RefriECO **Project Proposal for the** DualCooler

January 20, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440/305W Project Proposal for DualCooler

Dear Dr. Rawicz,

On behalf of our team, I am enclosing the proposal for our ENSC 440 project. Our product makes refrigerators more energy efficient than what is available on the market at the present time. The technology will utilize the naturally cooler temperatures, of places with winter temperatures that can dip below 5°C, to cool refrigerators.

The attached proposal contains, a more detailed overview of the system, as well as the various solutions we will consider, evaluate and then finally choose one to implement. Also included in the proposal is a schedule of the project, budget and related funding information, company organization and information.

Our team is composed of five talented, creative and determined engineering students: Abantika Oishee, Gonsakar Gunasingam, Allan Vincent, Hasan Syed and myself. If you have any questions or concerns, please feel free to contact me by email at rravi@sfu.ca.

Sincerely,

Ranjita Ravi

Ranjita Ravi

Chief Executive Officer (CEO), RefriECO

Enclosure: Proposal for DualCooler

RefriECO

DualCooler Refrigeration System

A more environmentally friendly Refrigeration System

Project Team: Ranjita Ravi
Allan Vincent
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Submitted To: Dr. Andrew Rawicz
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School of Engineering Science
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Executive Summary

"A nation that can't control its energy sources can't control its future." – Barack Obama

It doesn't require rocket science to understand how essential it has become to conserve energy in recent times. Every day we are wasting huge chunks of energy through industrial and commercial uses, largely due to the inefficiency in our part to control and conserve. It has come to a point that every bit of energy that we could save counts, the kind of advanced technologies that are accessible to us are a reason enough to work towards maintaining an energy equilibrium environment.

"Home appliances accounted for two-thirds of the energy consumed in the average home, according to a 2001 study from the U.S. Energy Information Administration"[1]

There are times when we can't help but be awed by how over reliant we are on our home appliances and often take the energy consumption factor for granted. For our project, we have decided to focus on a refrigerator since it's considered to be the prime suspect behind a home's energy usage. Having reached a decision, we reflected on our options, and what could be better than utilizing a renewable energy resource. Our primary concept is to use the outside air in winter seasons to cool the refrigerator. Depending on the outside temperature, we will be drawing in cold air in order to reduce energy usage of the compressor, thus saving the heat energy that would otherwise be taken up by that component of the fridge.

We will be using an Arduino microcontroller to seamlessly regulate the use of a compressor orreduce the time required for the compressor to run.

The RefriECO team is excited to make a prolific use of this opportunity that we have been provided with and would be exploiting all the resources that we could get. Each member will contribute their valuable expertise to develop the final prototype and make this a success. We are hoping to complete this within the given deadline and our estimated budget.

Introduction

Over the past decade or so, the world is drastically implementing various energy saving and energy consumption methods. Natural energy has been the most popular source used in the energy saving method. However, there are rarely efforts put into taking advantage of colder climates for green energy uses. Our project seeks to reduce refrigeration power consumption by exploiting cold temperatures. Colder climate countries like Canada, Norway, and America and so on can capitalize the colder temperature use as a source and reduce the use of the electrical power. Refrigeration energy consumption is a major cost when adding up the energy consumed by families, restaurants, grocery stores and warehouses. Industrial and household refrigerators can be benefited from the cold climate. Purpose of the project seeks to reduce the refrigeration power, in other words to reduce the use of electrical power supplied to the refrigerator, and use the outside wind as a source to cool the internal structure of a refrigerator. When the external wind temperature is 5 degrees Celsius or below, the device will draw the cold air into the refrigeration system and supply it around the internal structure, to keep the fridge cooler. During this process the regular compression cycle will be disabled, which reduces the energy consumption.

The device will be built for a mini-sized refrigerator as a model, however, the data received from the analysis of the mini-sized refrigerator will be used to make predictions of how much energy savings can be realised if such a system were implemented on a bigger scale.

