University of Nevada, Reno

GreenGlove
A Solar Powered Heated Glove to Help Maintain Comfortable Temperatures

A thesis submitted in partial fulfillment
of the requirements for the degree of

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

by

DEREK BISSELL

Benjamin Del Rosario

Alexandria Hill

Jennifer Mabus

Scott Swinford

Derek Bissell, Bachelor of Science in Mechanical Engineering, Dr. Kam Leang

May, 2012

Table of Contents

Executive Summary

The product designed by GreenGlove is a heated glove that operates using flexible solar panels. While conventional heated gloves currently on the market rely on battery power to operate, GreenGlove harvests 100 percent of its energy using solar power. Through this, GreenGlove is able to provide a more sustainable alternative to current heated gloves. The use of solar panels eliminates the need for continuous replacement, recharging, and disposal of batteries. This ultimately leads to less waste being dumped in landfills and less inconveniences for the customer. Moreover, the solar panels are extremely lightweight and flexible, thus virtually eliminating any concern of additional weight being added or loss of mobility. This is a key benefit of the gloves, since GreenGlove is then able to eradicate the need for any type of heavy and bulky power storage device. One drawback of this form of power generation is that the power that can be generated is less than the amount battery packs are capable of generating. Therefore, the focus of GreenGlove is to maintain comfortable temperatures in the glove, rather than generate large quantities of heat at high temperatures. By ensuring a comfortable temperature is maintained inside the glove, this product is ideal for frostbite prevention, as well as people with Raynaud's Disease, which is a condition in which the blood flow to the fingertips is significantly reduced during cold weather.

The primary method used to maintain heat is through the addition of a material with exceptionally high insulating properties. Cryogel Aerogel, which when compared to other types of insulation, is significantly more lightweight and has much higher insulating properties. To ensure the heat loss in each finger is minimized, the glove was designed with emphasis on insulating the fingers with large amounts of Aerogel. Within the Aerogel is a weather resistant barrier, implemented to both eliminate any moisture to the hand, as well as block any dust generated by the Aerogel from reaching the hand. Inside the weather barrier, one polyimide heaters is located on the top of each finger on the surface of a cotton inner glove. These heaters are also encircled by the Aerogel, thus ensuring a minimal amount of heat is lost.

The ideal power that can be generated by the solar panel design is 0.96 W. Based on a heat transfer analysis of the glove, this amount meets the requirement of maintaining an 80 degree Fahrenheit temperature within the glove. During prototype testing, the maximum power attained was 0.44 W. With this amount of power generation, the temperature inside each finger was raised approximately 7 degrees F. These results were deemed acceptable which verified the effectiveness of the glove's primary purpose.

A market study was also conducted to identify the potential need for the heated glove, and to which demographics the product should be advertised to. Because of the utilization of solar panels as the primary power source, it was determined that increased reflectivity of sunlight due to snow would make the heated glove ideal for use in winter sports such as skiing and snowboarding. Additionally, the heated glove may be used in medical applications as a treatment for Raynaud's Disease and as a better method to combatting the onset of frostbite. A competitive analysis was also performed to compare

the solar powered heated glove's design against products already on the market. The size of the heated glove market is relatively small, with a few companies such as Gerbing Heated Clothing dominating the market. Despite variances in the types of heaters used in these gloves, almost all gloves currently on the market require battery packs, whether rechargeable or replaceable. It is the elimination of these bulky, expensive battery packs that motivates the sustainable, renewable energy aspect of the solar powered heated glove. GreenGlove hopes to expand its market by advertising the solar powered heated glove as a passive device whose novel, passive, low maintenance, sustainable, and environmentally friendly design will justify its relatively high initial cost compared to other heated glove on the market.

Decisions and Justification

The primary goal for the project is to design a glove that will utilize renewable energy to supply heat to a glove. This goal was achieved through a series of objectives and through use of the design process. When creating the final product in this design, it was imperative to use the design process to ensure that the optimal design was reached. Initially, various forms of energy generation were considered for the final design including solar power, kinetic energy, and Seebeck devices. Using Pugh's decision matrix, each of the power sources and materials were analyzed with side by side comparison in order to ensure that they were the right products for the glove. Table 1 illustrates which products were chosen for comparison.

Table 1: Pugh's Decision Matrix
Seebeck Device Specifications [Tellurex, website] [Custom Thermoelectric, website]
Solar Panel Specifications [Flex Solar Cells, website]

PUGH'S DECISION MATRIX												
Criterion	Concepts											
	Weight %	Outer Material			Solar Panel Type		Kinetic Energy		Seebeck Devices		Insulation		
		Leather	Cotton	Nylon	SP3-12	MPT6-75	Shakeable	DC motor	G2-40-0329	1261G-7L31-10CX1	Thinsulate™	Aerogel	Polyurethane Film
Appearance	5	+	-	+	+	-	0	0	0	0	0	0	0
Size	5	0	0	0	+	-	-	-	+	+	+	+	+
Cost	10	+	+	+	+	-	-	-	+	-	-	-	-
Durability	5	+	-	+	+	+	+	+	+	+	+	+	-
Safety	5	0	0	0	0	0	0	0	0	0	+	-	0
Uniqueness	5	+	-	-	+	+	+	+	+	+	-	+	+
Energy Produced	20	0	0	0	-	+	-	-	+	+	0	0	0
Plausibility	5	+	+	+	+	-	-	-	+	+	+	+	-
R Value	20	-	+	-	0	0	0	0	0	0	+	++	+
Waterproofing	10	+	-	+	0	0	0	0	0	0	+	+	+
Manufacturing Ease	10	+	+	+	-	-	-	-	-	-	+	0	-
TOTAL +		50	35	45	35	30	10	10	50	40	60	70	40
TOTAL -		-20	-25	-25	-30	-35	-50	-50	-10	-20	-15	-15	-30
Selection Winner:		30	10	20	5	-5	-40	-40	40	20	45	55	10

The Pugh's decision matrix immediately eliminated all forms of kinetic energy power generation from the design. The proposed design was initially to include SP3-12 solar panels, a G2-40-0329 power generator (Seebeck device), aerogel insulation, and leather exterior. These items were then further examined for effectiveness, and it was determined that the Seebeck device should be removed from the design. Justification and information for the solar panels, aerogel, and leather can be found in the Technical Analysis section.

Seebeck Device

Seebeck devices use temperature differences to create electricity. It was initially planned that the device would use the temperature gradient between human skin and cold air to help provide energy when weather conditions were not ideal for solar panels, such as cloudy or nighttime conditions. Several methods of testing were used to determine how much power the Seebeck device could generate. The first method placed the “hot side” of the device against human flesh while the “cold side” was exposed to the outside ambient air through a finned heat sink. This set-up imitated the how the configuration of the device would be used within the glove with one side on the interior of the glove and the other exposed to the external air of the glove. When results failed to meet effective power generation, another testing method was used in hopes to better replicate the insulation within the glove. This method utilized aluminum plates which were connected to the device using thermal grease and then placed in boiling water and ice water for the hot and cold sides respectively. However, this did not represent a drastic enough temperature gradient to be fully representative of the interior to exterior temperature change of the glove. As a result, one final ideal method was used. The final method used was to directly apply the boiling water and ice cubes to the Seebeck device in order to create a large temperature difference. However, even with this drastic, roughly 60 °F temperature difference, the maximum power output was only 0.03 W. These results simulated more ideal conditions than would be replicated within the design, and still yielded underwhelming results. When comparing these results with the 0.623 W which were able to be generated from the solar panels, it became apparent that the Seebeck device was much less effective than anticipated. With such a low power output, the team could not justify spending $168 dollars to place two Seebeck devices on the final product. As a result, the device was deemed impractical and removed from the final design despite the advantages it provided for cloud and nightfall.

