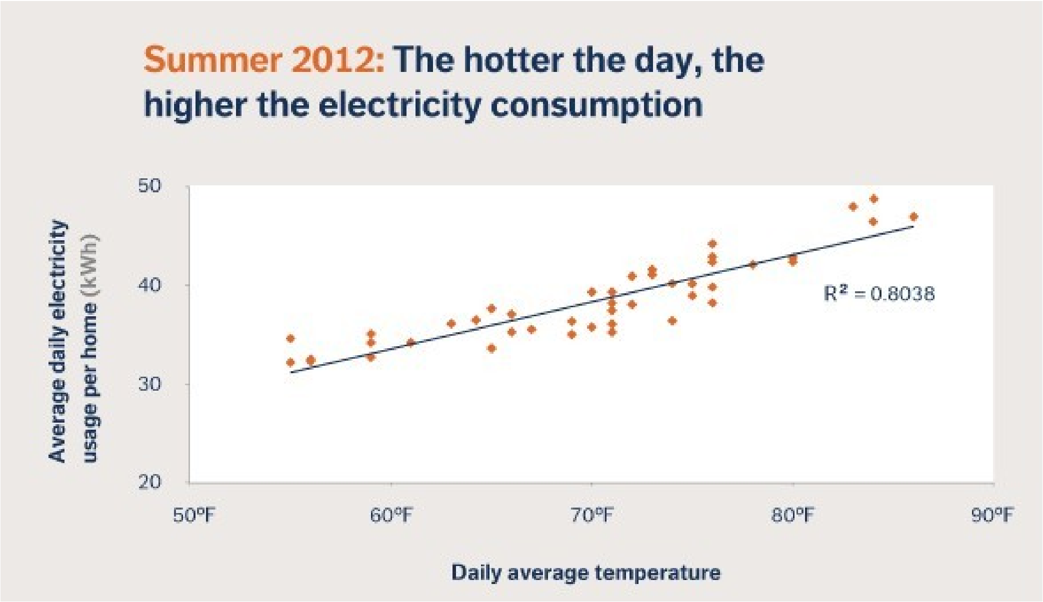


Figure 2.1.1: temperature and electricity consumption [4]

From U.S. Energy Information Administration, our group finds out that most of the electricity used is for air conditioning and lighting. (Shown in Figure 2.1.2)

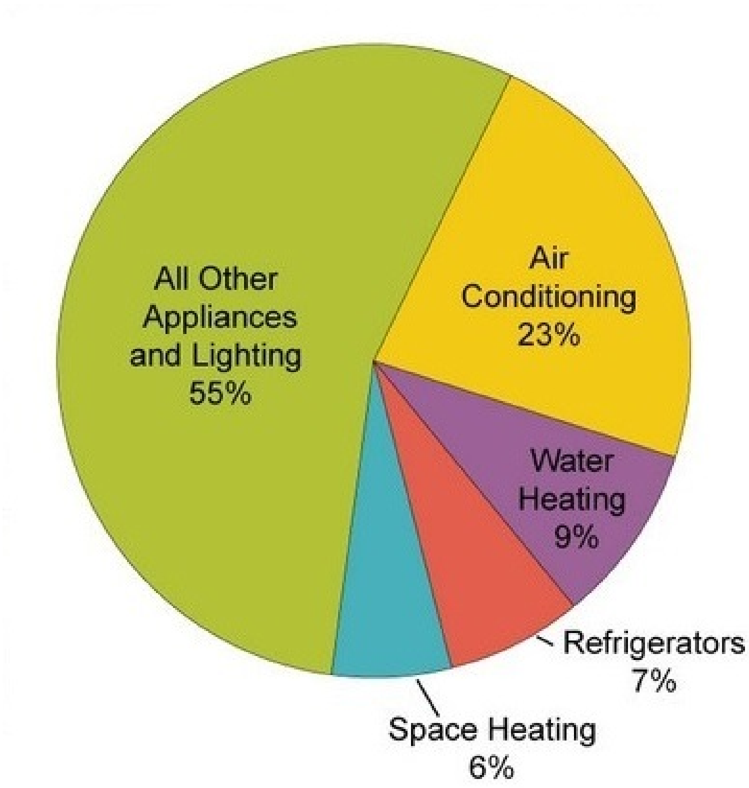


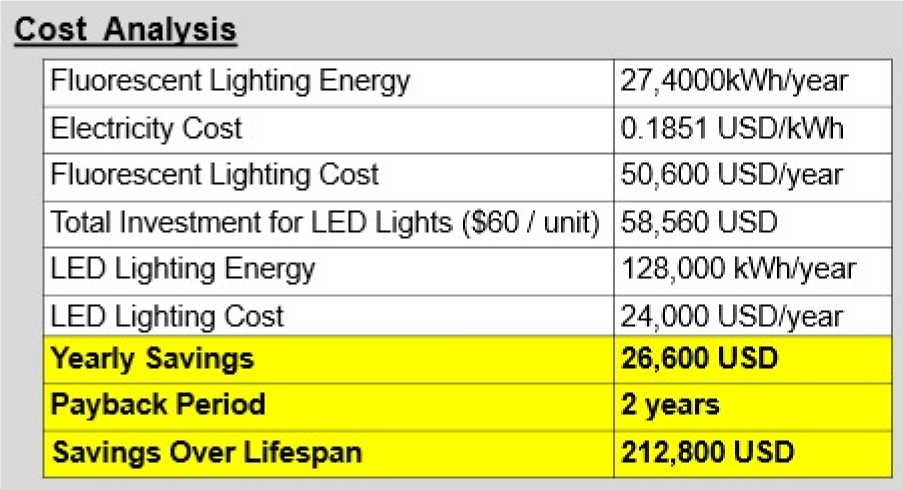
Figure 2.1.2[5]

To reduce the utility of electricity, a better way of energy management need to be found. This IQP project provides two solutions to solve the problem. Install motion sensors in the proper locations could provide a new economic model for lighting electricity used. Install automatic control system in air-condition could reduce 50 percent of energy cost.

In this section information pertinent to the discussion later in the report is presented. Such information helps reader to understand later discussion topic such as cost and feasibility. Topics in the background section include description of lighting standard, types of lighting that are commonly used, and types of motion sensor.

2.2 Types of Lighting

The types of lights in WPI vary from classroom to classroom in order for rooms with different lighting extents to gain the same visibility. For these reasons, the types and load of the lights therefore are different from one to another, which potentially causes some kind of difficulty for our group to collect data and do the calculation. For example, in Atwater Kent Lab, the fluorescent LED tubes are the dominant light providers. With the load of 30 watts, these light generators produce satisfactory visibility and maintains for a long time. Actually, these LED lighting tubes, with highly maintainability and fluorescent strength, actually could help saving more than 90% energy than the traditional incandescent light bulbs, not to mention lasting about 10 times longer than incandescent light bulbs. Moreover, a 1-watt LED bulb could generate the same amount of light output as a 15-watt incandescent light bulbs do. Even though with all these benefit, LED lights, as one of the modern invented technology, generally cost four times more money than the conventional incandescent technology. Please see the figure 2.2.1[6] to check the comparison between the traditional incandescent light bulbs and fluorescent LED lights.



Cost Analysis

Fluorescent Lighting Energy	27,4000kWh/year
Electricity Cost	0.1851 USD/kWh
Fluorescent Lighting Cost	50,600 USD/year
Total Investment for LED Lights ($60 / unit)	58,560 USD
LED Lighting Energy	128,000 kWh/year
LED Lighting Cost	24,000 USD/year
Yearly Savings	**26,600 USD**
Payback Period	**2 years**
Savings Over Lifespan	**212,800 USD**

Figure 2.2.1[9]

Other types of lights could also be found in the AK lab, such as spotlight, T9 light LED, U-Shape LED tubes and so on. However, as the total number these types of lights are small and therefore don't have as much effect as the fluorescent LED lights have, we just ignore the variability in these case for convenient reasons and the side-effect by doing so should be so negligible that cannot influence greatly on our final result. The figure 2.2.2[7] is a sample of LED T8 Fluorescent Light Bulb.

Figure 2.2.2[10]

2.3 Standards of Lighting

Usually, in order to get a satisfactory visibility in the school for educational reasons, the classrooms or labs require good quality of lighting. The good performance of lights therefore plays a crucial role in keeping the psychological and biological healthy of the students. Besides the consideration for the students' visual and physical conditions, schools also need to think about the energy cost of the electric lights. In this case, the maintainability, duration and power load of the lights become the important part in choosing the luminance generators.

In addition to the conditions of lights, the physical situation of room, windows number and room direction should be taken into account. For examples, some room could achieves high visibility during the daylight time and thus require no extra radiance by lights, while some others, due to the few number of windows, require a lot more lighting provided by lights. Also, knowledge of the task usually done in the room is also important when people try to determine the lights to be installed in the room. The table 2.3.1[8] is the overview of classrooms' requirement for lighting due to their different tasks.

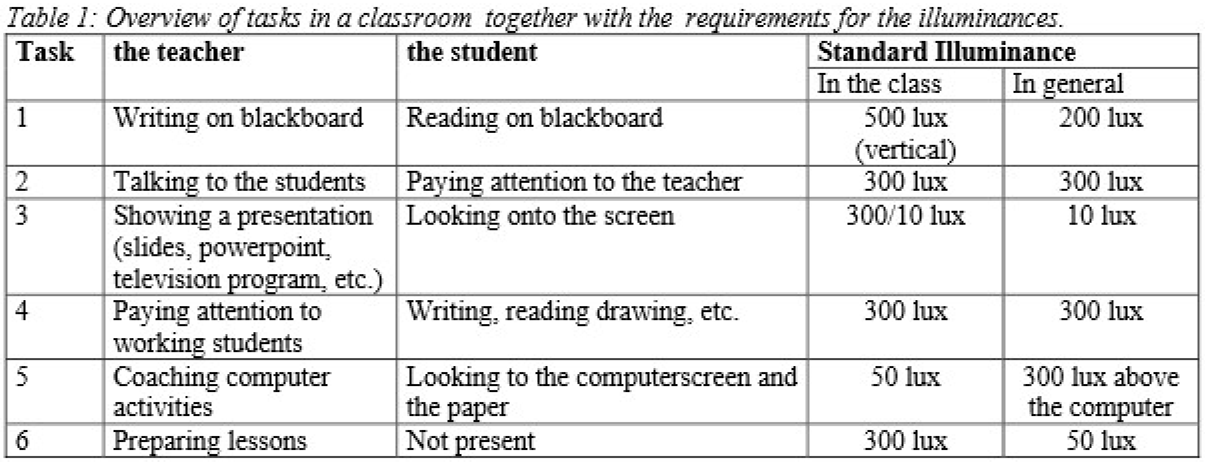


Table 1: Overview of tasks in a classroom together with the requirements for the illuminances.

Task	**the teacher**	**the student**	**Standard Illuminance**	
			In the class	In general
1	Writing on blackboard	Reading on blackboard	500 lux (vertical)	200 lux
2	Talking to the students	Paying attention to the teacher	300 lux	300 lux
3	Showing a presentation (slides, powerpoint, television program, etc.)	Looking onto the screen	300/10 lux	10 lux
4	Paying attention to working students	Writing, reading drawing, etc.	300 lux	300 lux
5	Coaching computer activities	Looking to the computerscreen and the paper	50 lux	300 lux above the computer
6	Preparing lessons	Not present	300 lux	50 lux

Table 2.3.1[11]

2.4 Usage of Motion Sensor

The use of motion sensors could be found almost everywhere in WPI. When there is no one in the bathroom for a while, the lights in the bathroom will automatically be turned off. Also, in the library, the motion sensor system would assist in shutting down lights in the area without people activities. Even in the classroom or labs, people sometimes just find the lights are magically being turned off as they were all in a motionless state for a long time. The installation of the motion sensor plays a significant way in saving electric energy cost in the whole school by reducing the useless usage lighting equipment.

The types of motion sensor used in WPI also vary according to the room's physical condition and the task of the room. For instance, the big classroom such as AK 116 is usually being installed with motion sensor of large sensor area and less sensibility to motions. On the contrary, the motion sensor installed in the bathroom is often with small area detector but higher sensibility. All these factors depend on the physical situation of room and the activities frequently hold in the room. The table 2.4.1 below lists motion detectors that are mostly often used current days.

Motion Sensor Information Table

Manufactor	Trade Name	Catalog Number	Maxinum Coverage Area(ft2)	Time Delay Range	Mininum Load Requirement(W)
Bryant Electric Inc.	Motion Switch	MSFL 1200I	1200	1 to 20 mins	25
		MSWS 1277	1200	0sec to 20min	120
Honeywell Inc.	H-MOSS Wall Switch	WSS 1200	1200	1 to 20 mins	50
Hubell Inc.	Hubell	EL2650 B 1066	1200	45sec to 15mins	25
		EL2650 B 1025	2500	45sec to 15mins	55

Leviton Manufactoring Company	Decora	6755	2500	0 to 30mins	55
Lighttoller Controls	INSIGHT	152 600VA	750	2 to 15mins	70
		IH52 1000VA	750	15mins	5
		153 600VA	750	2 to 15mins	15
		IH53 1000VA	750	15mins	55
		152 IKVA 277	750	2 to 15mins	50
		Ih52 IKVA 277	750	15mins	5
		I53 IKVA 277	750	2 to 15mins	50
		IH53 IKVA 277	750	15mins	15
Lithonala lighting	Lithonric	LIRW	1000	30sec to 30mins	50
Mytech	LowPro2	LP 2	900	0 to 20mins	70
Pass & Syemolesguard	N/A	WS 3000	900	30sec to 30mins	50
RAB Electric Manufactoring	Light Alert	LOS 300	300	0sec to 15mins	55
		LOS 900	1500	9 to 11mins	25
		LOS 1000	1000	0 to 30mins	70

Table 2.4.1

Chapter 3 Method of Motion Sensor

3.1 Introduction

This chapter explains how each topic area was approached from a scientific point of view. Such topics include physical condition influence, light type influence, and lighting consumption calculations for Atwater Kent.