System Overview

The DualCooler refrigeration system we will be working on involves using the outside temperatures of countries with cold winters (enough to be below the temperature a fridge needs to operate) and cooling the inside of the fridge. The purpose of this idea is to make the fridge run for a lower period of time and therefore saving energy. The DualCooler refrigeration system will be active when the outside temperature falls below a certain required temperature or any temperature that the user sets on the thermostat. The cost of making the new refrigeration system will be higher than a normal mini refrigeration system that is available in the market right now, but the amount of energy usage of the new refrigeration system will be significantly lower than a normal refrigeration system depending on the region. By using the DualCooler refrigeration system, a typical consumer will be able to save about one third of their normal refrigeration energy cost. Not only will the user be saving money on their energy bill, they will also have a positive impact on the environment.

Proposed Solution One

Our main purpose is to capitalize on using reliable, natural energy source “wind” and the naturally colder temperatures to reduce the use the refrigeration cycle elements such as compressor, condenser fan or the evaporator. Such a method would be as reliable as a regular refrigeration system.

When the temperature sensor outside detects the temperature of 5 degree Celsius or below, then the damper will open wide enough to let the cold air go through the duct and reach into the internal structure of the refrigerator. The damper opens only when the fan is on, letting the cold air flow into the fridge and warm air out. The dampers are closed when the fan is switched off to cut off the air circulation from the outside. When the refrigerator’s compressor system is turned on the circulation system is turned off and the damper remains shut.

The entire refrigeration system is controlled by a microcontroller and a series of relays and a switch. This system has three analog inputs: a temperature sensor and a temperature adjustment switch attached in the internal structure of the fridge and also another temperature sensor attached to the outdoor duct. The microcontroller programmed to control the supply fan, damper, and return fan (if needed), which are the analog outputs we are using in the system. The microcontroller is programmed to switch between the external air device (supply fan) and the normal refrigeration cycle (compressor) in order to cool the refrigerator depending on external temperatures. A filter is used to clean the air to reduce the buildup of moisture inside the fridge.

Air will be circulated by using a return duct and a return fan.

Proposed Solution Two

As in the previously explained solution, we would like to use the colder external temperatures as well as the wind energy (if present) to cool down certain components of the compressor, so that it has to work less during the winter months.

The refrigeration cycle consists of a condenser, compressor, evaporator and an expansion valve. The condenser is where most of the heat is released. The cycle loops until the refrigerator has reached the desired temperature at which point the compressor stops. In order to make this system more efficient, we propose to use cooling tubes, similar to some cooling systems in PC's. The tubes of water, will be cooled using the same cool air described in the previous solution. However, the air will not go through into the fridge. Instead a small radiator will be installed and the water from the cooling tubes will be routed through the radiator to exchange the heat gained from the condenser. We will still require the use of dampers and fans.

We propose to use water since it has a high specific heat capacity and is environmentally safe. As in solution one a temperature sensor placed outside will trigger the system to switch on and off as needed. We came up with this idea while brainstorming a way to keep the refrigeration compartment closed (no drilling of holes through to the inside of the fridge) and not having to use too many filters.

We would like to thank Professor Parameswaran for inspiring us with his "water jacket" idea.

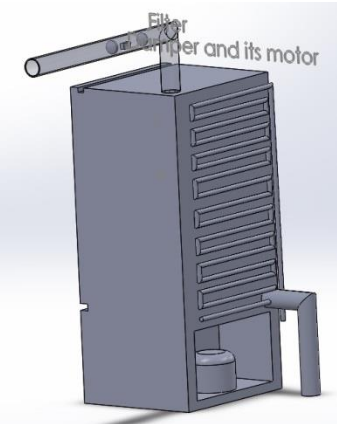

Figure 1: Model of Solution 1

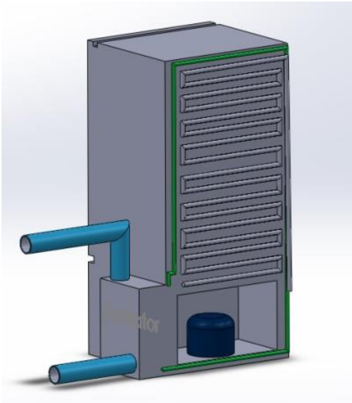

Figure 2: Model of Solution 2

Market Analysis

The structures of buildings are always being refined to adapt themselves to the constantly changing social needs. As of today, the focus is mostly on minimizing the energy consumption rate and aiming towards a more “green” environment. Keeping that in mind, our energy efficient refrigerator will work towards conserving energy and saving power.

