World Innovative Technologies

Global Product Development 2007
Team 4

Final Design Review

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Executive Summary

World Innovative Technologies is developing global products that use the internet to enable a closed-loop economy. A group of international engineers has developed a product to test as a prototype meeting these requirements. Product selection was done by comparing a variety of different concepts with the criteria of the market. The problem selected is to reduce the change in temperature and humidity in a refrigerator by minimizing the amount of cold air escaping the refrigerator through the consumer's use of internet-ready communications between themselves, their refrigerator, and their supermarket. A market analysis was performed and the United States was selected as the primary market with 1.32 million potential customers and Germany was selected as the secondary market with 0.4 million potential customers. Important customer requirements are aesthetics, energy consumption, additional features, and price. A competitive analysis confirmed that the company has a place in the market for our product. The product will be sold for about $1500 – $2000 in the US market and about $600 – $800 in the German market.

After the market analysis, a functional breakdown was done of each of the product functions. There are four parts of our system that interact namely the storage part of the refrigerator, the customer, the information (internet-ready) system, and the supermarket. With the working principles created from the functional analysis, four design alternatives were made for comparison. Our design was selected using a weighted grading system. The main features of the selected refrigerator design are as follows: multi-door system, LCD user interface, vegetable and fruit drawers, interactive/memory based placement of foods, "smart" refrigerator in reference to the quantity of eggs and liquid inside a container, latch door mechanisms, and internet applications. The internet applications include the supermarket sending information about a consumer's purchase to the fridge, the consumer ordering products from the supermarket through the fridge or email, the fridge sending an email to the consumer when a product is empty, the fridge searching a recipe database online, and the consumer listening to music through the fridge. Some of these features vary slightly in different markets; however, a platform structure was implemented in the design to minimize the cost for manufacturing for the two markets. The main difference between the two markets is the size of their products and refrigerators.

With the design concept selected, the technical design of the product was completed. The assembly of the product was simulated using computer-aided drafting tools. An airflow analysis of the inside of the refrigerator was done. Calculations show that the product will reduce the energy loss by opening the door of the fridge by 50% and thereby ensuring a closed-loop economy. Strategic planning was done for the manufacturing strategies and business strategies. The company will profit from producing this product and introducing it to the market.

Finally, a working prototype is operational to demonstrate various functions of the actual design of the refrigerator. The prototype implements the internet-ready kit, and allows the user to know how much of a liquid is contained in the refrigerator as well as know the amount of eggs is contained in the fridge. The user can access a list of the contents of their refrigerator and open the respective door for each piece of food. The designed product is marketable, profitable, and functional; therefore, there will be successful launch of the product.

1. Introduction

World Innovative Technologies (WIT) has given a group of six engineers the task to create an innovative engineering solution to a global problem in the marketplace. The company has made an initiative to provide environmentally sustainable products. Also many regions have seen a shift in innovation towards products that provide benefit to the consumer by the use of the internet. Therefore, the team is focusing on a consumer appliance in which the internet-readiness of the product enables a closed-loop economy. The product must be designed upon a global platform in two main regions in the world. It must also be a mechanical device. The team consists of two students from Seoul National University in South Korea, two students from the Berlin University of Technology in Germany, and two students from the University of Michigan in the United States. The team has core competencies in CAD modelling and analysis, mechanical design, industrial engineering, mechatronics/robotics, composite materials, and information/communication systems. With these competencies, the team will develop, design, manufacture, and market a product that meets WIT design specifications.

2. Needs identification and Problem statement

The team brainstormed project concepts that meet the design specifications and the top five ideas are as follows:

- **Refrigerator** that receives information from the supermarket through the internet about the consumer's purchase of refrigerated goods. The product reduces the amount of energy wasted to the environment by opening and closing the door less frequently and enabling a closed-loop economy.
- **Trash basket** that senses recyclable contents by referencing the internet and informs the user that a recyclable object has just been placed in the trash. This is a closed-loop economic product because it helps a user recycle.
- Energy is wasted when people leave electronics plugged in when not in use. An **electrical socket** can reduce that wasted energy by switching the outlet on and off through the internet. This is a closed-loop economic product because it reduces the amount of electricity a person uses in the home.
- A **farm** can water its plants based on the weather that is accessed through the internet. This can be considered closed-loop economy because it reduces the number of times the plants are watered when not needed.
- It is inconvenient for a person to take time off when they need to be home for the cable or other things to be fixed. The solution would be to open the door of a warehouse or house by an internet-ready device that is accessible from the office or PDA. It is a closed-loop economy because it will reduce the number of times a person drives back and forth to their house by being able to access a locked door when not at home.

Using consumer and engineering based criteria and a grading system (seen in Appendix A1), the refrigerator product was chosen. The product fulfills the project specifications and can also be designed and manufactured with the team's expertise. The product is marketable because it will be making the life of the consumer simpler while reducing the amount of time spent at the refrigerator. Also, the consumer will find value in helping the environment by reducing energy loss in their refrigerator. Using consumer data from Whirlpool Corporation, on average a user opens their refrigerator 30 times a day for 30 seconds. This creates energy loss from the refrigerator to the ambient kitchen environment. After some research it was found that the product is not currently being sold in the appliance market; therefore, it would be considered innovative if designed and manufactured within a reasonable amount of time.

The product price is competitive with the features offered, and the design was done with ease of use as a top priority.

Problem statement: Reduce the change in temperature and humidity in a refrigerator by minimizing the amount of cold air escaping the refrigerator through the consumer's use of internet-ready communications between themselves, their refrigerator, and their supermarket.

One of the important specifications for WIT is to enable a closed-loop economy through the product. An average user opens the refrigerator door for 30-45 seconds at a time to decide what they would like to eat, retrieve those contents, and shut the door. Our product can change these user habits by making the consumer more informed of the contents of the refrigerator by creating a list of its components on the outside of the fridge and through email or PDA. Therefore the well informed user will not need to open the refrigerator door for long periods of time or as often. Also, the list of goods will remind the user of perishable goods that are in their refrigerator and this may reduce the amount of wasted food. The product will contain smaller doors within the system. These smaller doors will have less energy lost to the ambient environment because of the reduced area exposed to the warm air. One of the design considerations was knowing the temperature and humidity that certain goods are stored as well as the frequency of the use of specific goods. The refrigerator remains colder towards the bottom of the refrigerator. Therefore, the design considers placing less frequently used goods towards the bottom of the fridge.

3. Market analysis

For our product we have chosen two large and wealthy markets. It is necessary that the people in these countries care about the environment, use the internet frequently, buy a lot of electric consumer goods and are able to pay more for products which save energy.

Primary Market – United States of America

The United States has an economy with the world's largest gross domestic product (GDP), $13.21 trillion in 2006. [i]The US economy also has a reasonably high GDP growth rate and a low unemployment rate.[ii] The US population is about 300 million people, and about 28.8% of them are at the age of our target customers.[iii][iv] 69 % of them are using the internet frequently.[v] About 67 % of Americans buy energy efficient appliances. In 2006, the US market has sold about ten million refrigerators. The market leader is Whirlpool Corporation.[vi]

Secondary Market – Germany

We decided to choose Germany as the secondary market because it is one of the world's most highly developed market economies. It is the world's third largest economy in USD exchange-rate terms,[vii] the fifth largest by purchasing power parity (PPP), and the largest economy in Europe.[viii] The population of Germany is about 26.1 million people between the age of 30 and 50 years old; this is equivalent to 31.7% of the whole population (82.31 million).[ix] [x] Nearly half of the German population lives in a secure wealth.[xi] 61% of Germans use the internet frequently[iii] and only 16% of Germans do not care about energy efficiency when they are buying electrical appliances. Most of the Germans care very much about the environment; 86% of them think that renewable energies should become the main energy source.[xii] Last year Germany had about two million refrigerators sold. The market leader is Bosch Haushaltsgeräte GmbH.

Market Size

For the US - market we calculated a market size of about 1.320 million potential target customers, and in Germany about 0.4 million. That calculation is based on the account of customers that fit to our customer profile and can be seen in detail in the Appendix A8.

Customer and requirements of our target customer

The customers of our refrigerator are single households, especially family households. They are middle aged (30 – 50 years) and are part of the middle to upper class. They care a lot about the environment and are ready to invest more money if they get an environment friendly or energy saving device. Our customers are early adopters; they like to buy innovative devices and are open-minded to those. The customers regularly shop in the supermarkets and often eat at home with the whole family; therefore it is important for them to know what is in their refrigerator. A list of customer requirements can be found in Appendix A10 and storyboard showing customer use can be found in Appendix A4.

Appearance: In both markets, the most common products are Fridge Freezer Combinations, with the freezer on the bottom and the refrigerator on the top. The biggest difference between both markets is the size of the refrigerator and the freezer. The US customer is used to a fridge which is more than twice the size of an average German one. In comparison to an average German family freezer, the average American freezer is three times bigger. Also the standard colours are different. In Germany a few years ago the only colour for fridges was white, however this has changed recently. The US trend of having a silver refrigerator arrived in Germany and has become very popular. Therefore, we decided to manufacture also for Germany a silver colored refrigerator, because our target customers are a modern families.

Energy consumption: The energy usage is the most important requirement for the German customer beside the appearance and the prize. In Germany nearly all domestic appliances are subdivided into different energy consumption classes. The most energy saving fridges are in the class A++ and the worst ones are in G. Our customer would only purchase products in the class A. For the US customers the energy efficiency is also an important point, but they want fridges which are ENERGY STAR qualified.

Functionalities: The US customer is used to having French doors with an ice machine and a water dispenser in the door. In Germany, the typical fridge has only one door without other functionalities in the door. Things like the ice machine in the door are not a requirement in Germany. Customers in both countries expect their fridges to have the basic functionalities like a defrost function, good quality, a temperature display and regulation or flexible interior elements.

Price: The average prizes in both markets for standard freezer fridge combination differ much. In the US the average freezer fridge combination costs about $1500 – $2000 in Germany $600 – $800. The requirement of our customer is, not to pay much more than the top of the average costs. But actually for additional functionalities like a very less energy usage he is willing to pay more.

The top four requirements for the US market are size and capacity, price, energy consumption, and appearance. The priority to the market is in that order. The top four for the German market are energy consumption, price, appearance, and additional functionalities.

