INTELLIGENT ENERGY SOLUTIONS GROUP

Design Review 3

Team 5

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2007

GLOBAL PRODUCT DEVELOPMENT

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EXECUTIVE SUMMARY

Intelligent Energy Solutions Group is a subsidiary of World Innovative Technologies. The group was formed to focus on creating products which would emphasize sustainability and technological advances. To achieve this aim, the area of energy savings within buildings was explored in depth. As a result, a mixed mode ventilation system was developed.

This system uses the internet to enable the closed loop economy by reducing the load off a heating ventilation air-conditioning system. These energy savings directly translate to significant cost savings for the users. Through simulations in Home Energy Efficient Design and Hourly Analysis Program, it was found that this ventilation system can save on average 37% of the yearly electrical costs.

A prototype was developed in two modules, which could broadly be divided into the mechanical window open/close module and the signal processing module. As expressed by their names, the modules are responsible for opening windows to allow for natural ventilation and cooling, and for receiving and processing an internet signal respectively. The product was designed to be retrofit-able to the most popular window types such as hopper, awning and slider. This retrofit-ability allowed the window to be a platform product, with small variations in support parts between window sizes, types and global markets.

The primary market for this product is California and New York in USA and the secondary market is Germany. These markets were selected because of high energy costs and usage, which directly translate to greater savings derived by using the system. These markets are also acutely aware of the need to save energy and marketing to energy conscious users would increase the acceptance of the product. It was decided to market this product primarily to offices and then to home owners, as larger office spaces lead to greater energy savings. It was calculated that this device would pay for itself in three to five years, after which the user would begin “earning” money. It was estimated conservatively that the life span of the product will be 20 years, during which a user operating in an office space of 600sq.ft with three windows, retrofitted with this device, would enjoy net savings of $4041.

In considering the business feasibility of this product, multiple manufacturing locations were first considered. A software known as Expert Choice 11 was used to determine the best manufacturing location based on: location, infrastructure, tax burdens, labor flexibility, government effectiveness, and access to finance. From the results produced, it was seen that California, which is a state that strongly encourages innovation, would be the best site to build our manufacturing facility. $5 million were therefore allotted in the financial plan to build a facility that produced 15,000 units in a year, allowing us to fulfill a demand of 13,613 units, estimated to be growing at 10% a year for the first five years as is the norm for an entrepreneurial venture in this field. This estimated demand corresponds to a conservative estimate that this innovation will capture 0.5% of the market share. A break even analysis was conducted, and it was found that the venture would breakeven in approximately three years at a product unit price of $450.

This price and the significant energy savings give us a competitive advantage in terms of cost as well as in terms of performance, as devices saving as much as our system cost $50-$150 per square foot., while our device costs only $3.23 per square foot. Our system is also retrofit-able, allowing the user to continue using the system even after changing the windows.

The product will be branded with the acronym RIMMS, which stands for Retrofit-able Intelligent Mixed Mode System. This will be the first retrofit-able product on the market offering significant energy savings at a low cost.

INTRODUCTION

World Innovative Technologies was formed as a multi-national consulting firm with a goal of offering innovative engineering solutions to global markets. The current focus of the company is on creating sustainable eco-friendly technology which enables a closed loop economy with the help of the internet. To meet this goal, an elite design team, known as the Intelligent Energy Solutions Group was created.

Team Members	Competencies
Alok Pradhan	Systems & Controls, CAD Design, Project Management
William Luong	Quality Management, Manufacturing Processes, Project Management
Minh Nguyen	Programming and CAD Design
Kyungdon Baik	CAD Design, Programming, CNC Control
Daehung Lee	Dynamic Analysis Program, CAD Design, Mechanical Design.
Yiran Li	Quality Management, Manufacturing Processes, Project Management

Table 1 - Team Competencies

These competencies will allow the team to create an automated electro-mechanical product that will have strong business marketability and provide high utility to customers by satisfying needs.

NEEDS IDENTIFICATION AND PROBLEM STATEMENT

TOP PROJECT IDEAS

Multiple project ideas aligning with the firm's focus were brainstormed, and narrowed to select the top five: 1. Weather Based Sprinkler System; 2. Automated Cab Identification/Retrieval System; 3. Automated Pet Food Dispenser; 4. Automated Clothesline System; 5. Climate Control System Using Window Ventilation Automation

FINAL CONCEPT

The top project ideas were then evaluated using the following criteria:

- Ease of Realization: How realizable is the product concept? Will the construction be overly difficult?
- Environmental Impact: Will the positive impact of this product on the environment be significant?
- Originality: Are there many existing products today which can provide similar functionality? How high would the barriers to entry be?
- Market Viability: Does a market exist for the product concept? Are there major needs that need to be met in those markets?

As a result of this evaluation method, the final concept chosen from the top project ideas was the Climate Control System Using Window Ventilation Automation.

PROBLEM STATEMENT

Reduce the energy consumed by a heating-ventilation-air-conditioning system within buildings to provide monetary and environmental benefits

INTERNET ENABLED CONTRIBUTION TO CLOSED-LOOP ECONOMY

The major contribution of any closed-loop enabled product is a reduction, reuse, or recycling of materials or energy. The chosen idea was a climate control system that received weather information from the internet, and automated the opening and closing of windows to maintain the temperature of the house or office building at a comfortable level. The internet is used directly in the product to access predictive weather data to increase the efficiency of the system. This directly enables the closed loop economy by significantly saving the electricity consumed to power a heating–ventilation–air-conditioning system (HVAC), by reducing the HVAC load through natural ventilation.

As commercial buildings will be our primary customers we expect that pre-existing internet connectivity will be available. As a result of using the internet, not only will the system save more energy, but the customers will also not need to incur the extra costs of sensors while also reducing system maintenance costs.

MARKET ANALYSIS

TARGET MARKETS

	Primary Market	Secondary Market
Country	United States – New York, California	Germany
Customers	Office/Commercial Building	Office/Commercial Building
Market Size	*1,747,575 Windows	**975,000 Windows

Table 2 - Target Segments (Region)

*Calculations for the market size were based on an assumption that there were 3 windows for a 600 sq. ft. area which equates to 97.97 ft. perimeter, and that building structure was square. In 1995 there were 692,000 office buildings smaller than 10 stories in the United States. Based on building growth statistics (0.2%) it was calculated that in (2007) 708,792 such office buildings would exist. The average office size in the United States is 15,000 sq. ft., which equates to 489.89 ft. of perimeter, resulting in 15 windows per office on average.[i]

**Calculations for the market size were based on an assumption similar to that of the U.S. with the exception that the general employed population had changed to incorporate Germany's current employed population (39,000,000 people).

Both target markets possess the need for the reduction in energy usage due to two primary reasons:

1) Cost – The current living costs within the U.S. states of New York and California as well as within Germany are some of the highest in the world. Energy costs in particular are very high within these regions.
2) Rising Environmental Concern – Within the United States as well as Germany, emissions and the consumption of resources have become a rising concern, creating awareness for sustainable products.

PRIMARY CUSTOMER REQUIREMENTS

1) Reduce energy costs
2) Reduce the consumption of resources
3) Easy installation
4) Small footprint (requires little to no alterations to existing buildings)

PLATFORM PRODUCT ATTRIBUTES

The key components that make our product a global platform product are:

1) Core Elements: Engineering design (1 basic design for all window types and sizes), data retrieval and analysis software, internet signal receiver, processor, motor
2) Non-invariant Elements: Dependent on size of window – screw shaft (3 lengths), encasement, supporting parts, curved link; Dependent on country – mechanical connector between curved link and window

This product has global platform attributes as German awning and hopper windows open inwards into the room while in USA, these window types open outwards. To address these requirements, while keeping one retrofit-able design, an extra mechanical connector ball joint will be used in Germany, which will not be used in USA.

COMPETITORS

On examining the competitors that currently exist in the market space, it has been noted that there are a variety of products which aid in reducing the consumption of resources. For example, new types of windows can provide greater insulation thereby reducing the loss of energy dissipated from buildings.

However, the only direct competitors to our product are mixed mode ventilation systems which rely largely on users to open or close windows themselves in order to save energy. For instance, the Phillip Merrill Environmental Center[ii] utilizes a signaling system in order to notify the occupants of the building to open their windows or close them. This notification only occurs when the facilities manager determines if the outside current temperature, humidity and air flow are optimal (as defined by their own personal analysis techniques), after which he will turn on the signaling devices, located throughout the facility, conveying to employees that it is the time to open and/or close the window.

The differentiating factors of our current product offering are:

- ✓ Software based data analysis will constantly monitor current weather elements (humidity, air flow, temperature etc.), increasing system efficiency by reducing human error
- ✓ Automated opening and closing of window eliminating the required human interaction of competitors, which may lead to increased savings as the system will be active all day
- ✓ Retrofit ability with regards to the automated opening and closing device, allowing for minimal installation requirements and alterations to be made to existing buildings.

PRODUCT ENGINEERING

REQUIREMENT LIST

The requirements that this product would have to meet were identified and broken down into nine sections, which were subsequently studied in detail. These sections defined the types of windows the product would retrofit[iii], the geometric constraints it would satisfy, how it would be positioned, and what it needs to do to maintain safety and security. This list also set the energy, material, signal, assembly and manufacturing requirements. The exact list of requirements is shown in greater detail in Appendix A – Table1.

FUNCTIONAL STRUCTURE

The product functions were separated into three modules, namely the signal processing, the locking/unlocking device and opening/closing device. The signal processing module receives weather information as an input signal along with electricity for power, and utilizing a programmed processor, logically derives an output signal. This signal is then transferred to the locking/unlocking device module which checks whether the window is locked or unlocked, and unlocks it or locks it according to the operation required. Depending on whether the window is being opened or closed, a signal is also sent to intimate to the HVAC system to either turn on or switch off the A/C or heating functions. Once the locking/unlocking module ensures that the window is unlocked, it indicates to opening/closing device to begin opening or closing the window. This module then receives energy from an electrical outlet, to perform the requisite mechanical function. The functional structure is shown in greater detail in Appendix A–Fig.1.

WORKING PRINCIPLES

Multiple working principles were designed for each sub-function within the function structure. The chart of working principles created is shown in Appendix A-Table2. These working principles were combined to create multiple concepts which were subsequently evaluated to choose the best design.

CONCEPT SELECTION

As a first step, when sub-functions had five or more working principles[iv], the working principles were evaluated to select the top two or three choices. Therefore, in the function, Locking and Unlocking Window, under sub-function, Use Mechanical Energy to Unlock Window (see Appendix A-Table2) the five working principles were evaluated based on cost incurred. It was found that the most feasible working principles were to use motor resistance to lock and unlock the window, or to design a system that does not lock the window. In the function Mechanical Opening of Window, under the sub-function Use Mechanical Energy to Open/Close Window, ten working principles were evaluated using a selection chart (see Appendix A-Table4). As a result, three designs were dropped as they could not retrofit to hopper and awning windows that opened to different angles. A binary analysis was then conducted (see Appendix A-Table5) for the remaining seven designs to compare them with each other in terms of ease of manufacturability, based on number of parts in each design, retrofit-ability to different opening angles and sizes of hopper and awning windows, and retrofit-ability to different types of windows. As a result, designs 1, 8 and 9 were the top choices[v]. These were then combined with other working principles to come up with four complete concepts shown in Appendix A-Table3. These concepts were then evaluated in detail, using cost, manufacturability, ergonomics, energy-savings, robustness, retrofit-ability and sealing and locking for security as criteria. This analysis is shown in Appendix A-Table6. Based on this analysis, where these criteria were ranked and used as weights, Design 1 emerged as the best design, with an 87% correspondence with the evaluation criteria. This design has been taken forward and analyzed in detail.

PRODUCT OPERATION

Design1 was then designed in detail, beginning with an exact functional layout of electrical and mechanical components, as show in the Appendix C-Fig.1. The setup for this product would involve bolting it onto the window frame, and removing the existing window linkages to prevent unnecessary energy loss through friction. Once operational, the temperature information, information on weather conditions such as rain and snow as well as warnings in the case of storms and tornadoes will be received as an input to the internet ready kit, along with the information whether the window is completely closed or completely open. This information will then be processed based on an algorithm, which will incorporate not only the data mentioned above, but also immediate future forecast, and the energy feasibility analysis to maintain high overall system efficiency. This is explained in detail in the next section.

The output to either close or open the window will be sent through the appropriate photo-coupler to the motor driver. The motor driver, which is used to increase efficiency, will in turn rotate the motor in the requisite direction. The motor is connected to the window through a mechanical linkage which will facilitate the opening or closing of the window. The final position of the window will be noted using two photo-couplers and returned to the processor on the internet kit, to be used as in initial condition in the future. Please note that an AC to DC converter, also known as an electric transformer, is used to enable the use of the local power source to operate the motor by converting the 110/220Volt alternating current to a 24Volt direct current.

The device will also allow a user to manually override the system by pushing a button to open and close the window to increase user comfort. In case of the loss of the internet signal, the device will run based on the latest data that it has stored button will allow the user to control the device at their discretion. The override button will also allow the user to operate the window if the internet signal gets cut and is therefore a security measure. When the window is closed, the window will be locked in place by the mechanical action, as the device has been designed to lock when the window is not being actuated by the motor.