Sustainability

One of the primary concerns for this product was how it would affect the environment. The product was designed with conscientious effort to improve product sustainability and limit any unnecessary waste. Each of the materials chosen was evaluated to ensure that it were not only the right fit for the product, but also the right fit for the environment.

Solar Panels:

Solar panels are used to generate power within the gloves and are extremely sustainable. Solar power is a renewable source that will never be depleted, their cells last a lifetime, and the panels do not emit any greenhouse gases [Advantages of Solar Power, website]. As a result they are one of the key factors in maintaining sustainability within the glove.

Aerogel:

Aerogel insulation was chosen not only for its thermal resistance but also for low carbon footprint. Table 2 demonstrates that Aerogel emits only 0.35 ECO2 per R-value per inch. Moreover, Aerogel maintains a much higher thermal resistance than other products with a similar ECO2 emission rate. As a result, using Aerogel will allow GreenGlove to be able to maintain as much heat as possible without significantly impacting the environment.

Table 2: Material Comparison [Pacor Inc., website]

Material	Thermal Conductivity (mW/m-K) [1]	Thermal Resistance (R-value per inch) [1]	Embodied Energy (EE) (MJ/kg)	Embodied CO_2 (ECO_2) (kg of CO_2/kg)	EE per Thermal Resistance (EE/R-value per inch)	ECO_2 per Thermal Resistance (ECO_2/R-value per inch)
Aspen Aerogels' Spaceloft®	12	12.0	53.0 [1]	4.2 [1]	4.42	0.35
Fiberglass (Recycled Glass)	40	3.8	28.0 [2]	1.4 [2]	7.37	0.36
Fiberglass (Virgin Glass)	40	3.8	39.2 [2]	1.9 [2]	10.32	0.50
Mineral Wool	40	3.8	16.6 [2]	1.2 [2]	4.37	0.32
Expanded Polystyrene	32	4.5	111.6 [3]	3.0 [2]	24.80	0.67
Polysocyanurate	24	6.0	69.8 [3]	5.5 [2]	11.63	0.92

Leather:

Leather was chosen primarily for its durability. The strength of leather is such that it is able to maintain dexterity yet provide substance to mount the solar panels. In addition, the leather resilient and will allow the gloves to be replaced less frequently than gloves made of other materials. However, leather is notorious for having a large carbon footprint because of the methane generated during the lifespan of the cow [Ball, website]. It was concluded that the benefits of using leather outweigh the negative impact it might have on the environment, so it was continued within the design.

Manufacturing and Retirement:

In addition to the materials selected, GreenGlove will use specific manufacturing and retirement techniques to ensure the environment is impacted as little possible during the entire lifespan of the product. The company will practice green manufacturing including making digital prototypes, recycling, and utilizing alternative power such as wind and solar energy to operate the factory. In addition, GreenGlove will offer a five year buyback plan and utilize materials which can be recycled including the aerogel, Kapton heaters, and leather exterior. The glove allows for high quality without sacrificing the environment and offers an alternative product to keep hands warm without damaging the environment with excess batteries or poor insulation.

Standards

When creating the glove, it was of primary importance to follow accepted standards to ensure safety and quality. Standards in power generation, insulation, and glove sizing all played key roles in the designing of this product.

Temperature Ratings:

Before selecting energy sources, it was necessary to determine the desired temperature inside of the glove and the amount of power needed to obtain this heat. The interior temperature of the glove allows products to provide a temperature rating that is intended to provide the user with a minimum temperature while maintaining thermal comfort and protection from hypothermia. In order to do this, American Society for Testing and Materials (ASTM), ratings were referenced. ASTM Standard F2732-11: Standard Practice for Determining the Temperature Ratings for Cold Weather Protective Clothing allowed for calculation of temperature rating while implementing ASTM Standard F1291: Standard Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin. These standards allows for two different calculations of temperature based on metabolic equivalents for task of both a passive and active user in cold climates. The standards used an assumption of 35 degree Celsius skin temperature and allowed for the determination of heat generation from the hand in order to determine the required heat generation within the glove [ASTM Standards, website].

Aerogel Insulation:

Insulation must adhere to ASTM standard C1728-12. This standard provides the necessary guidelines for maximum temperature that insulation can withstand. According to the standard, insulation must not exceed 300 degrees Fahrenheit. GreenGlove operates at temperatures not exceeding 130 degrees Fahrenheit so the maximum temperature should not be a major issue. Moreover, Aerogel will shrink less than two percent in any direction when exposed to different temperatures, has poor water retention rates and has been tested to ensure that it is both flexible and a poor thermal conductor. GreenGlove will implement the aerogel in a manner where the shrinkage will not be a factor and so that water will not reach the aerogel [ASTM Standards, website].

Glove Sizing:

Unlike more common types of apparel such as shirts, pants, and shoes, gloves do not have a widely used standard when it comes to sizing. However, most companies determine their sizing based on what other companies have done. As a result, most sizes do translate from one brand to the other. For this reason, GreenGlove will institute its own standard regarding glove sizes, using accepted measurements of current gloves as a guideline. The glove-sizing guide can be seen in Table 3, with the measurement being made around the knuckles below the fingers. This table will be available on the company website.

Table 3: Glove Sizing Standard

	Size					
	XS (in / cm)	S (in / cm)	M (in / cm)	L (in / cm)	XL (in / cm)	XXL (in / cm)
Youth	(5 / 12.7)	(5.5 / 13.97)	(6 / 15.24)	(6.5 / 16.51)	(7 / 17.78)	
Women's	(6 / 15.24)	(6.5 / 16.51)	(7 / 17.78)	(7.5 / 19.05)	(8 / 20.32)	
Men's	(7.5 / 19.05)	(8 / 20.32)	(8.5-9 / 21.59-22.86)	(9.5-10 / 24.13-25.4)	(10.5-11 / 26.67-27.94)	(11.5-12 / 29.21-30.48)

Solar Panels:

ASTM standard E744-07 focuses on the standard practice for evaluating solar absorptive materials for thermal applications. This includes the testing methodology of solar panels. Section 7.1 specifically references how to test the solar panels at room temperature to ensure that the surface is durable through liquid penetration and dust particles. This is imperative as the panels will be in contact with liquid in the form of snow during skiing/snowboarding application. In addition, Section 7.2.2 specifies outdoor exposure of the panel to enable them to work properly. This testing helps ensure long-term quality of the product [ASTM Standards, website].