There are a number of requirements that allow our product to be a global platform product. In today’s world, most of the governments have an initiative to save energy due to the increasing costs of energy and ecological reasons. The governments try to cut down the emissions of CO_2 and lower the energy consumption. As well as the government, many customers try to reduce their impact on the climate; therefore there is global demand for energy efficient products. The refrigerator is running 24 hours for 365 days a year. Therefore it is responsible for a certain amount of the energy consumption of a household. In the US and Germany, more and more costumers want to cut their electricity bill by using energy efficient products. There are some differences in the demands in the requirements of a fridge but the products can be used in both markets.

Competitor Analysis

- **Coolview Energysaving Refrigerator**[xiii]

A Patented Coolview Energysaving Refrigerator which saves money & energy because it reduces costly air exchange. The front face of the refrigerator door appears as a mirrored surface. When the inside is lit up, you can see the refrigerator's contents. Minimizing the time the door is open reduces costly air exchange. This refrigerator is not manufactured yet, but is just a patent. The idea to save energy by reducing air exchange is nearly the same. The solving of the problem is different. We work together with the supermarkets via internet. We can see at a LCD display that is in the fridge. Our refigerator also enables this kind of energy saving through an innovative door system. Futhermore our refrigerator enables you to see what is inside not only at home without opening the door but also though the internet anywhere.

- **Switching Device for Refrigerator**[xiv]

This is an invention in which the refrigerator door is opened with a hinge assembly and transmitting external electrical signals to the integrated product. The signal communicates with a display that is installed on the front surface of the door of the refrigerator. The invention uses a mechanical device to open the door of the refrigerator. This is a patent in application by LG. Our product includes a way to access the goods in the back of the refrigerator, which this patent does not include.

4. Engineering Product

World Innovative Technologies is considering in developing a product to deal with the problem of depleting energy resources. We are designing a refrigerator system which aims at saving the energy losses caused by excessive opening time of the doors. The system is made internet-ready by sending a list of items bought in the supermarket via the internet. The list will be displayed on the LCD screen on the refrigerator. This will help the customer to choose the item he wants without opening the door. The product promises to make the refrigerator considerably efficient in terms of energy usage. The product requirements list can be found in Appendix A5.

Functional Analysis

There are four parts of our system that interact namely the storage part of the refrigerator, the customer, the information (internet-ready) system, and the supermarket. The main interaction between the customer and refrigerator is food, and the food must be purchased/ordered and stored within the fridge. Please refer to Figure 1 and the green line to represent food. The functions needed to store and purchase food are to open and close main door, to store food, to unlock selected food area, and to open and close small doors. The main interaction between the supermarket and refrigerator is information. To reduce the amount of time that a refrigerator door is open to find what the consumer wants to eat, they must be informed of its contents. This can be done by sending the data about a consumer purchase directly from the supermarket to the refrigerator via the internet (represented in blue). The functions of the information system are to send the information inside, to check food location and quantity, to insert data from supermarket, and to inform customer about its contents. We must also include the functionality of the internet. There are nine functions in our functional analysis and we have working principles in the nine functions.

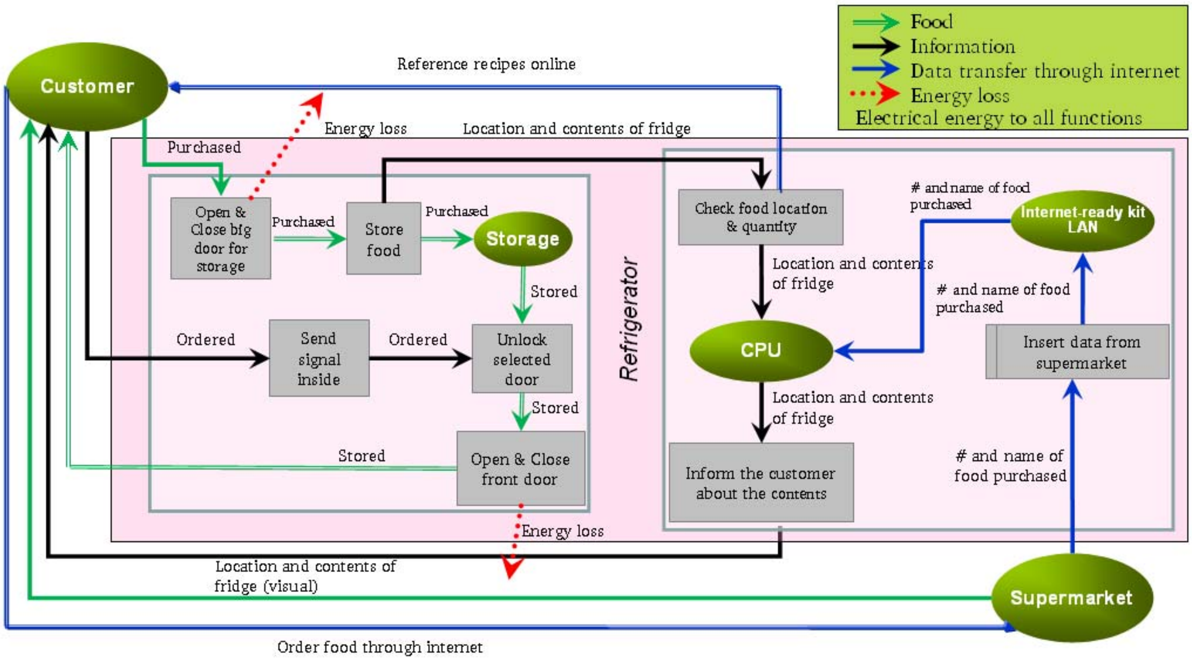


Figure 1: Functional Analysis

By brainstorming, drawings were made with different concepts for each working principle. These concept drawings can be found in the table in Appendix A6. The different designs for each working principle will be discussed now, and with these designs, selections were made through the use of a decision matrix on four product design alternatives made by combining functions found in Appendix A7.

Design Alternatives and Working Principles

1. **Opening and closing mechanism.** The first two working principles are to open and close both the main and smaller doors within the refrigerator. Some examples in which to open and close the small doors are as follows: provide an opening in the door that tilts out and stops at a particular angle to allow the user to retrieve the item in the door. This would typically be used for liquids. Doors are opened by sliding vertically or horizontally. In the final design, the refrigerator will have a full main door, which will be used while loading different products into the refrigerator and for cleaning purposes. When this door is opened, it will contain the smaller doors along with it which are integrated in the framework. There will be a number of doors that open on a hinge like a typical door. An advantage of this system is that the opening area of the smaller door is reduced when compared to the opening area of the entire door of the refrigerator, and energy is saved. A special design mechanism is used for the liquids in the refrigerator like milk and juices. A ‘pocket door’ mechanism is used. When a customer selects a liquid, the pocket door collapses down at the front. This is an effective mechanism and energy efficient as there is hardly any opening of the refrigerator. Drawers will hold vegetables and fruits.

2. **Store food.** The next working principle is to store food. The food can be stored at levels within the refrigerator based on temperature and how frequently the item is used. Items that need to remain colder should be placed towards the bottom while items that are used more frequently should be placed towards the top of the refrigerator. Every item could have a specific spot that it should be placed within the refrigerator. We will store the food so that we optimize the energy usage within the refrigerator. The freezer is placed on the bottom of the unit because the cooling system is towards the bottom of the refrigerator; this will be most energy efficient. Fruits and vegetables have specific temperatures and humidity that they should be stored at to increase life. On average vegetables should be kept at a higher humidity than fruits. Therefore, the fruits will be placed in a drawer below the vegetables.

3. **Access to food.** The next working principle is to access the food. The user can interact with the LCD screen on the refrigerator in different ways. They could select the food that they would like, they could select the door that they would like to open, or they could select the shelf that they would like to access. The user has the option of inputing the location of each item within the refrigerator. Over time the refrigerator will begin to remember where certain items are kept through the software. However, not every user will want to spend that initial time in selecting the location of their goods. We decided that the user has the option of selecting the door that they will want to access through the LCD screen to remove food or input each items location.

4. **Interaction between refrigerator and user.** The next working principle is for the user to interact with the refrigerator through some user interface. This can be done with a screen that has buttons placed along the side in which a button is chosen based on the corresponding selection in the screen. This idea is similar to an ATM machine. A touch screen could be implemented or a computer or PDA could be used for interaction with the consumer. It was decided that a LCD screen will be mounted on the front door for interactive purposes. The screen will display the contents of the refrigerator. It may also have some added functionalities depending on the market. This concept provides a benefit for manufacturability.

5. **Location and quantity of products**. The refrigerator should know the location and quantity of food placed with it. The fridge could have specific locations within the fridge that have a scale that weighs an item and sends a signal to the consumer when the item is running out or empty. The user can confirm that an item has been placed in the refrigerator. The supermarket can provide data about the expiration date of an item and the date it was bought when the consumer purchased the good. Otherwise the consumer could select how full each item remains and the refrigerator begins to remember through its history how often and long an item is used. It has been decided that there will be a select number of items that will be monitored in quantity. There will be a scale for the liquid compartment of the refrigerator to quantify the amount of milk. A counter will be used to quantify the number eggs are contained in their section.

6. **Confirmation of purchased products.** The refrigerator must know that the items bought by the consumer actually are placed inside of it. This can be implemented by having the consumer confirm that they have been placed within the fridge. A bar code reading can be done with each item. The refrigerator could begin to remember how long items are placed in the fridge and which items the user typically buys. It was decided that the user must confirm that items are placed in the refrigerator, but over time the software will remember what items should be refrigerated. The first time the customer has to confirm each product that he

puts in the fridge, through the software the system learns which products belong to the fridge. The second time the customer buys for example milk the fridge knows that the milk belongs to the fridge.

7. **Internet-ready interaction.** The last working principle is the internet-ready interactions. The options are having the supermarket send the refrigerator information about the purchases at its store. This is important so that the internet-readiness of the product enables a closed-loop economy. It enables a closed-loop economy by informing the user of the contents of their fridge without having to open the doors. This not only reduces the overall time of opening the refrigerator doors, but it also reduces the area of opening by a large amount through the smaller doors. The next internet option is that the user could order from the supermarket through the internet. This option will reduce the amount of time that a consumer will need to shop at the store, and time is important to our customer. The refrigerator could send the user an email or a message to their PDA or any internet connection if they have run out of an item. The refrigerator could look up recipes that require the goods that the user has contained within the refrigerator. This could provide for less food waste within the fridge because it will increase food use before going bad. It was decided that all features will be offered in our product. There are many more ideas about each working principle that can be found in Appendix A6.