CONTROL ALGORITHM

The logic algorithm used to control the product is shown in detail in the form of a flow chart in Appendix C-Fig.4. The algorithm highlights the use of internet throughout the process of calculating when to open or close the window, by using the predictive data for greater efficiency. The two main logic questions answered in the flow chart are:

a) When should the window open and switch off the HVAC system?
   A device, which is referred to as an internet kit i.e. it combines an internet signal receiver and processor, is used to receive information from a weather website. This information includes both current and predictive weather data for the next one hour. The inside room temperature is checked through the HVAC control unit following which it is checked whether the user has used the window override mode. If the override mode has been used in during office hours, the window will follow the override till the end of office hours. After office hours, this override will last a certain specified time, as pre-defined by the office manager. The system will allow override for individual windows the system of multiple windows. Following this the current outside temperature is checked through the internet, and if it is in range, the predictive temperature in the next one hour is checked. If the predictive temperature is significantly outside the temperature range, then the window will not open. If it is in the comfortable range, and therefore the window can be opened for a significant period of time, it is checked through the internet whether it is currently raining or stormy or if there will be adverse weather in the next one hour. If so, the window will not be opened. If the weather is good, and predicted to remain good in the short run, the window will be opened and a signal will be sent to turn the HVAC system off. In certain cases, the ventilation portion of the HVAC system will be run at a reduced load and not completely shut off, depending on wind velocity data obtained from the internet, as well as the building ventilation efficiency.
b) When should the window close and switch on the HVAC system?
   If the current room temperature is greater or less than the requisite room temperature comfortable range set by the user, and the temperature outside is outside the comfortable range, the window will be closed. However, if the outside temperature is nearly at the temperature set by the user and the room is not in the comfortable range, the window will be opened and the HVAC system will be turned on simultaneously to reduce the cooling/heating load off the HVAC. In this case, the window will not be closed if it is already opened.

CAD MODEL

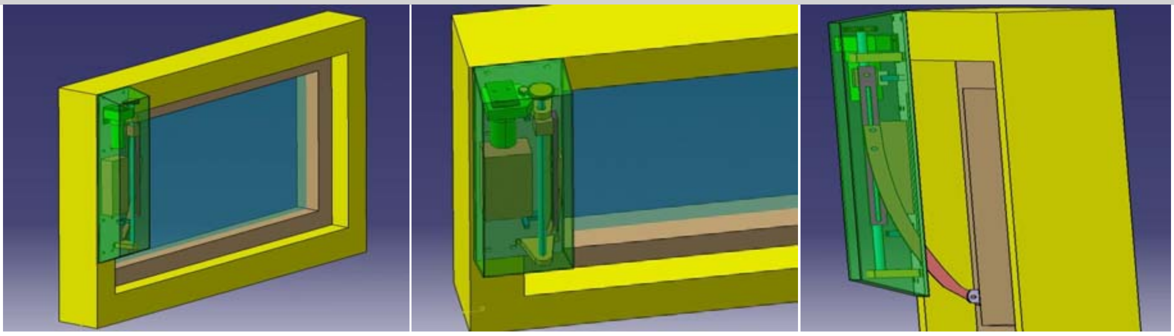


Figure 1 - Detailed CAD Model

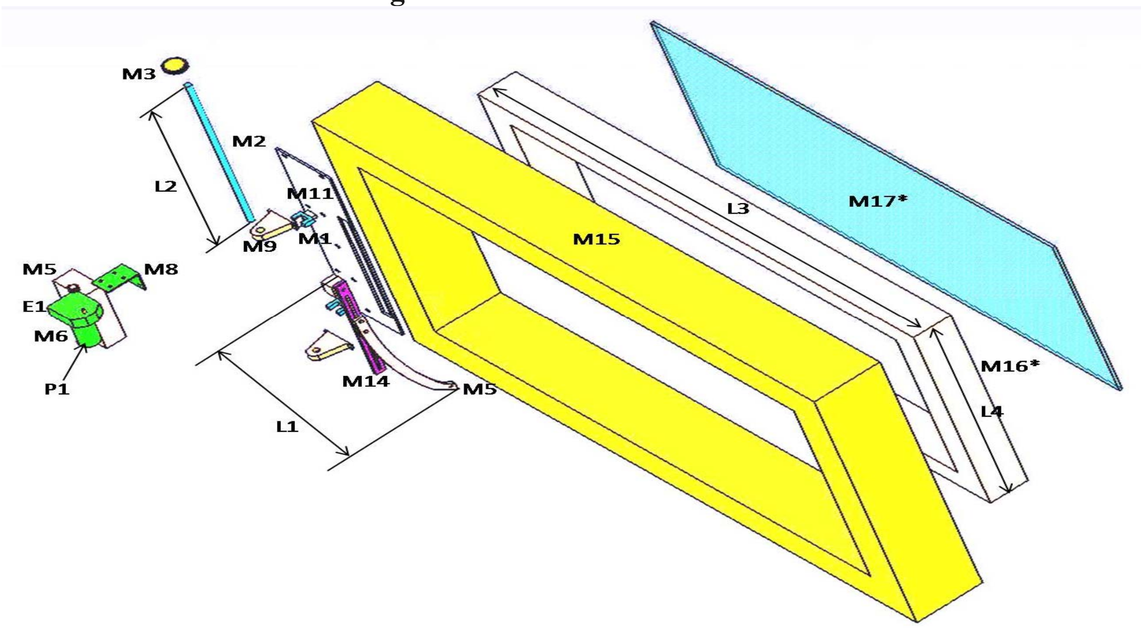


Figure 2 - Exploded View with Parts Referenced to Bill of Materials

In Figure 3, above, M refers to the Mechanical Parts section within the bill of materials (Appendix C–Table1) while E refers to the Electrical Parts section. The numbers appearing in the figure correspond with those in the Bill of Materials. It should be noted that bolts and nuts (M7), joint support parts (M10), and cover (M13) were ignored in the exploded view, because including them would have obscured the major components. Parts E2 through E6 are not shown in this design as they are electronically connected and will form a separate box shaped module with involving no mechanical design. M15 and M16 are window frame components that are not included in the parts list, but are shown in the CAD drawings to better demonstrate the product.

PRODUCT LIFE CYCLE ANALYSIS

The life of the product was analyzed to evaluate the lifetime of the product and to calculate the overall costs of this product over its entire lifetime. This is shown in detail in Appendix C-Table.2. It can be seen that this product has a minimum life span of 20 years, but certain parts will need to be replaced after 5 years, and others after 10 years. The parts replaced after 5 years are: revolute joint, screw shaft, screw bolt, and gear pairs. The parts that will need to be replaced after 10 years include the gear motor, cover, and most electrical parts. The internet kit i.e. the signal receiver and processor will need to be serviced. The cost of replacing these parts for one product module in an office, over a 20 year life span is $131, while the cost of replacing and servicing electrical parts will be spread across multiple modules being used. Therefore, for an average office the cost per module of replacing electrical parts is $4.4, while in an average home, it will be $22 per module.

After the life of the parts, the PVC cover will be recycled, along with the aluminum curved link. The joints, gears and motor will be sold to allow reuse, while the support parts like bolts and nuts will be scrapped for recycling. The return on investment for customers takes into account these maintenance costs. It is seen that over its 20 year lifespan, this system of 3 modules for an average apartment or office space, the user will spend $1809 buying and maintaining the system, while the user will save $5850 in energy costs. Thus the user will save $4041 over the life span of the product.

ENGINEERING DESIGN FEASIBILITY

This CAD model was then imported into ADAMS whereby an analysis of the dynamics of the design was conducted by simulating its motion. In this simulation, the size of the window was varied four times as the design is to retrofit as many sizes of windows as possible; the dimensions for the window variations were derived from the requirements list, and in one case from probable prototype dimensions.

In these simulations, the major components mentioned in the previous section, namely the screw shaft, curved link and the motor were analyzed in depth. The varying dimensions of the screw shaft, and the curved link were obtained, along with the maximum motor power required for opening and closing and the window. The energy utilized in the opening and closing the window was also obtained.

To maintain a size for the device that is consistent with our wish that the device should be unobtrusive, the screw shaft length was limited to 500mm, thus limiting the maximum window area to 1200mm by 900mm. The diameter and length obtained for the screw shaft in each simulation were found to be feasible physically, as the values ranged from 9mm to 16mm and 340mm to 500mm respectively. Such shafts, with a pitch of 1mm, as simulated, were available for $6 to $10 from McMaster-Carr, one of our possible suppliers.

The data from the curved link was used to conduct a finite element analysis to check the stress in the link and appropriately select a suitable material. As a result, it was found that aluminum (Al-356) link with the thicknesses specified in Appendix C-Fig.2 would be substantially strong[vi]. In the worst case of the largest force on the largest link, the maximum stress in the curved link was 16.82MPa, while the yield strength of aluminum is 152MPa. Thus the curved link will not yield or deform plastically under the loads exerted on it. This allows for the requisite safety and durability. Such linkages will have to be custom-made for our company. However, the curved link consists of two smaller links which can be adjusted to retrofit any window dimension (See Appendix C-Fig.3), and the curvature of the link is the same for all window types[vii]. As a result, there will only be one dye required and sourcing this part from an aluminum dye casting firm, will prove cost effective.

It was found that the maximum motor power required to open the largest window will be satisfied by motors available from suppliers, at prices well below $80. This keeps the total cost of parts within a reasonable range (i.e. below $300). All the components in the design will be made out of non-corrosive or corrosion resistance materials, making this system less prone to water leaks. The recycled plastic wood cover should prevent majority of the parts from weather related damages and vents in the plastic cover will ensure that this system does not overheat. As the product is designed to be placed inside the room to prevent weather related damage in the first place, this design will be durable.

It was decided that this product will be marketed in three sizes, to prevent wastage of material, improve efficiency in saving energy (see Figures for power required and energy consumed in Appendix C-Fig.2), reduce cost and keep the product as unobtrusive as possible.

Product Size 1: 600mm*600mm ≤ window size ≤ 700mm*500mm
Product Size 2: 700mm*500mm < window size ≤ 900mm*700mm
Product Size 3: 900mm*700mm < window size ≤ 1200mm*900mm

As can be logically concluded from the simulations, between each range there is a reasonable step size, which will keep product size overlap at a minimum.

PRODUCT ENERGY SAVINGS FEASIBILITY AND BENEFITS

Two software packages called Home Energy Efficient Design (HEED) and Hourly Analysis Program (HAP) were used to simulate the savings obtained by using our product (see Appendix D for greater detail on these software packages). These simulations were conducted to calculate the energy savings from the device using which the device feasibility was checked from both an engineering and monetary perspective. The energy consumed with and without our system was calculated for a 600sq.ft room with three windows. This was the size assumed for an average apartment home. It should be noted that this is the worst case scenario in terms of energy savings as the load reduction from the HVAC system is larger in offices spaces. An average office space was assumed to be 15,000sq.ft with 6 windows, offering greater energy savings. This simulation was run for five cities by varying the window size twice in each case. The first window size considered was 609.6mm x 609.6mm and the second size was 1798mm x 2194.5 mm. Three rates of ventilation were also considered for each city and window size, and are defined as High (20.0 air-changes/hour), Good (5.0 air-changes/hour) and Minimum (1.0 air-changes/hour) as per civil engineering standards (see Appendix D for greater detail on simulation settings). These results were then interpolated to calculate the energy saved in one hour by using our device in the three sizes we intend to sell this device in i.e. Type A, B and C. This was then compared to the energy consumed by the device in one complete open and close operation (as seen in Appendix D-Table 2) to obtain the exact time the window would need to remain open, to overcome the energy lost from opening the window to begin saving energy. This stems from the logic that to remain feasible and save significant amount of energy, the window has a maximum number of times it can be opened per day. While this number is fairly high, it varies by month, as energy savings vary by month, and therefore this limit needs to be checked. It was found that in the worst case scenario of low energy savings and accounting for energy dissipation through mechanical friction and electrical inefficiency by applying a factor of safety of two, the window needs to be open for 1 minute 42 seconds to begin saving energy.

The exact monetary benefit of the system in a 600sq ft. office room or apartment, with three windows was also calculated for two window sizes. For example, in New York, the energy cost of air-conditioning system is $801.23 as defined in HEED. If our devices are used for 609.6mm x 609.6mm windows, then we can save

- High Nature Ventilation, we can save $801.23-$472.46=$328.77/year
- Good Nature Ventilation, we can save $801.23-$508.52=$292.71/year
- Minimum Nature Ventilation, we can save $801.23-$534.64=$266.59/year

Therefore the average energy savings with are ($328.77+$292.71+$266.59)/3=$296.02/year

For 1798mm x 2194.5 mm windows, we can save:

- High nature Ventilation, we can save $801.23-$493.09=$308.14/year

- Good Nature Ventilation, we can save $801.23-$508.52=$292.71/year
- Minimum Nature Ventilation, we can save $801.23-$534.64=$266.59/year

Therefore the average energy savings are ($308.14+$292.71+$266.59)/3=$289.15/year
Combining this data, to accommodate varying window sizes, we calculate the average saving ($296.02+$289.15)/2=$292.59/year. This equates to about 37% energy savings per year when using our system. Similarly, the yearly cost benefit of using our system in other cities is shown below.