Technical Analysis

In order to maintain the temperature inside the glove, it is first necessary to calculate the amount of heat loss through the glove due to various heat transfer mechanisms. Several assumptions were made to simplify analysis. The first major assumption made is to use a 1-D model of heat transfer starting from the surface of the hand to the ambient atmosphere. The majority of heat loss will be in this direction and the heat transfer through the side of the glove and side of the fingers can be ignored. By assuming 1-D heat transfer, a thermal circuit was developed as shown in Fig. 1 below:

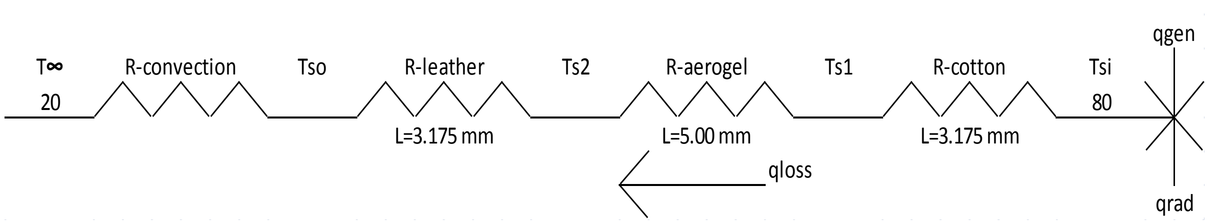


Figure 1: Thermal Circuit Describing Heat Transfer though Multiple Glove Layers

Conductive heat transfer through the multiple glove layers, the cotton buffer between the hand and the heaters, the aerogel insulation used to trap escaped heat, and the leather glove exterior were all considered. The formula for the thermal resistance due to conduction is given in Eq. (1):

$$R = \frac{L}{kA} \quad (1)$$

Where L is the thickness of the layer, k is the thermal conductivity of the material, and A is the cross sectional area. By analyzing this formula it can be justified ignoring conductive heat transfer through the sides of the glove as the cross sectional area of the top and bottom of the gloves are much greater than the cross sectional area through the sides. The thermal conductivity of the various material layers are shown in Table 4 below:

Table 4: Thermal Conductivities of Glove Materials, note high conductivity of aerogel compared to other layers.

Thermal Conductivity [W/mK]		Material Thickness [m]
cotton	0.060	0.003175
leather	0.159	0.003175
aerogel	0.014	0.005

From Fig. 1, several boundary conditions were applied to the analysis. First is applying a temperature difference between the ambient temperature outside the glove and the temperature within the glove. These values are assumed to be 20^{o}C and 80^{o}C, respectively. Convective heat transfer was assumed between the surface temperature of the leather exterior and ambient air. The thermal resistance due to convection is given in Eq. (2).

$$R = \frac{1}{hA} \quad (2)$$

In order to calculate the convective heat transfer coefficient, h, due to natural convection, the Rayleigh number and average Nusselt number must also be calculated. The Rayleigh number associated with free convection is given in Eq. (3):

$$Ra_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu a} \quad (3)$$

Where g is gravity, β is the expansion coefficient, defined as $\frac{1}{T_f}$, where T_f is the film temperature on the outer surface of the glove, T_s is the outside surface temperature of the glove, T_∞ is the ambient temperature outside the glove, L is the characteristic length of the glove, ν is the kinematic viscosity, and a is the thermal diffusivity. Using the Rayleigh number, the Nusselt number can be calculated as Eq. (4):

$$\overline{Nu} = 0.68 + \frac{0.67 Ra_L^{\frac{1}{4}}}{\left[1 + \left(\frac{0.492}{Pr}\right)^{\frac{9}{16}}\right]^{\frac{4}{9}}} \quad (4)$$

Where Pr is the Prandtl number for air at the film temperature. From the average Nusslet number, the convective heat transfer coefficient can be calculated as in Eq. (5):

$$h = \frac{\overline{Nu}k}{L} \tag{5}$$

Where k is the thermal conductivity of air at the film temperature and L is the characteristic length of the glove. Values associated with the convective heat transfer analysis can be found in Appendix A.

The final boundary condition associated with this analysis is the heat radiation from the human body. Radiation heat transfer can be calculated as follows in Eq. (6):

$$Q_{rad} = \varepsilon\sigma A\left(T_{skin}^4 - T_{s,i}^4\right) \tag{6}$$

Where ε is the emissivity, σ is the Stefan-Boltzmann Constant, A is the surface area of the hand, T_{skin} is the temperature of the surface of the hand, and $T_{s,i}$ is the inner surface temperature of the glove. Taking all these factors into account, the total heat loss due to conduction, convection, and the temperature difference can be calculated as Eq. (7).

$$Q_{loss} = \frac{T_{s,i} - T_{\infty}}{R_{tot}} \tag{7}$$

The total thermal resistance, R_{tot}, is calculated as the series resistances due to convection and conduction and are shown in Appendix A. The total heat that needs to be generated by the flexible heaters must be enough to offset the difference between the heat loss due to temperature difference and the heat radiated by the human body. Table 5 summarizes the heat transfer analysis [Incropera, 2007].

Table 5: Calculated Difference between Heat Loss and Heat Radiated by Human Body. The difference, Q-gen, is the minimal amount of heat the flexible heaters must generate to maintain temperature.

Heat Analysis	
Q-loss [W]	2.308
Q-rad [W]	1.412
Q-gen [W]	0.896

Now that the amount of heat needed to maintain the inner temperature is known, the circuitry between the solar panels and the flexible heaters can be designed. Selection of the solar panel arrangement depended on the arrangement of the heaters within the glove. Fingers were assumed to act like heat transfer fins, and thus heat transfer due to the convection from the fingers is increased. The flexible heaters would be placed over the fingers to off-set this effect. Based on the power generation needed to maintain temperature (shown in Table 5) and size limitations, five Kapton Polyimide Model BKLP3013 flexible heaters were selected each with a resistance of 156.8Ω. By wiring the heaters in parallel, the equivalent resistance decreases and the voltage from the solar panels needed to generate heat will also be decreased. By using simple Ohm's law analysis in Eq. (8):

$$P = Q_{gen} = \frac{V^2}{R_{eq}} \tag{8}$$

The voltage required to generate heat can be calculated. For an equivalent resistance of 31.36Ω, this voltage was determined to be 5.3 V. Solar panels were selected based on that voltage. Based on this power requirement and size limitation on glove surface, an arrangement of 12 solar panels was selected. Two large 3.0" X 4.5" PowerFilm MPT6-75 solar panels rated at 6 V would be placed on top of the hand, and 10 smaller solar panels, 0.5" X 2.5" PowerFilm SP3-12 solar panels rated at 3 V each were placed on top of the fingers. In order to achieve equivalent voltage of 6 V, the two larger solar panels were wired in parallel while each pair of solar panels on the fingers were wired in series, and these five pairs were subsequently wired in parallel to achieve the desired voltage. An equivalent circuit diagram for this arrangement is shown in Fig. 2 below:

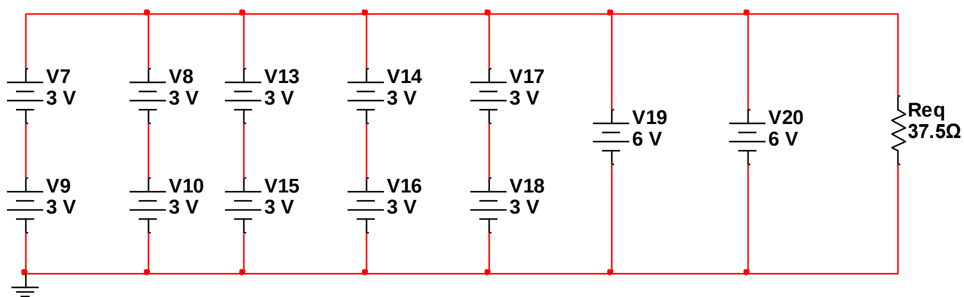


Figure 2: Circuit diagram showing wiring for solar panels (voltage sources) and the film heaters (lumped as an equivalent ideal resistance)

A schematic of the physical wiring inside the glove is shown in Appendix B. Based on a 6 V power source, the ideal resistance to generate max power is greater than the experimental case, as shown in Fig. 2. An ideal power output for this arrangement was 0.96 W. Because the equivalent resistance of the heaters chosen are not ideal for a 6 V power source, power generation will not achieve this 0.96 W.