Platform Product Structure

Designing a product for ease of manufacturability and production on a global scale is always an important aspect of design. The product has a common core element which exists among all the product models sold around the world, and the extra components are tailored and produced according to the market needs. In the refrigerator we use several core elements. In both markets, the same cooling system, mechanism for opening the small doors and pockets, and the LCD assembly will be made in a platform manner. There are some parts we have to build different variants for the two markets. The pocket doors are adapted to the local needs. For the US the doors are wider so that bigger bottles will fit in. Lastly, the American market has on average larger refrigerators, so the refrigerator base frame will be different sizes.

Embodiment Design

With all of these decisions made, many engineering details have been made for the systems and its subsystems. Detailed assembly drawings have been created for both the US and German market as seen in Figures 2 and 3 respectively. The major differences between the two markets are the size of the product and compartments. The US product is 1772 x 838 x 845 mm, and the German product is 1430 x 580 x 650 mm. Figures 4 and 5 elaborate the differences in the main door systems with the use of dimensions.

Figure 2: US Final Product **Figure 3: German Final Product**

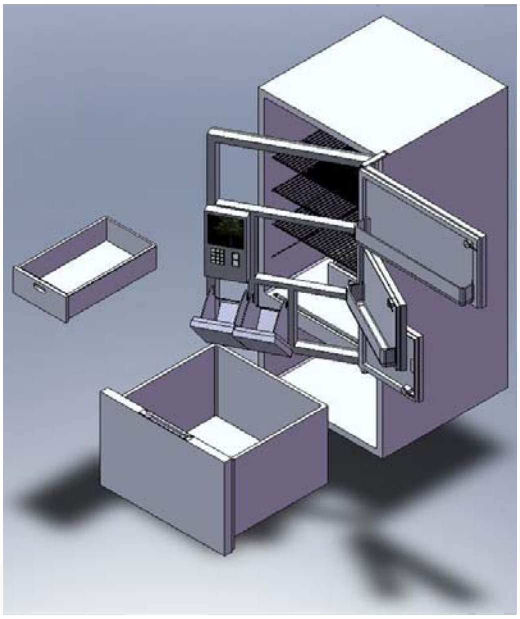
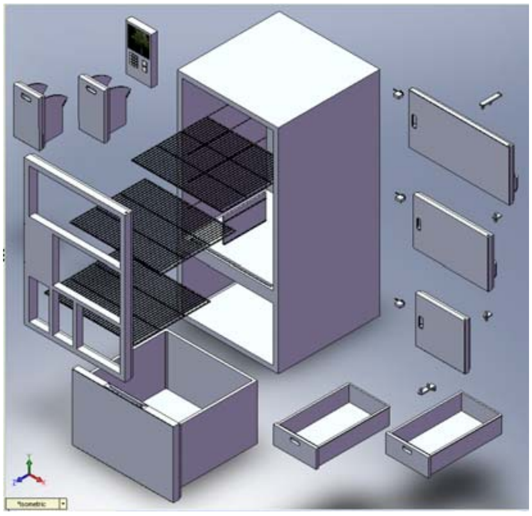


Figure 4: US Assembly Drawing **Figure 5: German Assembly Drawing**



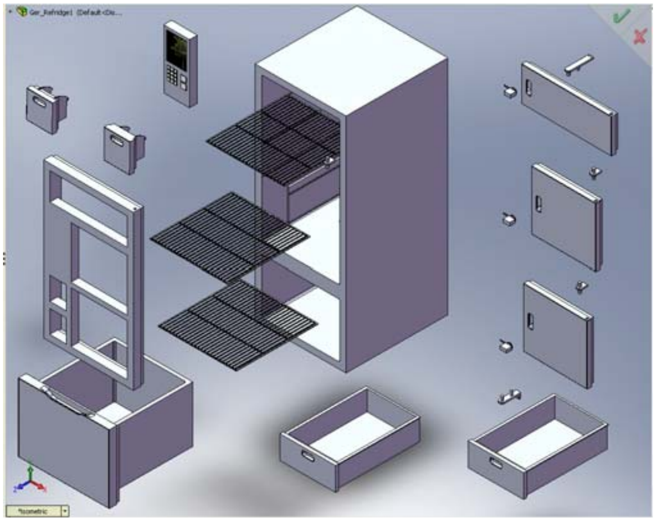


Figure 6: US Assembly Drawing **Figure 7: Germany Assembly Drawing**

A representation of the assembly of the door systems can be seen in Figures 4-7. There will be a sub-assembly line for each of the doors that will feed into the main assembly of the fridge. The doors will be screwed together between the inner mold and the sheet metal frame, and insulation will be injected inside. Then the latch assembly will be placed on the doors. The LCD assembly will be placed on the main door assembly. In the main line, the base of the refrigerator will be made and the cooling components will be assembled. Next the shelves and vegetable/fruit drawers will be place in the fridge. Then the hinges will assemble the doors to the main door, and the main door assembly to the base fridge will proceed.

In order to be energy efficient, there will be need of sufficient airflow within the refrigerator to keep all items cool. Figure 8 shows how the air will flow in our product to maintain this energy efficiency.

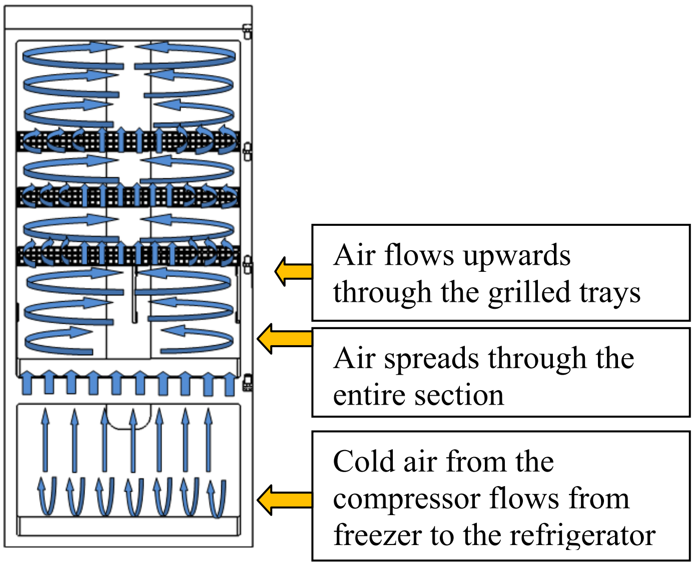


Figure 8: Air flow in refrigerator

The closed-loop aspect of our product is saving energy. Nine percent (See Appendix 2) of the energy used by a fridge-freezer combination is lost by opening and closing the door of the fridge. We assume that the user does not put hot meals in the fridge and other energy losses the customer can influence. The design of the isolation didn't change. We focused on the problem of air exchange which occurs rapidly, due to buoyancy. As the warm air water vapor enters the fridge, it condenses because cold air can't hold as much water vapor as warm air. The enthalpy of evaporation has to be spent by the cooling mechanism so there is a strong connection between the loss of energy and the condensation of water. Especially in the case of high humidity and hot temperatures it is very important to minimize the exchange of air. Due to our design concept for the front door, the complete door will not be opened often. The flap doors for liquids are an effective way to minimize air exchange combined with customers comfort. All together we cut down the energy loss by opening the door by 50% with all the power we need for the necessary and additional functionality for the customer. This correlates to the LCD/internet-ready usage on average reducing energy loss by 50%. Details are found in Appendix 2.

The critical components of our design are the electrical components. If there is an error in any of the internet communications or components, the connection between the supermarket and refrigerator will be lost. This will result in a service call and cost the company money. The sensing components (pressure transducer, phototransistor) are also critical components. There are many ways that these components could draw an error. For instance, if the user puts something other than eggs in the egg compartment the LCD screen will show that the user has plenty of eggs, which they do not. Electrical connections can also be lost with these components, which can drive bad quality like the internet connection.

For supermarkets the loyalty of costumers is one of the most important goals of marketing. There is a strong correlation between the successes of companies in the Business to Consumer (B2C) market and knowing as much as possible about the customers. Due to the database we use, the supermarkets have access to all the contents of the fridge (only if the costumer agrees) so they are able to send out personalized advertisements directly to the screen on the fridge. If the customer allows e.g. the Multi-Company Bonus System Payback (Germany) to advertise on his screen, they could lower the price for the refrigerator or offer him a long-term discount on the shopping. The possibility to advertise directly with the information the companies collected before is very useful for the companies. There is less waste coverage of marketing, so they have more possibilities to offer coupons, rebates or bonus points to the customers. The customer can order directly through the fridge, PDA, or the internet the shopping, so he just goes to the supermarket, shows his customer-card and will get his groceries. This is a major selling point for the customer. However, we are concerned with the customers willing to offer the information to supermarkets. There will be the possibility for the customers to decide whether the information flows only from the supermarket to the fridge or in both directions.

5. Product Manufacturing

A Bill of Materials (BOM) was created so the company can manufacture, procure, and finance the product. There are a series of sub-assemblies throughout the refrigerator assembly. Our project specializes in the door assembly, and all other assemblies and sub-assemblies will utilize existing manufacturing expertise like the cooling components assembly. The full assembly is the refrigerator assembly containing other sub-assemblies. The base of the refrigerator will be sub-assembled and placed in the main assembly along with the shelves and drawers to be placed inside the base. The door sub-assembly consists of each sub-assembly of the smaller doors. Also for each door there is a subassembly for the latch mechanism. The main door contains all the components that consist of the electronics including the user interface. Due to the size of the BOM, it can be found in Appendix A13.

Many of the manufacturing processes are outsourced to maintain emphasis on our core competencies. For instance, an appliance company does not find it efficient to invest overhead on an engineer to determine the best fin length in a heat exchanger, because there are already many suppliers who can produce the heat exchanger efficiently and effectively. For a product like fasteners, there is no profit margin for the part at low volumes. Often times a supplier will send the same fastener to different clients with the same need, thereby making a profit on the part. A study has also been done on the refrigerator manufacturing processes of a Whirlpool facility that outsource many of its manufacturing processes. Many of the decisions have been made based on their expertise. Outsourcing will reduce our capital expenditures and operating costs, thereby maintaining our core competencies. The outsourcing suppliers will be chosen based on quality, price, and engineering ability. The following raw materials and parts will be outsourced.