	Los Angeles	New York	Munich	Milan	Beijing
Energy Saving Per Year (US Dollar)	302.23	292.59	222.51	281.05	156.79

Table1. Yearly Cost Benefits of using our system

Through numerous calculations, the potential impact that this product will have on our target market was determined. This is explained in greater detail in Appendix D for New York.
It was calculated that in New York alone:

- We can potentially generate savings of over $17 million per year in the state of New York alone
- We can reduce electricity consumption by 1,191,062,123KWH per year in New York
- We can reduce CO_2 consumption by over 1 million tons per year

It should be noted, that due to the high savings that can be generated in Milan, Italy will be considered as a future market. However, due to team knowledge and competency with regard to marketing and catering to the German market, Germany presents a strong secondary market.

CRITICAL ELEMENTS OF DESIGN

Retrofit-ability

This product is designed to retrofit to hopper, awning, casement, sliding as well as double hung window types, as shown below in the Figure4 and for window sizes between 600mm*600mm and 1200mm*900mm. This retrofit-ability will allow the marketplace to easily adopt this technology, by not requiring the user to completely change windows. It will also draw a large customer base, as it is not limited to one window type or size. The retrofitting design also allows the customer to continue using the product even if they change windows, which increases the benefits received and the perceived value of the product. Retrofit ability is deeply ingrained in the design process, and the cost incurred to make this design retrofit, can largely be associated with design fees. The groove in the curved link, varying screw-shaft lengths, an extra ball joint, outer case sizes do result in an increase in variable cost to produce the device, but the benefit they provide our company in terms of marketability will allow us to generate far greater revenues. As a result of retrofit-ability of the product the financial prospects of the company remain sound (See Appendix B). The retrofit-ability also makes this product a global platform product, as one device can fit numerous types of windows in both our primary and secondary market, with minor changes. This allows the company to present the product under one image and banner, decreasing advertising costs and increasing brand value.

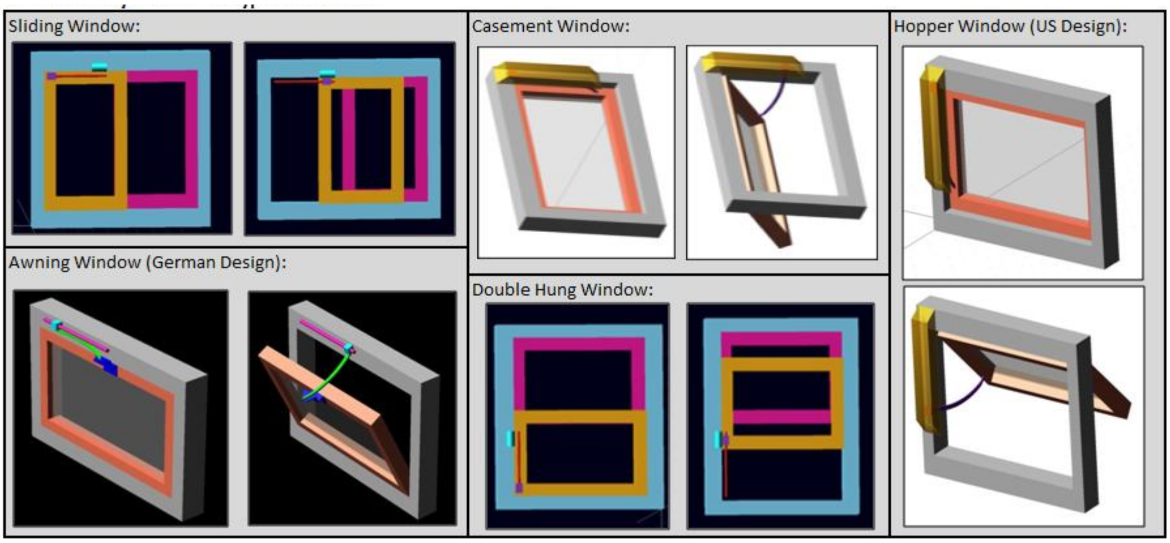


Figure 3 - Retrofit-ability to Different Types of Windows

Internet Enabled Closed Loop

The product uses the internet to enable closed loop savings. As both office buildings as well as most homes, in New York, California and Germany will have the internet, our customers will incur no additional costs, while receiving benefits from saving the additional costs that multiple sensors would add to the product. Not only will using sensors to detect snowfall, temperature, humidity and other weather conditions be expensive, they will be harder to maintain, essentially decreasing the life of the product. Since the product will be based on opening and closing in a range of temperatures exact temperature data is not required. The internet also allows the device to be alert to tornado or storm warnings, allowing the product to react intelligently and safeguard users; and it provides future predictive weather data from more advanced sources, which will be used in the programming logic to decide when it is best to open windows, to allow them to be kept open for a longest possible periods of time. Therefore the internet is used to impact the closed loop economy, which keeps product cost low, increases product intelligence, and as proved before, generates substantial energy savings at a lower cost compared to most other products available in the marketplace. The exact cost benefit per unit of the product gained by utilizing the internet is the total cost of sensor installation, which is shown below and additional upkeep and maintenance costs. As can be seen below, there is a substantial cost advantage gained by utilizing the internet.

Temperature Sensor	$69.93[viii]
Rain Sensor	$29.09[ix]
Wind Sensor	$26.95[x]
Barometric Sensor	$45.00[xi]
Total	$170.97

PRODUCT MANUFACTURING

BILL OF MATERIALS

A detailed list of parts was compiled after breaking down the mechanical and electrical design of the product. It was seen that this design required twenty one variegated components (see Appendix C-Table1). The figure below shows all the components along with how they fit into the compact design of the product:

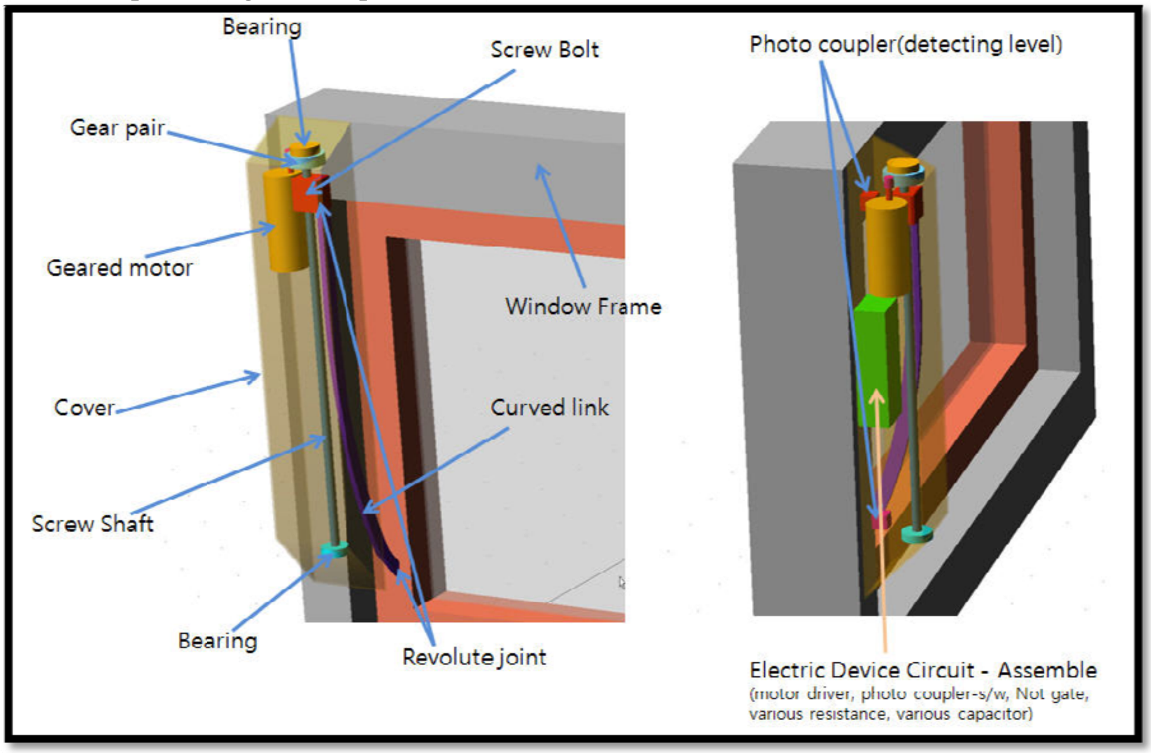


Figure4 – Assembly of Parts

The major components of product, namely those that primarily influenced the highest weighted concept selection criteria such as retrofit-ability, energy savings and cost were analyzed in greater detail. Through this detailed analysis of the screw shaft, the curved link, and the motor shown in Appendix C-Fig.2, exact dimensions were obtained for the length and diameter of the screw shaft, the length and width of the curved link and the maximum power consumed by the motor. The detailed analysis highlights the feasibility of the engineering design and is covered in greater depth in the next section.

All the other parts, were also dimensioned when required, and were assigned appropriate material properties. As an original equipment manufacturer, it makes most economic sense to buy as many parts from suppliers who enjoy, and can therefore pass on benefits of economies of scale and scope through specialized manufacturing of various components. As a result of all components being available in the marketplace, in one case, made to order, it was decided that all parts for this product will be purchased. A detailed parts list of all components, their material properties, source of purchase, specification, part number and cost is shown in Appendix C-Table1. The parts are separated into mechanical and electrical parts based on two modules that will create the entire product, one module which is largely mechanical and the other which provides electrical support. It was found, based on the parts required, that the estimated total cost of materials for this product would be $245, with the largest component of the costs attributable to the gear motor at $37.42 a piece.

MANUFACTURING LOCATION

A software known as Expert Choice 11 was used to determine the best manufacturing location. Initially 4 locations were chosen for potential production facilities: Dalia (China), Mumbai (India), Birmingham (UK), and Los Angeles (USA). These initial locations were chosen due to factors such as proximity to customers as well as labor costs. Each location was then analyzed based on: location, infrastructure, tax burdens, labor flexibility, government effectiveness, and access to finance.

From the results produced, it was seen that California, which is a state that strongly encourages innovation, would be the best site to build our manufacturing facility. A production facility in Dalian would be a suitable alternative if parts prices obtained are substantially cheaper in China than in the United States. The distribution strategy is explained in greater detail in the business plan.

PROTOTYPE

The prototype was manufactured in two separate modules. The mechanical module was fabricated in South Korea as the team possesses both the manufacturing skill and facilities required to produce this module in Seoul. The mechanical module consists of the window open/close and lock/unlock sub-functions as seen in the function structure. In Germany, the signal processing module, which corresponds to the signal processing sub-function, will be created as the team strengths in Berlin include mechatronics and programming. This module is also fragile, and therefore will be created in the location where the final prototype will be demonstrated to prevent damage during transit.

Mechanical Module: To demonstrate the functionality of the product, each of the mechanical parts used in the product is used in the prototype. The prototype is scaled to 1:1.45 (with respect to size of Type A) due to budget constraints. However, the prototype will be manufactured to the exact scaled engineering specifications of the product to demonstrate the complete functionality, detailed design and ergonomics. The method of manufacturing of certain mechanical parts in the prototype will vary from the product. The mode of obtaining each part for the prototype and the various manufacturing methods utilized are shown in detail in the Bill of Materials in Appendix C-Table1. The case of our prototype will be manufactured from Plexiglas to better demonstrate the functioning of the internal machinery, as opposed to PVC in the real product. All the other materials utilized in the prototype are exactly the same as the ones incorporated in the real product. A window frame will also be constructed to demonstrate how the product will fit to a real window frame. This frame will be made from aluminum and will not be a part of the product.

Signal Processing Module: This module involves complicated programming logic and the budget accounts for outsourcing the precise development of this module (see Appendix B-Table 1). In the case of the prototype, the interactivity with the HVAC system of buildings will be displayed through an LED on the internet kit. For demonstration purposes, a laptop is used to highlight product functioning, which will not be required by the product. Majority of the processing for this module is done on the laptop. However, in the product, the internet kit will be utilized with a stronger processor.

The current and predictive weather data is simulated using QT programming and creating a graphical user interface. This data is not mined from internet sources, for two reasons. Firstly, simulation allows for the demonstration of product functionality in various weather scenarios. The real weather forecasts that would have been mined by the product would not change significantly during the period of prototype demonstration. Secondly, budget constraints for prototype manufacturing do not allow us to incorporate this in the prototype. However, the cost of data mining software and licenses utilized to obtain requisite predictive data from the internet is listed in the financial statement in Appendix B-Table1.

BUSINESS PLAN

DISTRIBUTION STRATEGY

We have determined that due to the significant energy and cost savings in the long term that will be provided to the customer, direct sales channels are the best distribution method. These benefits will be better explained by a sales force maintained by the company that is well versed with the product and can demonstrate how it can be adapted to existing HVAC systems that our potential customers will possess. This sales force will also be responsible for overseeing the installation of the device as well as trouble shooting. The cost for the direct sales force can be justified by the fact that large corporations or building complexes will require this product in bulk and as a result, a large percentage of our sales will occur in chunks. The company will maintain eight technical-sales representatives as staff, at the cost of $400,000 per year totally. Installation support will be outsourced to companies that can provide reliable local manpower. $200,000 has been allocated for these outsourcing contracts.