Market Overview

The heated glove industry has become a subset of the entire glove and mitten industry, with the concept of heated gloves being fairly new. One of the largest heated clothing companies, Gerbing's Heated Clothing Inc. founded in 1976, did not start manufacturing and selling heated gloves until the early 1990's. According to statistics from the 2002 U.S. Census Industrial Report on Gloves and Mittens [U.S. Census Industrial Report on Gloves and Mittens, website], approximately 400 million pairs of gloves and mittens were sold in the United States. Of the 400 million pairs sold, Gerbing's share was only 4,000 pairs [All Business, website]. That accounts for .001% of the total pairs of gloves sold for that year. In the same report conducted in 2006, it was reported that Gerbing's sales increased to 15,000 pairs. Assuming a modest linear growth in these four years, an estimate can be made that Gerbing's sales would increase to 31,500 pairs of gloves in 2012. Due to the U.S. Census discontinuing the Industrial Report on Gloves and Mittens in 2006, the quantity of gloves and mittens sold in 2012 must be estimated. The 2010 U.S. Census reported a population of 310 million Americans, and based on perceived "cold weather" climate demographics, a reasonable estimate can be made as to the number of gloves that would be sold in the U.S. in 2012. Assuming three-fourths of the population lives in areas where the temperatures drop below freezing consistently for at least three months out of the year, one can assume that one-eighth of these people will purchase gloves within a year. The estimated number of glove sales will range between 30 and 40 million pairs. Taking an average of this projection, Gerbing's share of the heated glove market would come to 0.09% for the year of 2012. GreenGlove desires to match 10% of Gerbing's sales.

Economics

GreenGlove's main target market will consist of skiers and snowboarders, primarily because they are out in the day where the sun is extremely accessible. The glove industry is currently on the rise, where Fig. 3 shows the annual participation for snow sports participants.

Total Number Of Snow Sports Participants

Season	Alpine	Snowboarding	Cross Country
2006/07	10,362,000	6,841,000	3,530,000
2007/08	10,346,000	7,159,000	3,848,000
2008/09	10,919,000	7,421,000	4,157,000
2009/10	11,504,000	8,196,000	4,530,000

Source: Physical Activity Council – 2011 SIA SnowSports Participation Report. These figures represent participants who are 6+ years old and participated in a sport at least once during the 2009/10 season.

Figure 3: Annual Participation in Winter Sports [SnowSports Industries America, website].

Each seasonal year, a growth in interest and participation in alpine, snowboarding, and cross country skiing has occurred, with the 2010/2011 winter season being a record year, according to SIA SnowSports [SnowSports Industries America, website]. A projection for the 2011/2012 winter season, as well as the next five years can be seen in Table 6. For the 2011/2012 season, an estimated 29 million people will participate in the main three winter activities, not including those who snowshoe, winter-mountain climb, hike, sled, or snowmobile. Those who ride motorcycles are also not included in the statistics, however, due to convection over the hands, heated gloves would be beneficial for this group of people as well.

Table 6: Projected Percentage Increase in Number of Winter Sports Participants through 2017

Year	Alpine	Snowboarding	Cross Country	Total	Difference	Percent Change
2006/07	10362000	6841000	3530000	20733000		
2007/08	10346000	7159000	3848000	21353000	620000	3%
2008/09	10919000	7421000	4157000	22497000	1144000	5%
2009/10	11504000	8196000	4530000	24230000	1733000	7%
2010/11				26410700	2180700	9%
2011/12				29315877	2905177	11%
2012/13				32833782	3517905.2	12%
2013/14				37102174	4268391.7	13%
2014/15				42296478	5194304.4	14%
2015/16				48640950	6344471.7	15%
2016/17				56423502	7782552	16%

Figs. 1 and 2 in Appendix C, which pertain to merchandise sold in stores and online, give a realistic representation of GreenGlove's market and potential buyers. Realizing that GreenGlove will be going against many large companies who dominate winter clothing and accessory sales, the possible buyers for GreenGlove will only make-up a small percentage of this market. Assuming not all 29 million winter enthusiasts are going to buy gloves this year, looking at the statistics from the figures in Appendix C can help provide an estimate for those who may be willing to buy. Including both in-store and online purchases, accessory sales reached nearly $920,000,000. With gloves taking up 25% of the accessory market, the total sales for GreenGlove's market totals around $230,000,000.

Due to the company's unique design using solar panels to heat a glove, many will be tempted to switch from their current glove brand to GreenGlove's because the use of renewable energy is attractive to many buyers. Assuming GreenGlove will take up 0.009% of the target market the first year, sales of around $1,200,000 can be anticipated. Product sales will be expected to increase after the first year due to increased popularity, customer satisfaction, more advertising, and other growth-factors. Moreover, renewable energy is becoming increasingly popular in society. As this interest continues to develop, the idea of a glove operating on solar power rather than disposable or even rechargeable batteries will become increasingly appealing.

The barriers accompanied by starting a new business in the heated gloved industry consist of competing with the large scale winter clothing companies that have famous brands and styles. Pulling their customers away and making GreenGlove more appealing and worthy enough to switch glove brands will be hard, yet possible due to GreenGlove's unique design of renewable energy. However, since the heated gloves created by the company use the sun for energy and power, this might deter people who want a heated glove at night. It will be costly to advertise and market solar powered gloves on the same level as the large scale companies, making money a possible barrier. The more endorsements and free advertising GreenGlove can acquire, the better the outcome will be for the company.

Advertising and Promotion

Advertising is a key element in market strategies because it can either make or break the product. It is then essential to identify the niche for any given product. Outside of specialty outdoor stores such as Scheels, REI or Sports Authority, heated gloves are not seen as widely available to buy. GreenGlove's advertising and promotion strategy must then be focused on very specific demographics. A broad marketing strategy to appeal the "ordinary" and "everyday" American would not be practical. GreenGlove is focusing on its advertising and promotional strategy with the winter sports market, specifically snowboarders and skiers, with a secondary market being outdoor sportsmen (hunters or campers for instance) and the general populace in colder U.S. climates.

GreenGlove's narrow intended customer base of winter and outdoor sports enthusiasts relies heavily on the advertising budget to take out ads in the media that will be frequently visited by this specific customer base. It is essential that GreenGlove take out page advertisements in magazines such as *Snowboarder, Skiing Magazine,* and *Outside Magazine.* Specifically, *Outside Magazine*, which features a searchable database/catalog on their website with which visitors and subscribers may search various types of outdoor gear, with heated gloves included will be beneficial.

Another advertising medium that GreenGlove considers viable is to hold displays at trade shows. This form of advertising, however, is a high risk/high reward endeavor. Trade show display set-ups are very expensive, ranging from $400 to an upward of $20,000 for certain displays [Trade Show Direct, website]. In addition to the display set-up, the registration fees and actual fee for the space at a trade show might be too expensive for GreenGlove based on projected first year profits. Such a marketing strategy would not become plausible until after the third year based on breakeven analysis, which is conducted in Fig. 5 in the financial section.