- Steel will be outsourced in the form of coils of rolled steel. It is used for the outer frame of the refrigerator and the outer part of the door. Steel suppliers include Atlas Steel Products Co., Steel Warehouse Co., Inc., and Nucor Steel.
- Most plastics will be outsourced which includes drawers, shelves, and shelf inserts. Some plastic suppliers that we may use are TH Plastics, Aweco Appliance Systems, and Crescent Plastics.
- Heat exchangers will be outsourced as part of the cooling system. Possible suppliers are Thermal Solutions Inc., Brazeway Inc., and Modine Manufacturing Company.
- Compressors are also needed to complete the cooling system. Compressors can be supplied by Tecumseh Power Company, ACC Compressors, or Bristol Compressors Inc.
- Injection foam insulation is to be injected into the door and main refrigerator base. : The foam material can be purchased by Honeywell (Ecomate systems) or Foam supplies, Inc.
- Rubber will be outsourced for creating the sealing gaskets. This will be done by Frank Lowe Rubber and Gasket Co., Inc., or Syntex Rubber Corp.
- The electrical hardware can be purchased by companies like Advanced Circuit Technology, Wago Corporation, and Microplastics, Inc. Also the electronics will be supplied by companies like Kingbright Corporation.
- Fasteners will be outsourced to Hastings Machine Co., Alloy Fasteners, or United Fasteners & Hardware Inc.
- The tooling for the processes that we complete in-house will be outsourced.

Processes that we will complete in house include the door and base assembly. The parts included in these assemblies are very large and expensive to transport to the manufacturing facility, and so they are formed and molded in-house. We have large presses that stamp and bend steel to create the doors and outer refrigerator base. These parts are then painted in their specified colors and dried as they are transported by conveyor to the beginning of the main assembly line. The plastic inner door and inner base of the refrigerator is injection molded and assembled to the steel door or base respectively. The base and doors are injected with foam insulation, and the base continues down the main assembly line while the doors are placed on kanban racks to be used when needed. In our case, the small doors will be assembled to the main doors along with the electronics and user interface. The doors will be assembled to the refrigerator in the main line assembly on the front of the refrigerator, while the cooling components will be assembled in the back. The main line assembly runs on a moving conveyor system, where each worker has a number of tasks to complete before the refrigerator has moved to the next worker/station. The products will go through a quality check where each product is plugged in and certain buttons are pressed to ensure functionality. The quality check is the most critical process in the production; it ensures that the consumer will get a functioning product. It is most critical because it will catch most problems that have occurred throughout the production of each part both manufactured and outsourced. The final process of the production is packaging. An representative assembly line can be found in Appendix 15.

The finished goods proceed to a distribution center in close proximity to the manufacturing facility. There will be three additional distribution centers strategically placed throughout the United States, and one additional distribution center strategically placed in Germany. The distribution centers will distribute product to our trade partners like Sears and other private retail outlets. The manufacturing facility will be located in the United States, because the projected American market is larger than the projected German market. It will be cheaper to transport the smaller volumes to Germany than vice versa. Also, the majority of the suppliers considered are based in the United States which will decrease transportation cost for each part. It will also decrease the lead time to receive each of the parts. The smaller lead times will require a smaller inventory for each part as the suppliers follow the just-in-time system. (Q* = (2AD/h)^(1/2) Where A is the order cost including transportation cost, as A decreases so does the optimal order quantity.) Some of the assets of the company are being held in inventory; therefore inventory should be minimized. Another reason for beginning production in the US is because of the weak foreign exchange rate for the US dollar. It will be more profitable to build in the United States because of this exchange rate.

6. Prototype

For the prototype, a small refrigerator was purchased and the door was removed to implement the design features of the refrigerator product. The prototype door was manufactured with a wood frame technique around the doors. The frame base construction is seen in Figure 9. Also, Figure 10 shows the door including the small doors and flap doors. The middle door contains the egg container where the light sensors will allow the user to know whether or not there are eggs in the fridge. The lower left flap door will contain the pressure sensor to inform the user on how much liquid is contained in that particular section of the fridge. The LCD screen of the fridge will be represented by a laptop due to budget constrictions.

Figure 9: Frame base of prototype

Figure 10: Finished prototype

The electrical aspect of the prototype is composed of three different parts including internet-readiness, light sensors for counting eggs, and pressure sensors for measuring the weights of liquids. The internet-ready kit is used to integrate the light sensor and pressure sensor with the refrigerator and supermarket. When we buy foods from the supermarket, a list is sent to our refrigerator (laptop) through the internet. Based on the list, we can organize the foods by confirming that the product is placed in the fridge by the 'bought list'. When we want to access our foods, we can choose the food from the list, and the LCD panel shows us the position of the food.

The light sensor part is for checking whether there are eggs in the refrigerator or not. This can be achieved by using a photo-transistor: emitter and receiver. This mechanism can be implemented by positioning eggs between the emitter and the receiver. If there are eggs in the fridge, they will break the lights passing. If there are not eggs, light will pass to make the connection. This can be done on each of the egg holding positions; however, in the prototype, we show this for two eggs.

The pressure sensor part is for checking the amount of liquid contents in a certain section in the fridge. It can be achieved by using a pressure-sensor. Resistance of the pressure sensor changes when weight is applied. By this resistance value, we can calculate the weight of liquid contents. Although we can calculate the exact amount of the liquid contents, we simplified it into only three levels of liquid contents. This is because exact values for the levels of liquid are necessary for users, because they will not understand what the value means.

The prototype differs from the designed product by not having all of the features of the product. Since the main functionality of the innovation is to create an interaction through the internet between the supermarket, the fridge, and the user we used this concept in the prototype. The cooling components of the fridge are not essential to show this functionality, and therefore it is not necessary to have a full refrigerator. Instead we have a small refrigerator for the prototype. We feel that using an actual refrigerator to test the energy savings is not necessary at this point in the design and engineering calculations are sufficient. We created a representation of a fridge door with smaller compartments like in our actual design. With these compartments, we show the functionality of the weighting scale for liquids, and sensor components. We have a laptop that represents the supermarket, and the scanning of goods is represented by typing a code into the "supermarket" laptop. The internet-ready kit transfers information to another laptop that represents the LCD screen on the refrigerator. We are using laptops to reduce cost as well as complexity in programming. The prototype does not show the use of the latch system. It also does not implement some of the internet features like recipe look-up and music. These features are not necessary to show functionality of the product.

The Bill of Materials for the prototype is shown in Figure 11. The prototype consists of the mechanical and electrical part. The mechanical part reused many materials, which helped enable a closed-loop economy.

Parts	Used/New	Quantity
Wood	Used	
Small fridge	Used	1
Egg holder	Used	1
Insulation	New	6 meters
Hinges	New	1 meter
Magnetic Latches	New	6
Screws	New	50
Steel	Used	10x15 cm
Power Strip	New	1
Internet-ready kit	New	1
Pressure sensor	New	1
Photo-transister	New	3
Emitter	New	3
Receiver	New	3
Resistor	New	9
Wire	New	20 meters
Chip - LM 324	New	4
Potentiometer	New	4
LED	New	6
Connector- 20 pin	New	2
Connector- 2 pin	New	7
Board	New	1

Figure 11. Prototype Bill of Materials

7. Business Plan

Price Strategy

Market Price and Calculated Volume

A normal fridge-freezer combination of our refrigerator size with low energy usage costs about $1600[xv] in the US and about $700[xvi] in Germany. If they also have a TV LCD screen they are much more expensive, in the US they cost about $3,200 and in Germany about $2,500.

We decided to go into the market in both countries with a “penetration strategy”. This means that we are starting with a lower price to attract the customers quickly, and if we have good sales of our product we will raise the price. Our market entrance price for the US is about $2000 and for Germany about $800. In the long term perspective, we want to achieve prices in the US at about $2,400 and in Germany about $950. With these prices we are more than 20% under the average costs than our competitors and will be able to develop the market faster. In the first year, we expect to sell our product to 5% of our calculated target customers. This corresponds to 66,200 products sold in the primary market and 20,100 in the secondary market.

Product Manufacturing Cost

In Appendix A9, we calculated approximated manufacturing costs per product including labor and material costs. We took the average manufacturing costs per product for a regular refrigerator in a comparable size and added the costs for our additional functions. The manufacturing of our refrigerator in the US-market will cost about $670 and in the German market $435. The $200 price differentiation comes from the difference in the size of the fridge-freezer combination. For the German market we will manufacture a total capacity of

220 liters while the primary market has a capacity of 620 liters. These costs do not include shipping, marketing, and indirect production labor costs. Adding these costs will make the manufacturing costs become approximately $713 for the US market and $614 for the German market if we sell to 5% of our target customers (Detailed calculation Appendix 14).

Marketing Communication and Distribution Strategy

For the market launch, a big initial investment has to be made in both markets. We plan for the first four months of our market launch to be significantly present in the media to advertise our product so the concept of the energy saving smart fridge becomes popular. Therefore we will use print media like magazines or digital media like television or internet to advertise. A large presence in the media is necessary because our product is innovative with all its functions and has a unique look. The potential customers must get used of the look of a fridge with a multi-door system. The other main reason for this big marketing campaign is that we are a new company in the refrigerator market, so we have to build up a good image. The other products of our company will also be more present to the customers in these four months. In this first step, we will have to focus on advertising not only to our target customers but also to society because everybody should get an idea of our product innovation. Plans are to target 75% of our advertisement to our target customer and 25% to the whole population. During the next six months, we will continue focusing only on our target customers and communicate with them the strengths and advantages of our product.

Selling

The customer will have three main possibilities (direct and indirect) to buy our product:

1. Directly from our company through our Homepage
2. Indirect in shops with electrical products and on their homepages
3. Indirect in supermarkets with a special price if the customer accepts the terms of the supermarket (For example, advertising on the LCD screen of the fridge, or joining a special customer program of the supermarket)

We plan to sell most of our products indirectly; the direct way is just in addition to the indirect. The plant allocation will include 10% for direct sales, 50% for indirect sales in shops, and 40% for indirect sales in supermarkets.

For the first five years, we plan for the United States to have the only factory for World Innovative Technologies for refrigerators. The German market will be supplied from the US. When we make profit and are established in the market we plan to build a second factory in Germany.

Market Launch and Entrance

Because of the increasing importance of the internet in our lives, more and more products are becoming internet ready. Our competitors are also designing internet–ready refrigerators; therefore we have to launch our product as soon as possible in both markets.