A company website will be established for home users and small businesses. Second parties and indirect sales channels like retailers will not be used to allow us to clearly communicate the corporate image, product quality and functionality. In the future, once brand image and equity is established, it is possible that secondary distribution channels will be used.

There will be one manufacturing plant built in California, which will supply the worldwide demand for the product. This plant has an estimated cost of $5 million and will produce 15,000 pieces a year. As we expect to sell a larger number of units in the US than in Germany, basing the manufacturing location in the US, near the primary market reduces overall distribution costs. As the company expands into newer markets, Dalian in China will be considered as a potential manufacturing location. Export duties and costs that will result have been taken into consideration in the product pricing.

FINANCIAL STRUCTURE: PRODUCT PRICING & SALES VOLUME

Based on market research it was determined that the average cost of a mixed-mode ventilation device to be $50 – $150 per square meter.[xii] Our product is able generate energy savings that are comparable to these existing ventilation devices.[xiii] Additionally, our product also provides automation to the windows and is also retrofit-able, reducing the cost incurred by the customer during installation. These attributes will provide the needed customer satisfaction and needs fulfillment to warrant the purchase of our product if the product is priced in a comparable range.

After taking into consideration the needs of the customer and the product attributes, the costs to be incurred by our firm were calculated to determine profitability of the venture, as shown in Appendix B-Table1. An income statement and a statement of predicted cash flow was created, and is shown in detail in Appendix B-Tables 2 and 3. It was estimated that in the first year, we will capture 0.5% of the market in California, New York as well as Germany. This estimate is extremely conservative to ensure the profitability of the entire operation while bearing in mind that this is a market segment is in a nascent stage. A growth rate of 10% for the first five years of operation, and 4% in the following period is assumed. This is consistent with the growth rate for small entrepreneurial ventures in the energy sector. Therefore, we expect to sell 13,613 units in the first year.

After calculating fixed costs and variable costs in detail, incorporating the tax rate and the cost of capital, the sales price per device was set to ensure financial viability of the venture. Thus, the product will be priced at $450, which will allow our firm to break even in 2.5 years. Therefore, an average office space will incur a total cost of $6750 to equip their space with this device, while an average homeowner will spend $1350. After adding in maintenance costs, it will take between 3.8 to 5.5 years for an average office to recoup these costs while an average home owner will recoup costs in 3.2 to 4.5 years. This difference in time arises due to varying electricity costs in different regions, as higher the electricity costs, greater the savings. To be consistent with the cohesive multi-national image of our company, the price of the device will not be varied across continents despite export costs and slight increase in manufacturing costs that will be incurred.

MARKETING STRATEGY

The product strengths and weaknesses were analyzed. It was seen that our product was comparatively low-cost than our direct competitors, was easy to install as it was retrofit-able, and was reliable due to the lack of sensors. The only real weakness was that certain systems that are currently being incorporated in buildings which involve completely replacing and restructuring HVAC systems can generate greater savings than our system. While these systems will not encroach on our primary market of existing buildings, they will impact new buildings. As a result, it was decided that we will form a strategic alliance with firms like Rocky Mountain Institute, to incorporate our devices in their overall remodeling in the HVAC systems for new buildings.

The strategic position of our product relative to our direct and indirect competitors in terms of energy savings and product price is shown in a positioning matrix in Appendix B-Fig.2. This product will be positioned as a low cost alternative to current energy saving methods, with the competitive advantage arising from the unique position in terms of significant energy savings at low cost.

As people get more conscious to energy savings, the threat of negative user perception of technology change is negated. This is one of the primary reasons why we have chosen California, New York and Germany, as our markets. These are areas of high awareness of the environmental and monetary benefits generated by saving energy.

There will be a change in the marketing strategy between the two countries due to the fact that in the USA, home owners and apartment owners consume more energy due to a lack of existing energy savings methods. As a result, we believe that this product will be more popular with our secondary target users i.e. home owners, in the USA than in Germany. Therefore, initially, the product will be launched in both countries for business users, but only in USA for home owners. Based on the feedback received by the firm from home owners, further marketing strategies will be developed for the more mature German energy savings market for home owners.

Since this is a nascent market, especially in the USA, and this is a novel product, the primary advertising channel will be a pilot project with a corporate partner, possibly our parent company. There will also be some advertising through print media targeted at businesses like Fortune or CFO magazines.

PROJECT SUMMARY

The objective that was first given to Team 5 was to create and internet enabled closed loop economy project. There was then a brainstorming phase where the group discussed possible needs which could be satisfied through and internet enabled close loop product and then product concepts were then tied to those identified needs.

A preliminary evaluation of the concepts and needs, which were produced from group discussion, was done by the supervising professors of the course. After recommendations of possible flaws or benefits of certain ideas were pointed out by the faculty, the group dismissed to choose a final product concept.

With the final product concept chosen, the group then proceeded to a brainstorming session in order to produce product designs. This was enhanced by a working principles formulation which aided in producing various product concept designs. The group convened discussing the strengths and weaknesses of various designs (incorporating such attributes as retrofit-ability) into the final decision process. When a final product design was chosen the group discussed the various modules that would be required by such a design. Taking into consideration the elements of the design, both mechanical and technical, and the core competencies of each member, the modules were dispersed to various members of the group for completion. Continuous updates were provided from of the members weekly in order to maintain a reasonable completion deadline.

At the final face to face meeting of the group, we constructed the presentation materials for the final exhibition and display of the final product as well as prepared the prototype for display. Because the group had constructed their individual modules separately for the prototype, the final integration of the device was completed during the final face to face meeting.

The final product created is called the Retrofit-able Intelligent Mixed Mode System. It combines a device which automatically opens/closes windows with the internet connectivity of an internet kit and a processor which performs calculations needed in order to determine when to turn on/off the internal HVAC system and open/close the windows for ventilation and cooling. The internet is used in order to pull data with regards to the outside environmental conditions, which is then used to determine whether or not to open/close the windows and turn on/off the HVAC system. Without the internet connectivity that retrieves the needed weather and meteorological data, savings would not be obtained due to the fact that opening and closing the windows require a certain amount of energy. If opened and closed too many times or at inopportune times, energy would be wasted instead of being saved.

The closed loop aspect of the product is the fact that RIMMS dramatically reduces the energy consumed (up to 37%) by using the HVAC system all the time and not utilizing the ventilation which could be provided by the outside environment at certain times.

LESSONS LEARNED

The original project objectives were to create an internet-enabled closed loop economy product on the global product/system space. The product that was finally realized satisfied both objectives. Through careful planning and several phases of analysis and brainstorming, we were able to successfully create an internet enabled closed loop economy product.

Many lessons learned during this whole product production process were that communication is truly the basis for all obstacles within any global product development group. Many of the problems that arose during our time together stemmed from the fact that language barriers slowed down the problem solving process as well as the manufacturing process. In order to overcome these obstacles, the group needed to carefully think of ways to communicate through irregular methods. For example by slowing down our normal speed of talking we were able to communicate more effectively, however this slowed down the process as a whole. It is important to understand that there will be misunderstandings and slowdowns during this Global Product Development course however all teams must put aside differences and preconceived notions of each other and focus on the goal at hand.

It is also important to know the best possible methods for communication. In Team 5's case, Skype represented the best method for long distance communication due to the fact that every member of the team possessed some knowledge of the program. Other instant messaging programs were only known by a select few. Email was also an important vehicle for communication due to the time differences between each country. Through the use of the email we were able to continuously chain our efforts. While those from Korea were sleeping, those from Germany and Korea continued to work and vice versa.

APPENDIX

APPENDIX A – PRODUCT ENGINEERING: CONCEPT CREATION AND SELECTION

Table1. Requirements List

Demand (D)/ Wish (W)	Requirements
	RETROFITTING
D	The device will fir Awning/Hopper window types which are identified as the dominant designs in offices
	Attention: Hopper window that is bottom-hung, opened towards the inside of the room is dominant in Germany; Awning window that is top-hung, opened outwards, is the dominant in Korea and USA
W	The device will fit Sliding, Casement and Double Hung windows
	GEOMETRY
W	Fit to maximum range of windows with following geometries*:
	Width = from 600mm to 1800mm; Height = from 600mm to 2200mm; Maximal Length = 2500 mm (< 2640mm)
	Thickness = Typical: from 45mm to 120 mm
	POSITION
D	To support ease of installation, maintenance and to protect the device from extreme weather condition, to avoid weatherproofing costs, the device must be positioned inside the room
W	Make device blend in with surroundings i.e. position to reduce visibility
	SAFETY& SECURITY
D	For safety and security reason, make device only open the window to a limited degree/angle, defined by the windows linkage system.
D	Incorporate a locking and unlocking mechnism for the window
	ERGONOMICS
D	To allow humans to open and close window according to their desire, there will also be a manual override. This override function will be easy to use
W	The device will not interfere with humans i.e. will not be noisy or conspicious
	ENERGY
W	Energy consumption in the opening and closing needs to be minimal, as the primary goal is to conserve energy. The device should use solar energy or alternative energy forms if possible, to conserve energy.
	MATERIAL
D	The device shoud be cost effective and durable.
W	The device should be recyclable
	SIGNAL
D	The device will use the information from the internet (www.weather.com National Weather Service) to activate the system, along with feedback of window position
	ASSEMBLY
D	The security and safety of the frame will not be compromised by the device.
W	The Device must be easy to attach to the frame of the window and must not compromise/destroy the frame in any way
	MANUFACTURING
W	Fabrication of pieces is not an efficient option, using available parts on the market is a better option for a small manufacturer i.e. we will try and buy as many pieces as possible as opposed to manufacturing