3.2 Physical Condition Influence

To determine the energy saving and cost resulted in motion sensor on the first floor of Atwater Kent, a layout of the floor was provided to show all locations of lights. The Atwater Kent Lab First Floor Layout (Figure 3.2.1) can not only enable the reader to identify with the space, but also serve as the guideline to install the motion sensor. In order to take advantage of the benefit that comes from installing motion, it is important to determine the installation location according to the physical condition of the building and lights condition. For example, there should be more motion sensors installed in large lecture halls since there usually be more space and more lights in these rooms. From the layout of the first floor of Atwater Kent, it is obvious that motion sensors are evenly distributed according to the area of the rooms. The Newer Hall (AK116) gets more motion sensors than the other rooms since it has the largest area. Bathrooms and elevate, according to their limited space, only gain one motion sensor. Length and wide were measured to calculate the area of each room. Number of motion sensor was determined in proportion of room space. Calculation and result are provided in section 3.5.

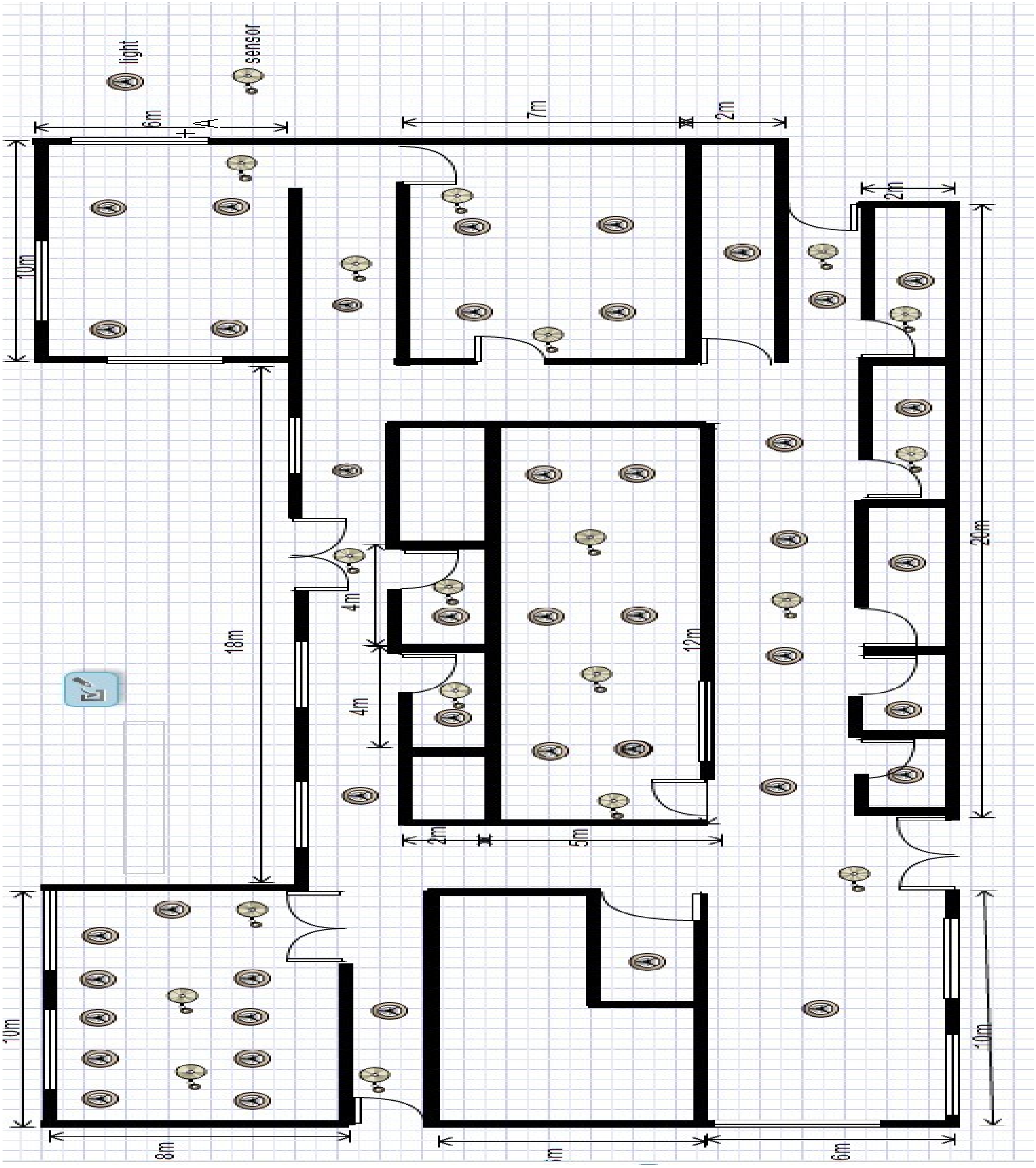


Figure 3.2.1(Atwater Kent First Floor Layout)

3.3 Light Type Influence

In order to determine the lighting consumption of Atwater Kent it was necessary to compare light load, unit price and life time of different light types. Different lights have different loads, thereby consuming different amount of energy per hour. Also, as the lights prices vary from on to another, the cost of the total saving would be influenced by the difference of prices. Except these obvious factors that matter, factors such as average usage hour should also be taken into account.

Figure 3.3.1

According to the group research on the first floor of Atwater Kent Lab, the team finds the dominant light types are the LED tubes with the load around 30 Watts per hours. The light information is listed in the table below. (Table 3.3.1)

Light Information Table				
Model Series	Watts	Description	Average Usage Hour	Unit Price
S11871	32	cool light	20000	$99
S19055	34	cool light	20000	$82
S11872	32	warm light	20000	$99
S11874	34	warm light	20000	$105

Table 3.3.1 (Light Type Table)

In the table provided above, there are cool and warm two different light type served by these bulbs. The warm light is more widely used than cold lights. This situation is corresponding to the condition of first floor of AK labs, where lights are dominantly warm lights. However, cool lights are use in lab classroom and large lecture rooms, where sometimes more strong light need to be provided. This factor could be ignored since the average usage hours of lights are the same. The average price of the lights is approximately 100 USD and it was used in later calculation.

3.4 Motion Sensor Type Influence

The type of motion sensor is one of the main factors to be considered in this research. However, as the aim of the project is focusing on the relationship between motion sensor and their assistance on saving money and energy, the team chooses to focus on cheap, durable and saving-efficient motion sensor. After some market research, the team enumerates some competitive motion sensors that could be used in the first floor of AK Lab to help save lighting consumption. The motion sensor information is list in the table (Table 3.3.2) below.

Motion Sensor Information Table

Manufactory	Trade Name	Catalog Number	Maximum Coverage Area(ft2)	Time Delay Range(min)	Minimum Load Requirement(W)	$35.00
Bryant Electric Inc.	Motion Switch	MSFL 1200I	260	1 - 20	25	$55.00
		MSWS 1277	250	0 - 20	120	$24.00
Honeywell Inc.	H-MOSS Wall Switch	WSS 1200	250	1 - 20	50	$24.00
Hubell Inc.	Hubell	EL2650 B 1066	280	1 - 15	25	$21.00
		EL2650 B 1025	500	1 - 15	55	$29.00
Leviton Manufactoring Company	Decora	6755	500	0 - 30	55	$14.00
Lighttoller Controls	INSIGHT	152 600VA	150	2 - 15	70	$32.00
		IH52 1000VA	150	15	5	$25.00
		153 600VA	150	2 - 15	15	$42.00
		IH53 1000VA	150	15	55	$19.00
		152 IKVA 277	150	2 - 15	50	$40.00
		Ih52 IKVA 277	150	15	5	$25.00
		I53 IKVA 277	150	2 - 15	50	$35.00
		IH53 IKVA 277	150	15	15	$35.00
Lithonala lighting	Lithonric	LIRW	200	1 - 30	50	$55.00
Mytech	LowPro2	LP 2	160	0 - 20	70	$24.00
Pass & Syemolesguard	N/A	WS 3000	160	30 - 30	50	$24.00

RAB Electric Manufactoring	Light Alert	LOS 300	60	0 - 15	55	$21.00
		LOS 900	300	9 - 11	25	$29.00
		LOS 1000	200	0 - 30	70	$14.00

Table 3.3.2 (Motion Sensor Information Table)

According to the statistics list above, the team finds the average cost of these motion sensors is about 30 USD while the average coverage area of the sensor is approximately 240 ft^2.According to the table, the minimum load for these motion sensors differ greatly from one to another; however, their cost of energy is so small that could be counted as negligible. In the calculation, the energy cost of every motion sensor is assumed to be 0.5 Watts per hours, which can be ignored by comparing the 30 Watts per hours of each light in real life.

3.5 Calculation

This section focuses on theoretical calculations used to decide upon the feasibility of install motion sensor. The calculations presented in this section include light consumption in Atwater Kent without motion sensor, as well as some calculations on how much money can be Saved from a motion sensor installation

3.5.1 Calculation with Motion Sensor

In table 3.5.1, the first column on the left lists all the room in the AK Lab first floor. Accordingly,

AK First Floor Lights Energy Consumption And Cost Table Without Motion Sensor

Area	Space (m^2)	Number of Lights	Light Load (W/Light)	AOT[1] Without MS[2]（hour）	Daily Energy Consumption (kWh)	Electric Fee (USD/kWh)	Daily Cost (USD)
AK116	200	50	32	8	12.8	0.12	1.536
AK113	50	20	32	16	10.24	0.12	1.2288
Bathroom(male)	10	3	32	16	1.536	0.12	0.18432
Bathroom(female)	10	3	32	16	1.536	0.12	0.18432
Elevator	2	1	32	0.5	0.016	0.12	0.00192
RBE LAB	80	20	32	18	11.52	0.12	1.3824
Department Office	50	10	32	10	3.2	0.12	0.384
Hallways	150	30	32	24	23.04	0.12	2.7648
AK111	30	10	32	14	4.48	0.12	0.5376
classroom	20	4	32	8	1.024	0.12	0.12288
storeroom	10	2	32	1	0.064	0.12	0.00768
common room	10	2	32	8	0.512	0.12	0.06144
Average	51.833333	12.916667	32	11.625	5.830666667	0.12	0.69968
Sum	622	155	N/A	139.5	69.968	N/A	**8.39616**

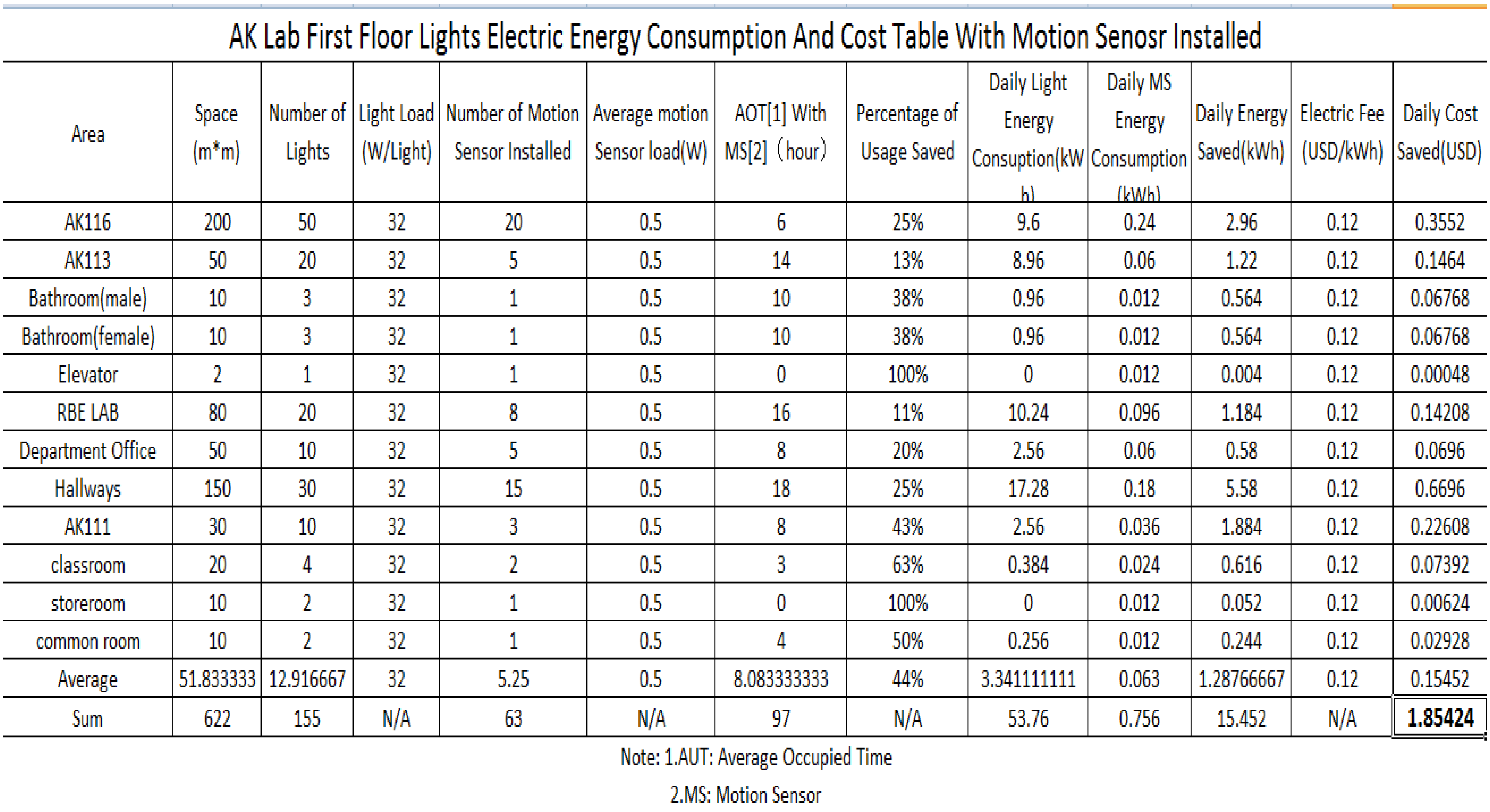
Note: 1.AUT: Average Occupied Time

2.MS: Motion Sensor

Table 3.5.1(AK First Floor Light Energy Cost Table without Motion Sensor)

the second column gives the space occupied by the rooms. The light number in each room is assumed to be proportional to the space of the room occupied, which is listed in the third column. The light load in this case is 32 Watt, which is gained by the light type table (Table 3.3.1) in pervious section. The average occupied time of each room and electric fee are also providing above.