Critical factors for a successful launch in September 2008 are that the following steps have been fulfilled:

Product

- First User Workshops Prototype one
- Feedback of our customers
- Second User Workshop Improved Prototype two
- Feedback User Workshop 2

- Final Design

Partners
- Money for initial investments
- Contracts with the supermarkets
- Contracts with distributors

Manufacturing
- Good suppliers found
- Factory rented
- Production Process working

Market launch First Market (as shown in Figure 12)
- Phase One "Aggressive Communication"
    - Nov. 08 – Feb. 09
- Phase Two "Light Communication"
    - Mar. 09– Aug. 09
- Phase Three "Continuous Communication"
    - Since Sep 2009.

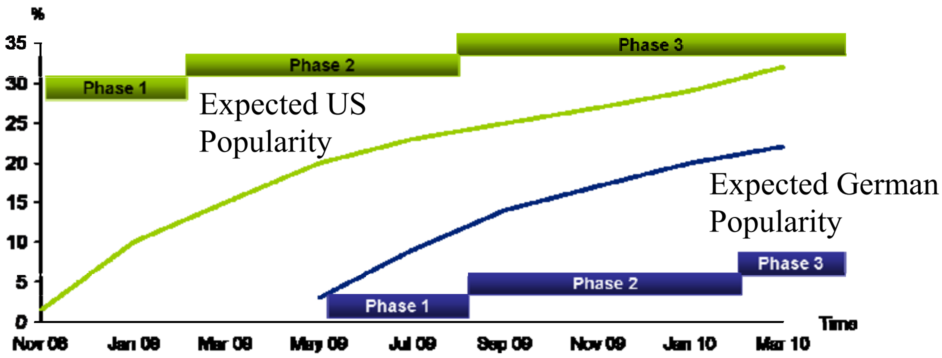


Figure 12. First Market Launch

We plan to launch the second market about 6 months after the first market. If we implemented and optimized all the features in the first market, we can use our resource of knowledge in technology and marketing to penetrate the second market In the German market, we will focus the marketing on the energy saving aspect. Germans are keen on saving energy and protecting the environment through energy saving devices. We will also address the experiences we have made on the first market. We will know what the most important features for the customers in the United States were and can adapt them for the German market. Also the success in the first market will be part of the marketing strategy in Germany. In the first phase of the marketing strategy, we try to make our products well known, so an aggressive marketing campaign will be set off. We will combine marketing via commercials, the internet, and papers to reach a big group of the target customers. In the second phase, we will focus on the features and the benefit for the customers. The third phase is the start of the permanent marketing for our product.

8. Project Summary

A product in which an internet-ready concept enables a closed-loop economy was brainstormed and selected by a group of six engineers. A refrigerator that receives information from the supermarket through the internet about the consumer's payment of refrigerated goods was chosen. The list of goods is sent to a display so instead of looking inside the refrigerator to decide what to eat, the consumer looks through the list. This reduces the amount of energy lost by opening the refrigerator door for longer periods of time. Smaller door compartments can be accessed through a mechanism to reduce the amount of cold air escaping the fridge. This is a closed-loop economic product because it reduces the amount of energy wasted to the environment. Different design aspects of the refrigerator were analyzed as functions, and the best concepts were selected. The design was selected with consumer requirements within the German and US markets as a priority. There will be some competition within the appliance industry; however the product exceeds the current innovation of refrigerators. A detailed design of the final product was done as well as an engineering analysis to support the product concept. Strategic planning was done for the manufacturing strategies and business strategies. The company will profit from producing this product and introducing it to the market. Lastly, a prototype was constructed and implemented with electronics to show the innovative features of the product.

9. Lessons Learned

The main objectives of the project were to develop a global product that uses the internet to enable a closed-loop economy. The product must also be mechanically based. The team feels that we have successfully achieved all of these main objectives. As well as creating a product that meets these requirements, we have planned a business market launch and manufacturing plan. The product meets these objectives with a functioning prototype to represent the product. There are many different learning points acquired during the Global Product Development course. The team has learned to work with global students, the global language, and product development.

Working with a global group of students was both enlightening and challenging. There are many differences between students globally. Some of these differences include experiences, culture, and character. Communication must take place to meet a collaborative goal between the students through a number of communication lines like video conferences. We found that the face-to-face meetings were the most effective. The video-conferencing was beneficial; however, the limited time allotted to each group did not allow work to be done but rather just discussion about work. At times more time was needed to make critical decisions about the project. We also used email and instant messaging to communicate; however, the discussion would require a time investment in comparison to a face-to-face meeting. Using email was not always successful; at times, no reply was sent by other teammates. It would have been beneficial to require the other teammates to reply within 24 hours of the sent email.

We have found the importance of global language. Some students felt that English wasn’t that important in understanding engineering and numbers (a global language); however, after taking the course they understand its importance. However, without global English interpretation of a problem or a concept can cost time and money. Teamwork requires language.

During the course and project, we found that each student specializes in their own specific ability. Our work was affected by these specializations. By dividing work to individual abilities, everyone could concentrate on their work and our goal was achieved.

Additionally, the team experienced developing a product from ideation to prototype. Due to time restrictions, a limited amount of time is allotted for making decisions about the design of the product. In the real world it would take at least a number of months to make these decisions among different layers within the company. We recommend that in the future a project is chosen before the first face-to-face meeting. There was a lot of time wasted in picking a project during the meeting, which made the rest of the meeting quite stressful.

10. References

Please see end notes

11. Appendix

Appendix A1: Decision Matrix for top five concept ideas

	Selection Criteria	Internet Ready	Closed Loop Economy	Designable	Manufacturable	Marketable	Different Regions	Innovation	Price	Easy to Use	**Total**
WEIGHT		**5**	**5**	**5**	**4**	**5**	**3**	**4**	**2**	**3**	**36**
Project Ideas											
Refrigerator - Contents List		5	5	4	4	4	3	4	3	3	**146**
Trash Can - Recycle		5	5	2	3	2	2	5	2	4	**124**
Socket Saver		5	5	1	1	3	2	2	1	3	**99**
Farm Watering by Internet		5	5	4	4	2	1	2	3	3	**122**
Door Enabler		5	1	4	4	3	3	3	4	3	**119**

Appendix A2: Approximation of Energy Loss

To approximate the loss of energy by opening the door we considered the following parameters. Every time we open the door the complete air is exchanged. This is a good approximation because of the buoyancy while opening and closing the door. Due to the higher density of cold air, the air flows as well the whole time out. An average refrigerator is opened 30 times per day (source: www.whirlpool.com).

Load Volume (refrigerator):	$V = 166l \leftrightarrow 0.166m^3$
Energy Consumption per day:	$W_{day} = 0.77$ kWh
Density of air:	$\rho = 1.2kg/m^3$
Ambient Temperature:	T = 295 K
Ambient Humidity:	60 %
Refrigerator Temperature:	T = 275 K
Refrigerator Humidity:	100%
Temperature Difference:	dT = 20 K
Heat Capacity of air:	$c_p = 1kJ/kg*K$
Enthalpy of evaporation:	h= 2256kJ/kg
COP:	COP = 1

The total exchanged Volume for a regular refrigerator is:
$V_{total} = 30*0.166m^3 = 4{,}98\ m^3 \approx 5m^3$

$$m_{total} = \rho * V_{total} = 1.2\frac{kg}{m^3} * 5m^3 = 6kg$$

Now the exchanged Volume for our fridge is calculated:
We expect that the complete door is opened 3 times a day, the flap doors 10 times, the highest section 8 times, the middle section 5 times and the lowest section 2 times. As well two times we don't need to open the door, because of knowing what is inside the fridge.

If we open a flap door nearly no air is exchanged!

If we open the highest section the following air is exchanged:
V_1= 0.434m*0.2m*0,41m= 0.036m^3

For the middle section:
V_2= 0.434m*0.36m*0.41m + V_1 =0.1m^3
This is because the air from the higher section will fall out as well.

For the lowest section
V_3 = (0.434m*0.36m*0.41m)/2 = 0.032m^3
Because of the two shelves

The new total exchanged Volume is:
$V_{newtotal} = 8*V_1 + 5*V_2 + 2*V_3 +3*(V_1+V_2+2*V_3) \approx 0.1m^3$

$$m_{newtotal} = \rho * V_{newtotal} = 1.2\frac{kg}{m^3} * 0.1m^3 = 1.2kg$$

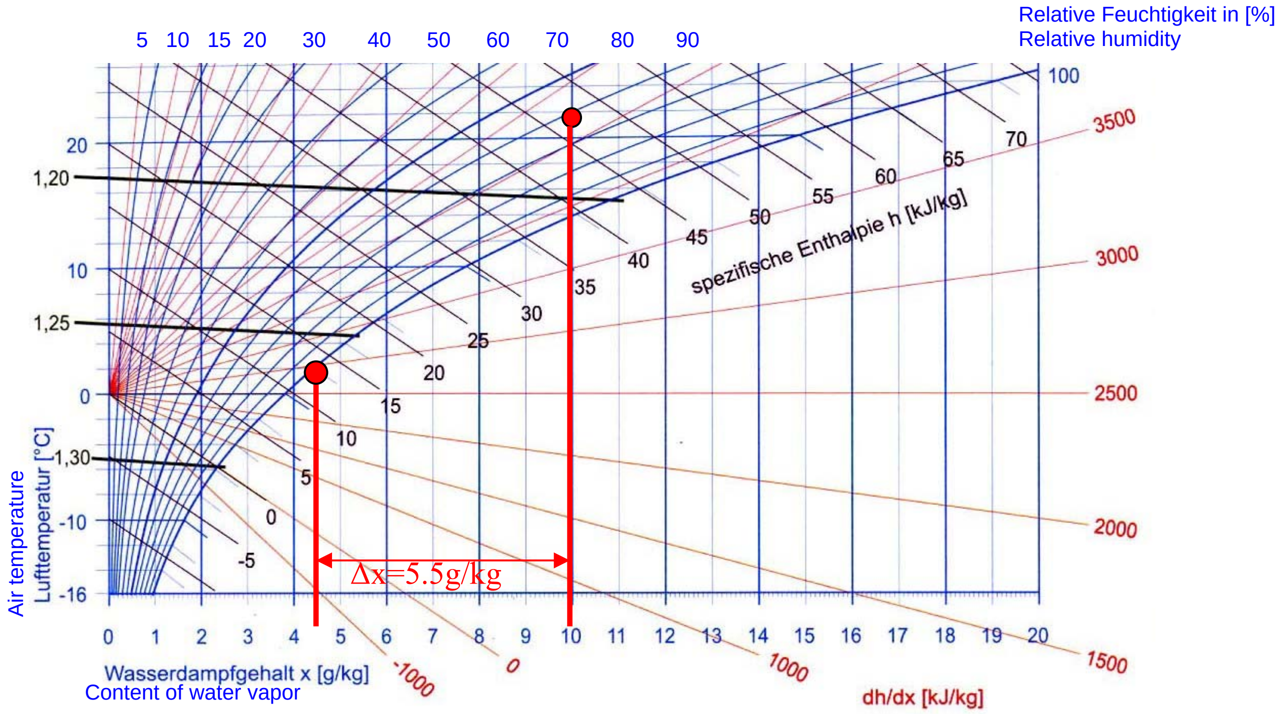
So only 1/5 of the air is changed with the new design.