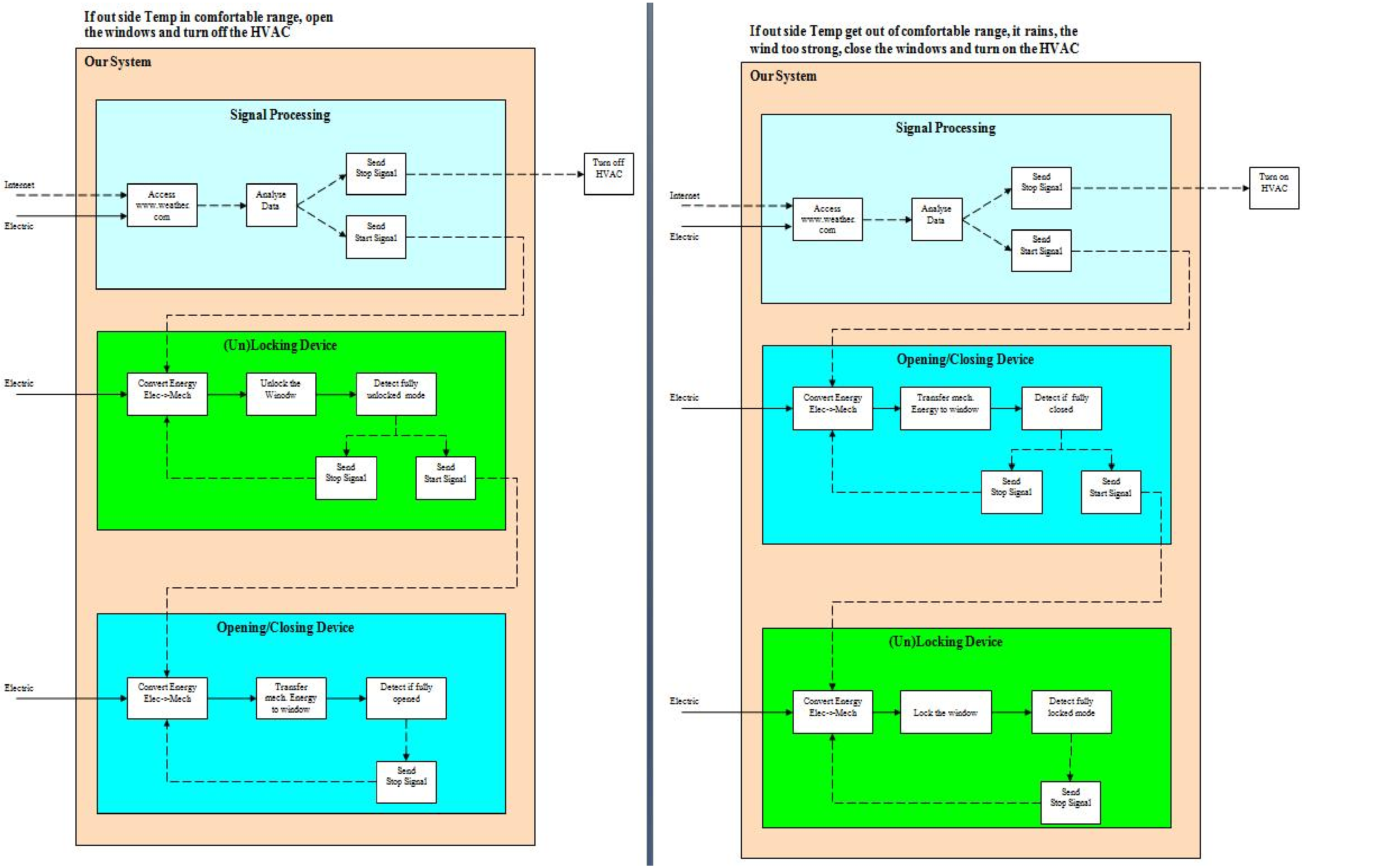


Figure1. Function Structure

Table2. Working Principles

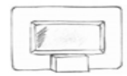
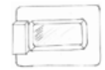
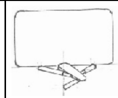
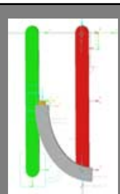
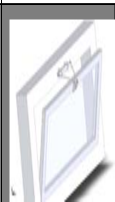
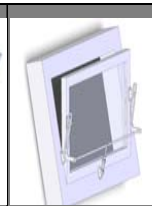
Functions	Sub Functions	Sub-sub Functions	Working Principles									
Attach device to Window	Position to attach device		device on frame - maybe in center 	inside room 	outside room 	device on frame - on one side 	device on window	on ceiling/wall to save space				
	Attach without damaging frame		glue	bolt								
Signal Processing: Receive appropriate signal input and convert to desired electrical output	Receive required input	temperature	internet	sensor								
		weather information (storm warnings, rain, snow)	internet	sensor								
		window initial condition information (locked/unlocked and completely open check)	electrical signal feedback	mechanical feeback/computer code								
	Process signal to generate desired electrical output	Internet Ready Kit - electrical processing	Internet Ready Kit - computer program processing	ADDA Control Card	SPS							
Locking and Unlocking the Window: Detect whether window is locked or unlocked and take appropriate mechanical action	Convert Electrical Energy to Mechanical Energy		motor 	actuator 								
	Use Mechanical Energy to Unlock the window				Ask janitors to close windows at night, and open in morning	Motor Resistance to lock device	No need for locking/unlcoking					
	Send Stop Signal to Signal Processing		Relays	Mechanical feedback from motors	Mechanical Feedback from rough areas on links							
	Send Start Signal to mechanical open window		Relays	Internet								
Mechnical Opening of Window: Open and close the window	Convert Electrical Energy to Mechanical Energy		motor	actuator								
	Use Mechanical Energy to Open/Window	(think of where you can attach linkages independent of motors actuators i.e. open window using hinge, or open window from left edge) ; rotational and transational										
	Detect if window opened fully		Mechanical feedback (from motor, increasing resistance on links etc)	Sensor feedback								
	Send Stop Signal to Signal Processing		Relay	Sensor feedback	Mechanical feedback							
Manual Override	Allow user to open/close window fully		Press button to activate motor	Press button, reduce motor resistance	Remove manually easily							

Table3. Multiple Design Concept Chart

FUNCTION	SUB-FUNCTION	SUB-SUB-FUNCTION	*Design 1*	*Design 2*	*Design 3*	*Design 4*
Attach device to Window	Position to attach device		vary according to window type	vary according to window type	Bottom of Window	Bottom of Window
	Attach without damaging frame		bolt screw shaft to frame	bolt screw shaft to frame	bolt screw shaft to frame	bolt screw shaft to frame
Signal Processing: Receive appropriate signal input and convert to desired electrical output	Receive required input	temperature information	internet kit	internet kit	internet kit	senor
		weather information (storm warnings, rain, snow)	internet kit	internet kit	internet kit	sensor
		window initial condition information (locked/unlocked and completely open check)	mechanical feedback - from link resistance when the window is open	mechanical feedback - from link resistance when the window is open	mechanical feedback - from link resistance when the window is open	mechanical feedback - from link resistance when the window is open
	Process signal to generate desired electrical output		Internet Ready Kit - processing by programming	Internet Ready Kit - processing by programming	Internet Ready Kit - processing by programming	Internet Ready Kit - processing by programming
Locking and Unlocking the Window: Detect whether window is locked or unlocked and take appropriate mechanical action	Convert Electrical Energy to Mechanical Energy		not applicable	not applicable	not applicable	not applicable
	Use Mechanical Energy to Lock/Unlock the window		motor resistance	motor resistance	motor resistance	motor resistance
	Send Stop Signal to Signal Processing		mechanical feedback - from maximum link extension	mechanical feedback - from maximum link extension	mechanical feedback - from maximum link extension	mechanical feedback - from maximum link extension
	Send Start Signal to mechanical open window		photocoupler	relay	relay	relay
Mechnical Opening of Window: Open and close the window	Convert Electrical Energy to Mechanical Energy		motor	motor	actuator	actuator
	Use Mechanical Energy to Open/Window		Window System Design 1	Window System Design 1	Window System Design 8	Window System Design 9
	Detect if window opened fully		mechanical feedback - resistance due to max extension of linkage	mechanical feedback - resistance due to max extension of linkage	mechanical feedback - resistance due to max extension of linkage	mechanical feedback - make the end rougher
	Send Stop Signal to Signal Processing		relay	relay	relay	sensor
Manual Override	Allow user to open/close window fully		push button to activate motor	have user mechanically move linkage	push button to activate motor	push button to activate motor

Table4. Selection Chart

WIT Corp	**Selection chart** for Window opening/closing device								
Solution variants	Solutions variants evaluated by Selection Criteria: (+) : yes (-) : no (?): lack of Information (!): Check Requirements List							Decision: (+): Pursue Solution (-): Eliminate Solution (?): Collect information (!): Check Requirements List for changes	
	A: Retrofitting to different angles of awning and hopper windows B: Full fill Locking/Sealing function C: Safety D: Manufacturability E: Cost F: G: Retrofitting to different types of window								Decision
	A	B	C	D	E	F	G	Remark (Indicator Reason)	
1	+	+	+	+	+	+	+		+
2	-							Not retrofit to different angles	-
3	-							Not retrofit to different angles	-
4	+	+	+	+	+	+	+		+
5	+	+	+	+	+	+	+		+
6	+	+	+	+	+	+	+		+
7	+	+	+	+	+	+	+		+
8	+	+	+	+	+	+	+		+
9	+	+	+	+	+	+	+		+
10	-							Not retrofit to different angles	-

Table5. Binary Evaluation Chart

Criteria: Manufacturbility (Number of Parts and Ease of Assembly)

Design No.	1	2	3	4	5	6	7	8	9	10
1	--			1	1	0	0	1	0	
2		--								
3			--							
4	0			--	0	0	0	0	0	
5	0			1	--	0	0	0	0	
6	1			1	1	--	0	1	1	
7	1			1	1	1	--	1	1	
8	0			1	1	0	0	--	0	
9	1			1	1	0	0	1	--	
10										--
Total	3	0	0	6	5	1	0	4	2	0

Criteria: Retrofit-ability 1 (ability to open to varying window angles)

Design No.	1	2	3	4	5 *	6	7	8	9	10
1	--			0.5	0.5	0	0	1	1	
2		--								
3			--							
4	0.5			--	1	0	0	1	1	
5	0.5			0	--	0	0	1	1	
6	1			1	1	--	0	1	1	
7	1			1	1	1	--	1	1	
8	0			0	0	0	0	--	0	
9	0			0	0	0	0	1	--	
10										--
Total	3	0	0	2.5	3.5	1	0	6	5	0

Criteria: Retrofit-ability 2(adaptability to different types of windows)

Design No.	1	2	3	4	5	6	7	8	9	10
1	--			0	0	0	0	1	0	
2		--								
3			--							
4	1			--	0.5	0.5	0.5	1	1	
5	1			0.5	--	0.5	0.5	1	1	
6	1			0.5	0.5	--	0.5	1	1	
7	0			0.5	0.5	0.5	--	1	1	
8	1			0	0	0	0	--	0	
9	1			0	0	0	0	1	--	
10										--
Total	5	0	0	1.5	1.5	1.5	1.5	6	4	0
Grand Tota	11	0	0	10	10	3.5	1.5	16	11	0
Rank	2			4	4	6	7	1	2	

* will restrict placement of device on frame

Note: window open/close concept in left most column in Working Principle Chart is concept no.1, followed by others sequentially from left to right

Table6. Detailed Evaluation of Concepts

S. No.	Evaluation Criteria	Importance	Rank	Weight	Design 1		Design 2		Design 3		Design 3	
					Value	Weighted Value	Value	Weighted Value	Value	Weighted Value	Value	Weighted Value
1	Cost	4	5	0.17	3	0.52	2	0.34	4	0.69	1	0.17
2	Manufaturability	6	3	0.10	4	0.41	3	0.31	2	0.21	1	0.10
3	Ergonomics	8	1	0.03	4	0.14	3	0.10	2	0.07	1	0.03
4	Eco-friendliness/ Energy Savings	3	6	0.21	3	0.62	4	0.83	2	0.41	1	0.21
5	Robustness/Life	7	2	0.07	4	0.28	3	0.21	1	0.07	2	0.14
6	Retrofit-ability: sizes of windows	1	4	0.14	4	0.55	4	0.55	2	0.28	2	0.28
7	Retrofit-ability: types of windows	1	4	0.14	4	0.55	4	0.55	2	0.28	1	0.14
8	Security (sealing and locking)	5	4	0.14	3	0.41	3	0.41	3	0.41	4	0.55
Total	out of 4		29	1.00	29	3.48	26	3.31	18	2.41	13	1.62
	Percentage satisfaction of criteria					**87.07%**		**82.76%**		**60.34%**		**40.52%**

Total: 1. Poor Design; 2. Satisfactory Design; 3. Good Design; 4. Perfect Design

APPENDIX B – BUSINESS PLAN: FINANCIAL AND STRATEGIC ANALYSIS

Table1. Production Costs

Fixed Costs:			
	Plant Cost ($):	5,000,000	
	Units produced at capacity:	15,000	
	SG&A ($):	600,000	(export costs included here)
	Annual Depreciation ($):	250,000	(20-year straight-line)
	Plant Maintenance:	5%	of plant cost
Variable Costs:			
	Raw Materials ($/unit):	245.00	
	Labor ($/unit):	7.53	
	Plant Working Capital:	10%	of cost of units manufactured
Corporate Facts:			
	Tax Rate:	25%	
	WACC:	10%	
Other Information:			

	First Year Sales (unit):	13,613	
	Annual Sales Growth (yr 2-6):	10%	
	Growth after Year 5:	4%	
Detailed Production Costs:			
	Raw Material (Mechanical/Electrical)	$245.00	
	Raw Material (Data Mining Software)	$900.00	http://www.iopus.com/store/
	Labor (HVAC Interface Software Development)	$10,000.00	
	Labor (Engineering Development)	$27,000.00	1000/month/person, 18/weeks, 6 people
	Labor (Part Assembly)	$5.00	

Table2. Income Statement

Widgets:	13,613
Sales Price ($/unit):	450.00
Revenue ($):	6,125,794
Raw Materials ($):	3,675,000
Labor ($):	112,900
Gross Profit ($):	**2,337,894**
SG&A ($):	600,000
EBITDA ($):	1,737,894
Depreciation ($):	250,000
EBIT($):	1,487,894
Taxes($):	371,973
Net Operating Income after Tax($):	**1,115,920**

Table3. Cash Flow Analysis

Plant operations begin in year 0	YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	
Operating:															
Unit Sales (widgets):		13,613	14,974	16,471	18,118	19,930	21,923	22,800	23,712	24,660	25,646	26,672	27,739	28,849	3
Revenue ($):		6,125,794	6,738,300	7,411,950	8,153,100	8,968,500	9,865,350	10,260,000	10,670,400	11,097,000	11,540,700	12,002,400	12,482,550	12,982,050	13,50
Raw Materials ($):		3,335,154	3,668,630	4,035,395	4,438,910	4,882,850	5,371,135	5,586,000	5,809,440	6,041,700	6,283,270	6,534,640	6,796,055	7,068,005	7,35
Labor ($):		102,460	112,704	123,972	136,368	150,006	165,007	171,608	178,472	185,608	193,029	200,751	208,782	217,137	22
SG&A($):	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000	60
Annual Increase in Working Cap($):		1,361	136	150	165	181	199	88	91	95	99	103	107	111	
Plant Maintenance ($):		250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	25
Investment:															
Plant Cost ($):	5,000,000														
Annual Cash Flow ($):	-4,288,975	1,494,323	1,728,784	1,986,507	2,270,062	2,582,159	3,257,654	3,421,996	3,592,998	3,770,603	3,955,206	4,147,456	4,347,297	4,555,377	4,77
Cumulative Cash Flow ($):	-4,288,975	- 2,794,652	- 1,065,868	920,639	3,190,701	5,772,860	9,030,514	12,452,511	16,045,508	19,816,111	23,771,317	27,918,773	32,266,070	36,821,447	41,59
Discount Factor (at WACC):	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241	0.3855	0.3505	0.3186	0.2897	0
Annual DCF ($):	-4,288,975	1,358,476	1,428,747	1,492,492	1,550,483	1,603,317	1,838,861	1,756,025	1,676,160	1,599,104	1,524,903	1,453,658	1,385,183	1,319,530	1,25
Cumulative DCF ($):	-4,288,975	- 2,930,499	- 1,501,753	-9,260	1,541,223	3,144,540	4,983,401	6,739,426	8,415,586	10,014,690	11,539,593	12,993,251	14,378,434	15,697,964	16,95
10-Year NPV(@WACC) =	11,539,593														