3.5.2 Calculation with Motion Sensor



AK Lab First Floor Lights Electric Energy Consumption And Cost Table With Motion Senosr Installed

Area	Space (m*m)	Number of Lights	Light Load (W/Light)	Number of Motion Sensor Installed	Average motion Sensor load(W)	AOT[1] With MS[2]（hour）	Percentage of Usage Saved	Daily Light Energy Consuption(kWh)	Daily MS Energy Consumption (kWh)	Daily Energy Saved(kWh)	Electric Fee (USD/kWh)	Daily Cost Saved(USD)
AK116	200	50	32	20	0.5	6	25%	9.6	0.24	2.96	0.12	0.3552
AK113	50	20	32	5	0.5	14	13%	8.96	0.06	1.22	0.12	0.1464
Bathroom(male)	10	3	32	1	0.5	10	38%	0.96	0.012	0.564	0.12	0.06768
Bathroom(female)	10	3	32	1	0.5	10	38%	0.96	0.012	0.564	0.12	0.06768
Elevator	2	1	32	1	0.5	0	100%	0	0.012	0.004	0.12	0.00048
RBE LAB	80	20	32	8	0.5	16	11%	10.24	0.096	1.184	0.12	0.14208
Department Office	50	10	32	5	0.5	8	20%	2.56	0.06	0.58	0.12	0.0696
Hallways	150	30	32	15	0.5	18	25%	17.28	0.18	5.58	0.12	0.6696
AK111	30	10	32	3	0.5	8	43%	2.56	0.036	1.884	0.12	0.22608
classroom	20	4	32	2	0.5	3	63%	0.384	0.024	0.616	0.12	0.07392
storeroom	10	2	32	1	0.5	0	100%	0	0.012	0.052	0.12	0.00624
common room	10	2	32	1	0.5	4	50%	0.256	0.012	0.244	0.12	0.02928
Average	51.833333	12.916667	32	5.25	0.5	8.083333333	44%	3.341111111	0.063	1.28766667	0.12	0.15452
Sum	622	155	N/A	63	N/A	97	N/A	53.76	0.756	15.452	N/A	**1.85424**

Note: 1.AUT: Average Occupied Time

2.MS: Motion Sensor

Table 3.5.2(AK First Floor Light Energy Cost Table with Motion Sensor)

According to the table, the saving is not as much as expect. After analysis, the group finds the saving is actually inversely related to the occupied time of the room. For example, if the room is only be occupied a very small amount of time, the motion sensor would help shut down light when there is no one using the room, thus cut the light energy consumption a lot. However, if the room is occupied by people for a long time, then the motion sensor and the lights are both working at the same time, which basically increase the energy consumption of the room. However, because the consumption of energy by motion sensible is too small to be taken into account, it is not the real factor. The real reason is that if a room is occupied a lot of time, then the percentage of shut-down time by motion sensor is reduced, so the saving energy and money is reduced.

Other information provided in the table is based on the fact that motion sensor is installed every $10m^2$, which is concluded from the average coverage area in the motion sensor list table(Table 3.3.2). According to the same table with field study on the AK Lab first floor, the average light-on time saved by motion sensor is assumed to be 25% per day. With this assumption, if the lights of a room is previously used 10 hours a day, then after installing the motion sensor, the light-on time becomes 7.5 hours a day (25% saving). The motion sensor number installed in each room is also according to the room space; moreover, it also depends on the light number. The proportion of light number and motion sensor number was assumed to be 5:2. In the table, there are 50 lights in AK 116 and therefore there are 20 motion sensors would be installed. One thing to be noticed, both of light number and motion sensor number are proportional to the space that the room occupied.

3.5.3 Calculation of Daily Cost Saved by Motion Sensor in AK116

Unknown:

Daily Cost Saved By Motion Sensors --> S_{daily} ($)

Variables:

Light Load ---> L_{load} = 32 (Watt per hour)

Light Number ---> L_{num} = 50

Light-On-Time ---> T_{on} = 8 (hour)

Percent Time Reduced By Motion Sensor ---> T_{saved} = 25%

Sensor Number ---> S_{num} = 20

Sensor Load ---> S_{load} = 0.5 (Watt per hour)

Electric Price ---> P_{eletrc} = 0.12 (kWh/$)

Equation:

$$S_{daily} = (L_{load} \times L_{num} \times (T_{on} \times T_{saved}) - (S_{num} \times S_{load} \times 24))/1000 \times P_{eletrc}$$

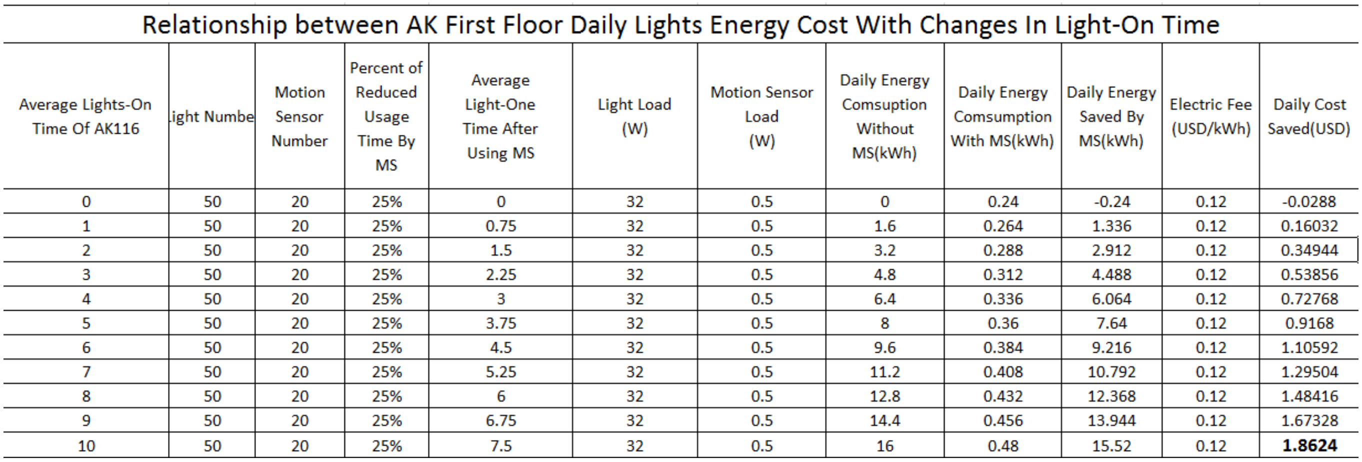
Replace Variables With Data:

$$S_{daily} = (32 \times 50 \times (8 \times 25\%) - (20 \times 32 \times 24))/1000 \times 0.12 = 0.3552\ (\$)$$

According to the data given by table, the team calculated the daily money saved on AK116 is 0.3552USD, which is lower than expectation, but still, reasonable. Using the same method, the daily cost saved by motion sensor for each room was calculated and result is provided in Table 1.1.5. From the calculation, the team found the total saving for the AK First Floor with motion sensor is 1.85424 USD a day.

However, there are also many other variables that could influence the effect of the motion sensor to save money, such as light-on time, light number and light load. For instance, if the light-On time is changed, certainly there will be a change correspondingly in the daily money saved. For this situation, the table below (Table 3.6.1) gives a detailed relationship between AK first floor daily light energy cost and changes in light-on time.

3.6 Relationship between Daily Money Saved and Variables



Relationship between AK First Floor Daily Lights Energy Cost With Changes In Light-On Time

Average Lights-On Time Of AK116	ight Numbe	Motion Sensor Number	Percent of Reduced Usage Time By MS	Average Light-One Time After Using MS	Light Load (W)	Motion Sensor Load (W)	Daily Energy Comsuption Without MS(kWh)	Daily Energy Comsumption With MS(kWh)	Daily Energy Saved By MS(kWh)	Electric Fee (USD/kWh)	Daily Cost Saved(USD)
0	50	20	25%	0	32	0.5	0	0.24	-0.24	0.12	-0.0288
1	50	20	25%	0.75	32	0.5	1.6	0.264	1.336	0.12	0.16032
2	50	20	25%	1.5	32	0.5	3.2	0.288	2.912	0.12	0.34944
3	50	20	25%	2.25	32	0.5	4.8	0.312	4.488	0.12	0.53856
4	50	20	25%	3	32	0.5	6.4	0.336	6.064	0.12	0.72768
5	50	20	25%	3.75	32	0.5	8	0.36	7.64	0.12	0.9168
6	50	20	25%	4.5	32	0.5	9.6	0.384	9.216	0.12	1.10592
7	50	20	25%	5.25	32	0.5	11.2	0.408	10.792	0.12	1.29504
8	50	20	25%	6	32	0.5	12.8	0.432	12.368	0.12	1.48416
9	50	20	25%	6.75	32	0.5	14.4	0.456	13.944	0.12	1.67328
10	50	20	25%	7.5	32	0.5	16	0.48	15.52	0.12	**1.8624**

Table 3.6.1 (Relationship Between AK First Floor Daily Lights Energy Cost With Changes in Light-On Time)

According this table and the equation used for calculating the daily energy saving, a proportional linear relationship between light-On time and daily money saved by motion sensor is clearly displayed by the table. The money saved daily of Average 10 hours light-On in this case is 1.8624 USD, compared to -0.028 USD of 0 hour light-One. The difference is obvious in this case. The linear graph below illustrates a clearer concept about cost and light-on time relationship. (Figure 3.6.1)

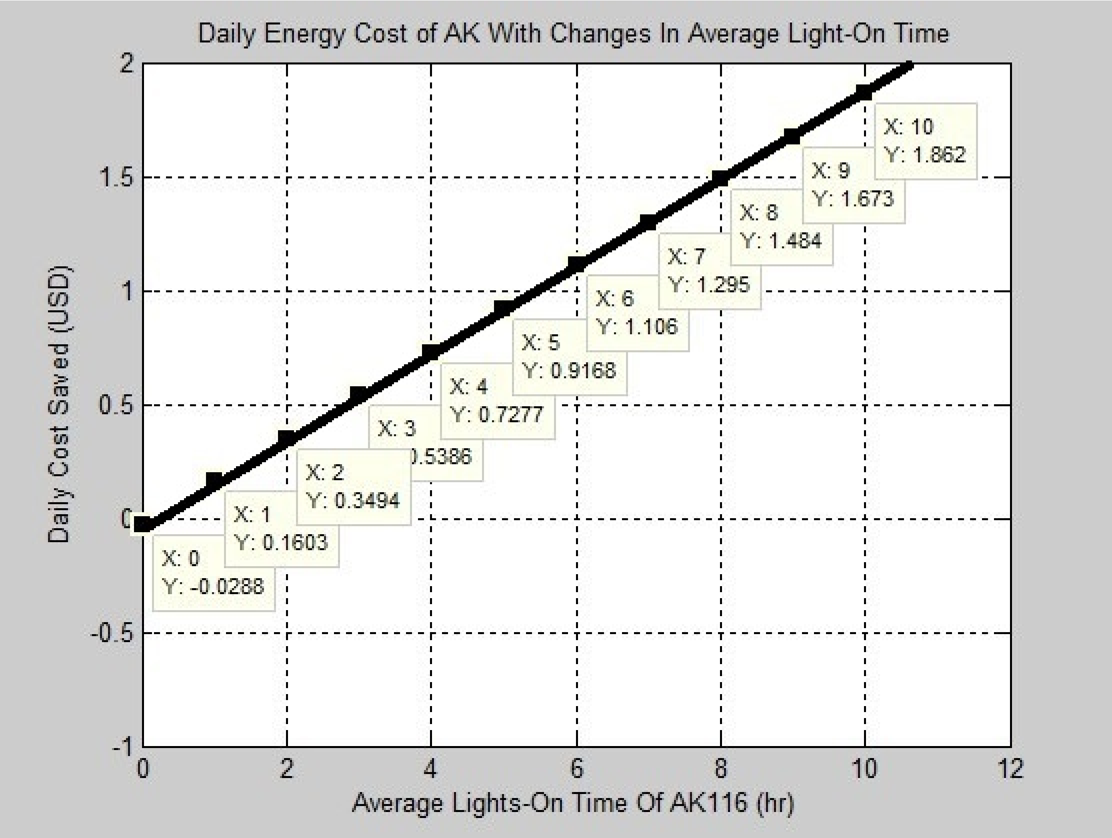
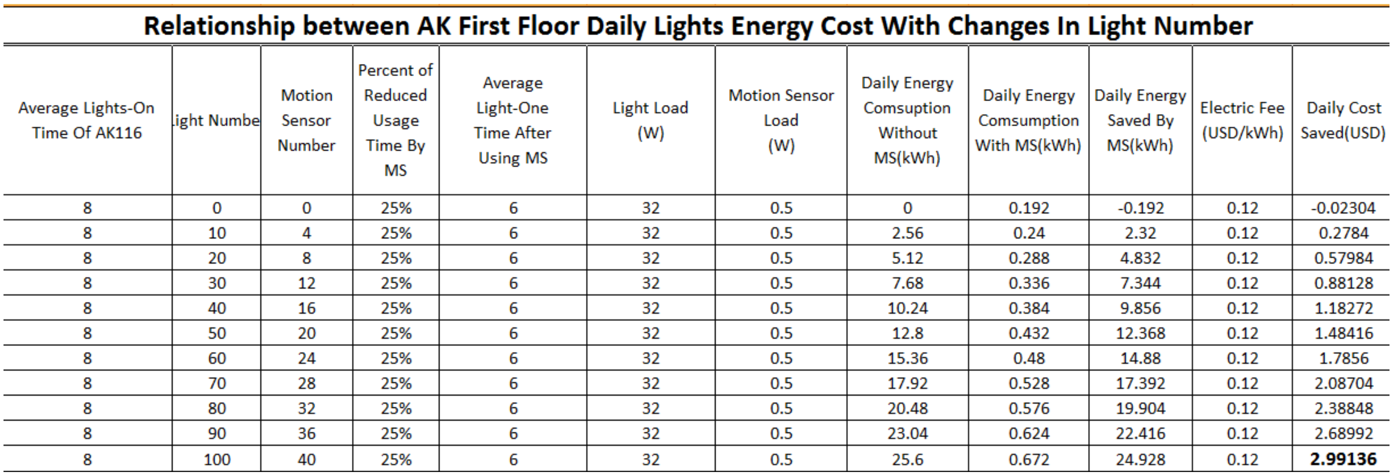