Now the specific Energy to cool down the air will be calculated.

$$\dot{q} = c_p * dT = 1\frac{kJ}{kgK} * 20K = 20\frac{kJ}{kg}$$

But not only the air has to be cooled down, there is as well a high amount of energy spent for condensation of humidity (Mollier-Diagram):

If you cool down Air from 295 K (22°C) with 60 % Humidity to 275 K (2°C) and 100 % humidity you have to condensate $\Delta x = 5.5\frac{g}{kg}$ water per kilogram air.



So the total Energy loss for the regular refrigerator is:

$$Q_{total} = q * m_{total} + m_{total} * \Delta x * h = 20\frac{kJ}{kg} * 6kg + 6kg * 5.5\frac{g}{kg} * 2256,5\frac{kJ}{kg} = 254kJ \Leftrightarrow 70Wh$$

$$Q_{newtotal} = \frac{1}{5} * Q_{total} = 50,8kJ$$

$$Q_{saving} = Q_{total} - Q_{newtotal} = 203.2kJ \Leftrightarrow 56.5Wh$$

We can say that because of the coefficient of performance (COP) of 1.

$$COP = \frac{|Q|}{W}$$

The loss of Energy in a regular fridge by opening and closing the door is:

$$\frac{W_{lossday}}{W_{day}} = \frac{0.07kWh}{0.77kWh} = 0.09$$

So 9% of the Power is wasted thru opening and closing the door.

But we build in some more electrical parts so we have to calculate the Power these devices consume (datasheets). There will be 5 Phototransistors and Photoemitters and 2 Pressuresensors.

$P_{internetkit}$=1000mW
$P_{presuresensor}$ = 25mW
$P_{phototransistor}$ = 250mW
$P_{photoemitter}$ = 180mW
P_{LCD} = 700mW

The sensors as well as the LCD-Screen are only running if they are in use. We approximate to have the LCD for each contact about 2 minutes in use. So the total time of usage is one hour a day. The standby power of all the devices is marginal.

$$W_{totalday} = P_{internetkit} * 24h + \sum P_{rest} * 1h$$

$$W_{totalday} = 1000mW * 24h + [700mW + 2 * 25mW + 5 * (250mW + 180mW)] * 1h$$

$$W_{totalday} \approx 27Wh$$

Now we calculate the saved Energy.

$$W_{savings} = Q_{savings} - W_{totalday} = 56.5Wh - 27Wh = 29.5Wh$$

Now we calculate the percentage of energy saved due to our door mechanism

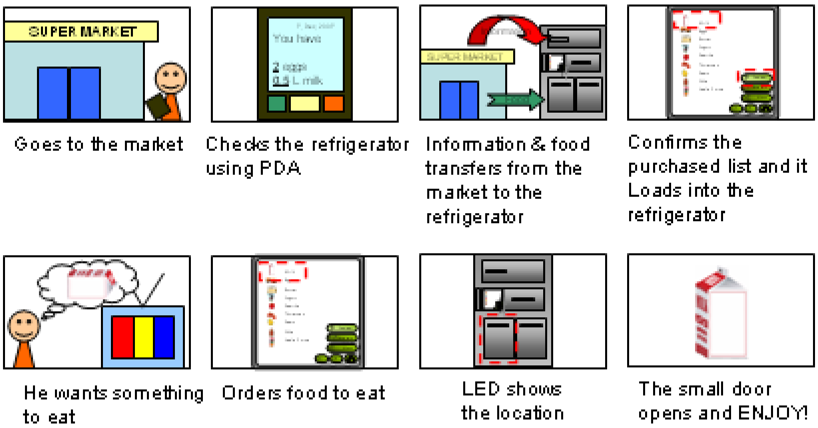
$$\frac{29.5Wh}{56.5Wh} \approx 0.52$$

We lower the loss of energy thru opening and closing the doors by approximately 52%.

This is only an example calculation. If you have for example a higher humidity you will need a lot more Energy to cool the exchanged air down. If it is dry air, our product will not save much energy. We need would need to make research with a working prototype in a laboratory to get real reliable data.

Appendix A3: Market Starting Point

Appendix A4: Storyboard

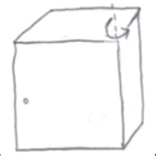
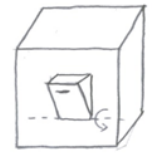
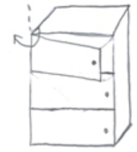
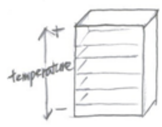
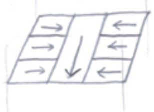
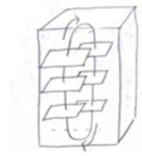
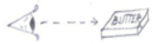


Appendix A5: Product Requirements List

Writer	Director	Requirements list for Refrigerator	2007.11.01
Ji-seok Kim	Kazu Saitou		page 1/1

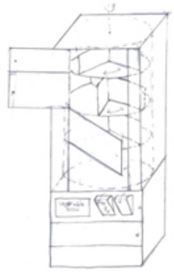
D/W	Required functions and constraints	
W	Material	Environment-friendly materials
W	Interface	User can know what is inside refrigerator and quantity
D	Internet-ready	Bill transfer
D	Energy consumption	Lower than typical refrigerator door opening mechanism
D	Refrigerate	Keep foods cold
W	Size (Geometry)	1350x550x600~1780x850x900 (width*depth*height)
W	Capacity	0.221~2.1 m3
D	Energy	110~220V
D	Signal	Maximum 16 input/16 output
D	Price	Total cost should be less than $2500

Appendix A6: Working Principles Chart

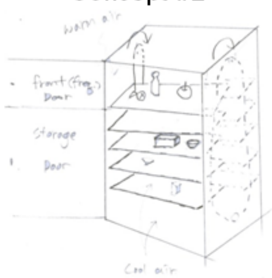
Storage door					
Food Storage					
Moving contents					
Internet-ready	Supermarket sends data to refrigerator	Order items from supermarket by email	Reminder to email or PDA to order items	Recipe search	
Checking contents					

Appendix A7: Design Alternatives

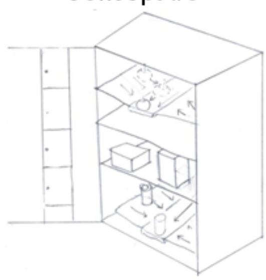
Concept #1



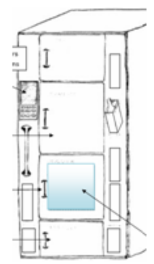
Concept #2



Concept #3



Concept #4



	Selection Criterion			Design Concepts			
	Item	Details	Weight	#1	#2	#3	#4
1	Commercial feasibility	Will people buy it?	2	2	4	3	4
2	Schedule feasibility	Limited to two months	3	3	1	2	3
3	Manufacturability	Easy to manufacture	3	4	1	3	3
4	Sustainability	Energy savings impact	3	3	1	2	3
5	Ergonomics	Is it convenient to use?	1	4	2	3	2
6	Space Utilization	Is there any dead volume?	2	3	2	3	4
7	Simplicity	Is it simple?	2	3	2	1	3
8	Adaptability	Adaptable to all products	2	3	4	1	3
		Totals		56	35	40	57

Appendix A8: Market Size Calculation

Calculation	Primary market United States	Secondary market Germany
Amount of target customers in the market	86,400,000	26,145,000
* the % of customers that are middle class	50.0%	45.9%
* the % of customers that have refrigerators	99.0%	99.0%
* the % of customers which uses the internet frequently	70.0%	61.0%
* the % of customers which will buy a refrigerator this year	6,6%[xvii]	
* the % of customers that use energy efficient appliances environment	67.0%	84,0%
Market Size	**1,323,841**	**401,781**

Appendix A9: Price Calculation

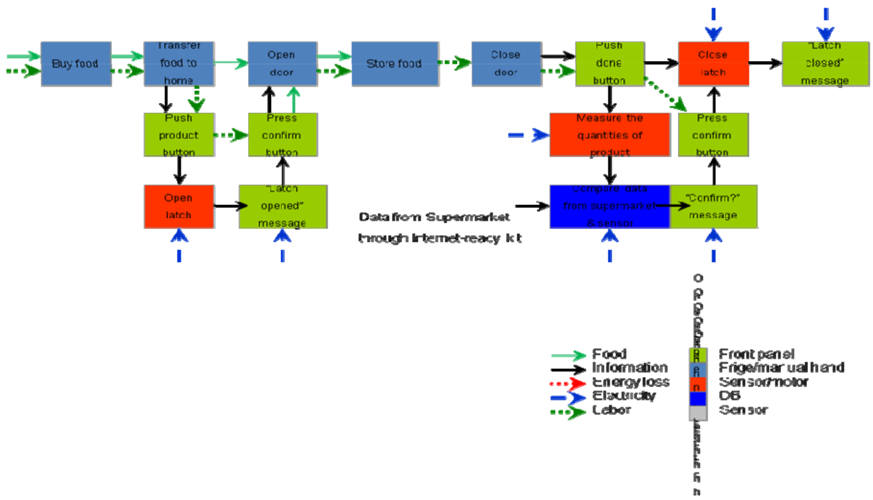
		Primary market United States	Secondary market Germany
Costs of a standard fridge in a standard size		$450,00[xviii]	$230,00
Additional costs	Computer costs	$150,00[xix]	$150,00
	Sensor costs	$20,00	$20,00
	Door costs	$50,00	$35,00
Total manufacturing costs		**$670,00**	**$435,00**