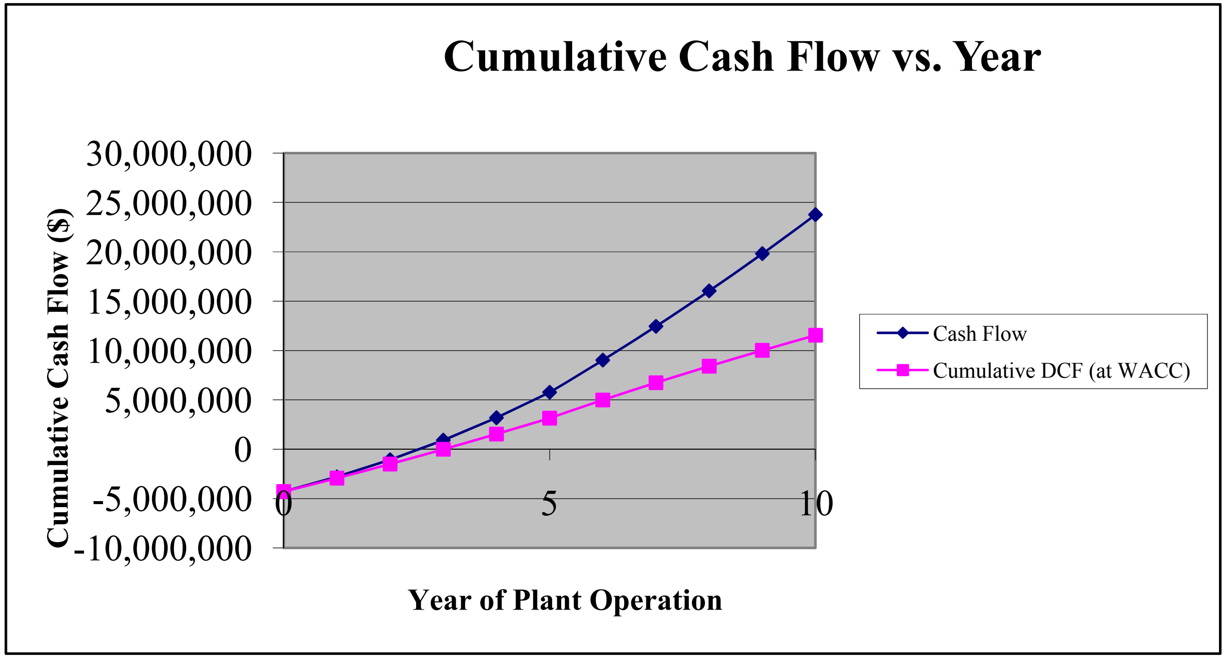
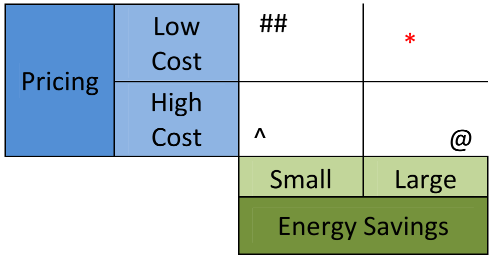


Figure1. Breakeven Analysis Plot

Table4. Strategic Environ Analysis

[redacted]



##	new glass window panes etc - indirect competitors
^	direct competitors - window installations
@	complete system overhaul
*	our system

Figure2. Product Positioning Matrix

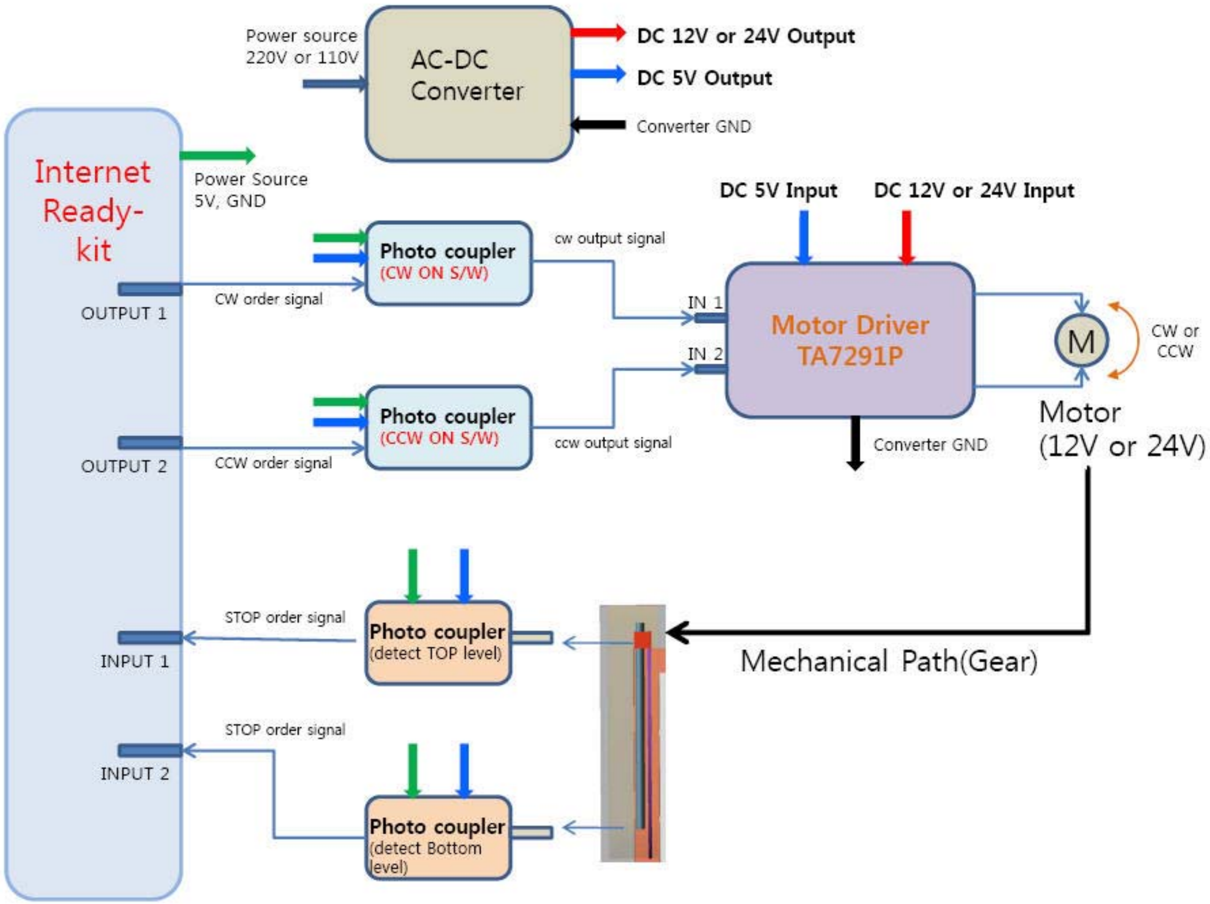


Figure1. Product Operation Diagram

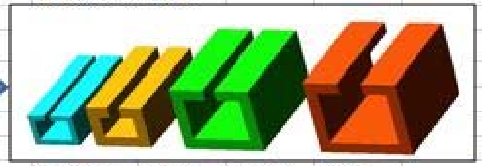
Detailed Analysis of Major Components in Design

Typical Window Sizes:
- Thickness = from 45mm to 120 mm
- Width W1 = from 600mm to 1800mm
- Height = from 600mm to 2200mm

Satisfied Ranges:
Thickness = 45mm to 100mm
Width = 600mm to 1200mm
Height = 600mm to 900mm

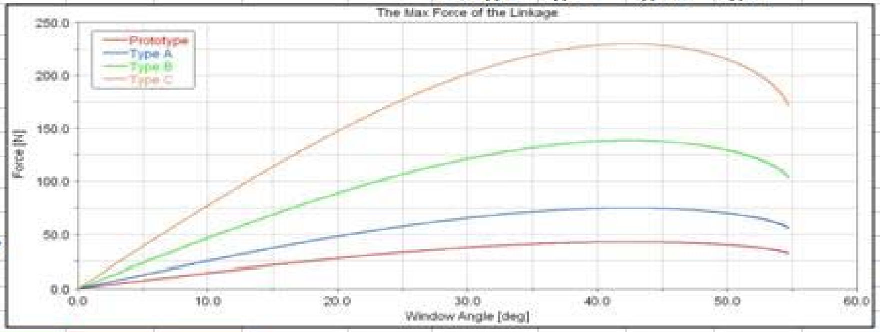
Window Size	Width	height	thickness [mm]	glass thickness [mm]	Weight [kg]	density
Prototype	600	400	40	1	3.2Kg	0.15755kg/10cm
Type A	700	500	60	2	6.9Kg	0.3562kg/10cm
Type B	900	700	80	3	13.13Kg	0.575kg/10cm
Type C	1200	900	100	4	21.6Kg	0.657kg/10cm

window frame model

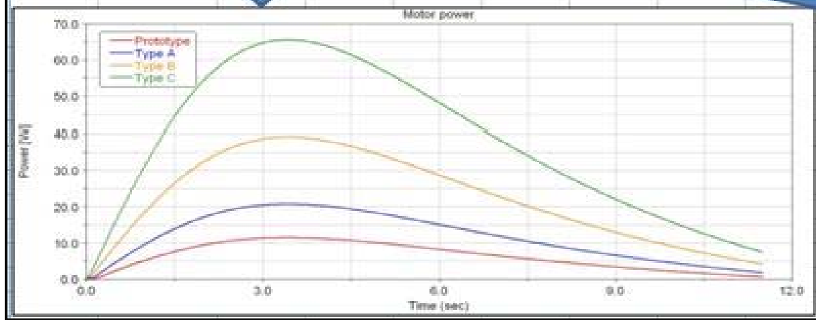


screw shaft	length	diameter [mm]	pitch
Prototype	280	7	1mm
Type A	340	9	
Type B	430	12	
Type C	500	16	

curved link	length [mm]	width	Max Force on the linkage
Prototype	250	10	42.62N
Type A	300	18	74.53N
Type B	380	35	138.35N
Type C	450	50	229.84N



Motor MAX power	open operation	energy consumed	close operation	energy consumed
Prototype	12.3W	0.2042Wh	10.74W	0.1983Wh
Type A	20.75W	0.3771Wh	18.12W	0.3578Wh
Type B	39.73W	0.7229Wh	35.37W	0.7082Wh
Type C	65.21W	1.2187Wh	58.93W	1.1435Wh



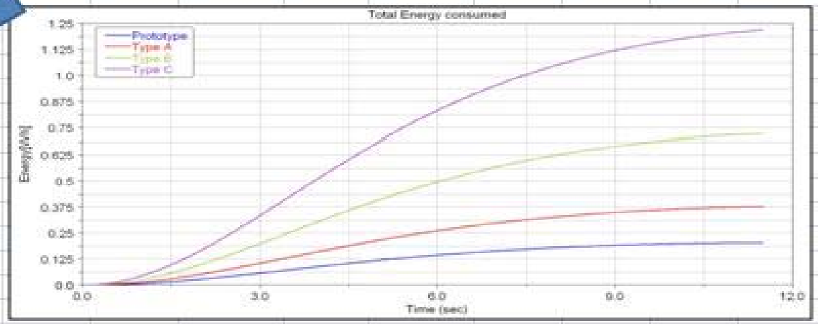


Figure2. Detailed Analysis of Major Components

Table 1. Bill of Materials

Type	Number	Material	Buy/Manufacture		Source	Specification	Name	Cost ($)
Mechanical Parts			Product	Prototype				
(1) Revolute Joint	2	Steel	Buy	in hand	McMaster-Carr	High Strength Ball Joint (male); 12.7mm thread; max rotation = 20° ; max static radial load = 26.11kN	4444T3	7.05
(2) Screw shaft**	1		Buy	Buy		Steel, Zinc Plated Fully Threaded Rod: Right Hand Thread M6, Pitch = 1mm; Length = 1m; Max Tensile Strength = 799.79MPa	99067A245	6.12
(3) Bearing	2	Steel	Buy	Buy	McMaster-Carr	Sleave Bearing: PTFE, 9mm diameter: Temp Range = -212.2°C to +260°C	2685T12	3.1
(4) Screw bolt	1	Steel	Buy	Buy	McMaster-Carr	Shaft Collar: Stainless Steel, Right Hand Thread M6, Bore Thread Size = 1mm; Outside Diameter = 40mm	2305K18	9
(5) Gear pairs	1	Steel	Buy	Buy	McMaster-Carr	14.5° Pressure Angle Worm Gear and Worm: Steel Worm, 12 Pitch	57545K527	24.18
(6) Gear motor **	1	Assembly	Buy	Buy	McMaster-Carr	Subfractional-hp DC gear motor: 24VDC, 25rpm, 5.65N-m	6409K26	37.42
(7) Bolts and nuts	~	Steel	Buy	Buy	McMaster-Carr	minor part - estimate price		5
(8) Motor support part	1	Recycled Aluminum	Buy	in hand	McMaster-Carr	minor part - estimate price		5
(9) Screw shaft support part	2	Recycled Aluminum	Buy	in hand	McMaster-Carr	minor part - estimate price		5
(10) Joint support part	2	Recycled Aluminum	Buy	in hand	McMaster-Carr	minor part - estimate price		5
(11) Screw bolt support part	1	Recycled Aluminum	Buy	in hand	McMaster-Carr	minor part - estimate price		5
(12) Bearing support part	2	Recycled Aluminum	Buy	in hand	McMaster-Carr	minor part - estimate price		5
(13) Cover	1	Recycled Aluminum	Buy	in hand	EPS Plastic Lumber/ PJ's Fun Crafters	Recycled Plastic Wood Box - Purified Fractional Melt HDPE - made to order		5
(14) Curved link **	1		Buy	in hand	Custom	made to custom curvature specification		10
(15) Window frame*	1	PVC Plastic	N/A	Buy	N/A	not applicable		
Electrical Parts								
(1) Motor driver	1	Assembly	Buy	Buy		TA7291P	TA7291P	26
(2) AC-DC converter	1	Assembly	Buy	Buy		minor part - estimate price		20
(3) Photo coupler/Relay	4	Assembly	Buy	Buy	McMaster-Carr	Circular Pin Relay: Control Voltage = 240VAC; two circuit on off	7170K15	11.95
(4) Not gate(TTL)	1	Assembly	Buy	Buy		minor part - estimate price		2
(5) Resistance	1	Assembly	Buy	Buy		minor part - estimate price		4
(6) Processor/Internet Kit	1	Assembly	Buy	in hand	Sena Technologies	Hello Device 1100 with 8bits microprocessor		40
							Total	**245.97**
* will not be part of product, only included in prototype demonstation					** please see detailed sizing and material selection analysis			