Figure 3.6.1(Curve Graph of Relationship Between AK First Floor Daily Lights Energy Cost With Changes in Light-On Time)

The relationship between the daily cost saved by motion sensor and the changes in light number and light load can be gotten by using the same method as used above. After calculation, the conclusion and results are clearly listed in Table 3.6.2 and Table 3.6.4, while the linear graphs 3.6.3 and 3.6.5 offers linear graphic relationships between variables and daily cost saved on AK first floor daily.



Relationship between AK First Floor Daily Lights Energy Cost With Changes In Light Number

Average Lights-On Time Of AK116	ight Numbe	Motion Sensor Number	Percent of Reduced Usage Time By MS	Average Light-One Time After Using MS	Light Load (W)	Motion Sensor Load (W)	Daily Energy Comsuption Without MS(kWh)	Daily Energy Comsumption With MS(kWh)	Daily Energy Saved By MS(kWh)	Electric Fee (USD/kWh)	Daily Cost Saved(USD)
8	0	0	25%	6	32	0.5	0	0.192	-0.192	0.12	-0.02304
8	10	4	25%	6	32	0.5	2.56	0.24	2.32	0.12	0.2784
8	20	8	25%	6	32	0.5	5.12	0.288	4.832	0.12	0.57984
8	30	12	25%	6	32	0.5	7.68	0.336	7.344	0.12	0.88128
8	40	16	25%	6	32	0.5	10.24	0.384	9.856	0.12	1.18272
8	50	20	25%	6	32	0.5	12.8	0.432	12.368	0.12	1.48416
8	60	24	25%	6	32	0.5	15.36	0.48	14.88	0.12	1.7856
8	70	28	25%	6	32	0.5	17.92	0.528	17.392	0.12	2.08704
8	80	32	25%	6	32	0.5	20.48	0.576	19.904	0.12	2.38848
8	90	36	25%	6	32	0.5	23.04	0.624	22.416	0.12	2.68992
8	100	40	25%	6	32	0.5	25.6	0.672	24.928	0.12	**2.99136**

Table 3.6.2 (Relationship Between AK First Floor Daily Lights Energy Cost With Changes in Light Number)

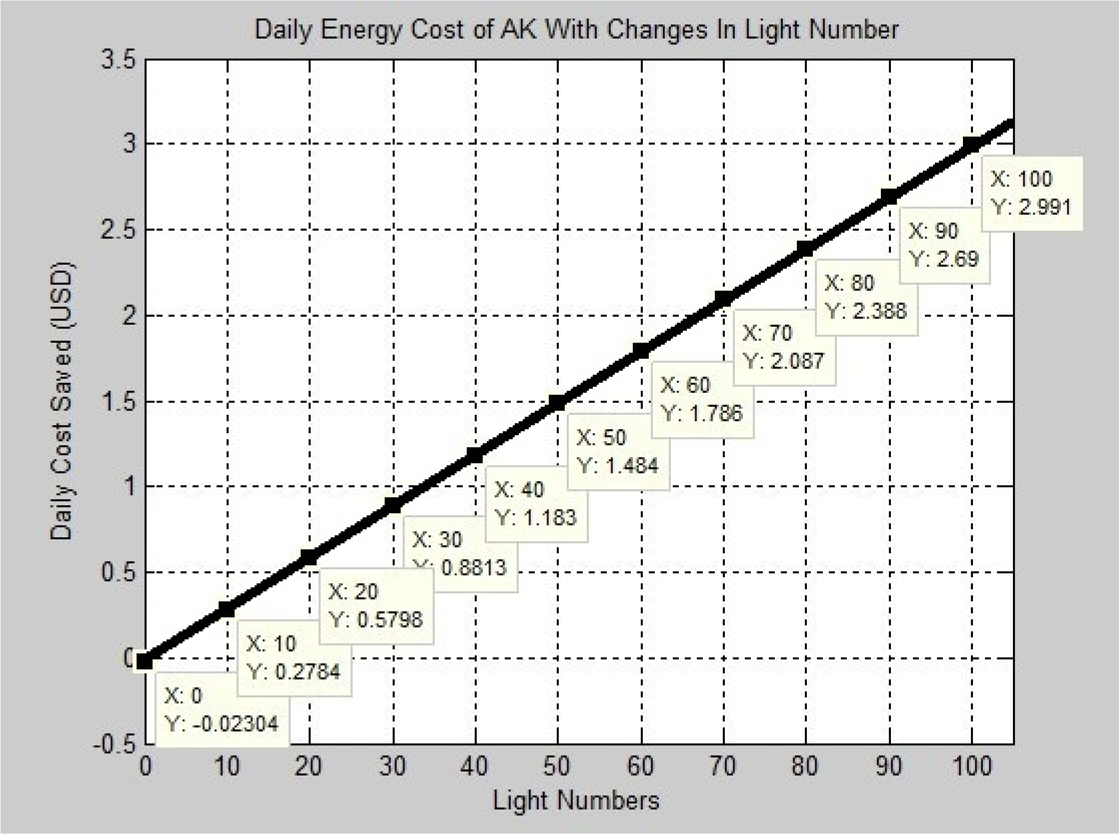
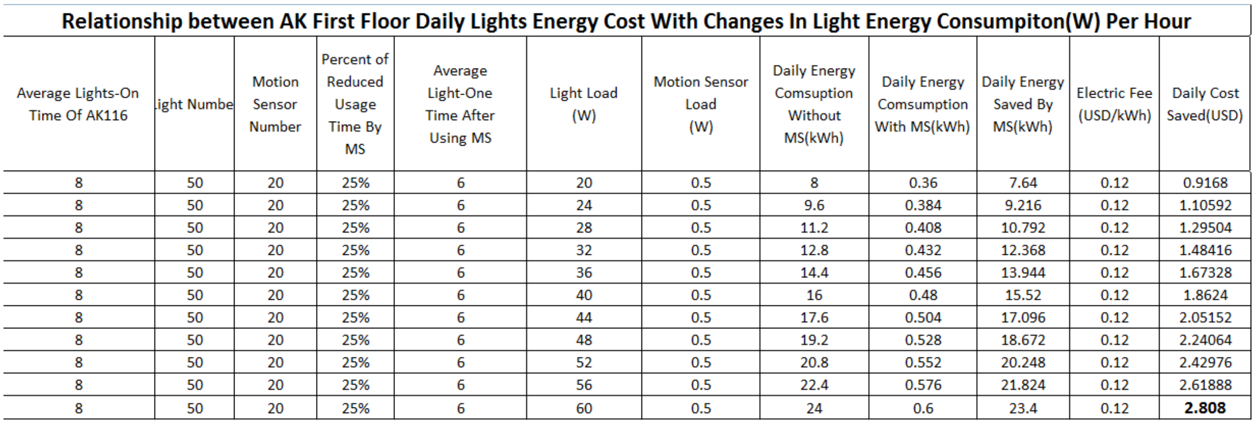


Figure 3.6.3(Curve Graph of Relationship Between AK First Floor Daily Lights Energy Cost With Changes in Light Number)



Relationship between AK First Floor Daily Lights Energy Cost With Changes In Light Energy Consumpiton(W) Per Hour

Average Lights-On Time Of AK116	ight Numbe	Motion Sensor Number	Percent of Reduced Usage Time By MS	Average Light-One Time After Using MS	Light Load (W)	Motion Sensor Load (W)	Daily Energy Comsuption Without MS(kWh)	Daily Energy Comsumption With MS(kWh)	Daily Energy Saved By MS(kWh)	Electric Fee (USD/kWh)	Daily Cost Saved(USD)
8	50	20	25%	6	20	0.5	8	0.36	7.64	0.12	0.9168
8	50	20	25%	6	24	0.5	9.6	0.384	9.216	0.12	1.10592
8	50	20	25%	6	28	0.5	11.2	0.408	10.792	0.12	1.29504
8	50	20	25%	6	32	0.5	12.8	0.432	12.368	0.12	1.48416
8	50	20	25%	6	36	0.5	14.4	0.456	13.944	0.12	1.67328
8	50	20	25%	6	40	0.5	16	0.48	15.52	0.12	1.8624
8	50	20	25%	6	44	0.5	17.6	0.504	17.096	0.12	2.05152
8	50	20	25%	6	48	0.5	19.2	0.528	18.672	0.12	2.24064
8	50	20	25%	6	52	0.5	20.8	0.552	20.248	0.12	2.42976
8	50	20	25%	6	56	0.5	22.4	0.576	21.824	0.12	2.61888
8	50	20	25%	6	60	0.5	24	0.6	23.4	0.12	**2.808**

Table 3.6.4(Relationship Between AK First Floor Daily Lights Energy Cost With Changes in Light Load)

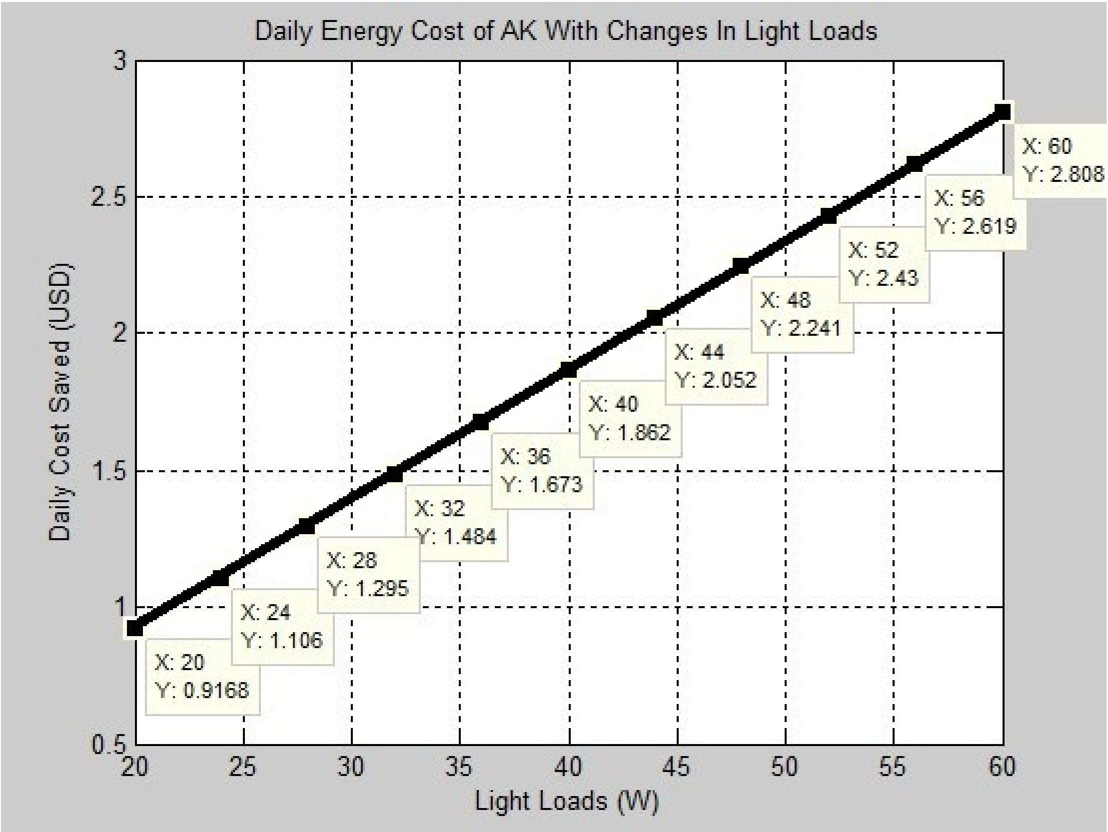


Figure 3.6.5 (Curve Graph of Relationship Between AK First Floor Daily Lights Energy Cost With Changes in Light Load)

Conclusion:

The analysis of all these relationships between daily cost saved and different variables (Average Light-On Hour, Light Number, Light Load) offers a clue about how the motion sensor would save cost more efficiently. More specifically speaking, with more light-on time, larger amount of light numbers and larger light loads, the motion sensor will do the money saving job more effectively.