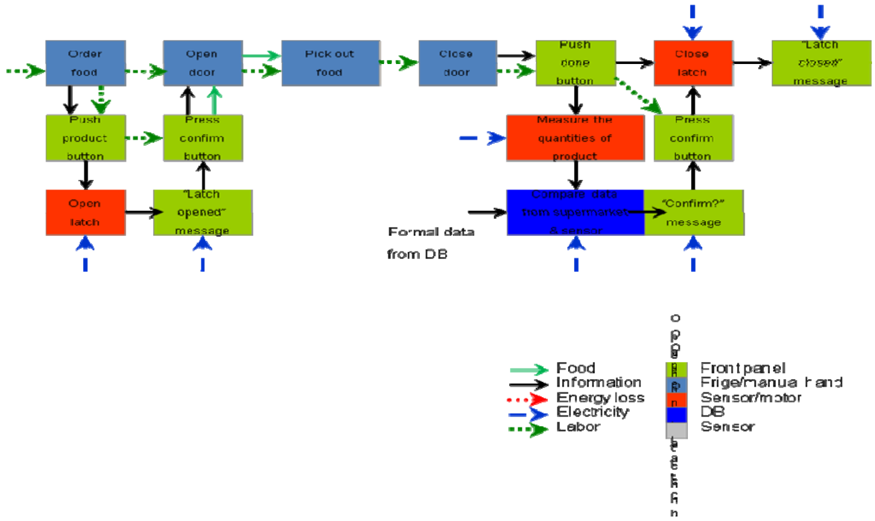
Appendix A10: Customer requirements

Customer Requirements	USA	GER
▪ Size	Big	Small
▪ Double doors	✓	(✓)
▪ Compartment size	Large	Small
▪ Size of the small doors	Large	Small
▪ Flex. interior element	✓	✓
▪ Standard of Quality	✓	✓
▪ Good energy Rating	✓	✓
▪ Durable	✓	✓

Customer Requirements	USA	GER
▪ Defrost function.	✓	✓
▪ Adjust the temp.	✓	✓
▪ Not too expensive	✓	✓
▪ Easy to use	✓	✓
▪ Good looking	✓	✓
▪ Ice machine	✓	(✓)
▪ Water in the door	(✓)	
▪ Able to be interactive	✓	(✓)