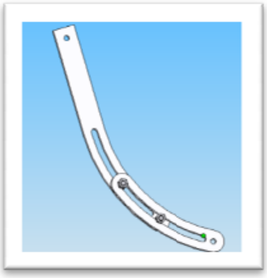


Figure3. Grooved Curved Link

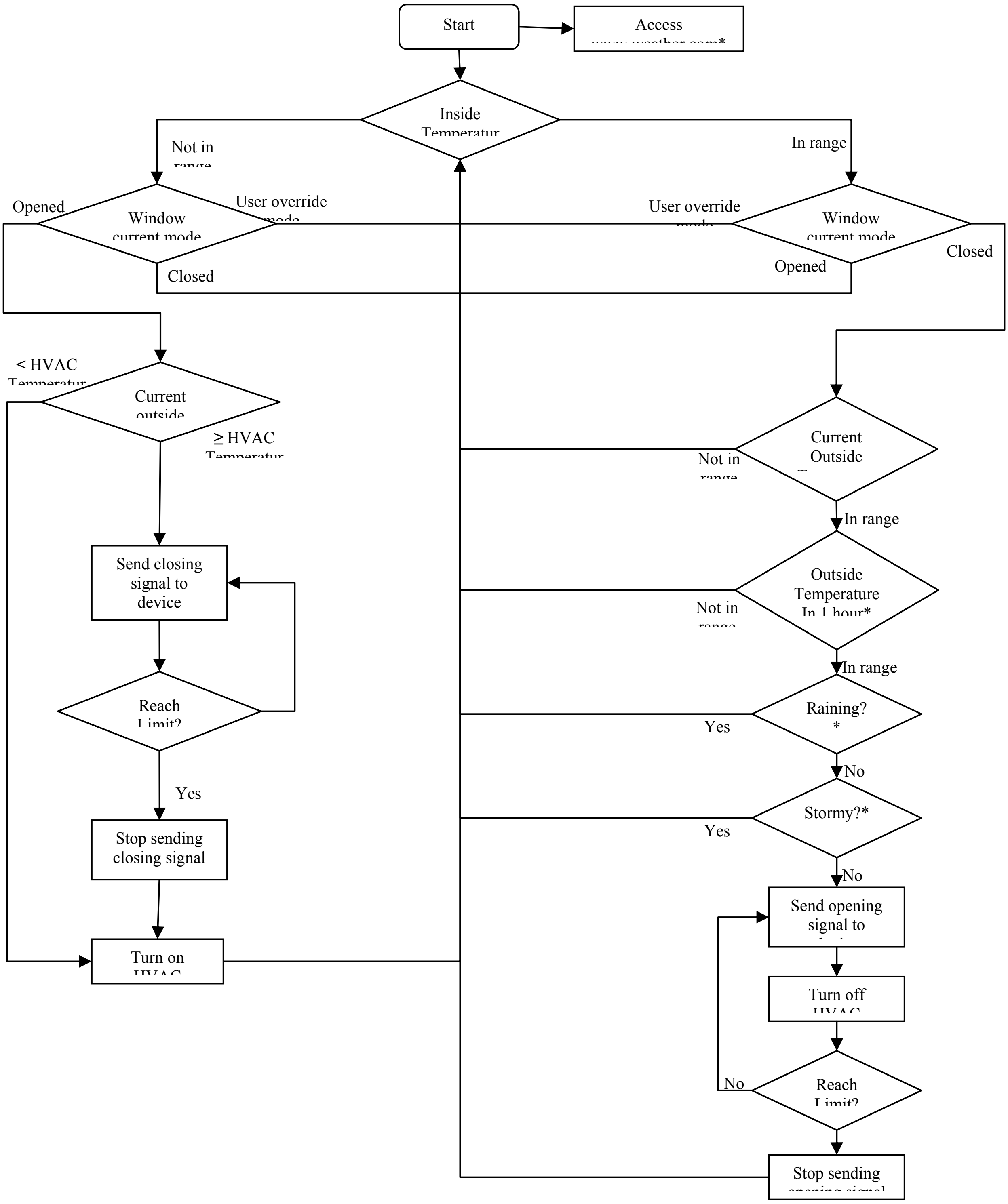


Figure4. Control Algorithm

Table2. Product Life Cycle

Mechanical Parts	**Product**	**Time (yrs)**	**After End of Lifecycle**	**Cumilative Cost ($)**	
(1) Revolute Joint	Buy	5	repair old parts and selling them for scraps	1$*4	4
(2) Screw shaft	Buy	5	repair old parts and selling them for scraps	6.12/2$*4	12.24
(3) Screw bolt	Buy	5	repair old parts and selling them for scraps	-	
(4) Gear pairs	Buy	5	repair old parts and selling them for scraps	10$*4	40
(5) Geared motor	Buy	10	repair old parts and selling them for scraps	37.42$*2	74.82
(6) Bolts and nuts	Buy	permanent	recycle	5$	5
(7) Motor support part	Buy	permanent	recycle	10$	10
(8) Screw shaft support part	Buy	permanent	recycle	20$	20
(9) Joint support part	Buy	permanent	recycle	1$	1
(10) Screw bolt support part	Buy	permanent	recycle	-	
(11) Cover	Buy	10	PVC material recycle	20$	20
(12) Curved link	Buy	permanent	aluminum material recycle	3$	3
(13) Window frame	N/A	N/A			
		Note	permanent = till expected product life = 20yrs	mechanical repair cost	131.06
Electrical Parts					
(1) Motor diriver	Buy	10	repair old parts and selling them for scraps	10$	
(2) AC-DC converter	Buy	10	repair old parts and selling them for scraps	50$	
(3) Photo coupler/Relay	Buy	10	repair old parts and selling them for scraps	0.2$*4	
(4) Not gate(TTL)	Buy	10	repair old parts and selling them for scraps	0.1$	
(5) Resistance	Buy	10	repair old parts and selling them for scraps	0.01$*10	66
(6) Precessor/Internet Kit	Buy	10	repair old parts and selling them for scraps	5$	
		Office	**$135**	electric repair cost	66
		Home	**$153**	Total Cost	

Table3. Detailed Prototype Parts List

Type	Buy/Manufacture		Method/Source
Mechanical Parts	Product	Prototype	
(1) Revolute Joint	Buy	in hand	Get it free
(2) Screw shaft	Buy	Buy	Buying it at Guro, Dae Sung Conpany. Threaded rod : 250mm, 6mm/1 rotation, D=8mm Rod for supporting : 50mm, D=7mm
(3) Screw bolt	Buy	Buy	Buying it at Guro, Dae Sung Conpany. Cylinder shpe, Inside Diameter=8mm, No bearing
(4) Gear pairs	Buy	in hand	Get it free at lab. Outside Diameter=50mm, Inside Diameter=8mm
(5) Geared motor	Buy	Buy	Buying it at Guro, GGM company DC gear motor : 15W, 24V, 1.1A
(6) Bolts and nuts	Buy	in hand	Get it free
(7) Motor support part	Buy	Buy	Buying it at Guro, GGM company
(8) Screw shaft support part	Buy	in hand	Get it free. Outter is retangular shape. Inside Diameter=8mm
(9) Joint support part	Buy	in hand	Get it free We modified it for attaching to screw bolt and window frame
(10) Screw bolt support part	Buy	in hand	Get it free Using 'L' shape elbow
(11) Cover	Buy	Buy	Buying acrylic plastics in Berlin
(12) Curved link	Buy	in hand	Using aluminum for material Cut it as the curved designed by cutting machine
(13) Window frame	N/A	Buy	Yoeng Heung aluminum frame company Order to make the awing & hoping window frame
Electrical Parts			
(1) Motor diriver	Buy	Buy	Eleparts company
(2) AC-DC converter	Buy	Buy	Whine electronics
(3) Photo coupler/Relay	Buy	Buy	Eleparts company
(4) Not gate(TTL)	Buy	Buy	Eleparts company
(5) Resistance	Buy	Buy	Eleparts company
(6) Precessor/Internet Kit	Buy	in hand	SENA Technologies

APPENDIX D – FEASIBILITY ANALYSIS

Home Energy Efficient Design (HEED):

HAP is a computer tool which assists engineers in designing HVAC systems for commercial buildings. HAP is two tools in one. First it is a tool for estimating loads and designing systems. HAP uses the ASHRAE-endorsed transfer function method for load calculations and detailed 8,760 hour-by-hour energy simulation techniques for the energy analysis. HAP estimates design cooling and heating loads for commercial buildings in order to determine required sizes for HVAC system components. Ultimately, the program provides information needed for selecting and specifying equipment. Secondly, HAP estimates annual energy use and energy costs for HVAC and non-HVAC energy consuming systems in a building by simulating building operation for each of the 8,760 hours in a year. Results of the energy analysis are used to compare the energy use and energy costs of alternate HVAC system designs so the best design can be chosen.

Hourly Analysis Program (HAP):

HEED uses as its thermal analysis computation kernel a program called Solar-5, developed at UCLA. It calculates an hourly heat balance for each of the 8760 hours in a year using the standard ASHRAE Manual J calculations, the Mackey and Wright time lag and decrement factor method of accounting for heat flow through opaque walls, and the Admittance Factor Method to account for internal thermal mass. It uses a successive approximation method to calculate the indoor air temperatures. Thus it can integrate loads and energy calculations at each time step, similar to the new Energy Plus technique, which means that the HVAC system only adds heating or cooling energy if the indoor air temperature has floated beyond the upper or lower comfort limits.

Inference from Day Maximum Solar Heat Gains Simulation

The various weather data's are plotted and simulated to analyse the effect of building orientation with respect to the window location. As from the plotted graphs we can easly identify that the windows which are facing towards South and North will be having less heat loads. Hence we are planning to set our equipments on the windows which are facing towards north and south.

Input Parameters for the Energy Savings Simulation

1. Apartment with entry from interior hallway
2. 4 storied apartment
3. 600sq. ft
4. Location
5. The apartment is located in the top floor (I have considered the top floor as it is exposed to maximum and minimum climatic conditions)
6. Modeling the floor plan.
7. Selecting the building orientation.
8. Setting the window parameters: Window location, quantity, height, width, depth, offset
9. Three dimensional modeling of the building

10. Frame type: Aluminum without a thermal break, Operable Window
11. Glass with Aluminum Frame Operable Windows.
12. Level of Insulation.
13. Reflective Foil Radiant Barriers.
14. Walls construction
15. Roof construction
16. Floor construction
17. Under the floor condition
18. Infiltration and weather stripping
19. Ventilation
20. Heating parameters
21. Cooling parameters
22. Shading details
23. Details of the appliances (cooking oven- gas/ electric) used in the building
24. Economic analysis
25. Generation of results and analysis.

Simulation Settings

For a 600 sq.ft room with 3 windows, we considered about 2 kinds of window size. One is 609.6mm x 609.6mm and another one is 1798mm x 2194.5 mm. We simulated this for 5 cities in both our current target markets and potential future markets i.e. Los Angeles, New York, Milan, Munich, Beijing. We simulated a common 4 floors building as drawing 1. The building faces south and the window type are all front windows.