There are different types of housing industry that we would be dealing with while installing this new refrigerator; residential homes, high rise apartments and other industrial complexes. Depending on how the piping is done, it might be more cost effective to mass produce them in apartments or commercial buildings. Considering that household appliances use the most amount of electricity, it will only be feasible that the concept of an energy saving appliance will be grabbed by the markets to use this opportunity as a means to cut down on the usage of power. Having said that, it will require some additional work to be done on buildings beforehand, to properly install the design block. Our initial prototype could cost more than expected but the markets could manufacture their final versions at a much lower cost.

Some of the industries that could be interested in marketing such a project are Danby, Samsung, LG, Whirlpool and other related refrigerator companies.

Energy Savings in a Glance

We will be making a model of our refrigeration system by modifying a mini fridge and setting it up according to the proposed solution 1 or solution 2. On average, electricity in Canada costs about **11.84 cents** per kWh and a regular mini refrigeration system uses about **325 kWh/year** which totals to about **$38.48**[2]. In order to measure the average cost savings by using our modified refrigerator, we decided to choose the statistics of the temperature of the City of Calgary, CA. By observing the percentile chart below and calculating the average time the proposed refrigerator will be on during winter, we were able calculate the difference in cost without adding the energy usage of the additional items for our proposed idea. Without adding the material cost of the refrigerator system, which will be shown later in the report, the calculation of the energy savings are shown below.

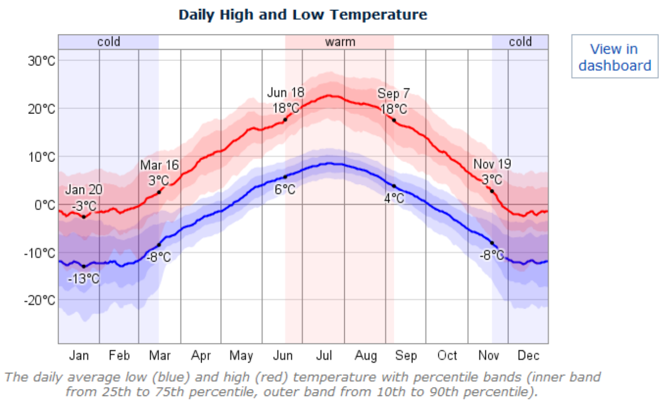

Figure 3: Percentile chart of the average temperatures of Calgary, AB between 1998 – 2012 [3]

As seen in Figure 3, Calgary maintains an average daily constant low temperature below the required temperature for the fridge to operate on a regular basis during the months of January, February and December. This reduces the energy used by the refrigerator by a quarter, therefore reducing the energy consumption to **244 kWh/year**. During the months of March and November, it can be safely assumed that the refrigerator will be running only for half the day. The month of April and October shows that the modified refrigerator will run for approximately a third of the monthly period for each month. Therefore the total consumption of energy can be further reduced down to about 200 kWh per year. The total savings comes out to be an average of **$14.80** per year without taking the energy usage of the additional materials being added on to the new fridge model.

The energy usage of the additional materials used to create the fridge proposed in solution 1 such as the two fans, two servo motors, the microcontroller and the temperature sensors can be added to the currently approximated total consumption of energy of **200 kWh/year**. Since the microcontroller is the only component of the new fridge which would run for 24 hours a day, every day of the year, its power consumption will be the highest among the additional materials. The table below shows the approximate energy usage per additional component.

Table 1: Energy Consumption of parts that are the same for both proposed solutions

Item	Input Voltage (V)	Input Current (A)	Power per item (kW)	Duration of runtime per day	Quantity	Energy consumption per year (kWh)
Microcontroller	9	0.2	0.0018	24h	1	15.768
Temperature Sensors	2.7	50×10^{-6}	1.35×10^{-7}	24h	2	2.3652×10^{-3}
Fans	12	0.2	0.0024	Varies. See Note Below.	2	0.672
Servo Motor	6	0.14	0.00084	5 minutes per day	2	0.0196

Note: 1 hour per day during the months of Jan, Feb, Dec. 30 min per day during the months of Nov and Mar. 20 minutes per day in Apr and Oct. Therefore 140 hours in total which comes to about 0.3836.