One of the most effective forms of advertising found in today's market is through social media such as Twitter, Facebook and YouTube. Heated clothing companies such as Gerbing's, utilize links to social media from their online store. The biggest advantage to using social media for advertising is the cost. Twitter, Facebook, and YouTube are all free to sign-up and are highly customizable which works to GreenGlove's advantage. The primary disadvantage to this sort of advertising is the scope. Heated clothing and heated gloves is a niche product and requires advertising that narrows its scope to a very specific demographic. It is difficult in social media sites to pick out specific demographics to target their appeal, as exposure is at the mercy of those who subscribe to the site. Establishing a Facebook page for the company does not guarantee visitation, but at the very least it establishes a "social" brand and gets the product into the market.

Competitive Analysis

GreenGlove will need to be able to compete with other heated glove competitors. Specifically, GreenGlove will need to beat out a portion of the market who would normally buy battery-powered or rechargeable gloves. Gerbing's Heated Clothing and ThermoGloves are the top companies within the heated clothing industry. To determine how this product will compare to the other glove services offered, a competitive analysis was created. The chart, which is seen in Appendix D, demonstrates the major strengths and weaknesses of both this product and those of the competitors while doing a side-by-side comparison of the three.

Competitive Advantages

GreenGlove's solar powered glove has many advantages over the current market competitors. One of the primary advantages is the glove's ability to provide heat without having to be recharged or have batteries replaced. Both Gerbing's and ThermoGloves require batteries in order to produce heat. The gloves produced by GreenGlove will enable the consumer to enjoy the benefits of heated gloves without the burden of locating chargers, changing batteries, or purchasing and replacing batteries. Another advantage of using solar power over traditional batteries is that it extends the time-span that power is available for use. Most products require recharging after only a few hours of operation; however, the solar paneled glove can provide heat as long as the sun is present. For example, Gerbing's must be recharged after only two hours of use at 100% power. This is only a fraction of the time that the gloves from GreenGlove will be able to provide heat, as they can operate as long there is sunlight present.

Moreover, this product is more lightweight than many of the competitors because they are able to operate completely battery-free. According to Gerbing's website, the approximate maximum surface temperature of the heating element is 135 degrees Fahrenheit [Gerbing's Heated Clothing, website]. Even with the significant decrease in power supplied by GreenGlove's heated glove, the surface of the heater can reach 120 degrees Fahrenheit. Comparable heated gloves by Gerbing's weigh up to 3 lbs., where the majority of the weight is due to the power source (i.e. battery pack). By using flexible solar panels as in GreenGlove's design, the total weight of the glove is significantly reduced, with the total weight of the panels amounting to only 0.28 oz. Also, GreenGlove utilizes Aerogel as the insulating material. This material has a significantly lower thermal conductivity value than the competition, thus providing more effective insulation. Finally, GreenGlove's heated gloves have an advantage in seizing a portion of the market for those who are extremely environmentally conscientious. These gloves allow for a green, renewable option to have heated gloves, but are capable of doing so without creating excess waste. This provides an advantage not only in seizing portions of the Gerbing's and ThermoGlove market, but also benefits the overall population as they leave a smaller carbon footprint than traditional heated gloves.

Competitive Disadvantages

As the product operates solely on solar power it will not function when there are poor weather conditions or during the night. This makes the glove less reliable of a product compared to that of the majority of products on the market. In addition, the solar power cannot generate as many watts of power as a battery is capable of producing. To compensate for this loss, the company has chosen Aerogel as the insulation for the gloves, where there is additional bulk due to the greater thickness of the Aerogel versus the Thinsulate™ seen in other heated gloves. Moreover, GreenGlove is just entering the marketplace and still has a limited selection of products available with very little name recognition. As the company gains more name recognition and builds their reputation, the company will acquire a larger portion of the market.

Niche

In order to be successful, it is imperative that GreenGlove obtains a specific corner of the market. The clearest sect of the glove market that GreenGlove wishes to obtain is a portion of consumers who wish to purchase heated gloves. Of these, the majority are either outdoor enthusiasts or motorcycle riders. Many of these people are outdoors for a long period of time, and as a result, GreenGlove will utilize their strength of longevity to cater more towards these consumers. In addition, GreenGlove's specific niche will be to capture the portion of this consumer market who are especially environmentally aware. GreenGlove will therefore cater their production to fit the tailored needs of a market that is lacking a fitting product: outdoor, environmentally aware heated glove consumers.

Another portion of the market that GreenGlove is targeting, are those who are diagnosed with Raynaud's disease, a rare disorder that reduces the blood flow to the fingers and toes. If those affected with this syndrome used GreenGlove's heated gloves during cold conditions or whenever their fingers were hurting from the lack of circulation, the pain and discomfort experienced by Raynaud's would drastically decrease. GreenGlove's placement of the solar panels on the fingers will significantly increase the circulation flow and reduce the discoloration of the fingers that occurs with Raynaud's disease. A pictorial representation of how Raynaud's disease affects the fingers is shown in Appendix E. About five percent of the U.S. population is affected by Raynaud's where their symptoms could easily be relieved by increasing the warmth in the fingers by using GreenGlove's solar powered gloves [What is Raynaud's?, website].

Financial Strategies

Product Pricing

The cost of materials for each pair of gloves will be $286. The expected price for each individual component of the glove is detailed in Table 7. In order to maintain a respectable profit margin, the gloves will be sold at a cost of $400, resulting in a profit of $114 per pair of gloves sold. While this value may seem high for a pair of gloves, it does fall within the upper range of current heated glove prices on the market. Heated gloves of lower quality can be found as low as $32, but higher quality gloves can reach approximately $400 after purchasing the gloves and the required accessories needed for recharging [Alpine Accessories, website].

Table 7: Cost of Materials

Item	Quantity	Price	Total
Solar Panels - Fingers	20	$ 1.95	$ 39.00
Solar Panels - Hand	4	$ 13.95	$ 55.80
Polyimide Heaters	10	$ 15.00	$ 150.00
Aerogel	1	$ 30.00	$ 30.00
Cotton	1	$ 1.00	$ 1.00
Leather	1	$ 9.00	$ 9.00
Plastic Covering	1	$ 0.10	$ 0.10
Inner Lining	1	$ 1.00	$ 1.00
Wiring	1	$ 0.10	$ 0.10
			$ 286.00

Startup Expenses and Capitalization

GreenGlove expects to encounter approximately $165,000 in expenses before the company begins any sort of operation. This includes building costs, equipment costs, insurance, patent filings, and website costs. To account for this, and while considering employee salaries that will need to be back-loaded for the first year, GreenGlove is requesting a $300,000 investment in return for 15% ownership of the company. This amount will be plenty as far as covering the expected $165,000 startup cost, and it will also leave GreenGlove with a positive cash flow at the end of the first year after salaries have been paid. Based on projected sales of 3,000 pairs of gloves for the first year, GreenGlove will incur a negative profit of $223,000. Adding the investment to this number will leave the company with a $77,000 cushion at the end of the year. This cushion will be valuable should any other unexpected costs arise during the year. Tables 8 and 9 illustrate the yearly fixed costs and the financial projections based on sales, respectively. These tables can be referenced to understand where the above values originated.