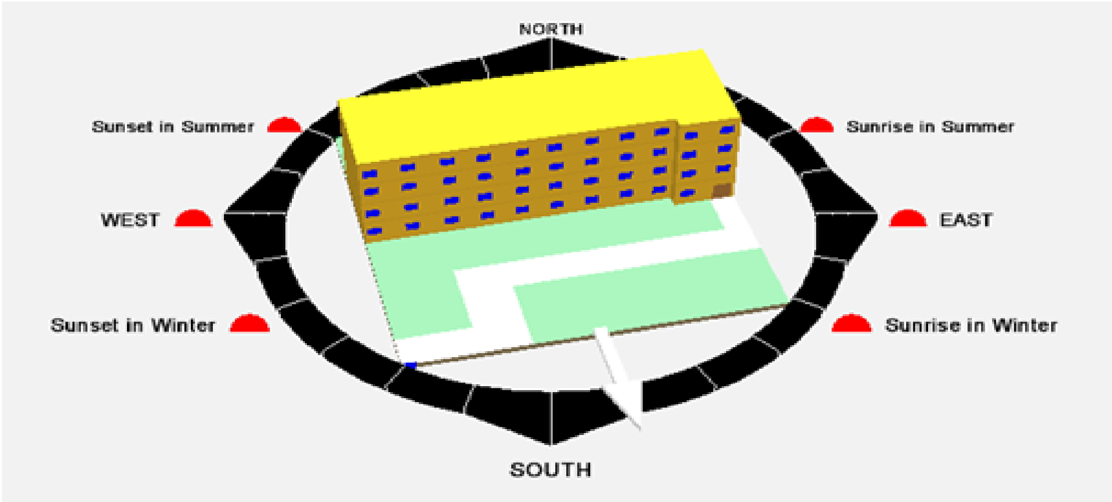


Figure1. Building Orientation in Simulation

We set the window parameters as: Window location and Quantity, front windows: 3, height: 2 feet/7 feet, width: 2 feet/ 6 feet, depth: 3.28 feet, offset: 1.33 feet

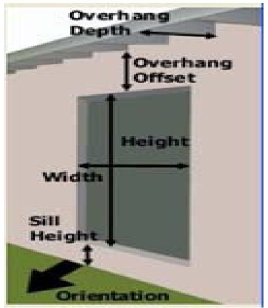


Figure2. Window Dimension Setup

Other input parameters for the simulation are as following:

1. The Frame type: Aluminum without a thermal break, Operable Window
2. Glass with Aluminum Operable Windows: Clear Argon filled Dbl Pane Low-E squared in aluminum frame.
3. Level of Insulation: Current Energy Code with Heavy Mass Walls (Wall R=2.44, Ceiling R=30, Floor R=19)
4. Reflective Foil Radiant Barriers: Radiant Barrier installed in Attic (shiny surface facing into vented attic above insulation in ceiling) or in Flat Roof (shiny surface facing into a vented air space above insulation)

5. Wall construction: Stucco, 2''+Polysyrene, 8'' Hollow Concrete Block, exposed/plaster board
6. Roof construction: White (Cool Roof) Elastomeric Membrane, Flat Roof
7. Floor construction: Ceramic over Wood Floor
8. Under the floor condition: No heat loss through floor, as there is another heated unit below
9. Infiltration and weather stripping: Add Air-retarding House wrap, all joints lapped and taped (4.4 SLA)
10. Ventilation:
   - Natural Ventilation – without any artificial ventilation – open and close window
   - Minimum Natural Ventilation (up to 1.0 air changes per hour) by opening windows as needed (no fan).
   - Good Natural Ventilation (up to 5.0 air changes per hour)by opening windows as needed (no fans).
   - High Natural Ventilation (up to 20.0 air changes per hour)by opening windows as needed (no fans).

Notes: at least 0.35 Air change per hour of outdoor air is assumed by the Energy code for good indoor air quality. (IAQ)

11. Heating parameters: Energy star furnace (90% AFUE, Annual Fuel Utilization Efficiency)
12. Cooling parameters: Energy Star Air Conditioner, Split System (14 SEER, Depending on Climate)
13. Shading details: Overhangs* are fixed all year long, never retracted, or there are no overhangs, shades, or Venetian Binds
14. Details of the appliances (cooking oven- gas/ electric) used in the building.

Energy Simulation Results:

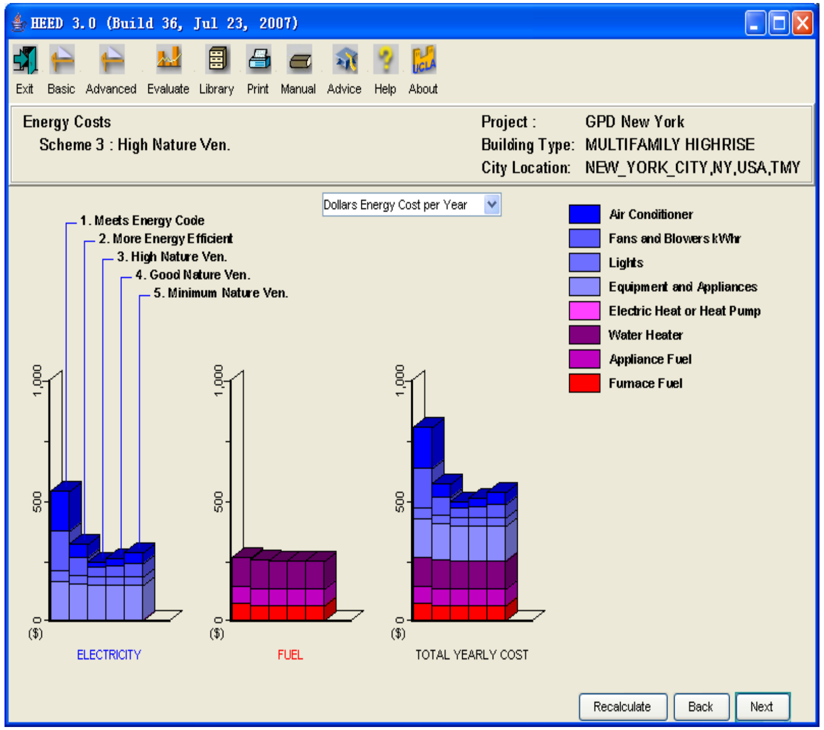


Figure3. Energy Cost Benefit

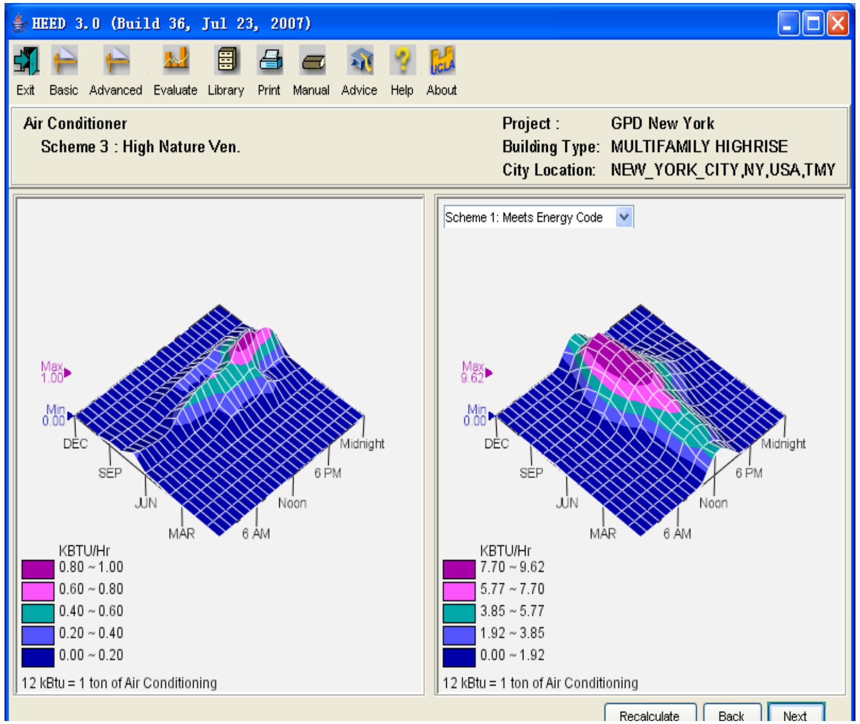


Figure4. Air Conditioner System Energy Consumed for Large

Detailed Calculations of Cost Benefits in New York:

If our devices are used for 609.6mm x 609.6mm windows,

- High nature Ventilation, we can save $801.23-$472.46=$328.77
- Good Nature Ventilation, we can save $801.23-$508.52=$292.71
- Minimum Nature Ventilation, we can save $801.23-$534.64=$266.59

We got the average energy saving ($328.77+$292.71+$266.59)/3=&296.02

For 1798mm x 2194.5 mm windows

- High nature Ventilation, we can save $801.23-$493.09=$308.14
- Good Nature Ventilation, we can save $801.23-$508.52=$292.71
- Minimum Nature Ventilation, we can save $801.23-$534.64=$266.59

We got the average energy saving ($308.14+$292.71+$266.59)/3=$289.15

Normally for office rooms, people use both sizes windows. So we calculate the average saving ($296.02+$289.15)/2=$292.59, about 37% energy saving compare with the office room without our device. Similarly, the yearly cost benefit of using our system in other cities is shown below.

	Los Angeles	New York	Munich	Milan	Beijing
energy saving per year (US Dollar)	302.23	292.59	222.51	281.05	156.79

Table1. Yearly Cost Benefits of using our system

Environmental Impact: Electricity Savings and Gas Production Reduction

Through our market analysis it was seen that there are 1,747,575 Windows in New York. As we can save $292.59 per year for three windows, this product can potentially generate savings of (1,747,575/3)×$292.59= $17,040,989.75. The energy cost values for our target markets in the USA, namely the states of New York and California, and Germany were obtained: New York: 14.31 cents/kW-h; Los Angeles: 12.31 cents/kW-h, Germany: 16 cents/kW-h. The energy saved by our product per day was then calculated. It should be noted that as we are checking feasibility and defining power saving characteristics of the system, the lower value of energy saved in a day is used for further calculations. So for New York, we can save $17,040,989.75/14.31cents/KW-h=1,191,062,123 KW-h electricity per year. If we produce 1 KW-h electricity, 0.92 kg CO_2[xiv] will be exhausted. So every year we can reduce 1,191,062,123 KW-h×0.92kg=1,095,777,153kg CO_2

Table2. Energy Efficiency Calculations

600 Sq.Ft. - 3 windows																
Energy Consumed by A/C			Size 1			Size 2	Scaling of Energy Saved			Consumed in one cycle (Kwh/cycle)				New York	Munich	with linkage
Month	Without (kBTU/hr)	With (kBTU/hr)	**Saved (Kwh/hr)**	Without (kBTU/hr)	With (kBTU/hr)	**Saved (Kwh/hr)**	Type A	Type B	Type C	Type A	Type B	Type C	Number of cycles per hour (cycle/hr)	Number of seconds the window needs to remain open		inefficiency, safety margin = 100% (mins)
August	4.889167	0.533333	1.27626	5.85167	1.48	1.28089	0.34495288	0.34505	0.34521	0.000735	0.0014311	0.0023622	146.1384937	24.63416659	32.39275	**1.079758333**
March	3.04375	0.2	0.83321	2.88333	0.49	0.70124	0.22542459	0.22263	0.21814	0.000735	0.0014311	0.0023622	92.34569455	38.98395066	51.26202923	**1.708734308**
				interpolation factor			to ensure 10% energy savings									
Area	Size 1	371612.2		1.3E-09								**window has to stay open for 1 mins 42 seconds in the worst case scenario**				
mm^2	Size 2	3945711		-3.7E-08			0.65517241									
	Size1	Size2														
High	328.77	308.14	Meduim/High		Low/High				BTU	kWh						
Medium	292.71	292.71	0.89032		0.81087				3413	1						
Low	266.59	266.59								0.000293						
with device		2*2			6*7											
August(hrs)	energy consumed		March		aug	march										
3	1			2.47	6				mm	mm	scale	Area (mm^2)				
4	0.8			1.97	4			Size 1	609.6	609.6	1	371612.16				
6	0.6			1.48	4			Type A	700	500	0.94184216	350000				
4	0.4			0.99	4			Type B	900	700	1.69531589	630000				
7	0.2		24	0.49	6	24		Type C	1200	900	2.90625581	1080000				
without device																
August(hrs)	energy consumed															
4	9.62		0	9.62	7	0										
4	7.7		0	7.7	5	0										
3	5.77		5	5.77	2	4										
3	3.85		4	3.85	2	4										
10	1.92		15	1.92	8	16										

[i] *Integrated Buildings: The Systems Basis of Architecture*, Leonard R. Bachman
[ii] *The Chesapeake Bay Foundation's Philip Merrill Environmental Center*, http://www.cbe.berkeley.edu/mixedmode/chesapeake.html (2000)
[iii] Types of windows selected are the most popular types: Energy-Efficient Windows, http://www.empowermentzone.com/windows.txt
[iv] An evaluation was not done for the Function – Attach Device to Window, as the position and type of attachment method would depend on type of window as well as retrofit criteria, and narrowing down was not logical
[v] The numbering is in ascending order in Appendix A-Figure3, with the first design being the one in the leftmost column of Working Principles
[vi] http://www.scicontech.com/spec/metalcasting.pdf, Scion Technology Corporation
[vii] Sliding and Double Hung Windows will not use the curved link
[viii] http://www.smarter.com/network-accessories/netbotz-temperature-sensor/pd--ch-2--pi-621516.html
[ix] http://www.nextag.com/rain-sensor/search-html
[x] http://www.amazon.com/dp/B000FM10CA?smid=A16021BDEPIY71&tag=nextag-kitchen-mp-20&linkCode=asn
[xi] http://webtrolley.org/mivastore/merchant.mv?Screen=CTGY&Store_Code=apogee&Category_Co de=O2S
[xii] *Natural Ventilation Technical Info Sheet*, AIRAH
[xiii] *Natural Ventilation Technical Info Sheet*, AIRAH, pg. 2
[xiv] http://forum.china.com.cn/ciicbbs/read.php?tid=83724