Therefore, taking the total energy consumption per year(from table1) of the additional materials, and adding it to the previously approximated total energy consumption of **200 kWh/year** gives a final total energy consumption of the proposed idea 1 as **216.46 kWh/year**. The final total savings would be around **$12.85.**

The energy usage of the additional materials used to create the fridge proposed in solution 2, will be very similar to that of proposed solution 1. The only major difference between the two ideas is that solution 2 will need a water pump pumping water through the tubes through the radiator. The energy usage of the water pump is shown in the table below.

Table 2: Energy Consumption of the part that is additional for solution 2

Item	Input Voltage (V)	Input Current (A)	Power per item (kW)	Duration of runtime per day (h)	Quantity	Energy consumption per year (kWh)
Water pump	12	0.35	0.0042	(0.3836) Varies. See Note Below.	1	0.588

Note: 1 hour per day during the months of Jan, Feb, Dec. 30 min per day during the months of Nov and Mar. 20 minutes per day in Apr and Oct. Therefore 140 hours in total which comes to about 0.3836.

Adding the extra energy usage of the water pump to the approximated final total energy consumption of the proposed solution 1 gives a total consumption of **217.048 kWh/year**. This value is close to the proposed energy consumption of solution 1 which was **216.46 kWh/year** and giving a final total savings of **$12.78** which is a bit higher than solution 1 as expected.

Budget

The table below lists the tentative costs of materials that are going to be required to build the system. The prices are approximate and based on the research that we have made over the components. Moreover, we have also listed the addition modules that we might need while performing the tests on the prototype.

For Proposed Solution 1:

Table 3: Outlined Costs of Proposed Solution 1

Equipment Required	Quantity	Estimated Cost
Arduino Analog Temperature Sensor	2	$5.58
Arduino UNO R3 Microcontroller	1	$20.88
Servo Motors	2	$10.00
4” duct volume damper	1	$9.99
Flexible Ducting Hose	1	$16.95
Filter	2	$10
Fans	2	$10
Mini Fridge	1	$50
Miscellaneous Costs	N/A	$50
Subtotal	N/A	$183.40

For Proposed Solution 2:

Table 4: Outlined Costs of Proposed Solution 2

Equipment Required for proposed idea 2	Quantity	Estimated Cost
Water Pump	1	$16
Arduino UNO R3 Microcontroller	1	$20.88
Flexible Ducting Hose	1	$16.95
Filter	2	$10
Fans (intake and exhaust)	2	$10
Mini Fridge	1	$50
Miscellaneous Costs	N/A	$50
Radiator	1	$20.00
Water tube	1	$15
Subtotal	N/A	$208.83

Funding

There are several funding resources that we are hoping to make use of. ESSEF will be the primary source of funding as it has an allowance of $50 for all ENSC 440 teams. Next, the Wighton Engineering Development Fund will contribute towards some of the funds.

Other options are also used to lessen the cost of equipment. Online resources such as EBay, Amazon and other electronic sites are used to obtain products at a cheaper price. The rest of the cost will be covered by the team members equally.

Payback Period

Payback period for proposed Solution 1:

The average cost of buying a mini/bar refrigerator is about $100 in North America. Solution 1 shows that the total material cost in order to build an efficient refrigeration system is about **$183.40**. The total energy savings after a year of using the fridge proposed in solution 1 is **$12.85** compared to a normal mini refrigerator. The total extra expenditure for the proposed fridge is about **$83.40** more than the current market price of a mini fridge. Taking into account that the energy saving per year is **$12.85** per year, it will take about **6.5 years** to make up for the material cost of the refrigeration system. The lifetime of the fridge will also be extended due to the fact that the compressor will run for a lower amount of time in the winter. The above expenses will be significantly reduced if materials for the fridge is mass produced and therefore resulting in a lower payback period for the fridge in the proposed idea.