Table 8: Allocation of Fixed Costs for the First Five Years

Fixed Costs	Year				
	1	2	3	4	5
Salaries	$400,000.00	$450,000.00	$600,000.00	$700,000.00	$700,000.00
Building	$ 50,000.00	$ 50,000.00	$ 50,000.00	$ 50,000.00	$ 50,000.00
Machinery	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00	$ 20,000.00
Insurance	$ 75,000.00	$ 75,000.00	$ 75,000.00	$ 75,000.00	$ 75,000.00
Patent	$ 15,000.00				
Website	$ 5,000.00				
Total	$565,000.00	$595,000.00	$745,000.00	$845,000.00	$845,000.00

Table 9: Breakeven Analysis Per Year Including Profit Margin and Cash Flow

Profit Per Unit	Year	Units Needed for Breakeven	Units Sold	+/- For Year	Revenue	Expenses	Profit Margin	Breakeven Status	Cash Flow
$ 114.00	1	4956	3000	-1956	$ 1,200,000.00	$ 1,423,000.00	$ (223,000.00)	$ (223,000.00)	$ 77,000.00
	2	5219	4874	-345	$ 1,949,634.80	$ 1,988,988.88	$ (39,354.08)	$ (262,354.08)	$ 37,645.92
	3	6535	7671	1136	$ 3,068,513.21	$ 2,938,986.94	$ 129,526.26	$ (132,827.82)	$ 167,172.18
	4	7412	11740	4328	$ 4,696,173.01	$ 4,202,763.70	$ 493,409.31	$ 360,581.49	$ 660,581.49
	5	7412	18133	10721	$ 7,253,112.76	$ 6,030,975.62	$ 1,222,137.14	$ 1,582,718.63	$1,882,718.63
Total		31535	45419	13883	$18,167,433.78	$16,584,715.15	$ 1,582,718.63		

Profit Margin

GreenGlove expects to start returning yearly profits in its third year of operation. Table 9 illustrates the expected profit margin for each of the first five years. This value takes into account the revenue gained by total sales, as well as both the fixed expenses for the year and the variable expenses associated with the amount of gloves sold. Fig. 4 shows how the profit margin improves each year based on revenue and expenses. In order to estimate the number of gloves sold in a year, the company used the projected numbers of skiers and snowboarders from Table 6. By targeting 3,000 glove sales for 2012/2013, GreenGlove reaches 0.009% of the market population. Using that same percentage and increasing it slightly per year, glove sales were calculated for each year's increasing market size. The estimated percentage of the market reached was increased to 0.013% for year two, 0.018% for year three, 0.024% for year four, and 0.032% for year five. GreenGlove expects to maintain the upward trend after the first five years as more people learn about the product and its benefits.

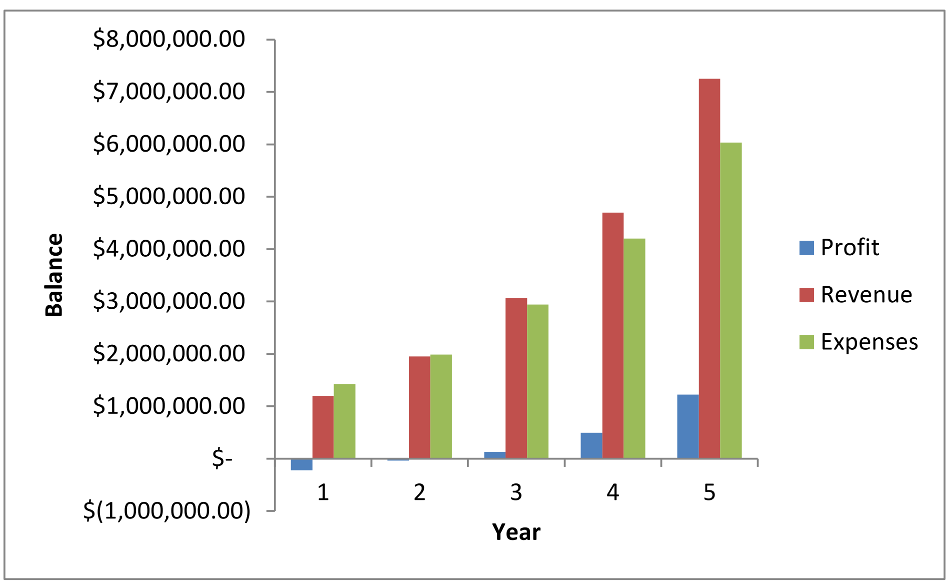


Figure 4: Graphical Representation of Revenue vs. Expenses. Losses are expected until the third year.

Breakeven Analysis

A breakeven analysis based on the projected sales totals results in GreenGlove reaching its breakeven point at the beginning of the fourth year of operation. The company will begin to climb towards the breakeven point during year three, and will rapidly rise above it once it has been reached in year four. The yearly breakeven status values can be seen in Table 9. While it may not be ideal to take more than three years to hit breakeven, it is necessary be very conservative when making projections about breaking into the glove market, especially for a high-priced heated glove. Fig. 5 illustrates GreenGlove's breakeven status for the first five years.

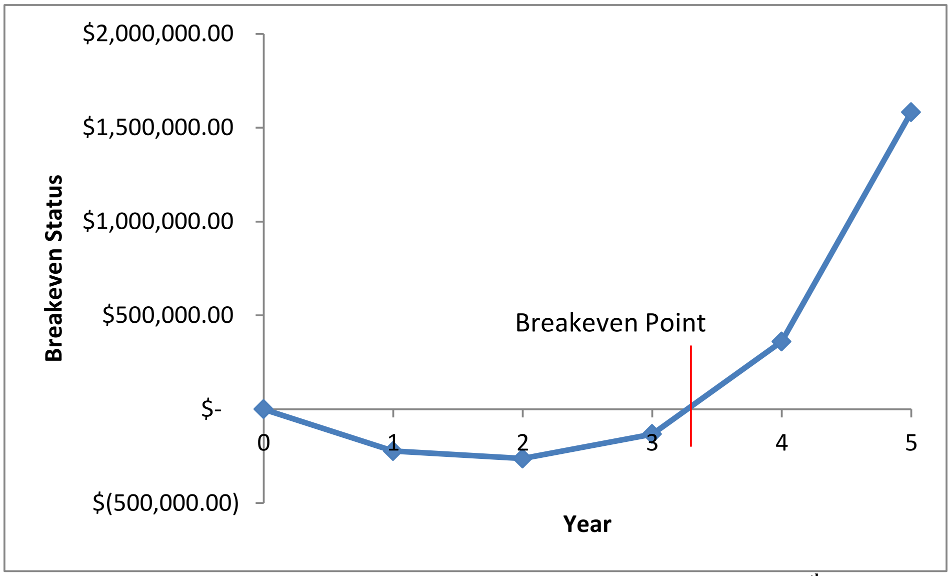


Figure 5: Graphical representation of break-even point expected during the 4th fiscal year

Cash Flow

Based on financial projections, the company will be able to maintain a positive cash flow for each of its first five years. After the initial investment of $300,000 GreenGlove will retain $77,000 at the end of year one. At the end of year two, after profits are again in the negative, there will still be $37,646 left for a cushion. Table 9 lists the cash flow expected for each of the first five years. By maintaining a positive cash flow each year, and barring any unexpected complications, additional investments and loans will not be needed to keep the company running. Also, as shown in Fig. 6, the cash flow will begin to increase rapidly after the third year. When this occurs, the return on the initial investment will greatly improve.