As to the breakeven time between when people start using motion sensor and when they can actually get the money back, it is largely depends on the price of the motion sensor that people choose to use. Taken AK first floor as an example, according to the motion sensor information table (Table 3.3.2), the average motion sensor price is 30 USD. Define X to be the time elapsing when the money saved by motion sensors is equal to their costs. With conclusion from table 3.6.1, the daily saved money is 1.86 USD by motion sensors on AK first floor. And the table also articulates that there are 63 motion sensors. So according to all these information, the breakeven time X can be gotten from the equation $X \times 1.85 = 63 \times 30$. After the calculation, breakeven time between starting using motion sensor and getting money back is about 1019 days, which means that people need to wait about 2 year 9 months to let the motion sensor actually save their money. (Figure 3.7.1 gives more clear relationship of this.)

3.7 Calculation:

Unknown:

Motion Sensor Cost and Saving Break Even Time ---> $T_{breakeven}$ (day)

Variables:

Motion Sensor Price ---> $P_{sensor} = 30$ ($)

Daily Saving By Motion Senosr ---> S_{daily}= 1.89 ($)

Motion Sensor Number ---> $MS_{num} = 63$

Equation:

$T_{breakeven} = (MS_{num} \times P_{sensor}) / S_{daily}$

Replace Variables With Data:

$T_{breakeven} = (63 \times 30) / 1.89 = 1000$ (day)

1000 days is approximately 2.74 years is about 2 years and 9 months

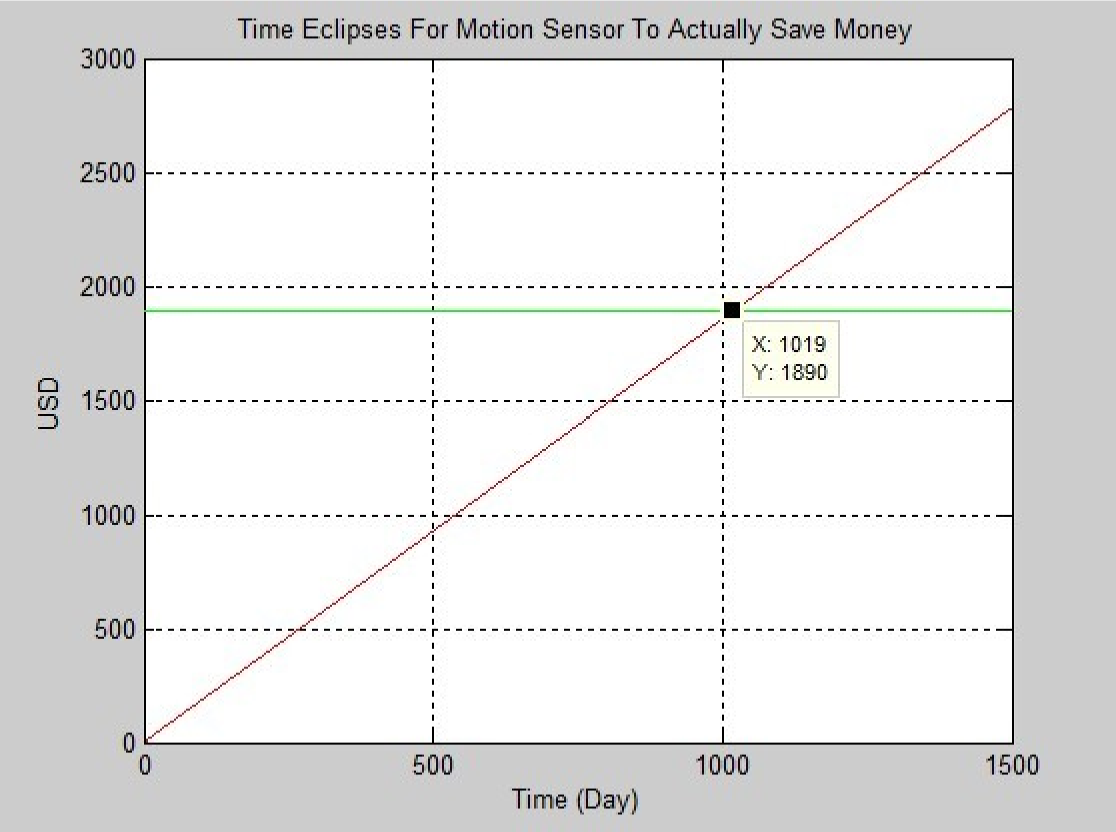


Figure 3.7.1 (Curve Graph Presentation of Break Even Time of Motion Sensor Cost and its Saving)

Chapter 4

Feasibility Analysis On Remote AC Intermittent Operation Controller

4.1 Introduction

Figure 4.1.1(Typical Air-Conditioners)

The second method that is used to save electric energy is the smart usage of air-conditioner. In the hot summer days, people usually prefer to keep the air-conditioners on all day long. However, it is not necessary for people to turn on air-conditioner consistently to achieve their body comfort. Sometimes, the overuse of air-conditioner will make the room too chilly to stay. People's preferences differ from one to another so that there is not a fixed temperature that is suitable for everyone to get thermal comfort. However, according to research by World Health Organization, 22 to 26 centigrade is the range of temperature that people feel most comfortable. Therefore, as long as the air-conditioner keeps the temperature in that range, it does not matter how it does. A smart, energy-saving way of inttermittently operating AC can beat the traditional consistent usage of AC.

4.2 Methodology

The intermittent operation of air-conditioner is not a complex method that is not feasible for the typical household to apply. On the contrary, the application of the method is very easy that only a remote air-conditioner controller would handle all the job. The underline principle for this method is also very easy to understand. In a room with perfect insulation capability, people could turn off the air-conditioner as long as the temperature in the room has been lowered to the prefered level. And because the room is prefect insulated, the temperature would keep in that level consistently. In this case, the opening time of the air-conditioner will be reduced to very small. However, in real world, there is no perfect insulated room, so the temperature will re-increase if people just turn off the air-conditioner. The apporiate way to both save energy and keep the room cool is to periodically open the air-conditioner. For example, if the air-conditioner is on for 15 minutes, just turn it off for another 15 minutes and then iterate the procedure. In this way, the temperatuer in the room would be controller in a prefered range; moreover, due to the intermittent turning off AC, the electric energy consumption wil lbe reduced by half.

The seemingly complex process actually can be compleled by just using a remote air-conditoner controller, which would controll the air-conditioner to ensure its intermittent operation. The simplified circuit graph is shown below.(Figure 4.2.1). According to the picture, the remote controller would take the responsibility of switching on and off air-conditioning periodically. The simplication of insutallation therefore make this method a feasible on for school or household to save elctric cost during hot summer days.

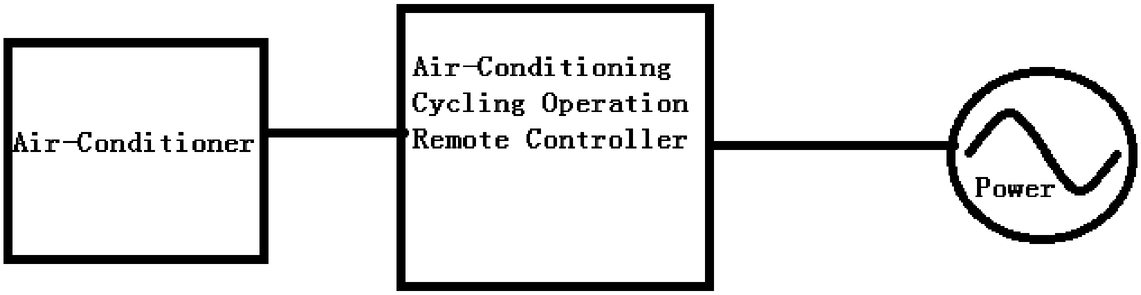


Figure 4.2.1(Circuit Graph of AC Cycling Operation)

4.3 Physical Factors

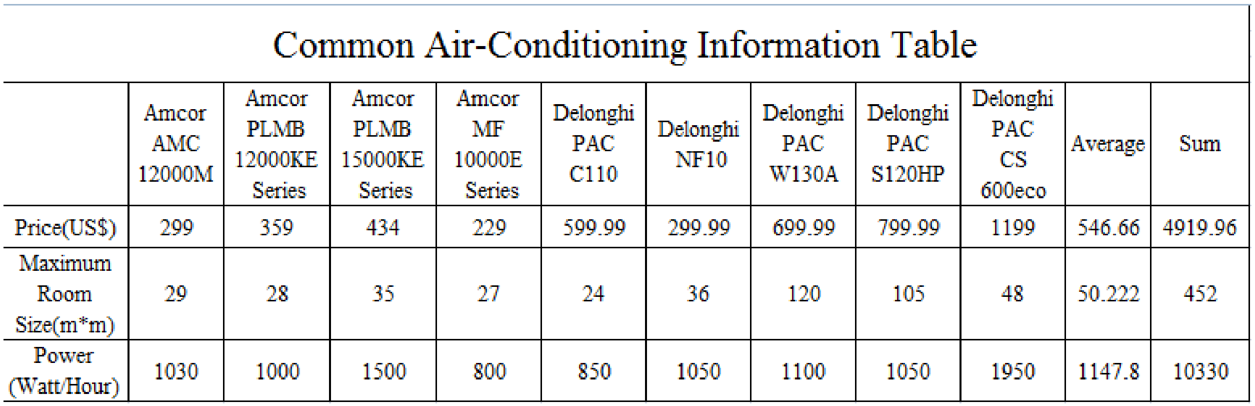
However, only simply installation cannot garantee the feasibility of this plan. The price and real benefit also matter a lot. If the price people need to pay for the remote air-conditioner controller is very hight, then nobody would buy it. The product would be unvaluable if the market doesn't like it, even though it may have a slogan of saving electric energy. Simiarly, it the benefit resulted in by this plan is trivial, it is then not a very good way for people to save money. Typically, when a custumer chooses to buy a long-time benefit product instead of traditional one, he or she wants to get the money back as soon as possible. Nobody want to wait more than 10 years to get start recieve benefit from the investment made before. So the breakeven time of retrieving the money of the remote AC controller by using it would be a key factor to determine if the plan is feasible or not.

To test the practicablity of the intermittent operation on air-conditioning. The group did the caclcualation based on physical environment of Atwater Kent lab first floor. According to the air-conditioner number in the floor, the group smiulated a model that would use the corresponding number of air-conditioning controllers to save energy during summer days. This simulation would helpe us to caluclate the price of air-conditioner controller. If the final price of the controller is very high, the feasiblity of the cycling operation plan will be low. On the other hand, if the calcualted price is low or acceptable, the plan then is deserved to be used at least.

The process of the calculation is very simple. To find the price of remote AC controller, some vaiables will be used in the process of calucation. They are Number of Air-conditioners in the first floor of AK, number of air-conditioner controller, air-conditioning load, number of days using AC anually, daily AC operation hour, percent of operation time saved by controller and electic price of the electric energy in the area.

4.4 Feasibility Analysis Calculation

Firstly, the average price and energy load could be gain by checking the table of commonly used air-conditioners(Table 4.4.1).



Common Air-Conditioning Information Table

	Amcor AMC 12000M	Amcor PLMB 12000KE Series	Amcor PLMB 15000KE Series	Amcor MF 10000E Series	Delonghi PAC C110	Delonghi NF10	Delonghi PAC W130A	Delonghi PAC S120HP	Delonghi PAC CS 600eco	Average	Sum
Price(US$)	299	359	434	229	599.99	299.99	699.99	799.99	1199	546.66	4919.96
Maximum Room Size(m*m)	29	28	35	27	24	36	120	105	48	50.222	452
Power (Watt/Hour)	1030	1000	1500	800	850	1050	1100	1050	1950	1147.8	10330

Table 4.4.1(Common Air-Conditioner Info Table)

By counting, the group finds the number of air-conditioner in the AK first floor is about 20. And correspondingly, the remote controller should be 5. After assuming the days of using air-conditioning and the daily hours, we did the detailed calculation below.

Calculation

Unknown:

Feasible AC Remote Controller Price ---> P_C ($)

Variables:

Number Of Air-Conditioning Controller ---> $C_{num} = 5$

Number Of Air-Conditioning ---> $AC_{num} = 20$

Air-Conditioning Load ---> $AC_{load} = 1147.8$(W)

Air-Conditioning Operation Days Per Year ---> $D_{on} = 120$(days/year)

Air-Conditioning Operation Time Per Day ---> $H_{on} = 10$(hours/day)

Percent of Shutting down Time Using Intermittent Operation ---> $Perc_{off} = 50\%$

(Intermittently shut down and open air-conditioners every 15 minutes)

Electric Energy Price ---> $P_{eletrc} = 0.12$ (kWh/$)

Equation:

$P_C \times C_{num} = ((AC_{load} \times AC_{num} \times D_{on} \times Perc_{off} \times H_{on})/1000 \times P_{eletrc})$

$P_C = ((AC_{load} \times AC_{num} \times D_{on} \times Perc_{off} \times H_{on})/1000 \times P_{eletrc}) / C_{num}$

Replace Variables With Data:

$P_C = ((1147.8 \times 20 \times 120 \times 50\% \times 10)/1000 \times 0.12)/5$

$P_C = 330.5$ ($) for one year

In real world, 5 years is a reasonable time to be considered as break even time

So $P_C \times 5 = 1652.8$ (\$)

Conclusion

If the price of the AC Cycling Operation Controller is not greater than 1652.8 $, then people could get our money back in 5 years by using the AC cycling operation controller. The figure we got above indicates that the cycling operation of AC is really a feasible way to save energy. Due to 1652.8 is really a big amount of money, it is not possible that the price for installation of a remote air-conditioner controller would reach that high price. Therefore, as long as the people spend less money than 1652.8$ on the remote AC controller, the plan could be served as a good way to save electric energy and money.