Payback period for proposed Solution 2:

The total material cost for making a fridge proposed in solution 2 was approximated to be around **$208.83**. Since the average cost of buying a mini/bar fridge in North America is $100, the extra expenditure for this fridge is approximately **$108.83.** There is barely and difference in the amount of savings using solution1 and solution 2 and therefore the payback period could be seen as a bit higher for the fridge proposed in solution 2. Using the approximate value of the energy saving of the fridge proposed in solution 2 (**$12.78**), it will take about **8.5 years** to make up for the material cost for this fridge. Similar to solution 1, the lifetime of the fridge will be increased as the compressor will run for a lower amount of time. Mass producing the materials needed for the fridge will also result in a lower expense and therefore lowering the payback period time for the fridge.

Scheduling

The Gantt chart below describes the breakdown of our activities throughout the term of the project. It also highlights how much time we intend to spend on each activity, one week per gridline.

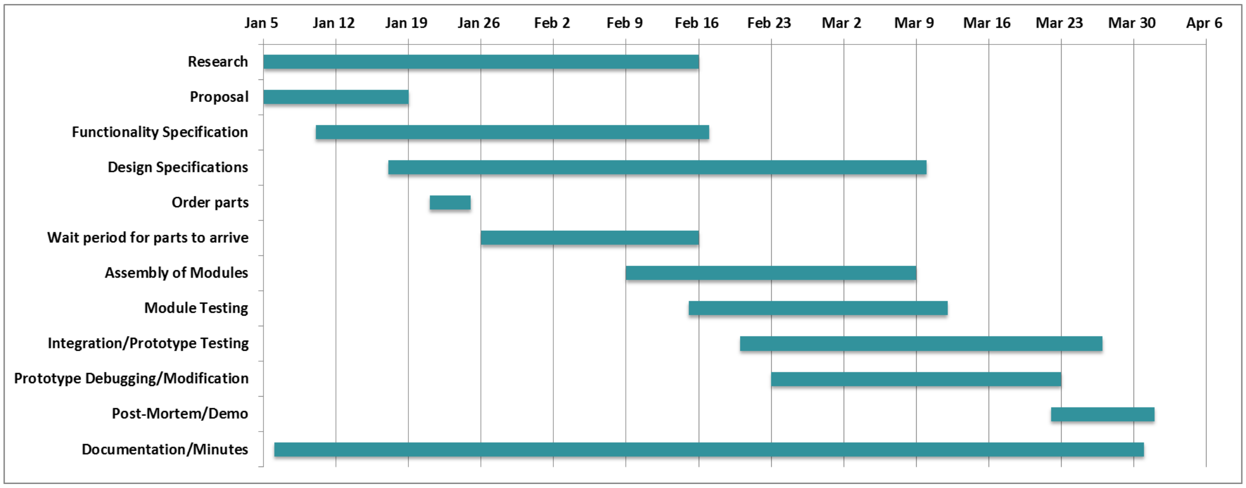

Figure 4: Gantt Chart of Project Time Breakdown

Table 5 below lists the milestones and deadlines we hope to achieve. All the deadlines are the due dates of the reports whereas the milestones are check points for the prototype itself. We will try to adhere to the milestones as best as we can so that we can spend more time fine tuning our prototype towards the end of March.

Table 5: Table of Deadlines and Milestones for the entire project

	Task	Date Due
Deadline #1	Proposal	January 20, 2013
Milestone #1	Finish planning and order parts	January 25, 2014
Deadline #2	Functionality Specification Report	February 17, 2013
Milestone #2	Finish Assembling all the modules	March 8, 2013
Deadline #3	Design Specification Report	March 10, 2013
Milestone #3	Finish integrating the modules	March 22, 2013
Deadline #4	Post-Mortem/Demo should be ready	April 1, 2014

The Team

Ranjita Ravi, Chief Executive Officer (CEO)

Miss Ravi is a fourth year Computer Engineering student studying at Simon Fraser University in Burnaby, BC, Canada. She has completed coops in Nokia as well as Teradici and has a wide range of experience in firmware development as well as some software development. She will be joining Allan and Oishee in programming and integrating the Arduino temperature sensors and actuators into the whole system. She will also be in charge of keeping the group organized as their team lead and CEO.