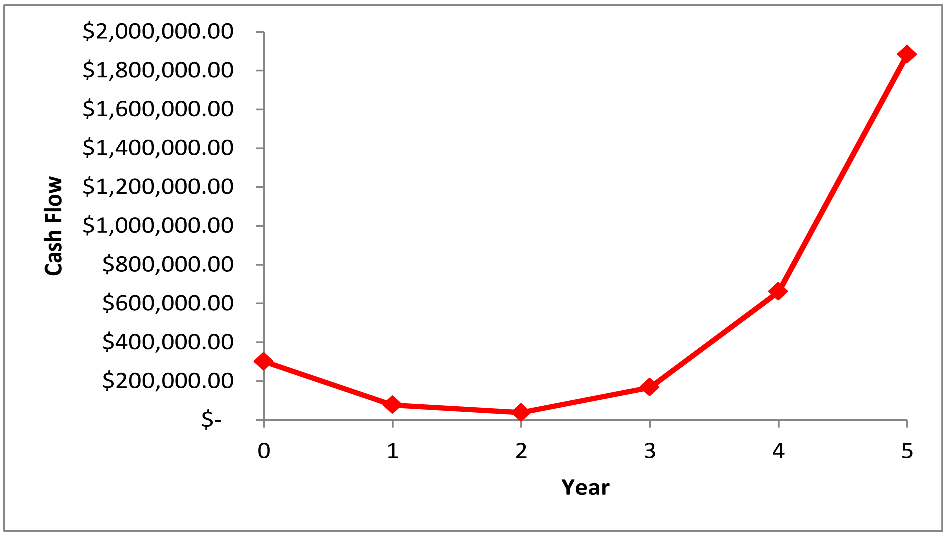


Figure 6: Graphical Representation of Cash Flow for the first 5 years of Existence. Cash flow is expected to be low until past the break-even point.

<u>Investor Return and Exit Strategy</u>

As shown in the above financial projections, GreenGlove can realistically break into the glove market and become a profitable company. By investing $300,000 initially, an investor can expect to earn their money back after approximately five years. After that point, the return on their investment will rapidly multiply based on the increasingly steep slope of cash flow. The founding members plan to remain with GreenGlove if it becomes successful, but other scenarios must be considered. Should GreenGlove have complications and not return a profit, the company will liquidate its assets in an effort to make up any losses it may have occurred. Another possibility is selling GreenGlove to a larger company. If GreenGlove becomes successful and a large company makes an offer to merge or purchase, the founding members and investor will reach a unanimous decision before taking such an action. This could be desirable because it will result in a large sum of money, but ownership will be decreased or completely eliminated. However, depending on the condition of the market, there will likely be an ideal time to sell the company while it is at its highest value. The members of GreenGlove will monitor this situation and will strive to exit the company during this situation in order to get the maximum return.

Final Prototype Results

The final prototype of the glove consists of all materials listed in the budget. The electrical and heat generating portions of the glove include a total of 12 solar panels: ten 3V, ½" x 2" panels located across each finger, and two 6V 3" x 4.5" panels located on the top of the hand. Wired to the solar panels are five 156.8 ohm Polyimide resistive heaters connected in parallel to achieve an equivalent resistance of 31.36 ohms. The layers of glove material include a leather outer layer, a layer of Cryogel Aerogel strategically placed throughout the glove, with emphasis on insulating the fingers, and a weather resistant barrier inside the insulation, both to keep water from the heaters as well as to keep the dust created by the insulation away from the hand. Lastly, the inner-most layer consists of a pre-manufactured cotton glove for comfort as well as additional thermal insulation. To ensure the leather shell of the glove was properly sized to accommodate all of the solar panels on the surface and all of the interior components, a large piece of leather was cut and sewn into a glove. This allowed GreenGlove to design the leather shell to accurately meet required sizing specifications. To ensure the solar panels remained in the correct locations on the glove surface, the panel dimensions were measured and slits were cut directly into the glove. The original proposal was to punch holes in the glove to allow for wiring, however by making the panels fit tightly in the slits, the panels were held secure in the leather. All wiring was soldered to ensure all connections were secure. To reduce manufacturing costs for the prototype, all sewing, wiring, and soldering was performed by GreenGlove. The completed glove is shown in Fig. 7.

Figure 7: Completed GreenGlove Prototype.

<u>Evaluation of Results</u>

After completion of the glove, the glove was then tested with the five parallel resistive heaters to determine the temperature increase that could be achieved. Because the glove was not completed until spring, the ambient temperatures during testing were much hotter than the temperatures that would be present during normal usage. In addition to the warm ambient temperatures, other factors including glove material (leather), and color (black), caused the glove to absorbed large quantities radiation from the sun. This resulted in the sun heating the glove more rapidly than the heaters. Therefore, to counteract the temperature increase due to the sun, as well as to simulate forced convection across the glove that would be present during skiing or snowboarding, a fan was faced towards the glove. This allowed the inside temperature of the glove to cool to a steady-state value. Once a steady-state temperature was reached, the heaters were engaged and the temperature inside the glove began to increase. After monitoring the temperature increase for about eight minutes, the heaters were disconnected, and the glove temperature began to decrease. This data is shown in Fig. 8.

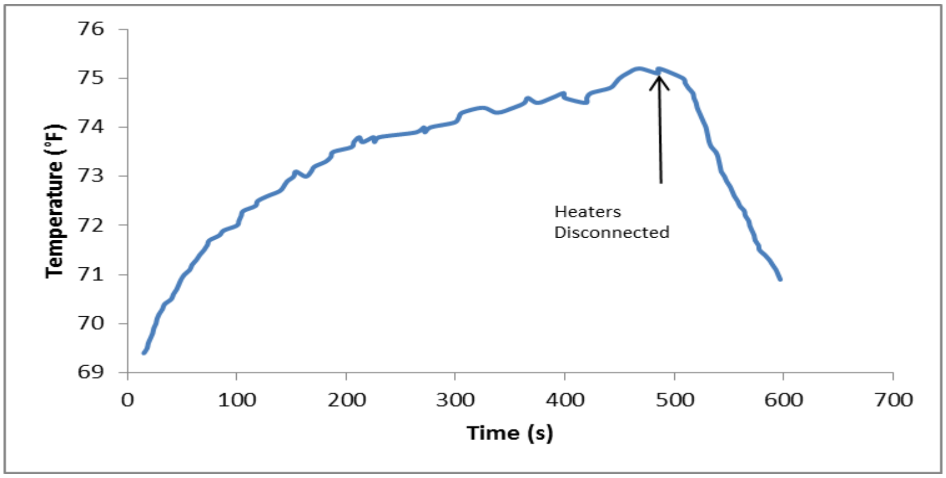


Figure 8: Temperature Variation vs. Time.

As shown in Fig. 8, the temperature steadily increases as the heaters are engaged. Though the initial temperature in Fig. 8 shows 69 degrees Fahrenheit, the actual initial temperature during testing was 68 degrees F. This corresponds to a temperature increase of approximately seven degrees F in the fingers. At t=480s, which corresponds to about eight minutes, the heaters were disconnected. At this point the temperature begins to drop, thus showing that the heaters were functioning properly. Additional testing provided consistent results, with an increase in temperature varying from approximately five to ten degrees Fahrenheit.

Due to the use of renewable energy sources in the design, rather than power supplies such as batteries, the maximum achievable power generation for the gloves is limited. While the ideal power generation from the solar panels is 0.96 W, the actual measured power generation during testing was 0.44 W. Because of the limited power generation capabilities of the glove, rather than producing large quantities of power and achieving temperatures as high as competitive battery-operated designs currently on the market, GreenGlove decided to focus their design on the retention of the heat generated in the glove. To do this, Cryogel Aerogel was added to the glove, with an emphasis on insulating the fingers. By focusing on insulating the fingers, the heat generated by radiation from the hand and by the heaters would be lost from the glove at a much slower rate, thus maintaining warmer temperatures inside each finger for longer periods of time.