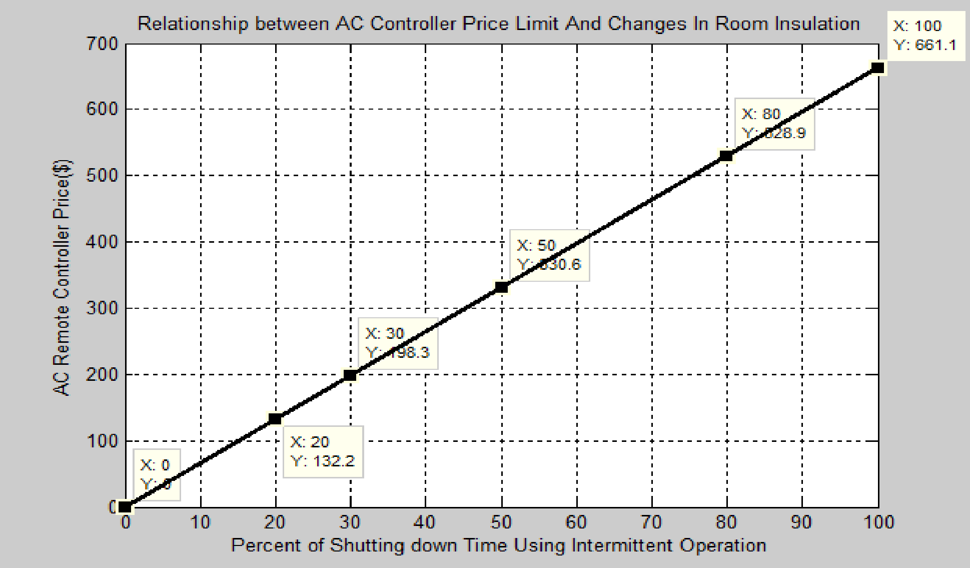
4.5 Insulation Influence

The calculation the group did above is based upon an assumption that the rooms are well insulated; however, if the rooms are not insulated, then to ensure people in the rooms to gain similar body comfort, the time break between shutting down the AC should be reduced, thereby decreasing the Percent of Shutting down Time Using Intermittent Operation ($Perc_{off)}$). The table below gives the changes in P_C with different room Insulations.

AC Controller Price Limit To Save Money In A Year With Changes of Room Insulation								
Insulation Extent	C_{num}	AC_{num}	AC_{load}(W)	D_{on} (Day/Year)	H_{on} (Hour/Day)	P_{eletrc} (\$)	$Perc_{off}$ (%)	P_C (\$)

Perfect	5	20	1147.8	120	10	0.12	100.00%	661.13
Good	5	20	1147.8	120	10	0.12	80.00%	528.91
Fine	5	20	1147.8	120	10	0.12	50.00%	330.57
So-so	5	20	1147.8	120	10	0.12	30.00%	198.34
Bad	5	20	1147.8	120	10	0.12	20.00%	132.23
Not At All	5	20	1147.8	120	10	0.12	0.00%	0.00

Table 4.5.1(AC Controller Price Limit with Changes In Room Insulation)



4.6 Central Air-Conditioner Analysis

Nowadays, more and more buildings and rooms use central air-conditioner to cool down the temperature during the hot summer days. In schools or mansions, the central air-conditioner gradually replaces the traditional AC and becomes the most important method to control thermal extent in the rooms. This is because for large rooms and buildings, the central air-conditioner could lower the temperature more efficiently than the typical ones while using the same amount of energy. Moreover, once being installed, the central air-conditioner could control the temperature with much larger area coverage than the traditional ones. With these advantages, it is now widely used in the world.

If the remote AC controller can work well with the central air-conditioner, the energy and money saved may outweigh those saved by controlling traditional AC. Therefore, the calculation below is focused on figuring out the feasibility to use remote AC controller for central air-conditioner. Again, the physical environment is assumed to be Atwater Kent Lab first floor.

Figure 4.6.1(Air Duct for Central Air Conditioner)

Similar to what the group did for the traditional air-conditioner controller, the calculation is aimed to figure out the breakeven price for remote AC controller price and the money saved by it in 5 years.

The table below (Table 4.6.2) is the power load and cost information for different central air-conditioner that are commonly used in the buildings.

Central Air-Conditioner Information Table		
Central AC Unit Brand	**Power Load (kW)**	**AC & Coil Installed($)**
Air Flow	51	1680
Amana	37	2550
American Standard	60	3195
Armstrong	55	1990
Bryant	38	2160
Carrier	54	3220
Coleman	61	1740
Comfortmaker	56	1740
Frigidaire	62	2910
Gibson	38	2265
Goodman MFG	44	2125
Heil	60	2630
Lennox	58	3410
Rheem	53	2450
Ruud	62	2440
Tempstar	37	1830
Trane	63	3290

Whirlpool	57	1910
York	46	2770
Average	52.21052632	2437.105263

Table 4.6.2(Central Air-Conditioner Info Table)

4.7 Feasibility Analysis Calculation

Calculation:

Unknown:

Feasible Central Air-Conditioning Remote Controller Price ---> P_C ($)

Variables:

Number Of Air-Conditioning Controller ---> C_{num} = 3

Number Of Air-Conditioning ---> AC_{num} = 3

Air-Conditioning Load ---> CAC_{load} = 52210.5(W)

Air-Conditioning Operation Days Per Year ---> D_{on} = 120(days/year)

Air-Conditioning Operation Time Per Day ---> H_{on} = 10(hours/day)

Percent of Shutting down Time Using Intermittent Operation ---> $Perc_{off}$ = 50%

(Intermittently shut down and open air-conditioners every 15 minutes)

Electric Energy Price ---> P_{eletrc} = 0.12 (kWh/$)

Equation:

$$P_C \times C_{num} = ((CAC_{load} \times CAC_{num} \times D_{on} \times Perc_{off} \times H_{on})/1000 \times P_{eletrc})$$

$$P_C = ((CAC_{load} \times CAC_{num} \times D_{on} \times Perc_{off} \times H_{on})/1000 \times P_{eletrc}) / C_{num}$$

Replace Variables With Data:

$$P_{AC} = ((52210.5 \times 3 \times 120 \times 50\% \times 10)/1000 \times 0.12)/3$$

$$P_{AC} = 3759.1(\$)$$

In real world, 5 years is a reasonable time to be considered as break even time

So $P_C \times 5 = 18795.7$ ($)

Conclusion:

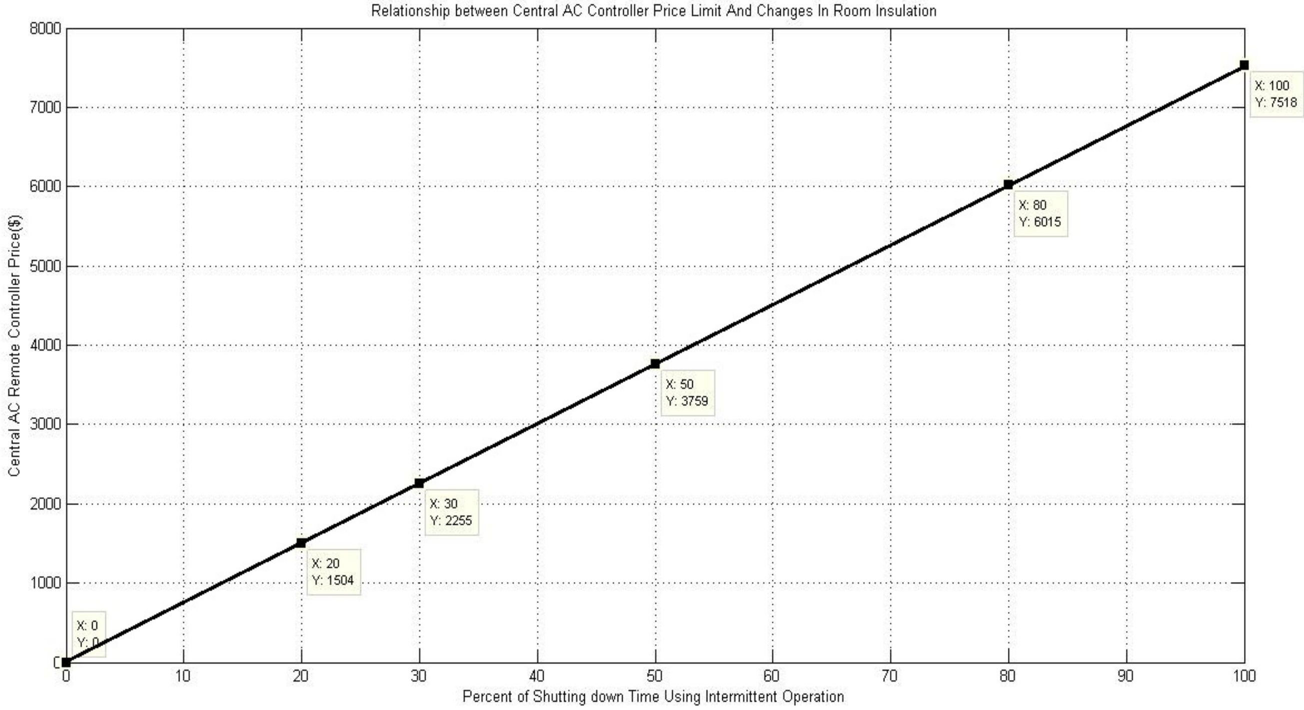
If the price of the AC Cycling Operation Controller is not greater than 18795.7 $, then it is possible to get money back in 5 years by using the AC cycling operation controller. Obviously, 18795.7 is a very large number so that it is very likely that the real cost of the central air-conditioner controller would not reach that higher. For this reason, it is reasonable to conclude from the calculation that the remote central AC controlling plan is feasible in this case.

Using the same methodology provided above, the table for the changes in P_C with different room is shown in Table 4.7.1.

Central AC Controller Price Limit To Save Money In A Year With Changes of Room Insulation

Insulation Extent	C_{num}	CAC_{num}	AC_{load}(W)	D_{on} (Day/Year)	H_{on} (Hour/Day)	P_{eletrc} ($)	$Perc_{off}$ (%)	P_C ($)
Perfect	3	3	52210.5	120	10	0.12	100.00%	7518.31
Good	3	3	52210.5	120	10	0.12	80.00%	6014.65
Fine	3	3	52210.5	120	10	0.12	50.00%	3759.16
So-so	3	3	52210.5	120	10	0.12	30.00%	2255.49
Bad	3	3	52210.5	120	10	0.12	20.00%	1503.66
Not At All	3	3	52210.5	120	10	0.12	0.00%	0.00

Table 4.7.1(Central AC Controller Price Limit with Changes in Room Insulation)



4.8 Circuit Method

Most of people experience large changes in temperature from season to season, but human comfort demands a constant temperature in homes through the year. In winter, this means preventing heat from escaping to the outside. In summer, this means preventing heat from entering the house. House insulation helps maintain the desire temperature by blocking heat flow. However, some materials are more effective than others. In order to determine the relationship between house insulation and indoor temperature, an RC circuit was used to simulate calculate the result. The following sections will provide methodology, calculation and result of this method.

House insulation helps maintain human comfort by blocking heat flow. Figure 4.8.1 shows how the house insulation works in winter time.

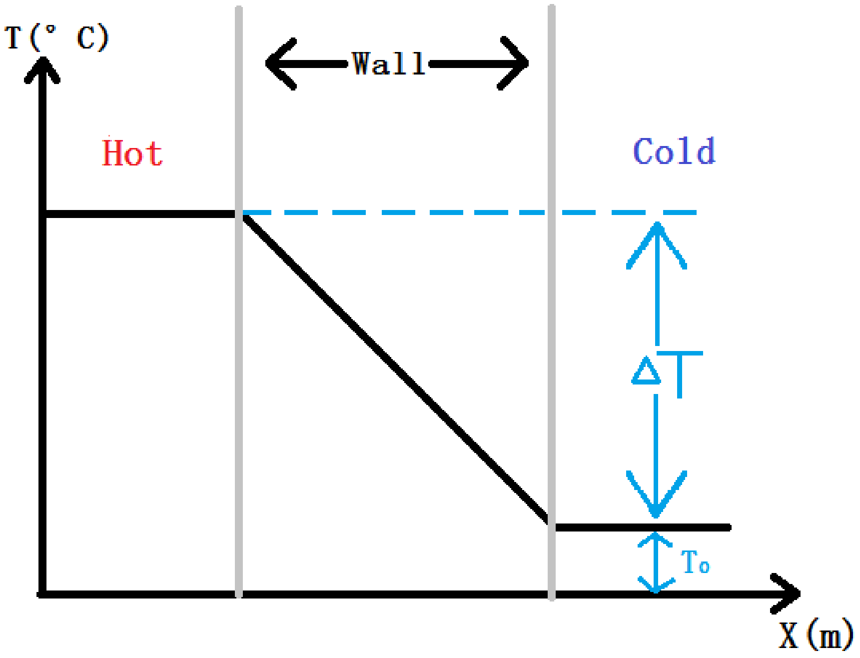


Figure 4.8.1

It is obvious from the graph that the indoor temperature (T_1) higher than the outdoor temperature (T_2). There is a temperature drop at the wall area, which shows heat flow from inside to outside. The relationship of power, temperature and house insulation can be representing in the following equations:

$\Delta T = T_1 - T_2$

$\Delta T = P \times R_T$ (1)

Where

T_1 is the indoor temperature;

T_2 is the outdoor temperature;

ΔT is the temperature difference between indoor and outdoor;

P is the power, which means how fast energy flows;

R_T is the house insulation constant.