Appendix A11: Functional Analysis





Appendix A12: CAD/Assembly Drawings

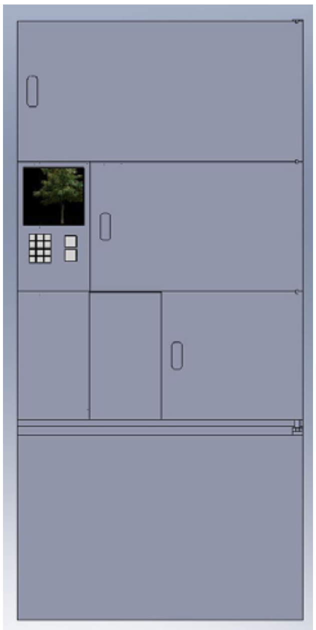


Figure: US Final Product

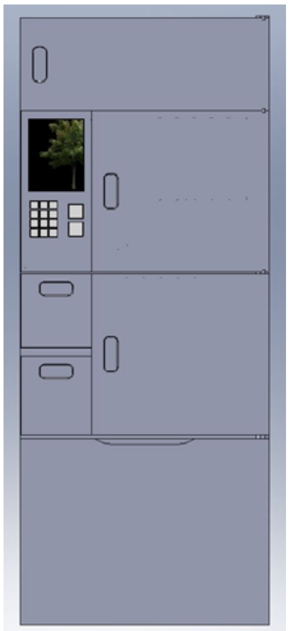


Figure: German Final Product

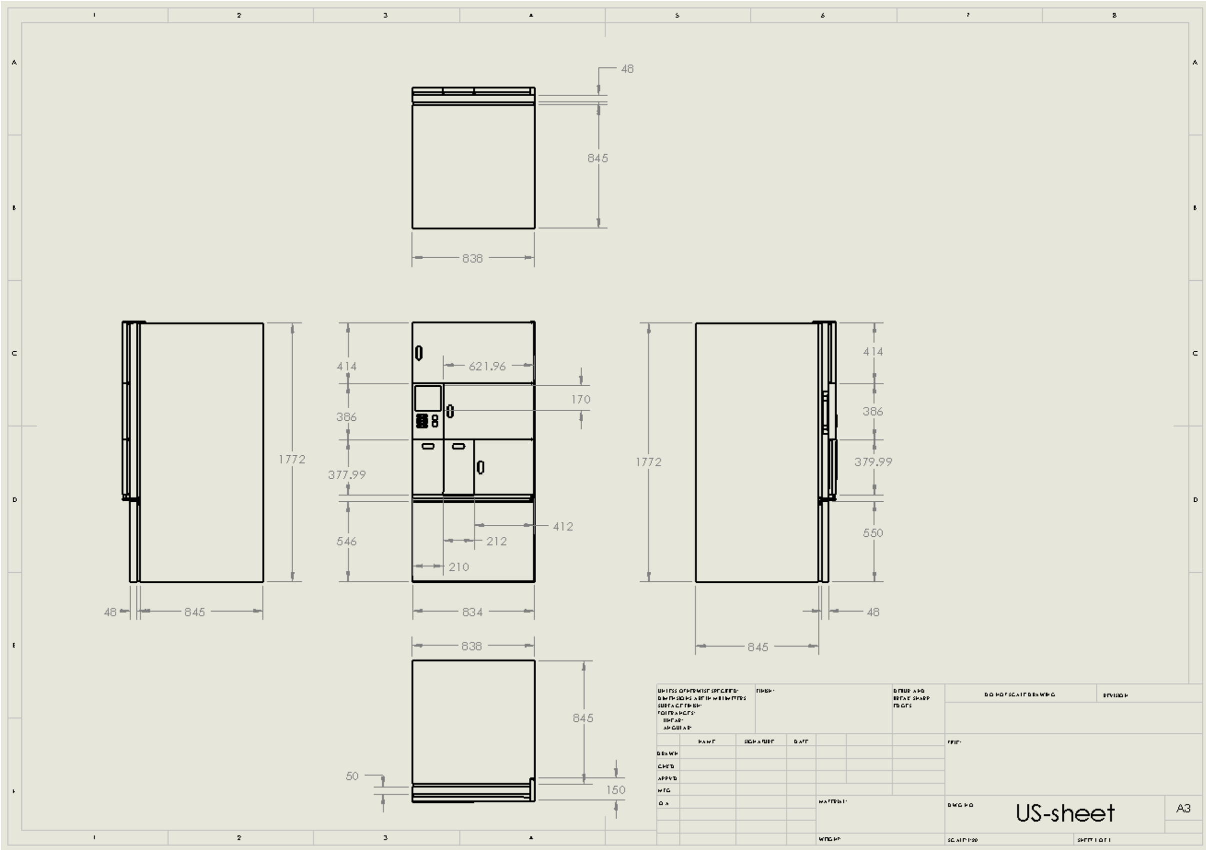


Figure: US Dimensional Assembled Drawing

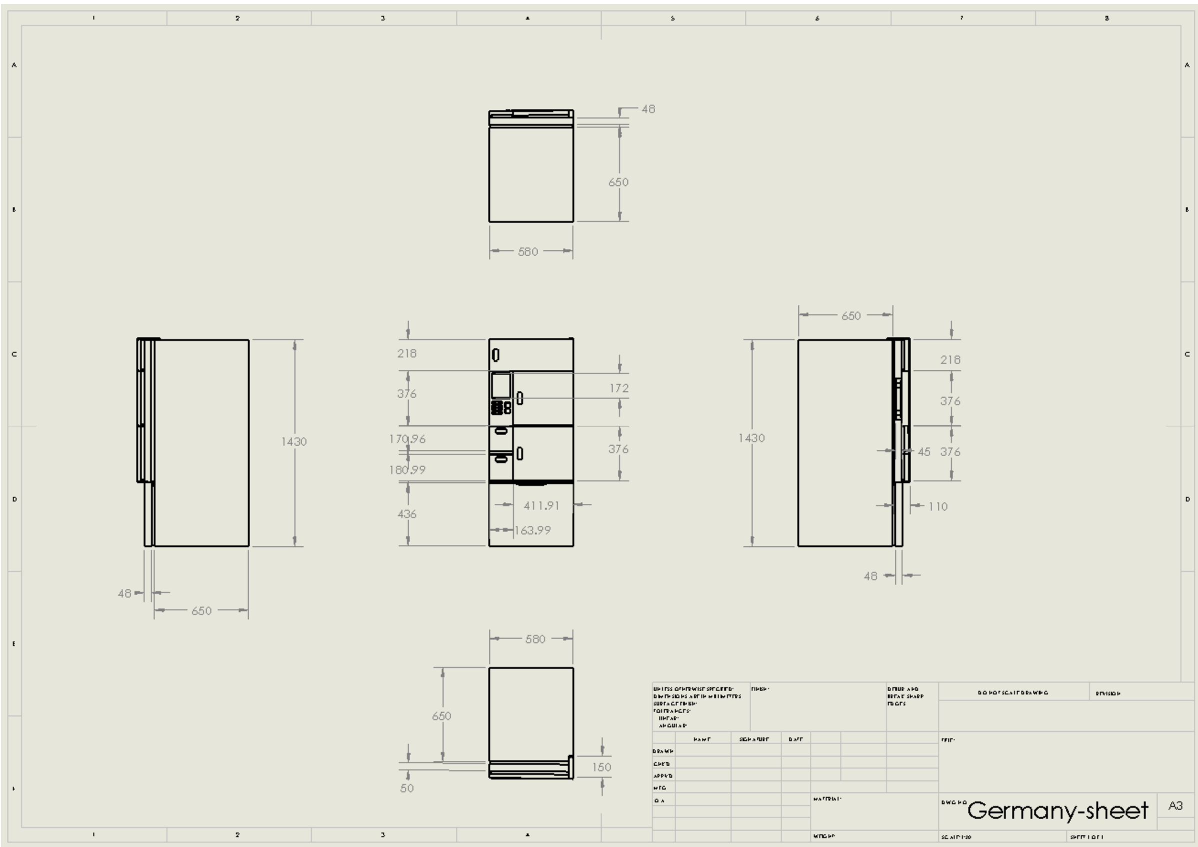


Figure: German Dimensional Assembled Drawing

Appendix A13: Bill of Materials

Assembly	Sub-assembly 1	Sub- assembly 2	Sub-assembly 3	Sub-assembly 4	Material	Part Number	Quantity	Make/Buy
Refrigerator					Various	WITR01US2007	1	M
	Base Assembly				Various	WITR01USA001	1	M
		Frame			Steel - Painted	WITR01USP001	1	M
		Mold - Inner			Plastic	WITR01USP002	1	M
		Screws			Standard 8 mm	WITR01USP003	16	B
		Insulation				WITR01USP004		B
	Cooling Component Assembly				Various	WITR01USA002	1	B
	Shelf - Top				Plastic	WITR01USP005	1	M
	Shelf - Middle				Plastic	WITR01USP005	1	M
	Drawer - Vegetable				Plastic	WITR01USP006	1	M
	Drawer - Fruit				Plastic	WITR01USP006	1	M
	Drawer - Freezer Assembly				Various	WITR01USA003	1	M
		Frame			Steel - Painted	WITR01USP032	1	M
		Mold - Inner			Plastic	WITR01USP033	1	M
		Screws			Standard 8 mm	WITR01USP009	16	B
		Insulation				WITR01USP010		B
		Latch Assembly			Various	WITR01USA006	1	M
			Latch		Steel	WITR01USP011	1	B
			Servo motor(HES-288)		Plastic Gear	WITR01USP012	1	B
			Servo motor driver		Various	WITR01USP013	1	B
			Servo Joint Wheel		Plastic	WITR01USP014	1	B
		LED, (MTE8080N)			Various	WITR01USP015	1	B
	Door Assembly				Various	WITR01USA004	1	M
		Door - Main Assembly			Various	WITR01USA005	1	M
			Frame		Steel - Painted	WITR01USP007	1	M
			Mold - Inner		Plastic	WITR01USP008	1	M
			Screws		Standard 8 mm	WITR01USP009	16	B
			Insulation			WITR01USP010		B
			Latch Assembly		Various	WITR01USA006	1	M
				Latch	Steel	WITR01USP011	1	B
				Servo motor(HES-288)	Plastic Gear	WITR01USP012	1	B
				Servo motor driver	Various	WITR01USP013	1	B
				Servo Joint Wheel	Plastic	WITR01USP014	1	B
			LED, (MTE8080N)		Various	WITR01USP015	1	B
		Hinge 1			Steel	WITR01USP034	1	M
		Hinge 2			Steel	WITR01USP035	1	M
		Door - Top Assembly			Various	WITR01USA007	1	M
			Frame		Steel - Painted	WITR01USP016	1	M
			Mold - Inner		Plastic	WITR01USP017	1	M
			Screws		Standard 8 mm	WITR01USP009	16	B
			Insulation			WITR01USP010		B
			Latch Assembly		Various	WITR01USA006	1	M
				Latch	Steel	WITR01USP011	1	B
				Servo motor(HES-288)	Plastic Gear	WITR01USP012	1	B
				Servo motor driver	Various	WITR01USP013	1	B
				Servo Joint Wheel	Plastic	WITR01USP014	1	B
			LED, (MTE8080N)		Various	WITR01USP015	1	B
		Hinge 3			Steel	WITR01USP036	2	M
		Door - Middle Assembly			Various	WITR01USA008	1	M
			Frame		Steel - Painted	WITR01USP018	1	M
			Mold - Inner		Plastic	WITR01USP019	1	M
			Screws		Standard 8 mm	WITR01USP009	16	B
			Insulation			WITR01USP010		B
			Latch Assembly		Various	WITR01USA006	1	M
				Latch	Steel	WITR01USP011	1	B
				Servo motor(HES-288)	Plastic Gear	WITR01USP012	1	B
				Servo motor driver	Various	WITR01USP013	1	B
				Servo Joint Wheel	Plastic	WITR01USP014	1	B
			LED, (MTE8080N)		Various	WITR01USP015	1	B
			Photo-transistor(MTD8000N)		Various	WITR01USP020	1	B
		Door - Veg & Fruit			Various	WITR01USA009	1	M
			Frame		Steel - Painted	WITR01USP021	1	M
			Mold - Inner		Plastic	WITR01USP022	1	M
			Screws		Standard 8 mm	WITR01USP009	16	B
			Insulation			WITR01USP010		B
			Latch Assembly		Various	WITR01USA006	1	M
				Latch	Steel	WITR01USP011	1	B
				Servo motor(HES-288)	Plastic Gear	WITR01USP012	1	B
				Servo motor driver	Various	WITR01USP013	1	B
				Servo Joint Wheel	Plastic	WITR01USP014	1	B
			LED, (MTE8080N)		Various	WITR01USP015	1	B
		Flap Door - Right			Various	WITR01USA010	1	M
			Frame		Steel - Painted	WITR01USP023	1	M
			Mold - Inner		Plastic	WITR01USP024	1	M
			Screws		Standard 8 mm	WITR01USP009	16	B
			Insulation			WITR01USP010		B
			Latch Assembly		Various	WITR01USA006	1	M
				Latch	Steel	WITR01USP011	1	B
				Servo motor(HES-288)	Plastic Gear	WITR01USP012	1	B
				Servo motor driver	Various	WITR01USP013	1	B
				Servo Joint Wheel	Plastic	WITR01USP014	1	B
			LED, (MTE8080N)		Various	WITR01USP015	1	B
			Pressure transducer(ASDX)		Various	WITR01USP025	1	B
		Flap Door - Left			Various	WITR01USA010	1	M
			Frame		Steel - Painted	WITR01USP026	1	M
			Mold - Inner		Plastic	WITR01USP027	1	M
			Screws		Standard 8 mm	WITR01USP009	16	B
			Insulation			WITR01USP010		B
			Latch Assembly		Various	WITR01USA006	1	M
				Latch	Steel	WITR01USP011	1	B
				Servo motor(HES-288)	Plastic Gear	WITR01USP012	1	B
				Servo motor driver	Various	WITR01USP013	1	B
				Servo Joint Wheel	Plastic	WITR01USP014	1	B
			LED, (MTE8080N)		Various	WITR01USP015	1	B
			Pressure transducer(ASDX)		Various	WITR01USP025	1	B
		LCD - User Interface			Various	WITR01USA011	1	B
			LCD Screen		Various	WITR01USP028	1	B
			Memory		Various	WITR01USP029	1	B
			Board		Various	WITR01USP030	1	B
			Internet-ready kit		Various	WITR01USP031	1	B

Appendix A14: Business Plan

		Primary market United States	Secondary market Germany
Manufactured Products		66.200	20.100
Total Maunufacturing costs p. p.		$655,00	$455,00
Shipping costs p.p.		$50,00	$150,00
Marketing costs	total per year	$300.000,00	$125.000,00
	per product	$4,53	$6,22
Labour costs Headquater	total per year	$208.200,00	
	total per product	$3,15	
Total costs per product		***$712,68***	***$614,36***

Initial Costs

Product Development Costs

	People	Monthly Salery	Duration in Months	Total labour costs	Total Material Costs
Engineering	4	$4.200	6	$100.800	$10.000
Industrial Design	1	$4.600	2	$9.200	$5.000
Software Design	1	$3.750	1	$3.750	$3.000
Total					***$131.750***

Production Process Building Costs

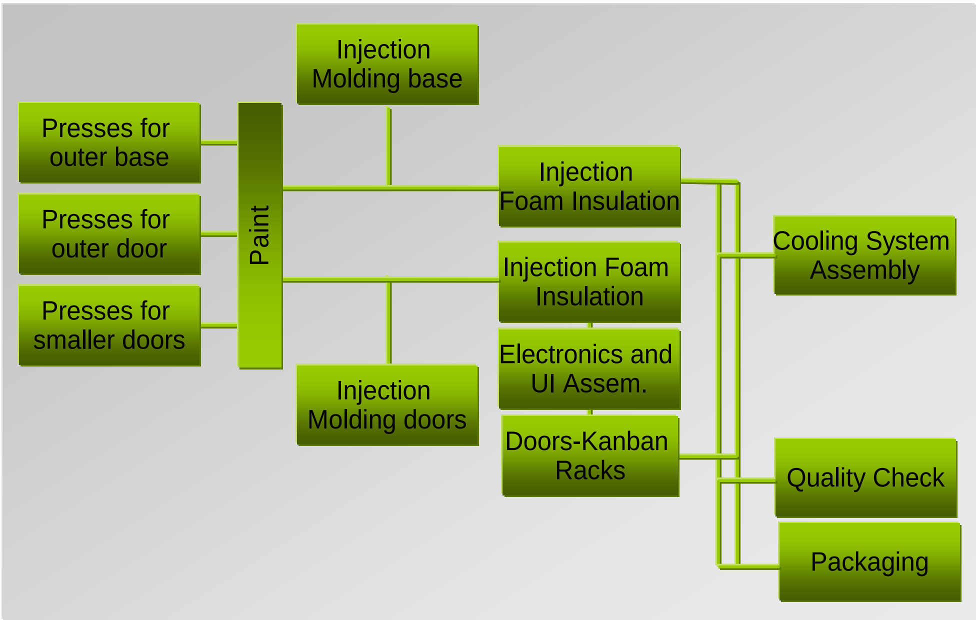
	People	Monthly Salery	Duration in Months	Total labour costs	Total Material Costs
Finding a Production Place	1	$3.500	2	$7.000	
Finding the Machines	1	$3.500	3	$10.500	
Bying the Mashines	1	$3.500	1	$3.500	
Mashine costs					$500.000
Transportation costs					$10.000
Set up the process	3	$4.500	3	$40.500	
Initial Tooling	3	$2.800	3	$25.200	
Total					***$596.700***

Product Testing

	People	Monthly Salery	Duration in Months	Total labour costs	Total Material Costs
Quality Test	2	$3.200	2	$12.800	
Customer-PreTest Design	1	$3.500	1	$3.500	
Customer-PreTest Usability	1	$3.500	1	$3.500	
Total					***$19.800***

Total Initial Investment ***$748.250***

Appendix A15: Manufacturing Assembly Line



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[xix] PDA Manufacturing costs, HP