Allan Vincent, Chief Information Technology Officer (CIO)

Allan Vincent is a fourth year Computer Engineering student studying at Simon Fraser University in Burnaby BC, Canada. With the different Computing Science courses he has taken in University, he has gained sufficient experience in multiple programming languages such as C, C++, Java and Python. Having worked at Schneider Electric as an embedded software tester, he has gained hands on experience with many power devices such as inverters and chargers and the embedded programming language called LUA. He has also gained knowledge in using many different communication protocols such as Xanbus, Modbus, Telnet, TCPIP, RS-485 Serial and FTP from workplace. These skills would be useful in programming the microcontroller for the requirements and features necessary for the DualCooler refrigerator project.

Abantika Oishee, Chief Financial Officer (CFO)

Abantika Oishee is a 3rd year Electronics Engineering student, who will be responsible for the management sector and overseeing all the financial issues. Abantika has done a one year co-op in Hydro One, where she was a part of the Power System IT department. Through work experience, she has gained extensive hands on experience in hardware development and acquired valuable knowledge in process engineering and project management; while schoolwork has exposed her to microcontrollers and electronic circuits. In addition, her involvement with various Engineering clubs has honed her leadership and communication skills.

Gonsakar Gunasingam, Chief Technology Officer (CTO)

Mr. Gunasingam is a fourth year Systems Engineering student at Simon Fraser University with a co-op experience at Honeywell Enterprises as a Junior Electrical Engineer. Knowledge that he gained from the co-op term is helpful to understand the basics of HVAC (heating, ventilating and air conditioning) control system. He is familiar with the use of the low voltage components such as sensors, actuators, valves, generators, PID controllers and higher voltage components such as transformers which comes in handy for this project. He is also well versed with the operations of most electronics equipment used in the lab such as oscilloscopes, power supplies, function generators, digital multi-meters.

Hasan Syed, Chief Operations Officer (COO)

Mr. Syed is a self-described “complete” engineer in the emerging field of robotics and systems engineering. He has developed and designed multiple projects in the field control robotics and haptics technology. In his spare time he enjoys tinkering with his personal Arduino set and always has a project idea ready to be designed. He quickly implements knowledge from material he has researched or gathered. Mr. Syed also has a good background in using SolidWorks which will come in handy for the design stage of this project.

Conclusion

The goal for the DualCooler refrigeration system is to reduce energy intake of refrigeration cycles by using the cold air temperatures from the external environment. There is yet to be a refrigeration system that has successfully minimized energy consumption by encompassing cold climates. The minimum target for energy reduction of this system is approximately greater than or equal to 25%.

The proposed solution will most likely be able to provide a viable alternative to current practices. If everything works out as planned, this solution might just be the beginning of a new revolution for efficient home appliances. Not only that, it will result in the users and customers to be more aware of appliances that could be used without a vast use of energy, even the companies could show interest in producing more energy efficient machines.

Our team strongly believes that a properly operational device could replace and improve current market of Refrigerators. It will be an easy-to-adopt and easy-to-use solution by their customers including household, condominium and for commercial companies.

References

[1] Dawn Walls. “Inefficient Appliances That Waste Energy at Home.” Internet: http://homeguides.sfgate.com/inefficient-appliances-waste-energy-home-78874.html, [Jan. 17, 2014].

[2] Author Unknown . “Comparison of electricity prices in major North American cities.” Internet: http://www.hydroquebec.com/publications/en/comparison_prices/pdf/comp_2012_en.pdf, April 1, 2012 [Jan. 17, 2014].

[3] Author Unknown . “Average Weather For Calgary, Alberta, Canada.” Internet:http://weatherspark.com/averages/28211/Calgary-Alberta-Canada, [Jan. 17, 2014].

Other Sources

The wonderful employees of HoneyWell Enterprises.

Professor Ash Parameswaran