The above equation works similar as Ohm's law, which implies the temperature and house insulation relation can be represent into a circuit. Figure 4.8.2 shows the circuit representation of temperature and house insulation.

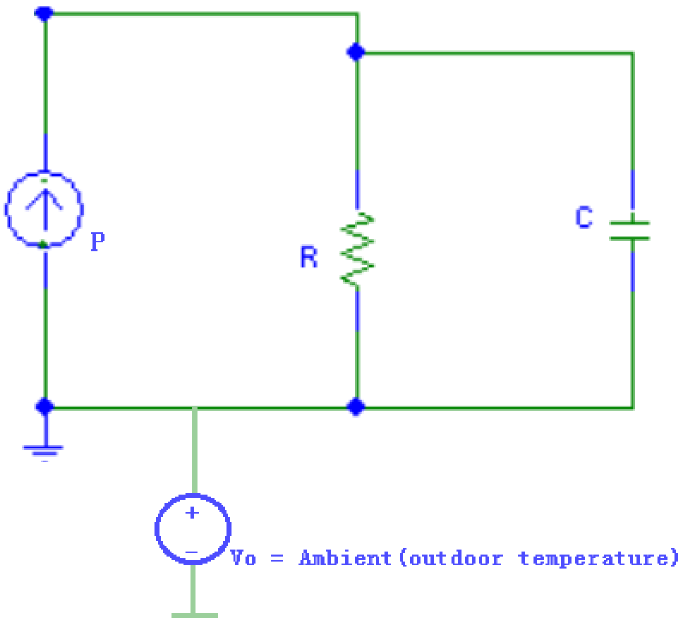


Figure 4.8.2

$V = I \times R$ (2)

$Z = R \times C$ (3)

Where

V_0 represents the outdoor temperature T_2

I represents the power P

R represents the house insulation constant R_T

C represents energy store in the wall

Z represents thermal time constant, which show how fast does indoor temperature change.

By using the information provided above, the relationship of indoor temperature and house insulation can be determined. To explain this idea more clearly, an example is provide below.

Assume in hot weather the outdoor temperature is 100 °*F*, air-conditioning power is 600W, house insulation constant is 809hW/°F and T is indoor temperature. Figure 4.8.3 shows the circuit representation for this condition.

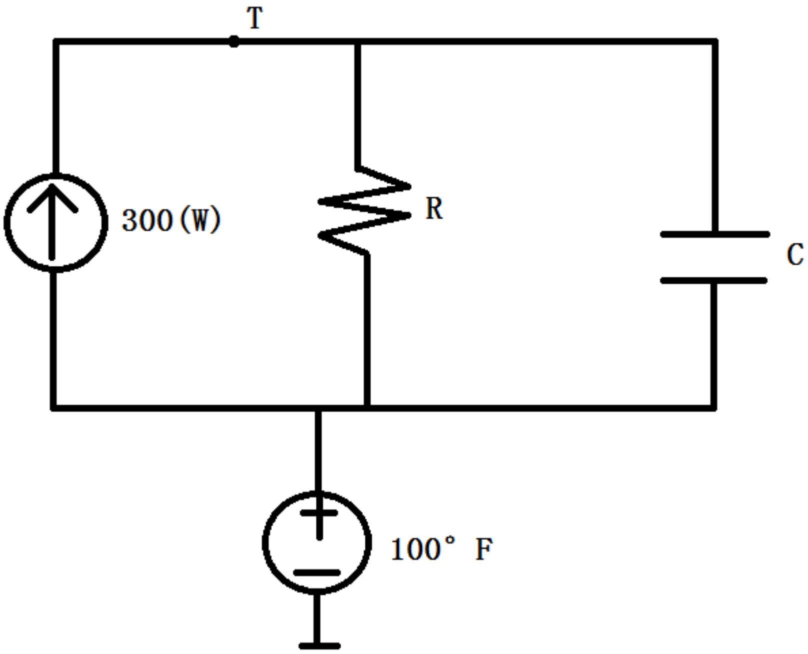


Figure 4.8.3

Form Figure 4.8.4, the average power of air-conditioning is 300W when it turns on-off for every 15minutes.

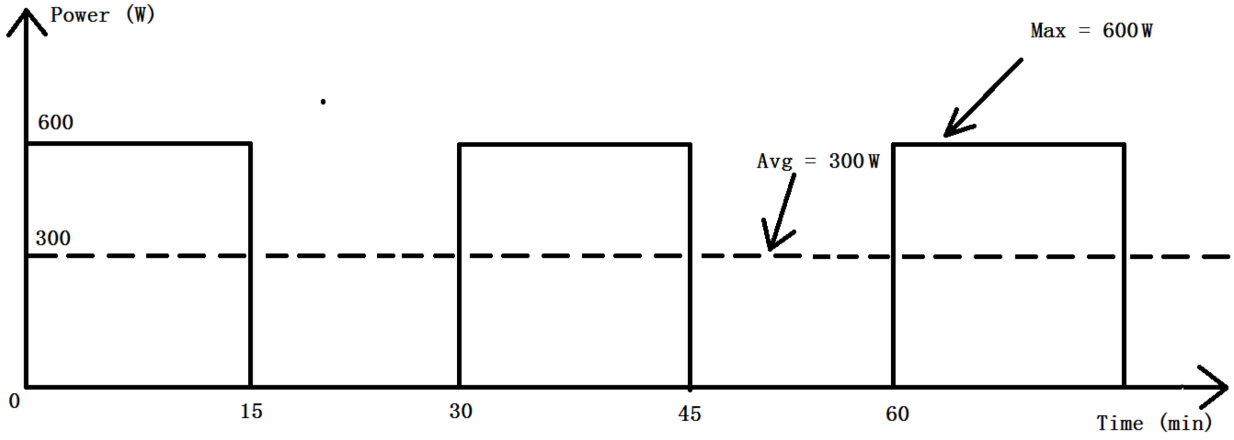


Figure 4.8.4

From equation (3), R could be written as R= Z/C = Z/809

By applying Kirchhoff's voltage law, the directed sum of the voltage around any closed network is zero.

$$T = 100 - 300R$$

$$= 100 - 300 \times (Z/809) \qquad (4)$$

Equation 4 represents the relationship between house insulation constant, indoor temperature and thermal time constant. Mat lab was used to graph corresponding indoor temperature and thermal time constant due to the change of house insulation constant and it is shown in Figure 4.8.5. Table 4.8.1 shows corresponding indoor temperature and thermal time constant due to the change of house insulation constant.

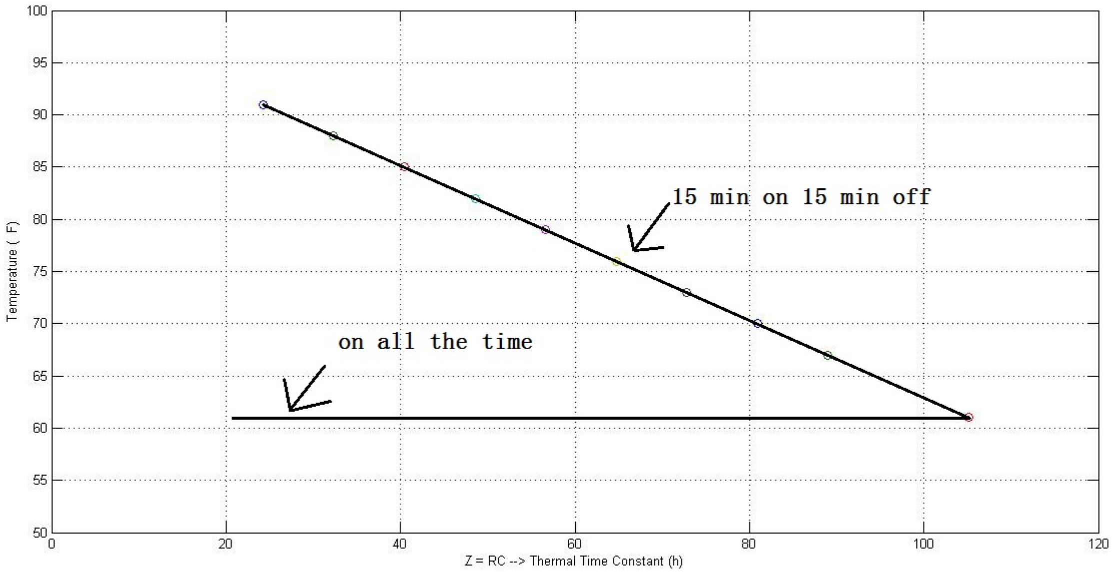
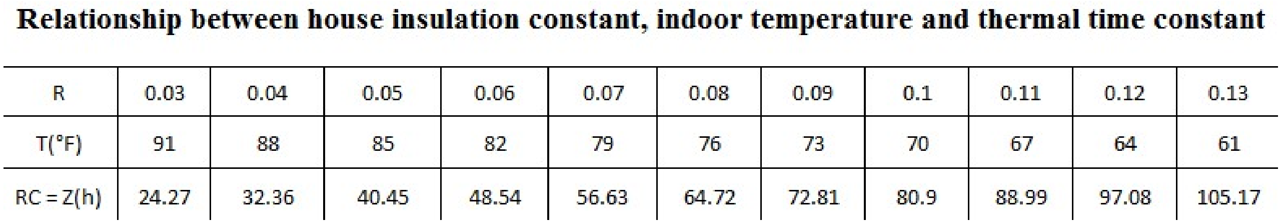


Figure 4.8.5


Relationship between house insulation constant, indoor temperature and thermal time constant

R	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1	0.11	0.12	0.13
T(°F)	91	88	85	82	79	76	73	70	67	64	61
RC = Z(h)	24.27	32.36	40.45	48.54	56.63	64.72	72.81	80.9	88.99	97.08	105.17

Table 4.8.1

From Figure 4.8.5 and Table 4.8.1, it is clear that the house insulation is the key factor to keep the house in a desired temperature. The better house insulation, the higher temperate keeps in indoor and house would also keep warm for longer time.

4.9 Social Implication

From the conclusion calculated above, some social implications could be gotten from here. The house insulation is very important to people’s body comfort than most people’s imagination. Living a house with good thermal insulation, people could definitely enjoy the life—easily cool down the room temperature in summer with less power while keep the room warm during the winter. In this case, people could achieve their psychological comfort with less energy consumption. However, they need to pay price when you took their houses with good insulation walls, which are too expensive to be afforded by ordinary people. Therefore, for those of forks who cannot live in a house with well insulation, they must face the severity of harsh weather. To gain the body comfort, these people have to spend more money on the electric device such as air-conditioners or radiators. Worse more, if they cannot even afford that expenditure, the harsh temperature may become a vital threat to their health and even life. This is why millions of people die each year from suffering extremely hot or cold weather in either tropical areas or polar regions.

Reference

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[2] Erik Newman, Andrew Laflash, and Nicholas Granata-Cappabianca, Atwater Kent Energy Audit and Solar Energy. 2010.

[3] http://www.eia.gov/energyexplained/index.cfm?page=electricity_use

[4] http://blog.opower.com/2012/09/hot-and-heavy-energy-usage-how-the-demand-and-price-for-electricity-skyrocketed-on-a-100-day/

[5] U.S. Energy Information Administration, *Annual Energy Outlook 2012, Early Release*, Table

[6] http://www.wpi.edu/Images/CMS/UGP/Atwater_Kent_Efficiency_Plan.pdf, Table

[7] http://www.buylightfixtures.com/images/view.aspx?productId=842

[8] http://lightinglab.fi/IEAAnnex45/publications/Technical_reports/lighting_in_schools.pdf

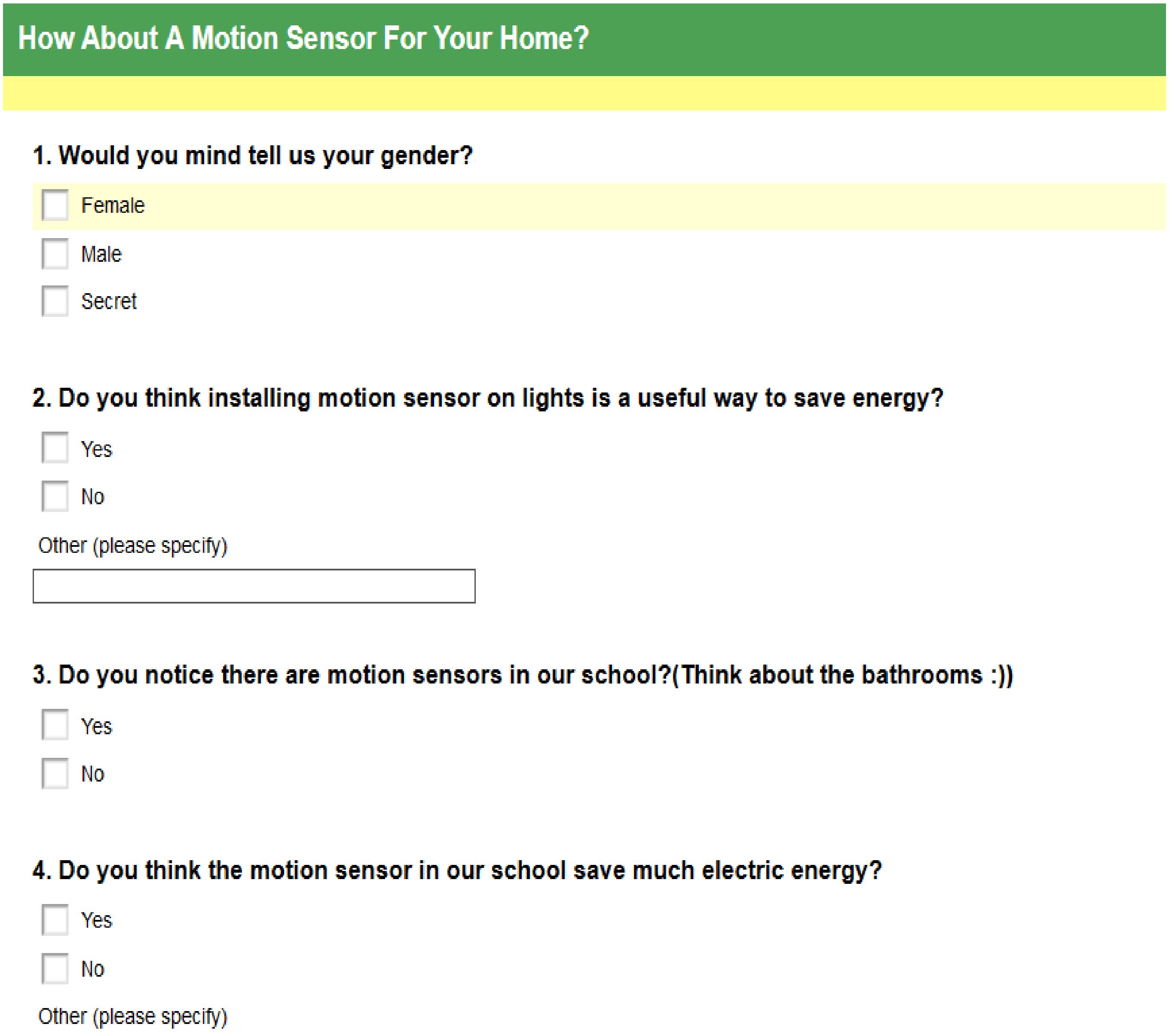
[9] http://www.wpi.edu/Images/CMS/UGP/Atwater_Kent_Efficiency_Plan.pdf

[10] http://www.buylightfixtures.com/images/view.aspx?productId=842

[11] http://lightinglab.fi/IEAAnnex45/publications/Technical_reports/lighting_in_schools.pdf

Appendices

A-1 Survey On Opinions About Installation Motion Sensor In Household



How About A Motion Sensor For Your Home?

1. Would you mind tell us your gender?

☐ Female

☐ Male

☐ Secret

2. Do you think installing motion sensor on lights is a useful way to save energy?

☐ Yes

☐ No

Other (please specify)

3. Do you notice there are motion sensors in our school?(Think about the bathrooms :))

☐ Yes

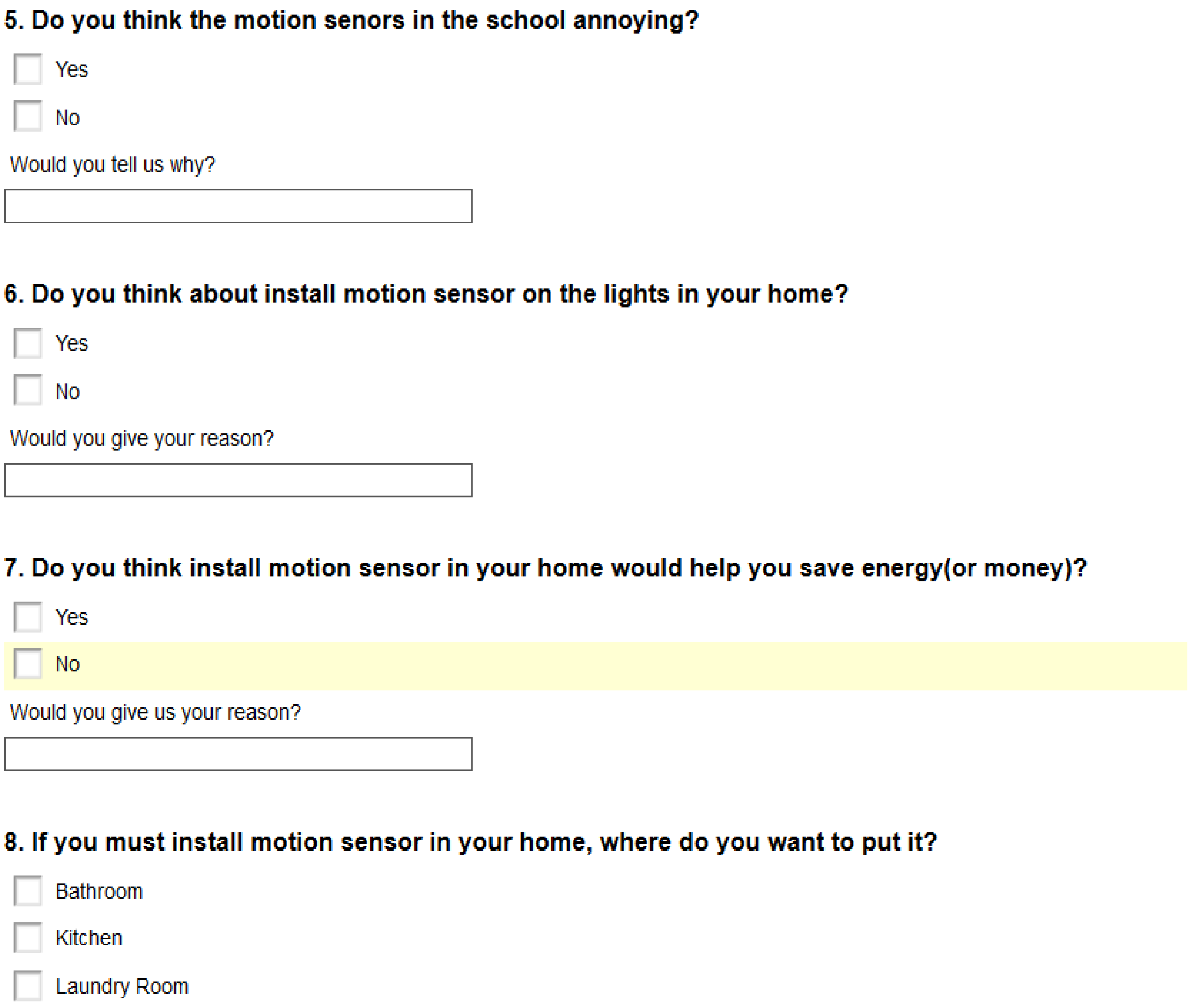
☐ No

4. Do you think the motion sensor in our school save much electric energy?

☐ Yes

☐ No

Other (please specify)



5. Do you think the motion senors in the school annoying?

☐ Yes

☐ No

Would you tell us why?

6. Do you think about install motion sensor on the lights in your home?

☐ Yes

☐ No

Would you give your reason?

7. Do you think install motion sensor in your home would help you save energy(or money)?

☐ Yes

☐ No

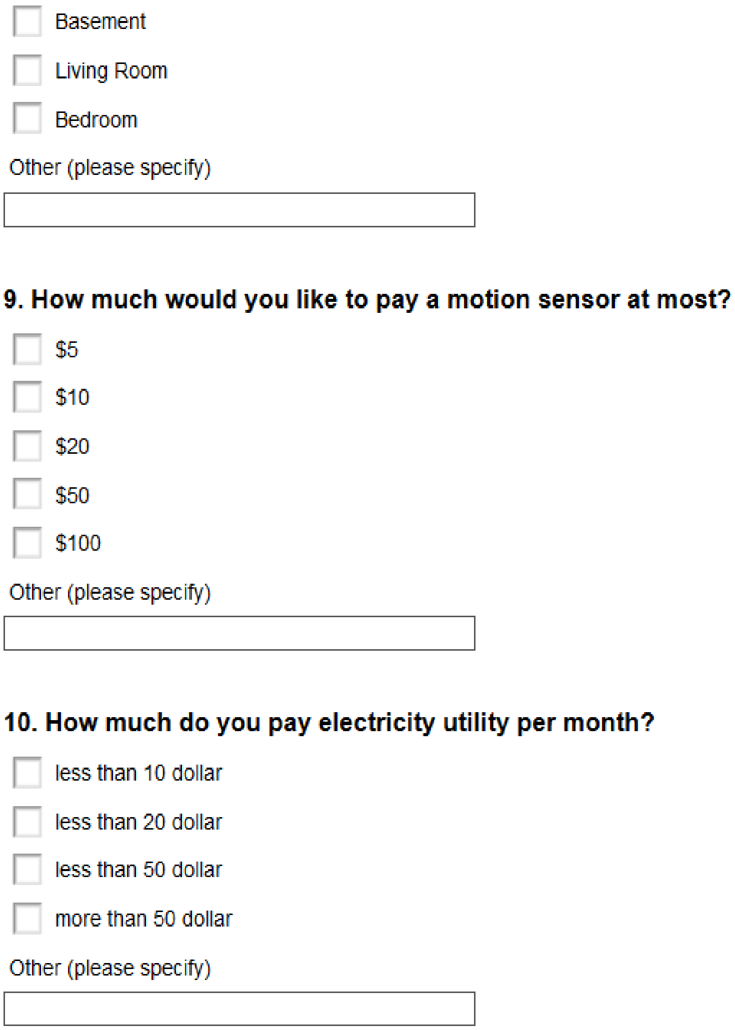
Would you give us your reason?

8. If you must install motion sensor in your home, where do you want to put it?

☐ Bathroom

☐ Kitchen

☐ Laundry Room



☐ Basement

☐ Living Room

☐ Bedroom

Other (please specify)

9. How much would you like to pay a motion sensor at most?

☐ $5

☐ $10

☐ $20

☐ $50

☐ $100

Other (please specify)

10. How much do you pay electricity utility per month?

☐ less than 10 dollar

☐ less than 20 dollar

☐ less than 50 dollar

☐ more than 50 dollar

Other (please specify)

A-2 Survey About Air-conditioning Control Method For International Students

Q1

1. On hot summer days, do you ever feel cold when you are in a classroom with air-conditioning working?

☐ Yes

☐ No

Q2

2. In the same condition described above, do you still feel hot?

● Yes

● No

Q3

3. During summer, do you always let the air-conditioning open when you are home?

● Yes

● No

Q4

4. Do you always leave the air-conditioning on when you are out?

● Yes

● No

Q5

5. Do you always let the air-conditioning on when you are sleeping on summer?

● Yes

● No

Q6

6. What temperature do you usually set for the air-conditioning on summer?

● 50-55°F

● 56-60°F

● 61-65°F

● 66-70°F

● 71-75°F

● 76-80°F

● 81-85°F

● 86-90°F

Other (please specify)

Q7

7. Do you ever used the timing shutdown function of air-conditioning to shut it down automatically after certain duration of time?

● Yes

● No

Could you give the reason for using or not using?

Q8

8. If there is a policy to force every air-conditioning to shut down for 15 minutes after being used the same amount of time, would you back or against this law?

● I would support it

● I would against it

● I don't care

Could you give the reason?

Q9

9. If instead of 15 minutes， you could make a break time for the air-conditioning, how long would it be?

● less than 15 minutes

● less than 30 minutes

● more than 1 hour

Other (please specify)

Q10

10. Do you think intermittent utilization of air-conditioning is a good tradeoff between human comfort and energy saving?

● Yes, It is a good tradeoff method

● No, it is good for energy saving but sacrificing too much comfort

● Absolutely no, due to inefficient energy saving and less comfort

Other (please specify)

A-3 Survey About Air-conditioning Control Method For American Students

Q1

1. On hot summer days, do you ever feel cold when you are in a classroom with air-conditioning working?

☐ Yes

☐ No

Q2

2. In the same condition described above, do you still feel hot?

● Yes

● No

Q3

3. During summer, do you always let the air-conditioning open when you are home?

● Yes

● No

Q4

4. Do you always leave the air-conditioning on when you are out?

● Yes

● No

Q5

5. Do you always let the air-conditioning on when you are sleeping on summer?

● Yes

● No

Q6

6. What temperature do you usually set for the air-conditioning on summer?

● 50-55°F

● 56-60°F

● 61-65°F

● 66-70°F

● 71-75°F

● 76-80°F

● 81-85°F

● 86-90°F

Other (please specify) ☐

Q7

7. Do you ever used the timing shutdown function of air-conditioning to shut it down automatically after certain duration of time?

● Yes

● No

Could you give the reason for using or not using? ☐

Q8

8. If there is a policy to force every air-conditioning to shut down for 15 minutes after being used the same amount of time, would you back or against this law?

● I would support it

● I would against it

● I don't care

Could you give the reason? ☐

Q9

9. If instead of 15 minutes, you could make a break time for the air-conditioning, how long would it be?

● less than 15 minutes

● less than 30 minutes

● more than 1 hour

Other (please specify) ☐

Q10

10. Do you think intermittent utilization of air-conditioning is a good tradeoff between human comfort and energy saving?

● Yes, It is a good tradeoff method

● No, it is good for energy saving but sacrificing too much comfort

● Absolutely no, due to inefficient energy saving and less comfort

Other (please specify) ☐