<u>Recommended Future Changes</u>

Though the prototype was successful and a sufficient temperature increase within the glove was achieved with the heaters, there are multiple improvements to the design that could be made. For example, the insulation used in the prototype was Cryogel Aerogel. Though this material has an extremely low thermal conductivity, it is much dustier than an alternative, Spaceloft Blanket, which has an equally low thermal conductivity. By reducing the dust generated by the insulation, the materials inside the glove would be much simpler and safer to work with. Moreover, when installing the solar panels, the slits cut into the leather provided the solar panels with relatively secure and immobile installation, however the final product would include a thin layer of clear coating that would cover each panel, both to decrease undesirable panel mobility on the glove surface, as well as to protect and increase the durability of the panels.

A more significant change for the future would be to either redesign the glove into a mitten, or add mittens to the product line. Multiple reasons exist for implementing this drastic change. First, mittens more effectively distribute the heat generated by the hand. Within a mitten, each finger is located in the same area, so the heat from each finger, as well as the hand itself is being distributed throughout the entire area of the glove. Alternatively, in a glove, each finger is isolated from one another, so the heat being generated is not distributed to the entire hand. Gloves also have a larger surface area than mittens, with additional surface area located between each finger. This increase in surface area results in an increase in total heat lost from the glove. Furthermore, though the Aerogel selected as the primary insulator is extremely lightweight and has unparalleled insulating properties when compared to alternative clothing insulation, it is relatively thick, thus reducing mobility and dexterity of the fingers. By designing a mitten, insulation would not be required between each finger, and the overall mobility of the hand would be improved. Lastly, if a mitten was designed, five separate heaters would not be required for heat generation. Rather, only one heater would be necessary, which could be placed above the fingers. Therefore, the heat being generated would also be localized to one area, thus increasing the temperatures that could be generated by the heaters. This last statement was verified during initial testing, when a single heater was used. When using a single heater of equivalent size, and equal equivalent resistance, the measured temperature reached approximately 120 degrees Fahrenheit. Using only one heater would also reduce the cost of the entire glove and become more appealing to potential buyers. Though there are multiple changes that could be made to the prototype, the prototype itself was successful, and proved to be a valid design.

References

1) Advantages of Solar Power (website). Retrieved from http://www.solarhome.org/infoadvantagesofsolarpower.html

2) All Business (website). Retrieved from http://www.allbusiness.com/public-administration/administration-human-resource/877725-1.html

3) Alpine Accessories (website). Retrieved from http://www.alpineaccessories.com/prodinfo.asp?number=THHGM2%20%20%20%20MEDIUM&variation

4) ASTM Standards (website). Retrieved from http://0-enterprise.astm.org.innopac.library.unr.edu/SUBSCRIPTION/filtrexx40.cgi?-P+COMPANY+Mathewson-IGT Knowledge Center+complete_standards.frm

5) Ball, Jeffery, "Six Products, Six Carbon Footprints" Wall Street Journal (website) http://online.wsj.com/article/SB122304950601802565.html

6) Cozy Winters (website). Retrieved fromhttp://cozywinters.com/shop/zs-hzx-liion.html

7) Custom thermoelectric (website). Retrieved from http://www.customthermoelectric.com/

8) Flex Solar Cells (website). Retrieved from http://www.flexsolarcells.com/OEM_Components.php

9) Gerbing's Heated Clothing (website). Retrieved from http://www.gerbing.com

10) Incropera, F, Dewitt, D, Bergman, T, Levine, A. Introduction to Heat Transfer: Fifth Edition. Hoboken, NJ: John Wiley & Sons, Inc. 2007

11) Pacor Inc. (website). Retrieved from http://www.pacorinc.com/pdf/Aspen-Pacor-Green-Table.pdf

12) SnowSports Industries America (website). Retrieved fromhttp://www.snowsports.org/SuppliersServiceProviders/ResearchSurveys/

13) Tellurex (website). Retrieved from http://www.tellurex.com/products/power.php

14) ThermoGloves (website). Retrieved from http://www.verseo.com/about-thermogloves.html

15) Trade Show Direct (website). Retrieved from http://www.tradeshowdirect.com/

16) U.S. Census Industrial Report on Gloves and Mittens (website). Retrieved from http://www.census.gov/industry/1/ma315d02.pdf

17) What is Raynaud's? (website). Retrieved from http://www.nhlbi.nih.gov/health/health-topics/topics/raynaud/

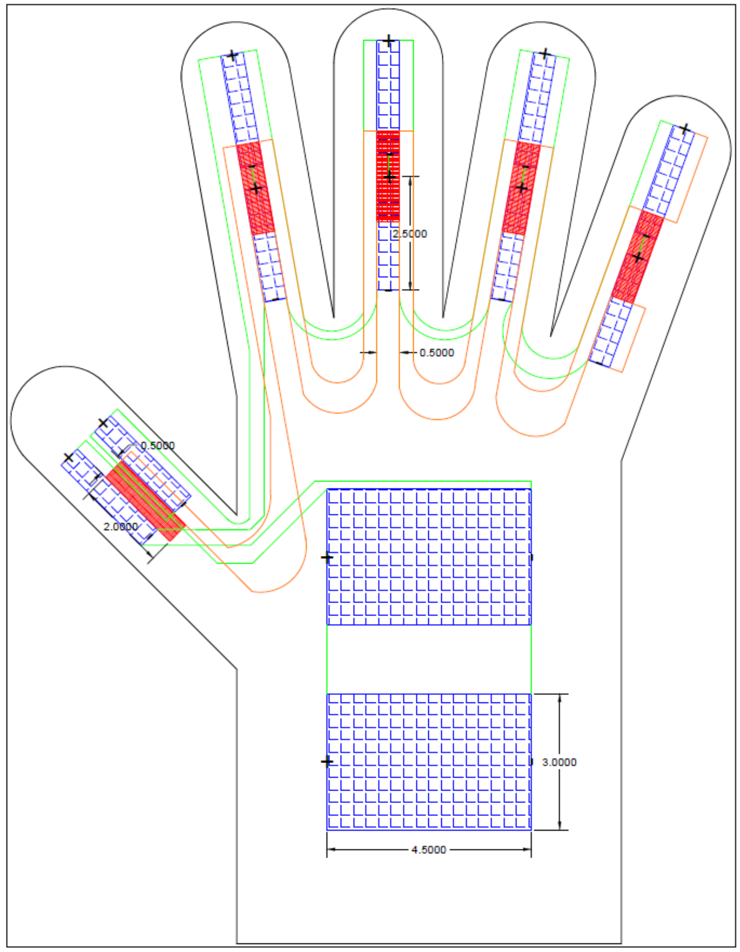
Appendix A:
Heat Transfer Calculations

Natural Convection	
Ts [K]	277.59
Tf [K]	272.04
B [1/K]	0.0038
v [m2/s]	1.340E-05
α [m2/s]	1.881E-05
RaL	12981518.52
Nu	31.57
Pr	0.7143
k [W/mK]	0.0241
h [W/m2K]	3.798

Radiation from Body	
emissivity	0.996
Tskin [K]	307.039
Tsi [K]	299.817
q [W]	1.412

Thermal Resistance [mK/W]	
R-leather	0.832
R-Cotton	2.205
R-Aerogel	14.881
R-convection	10.970
q-loss [W]	2.308
q-rad [W]	1.412
q-gen [W]	0.896

Appendix B:
Wiring Schematic


2.5000
0.5000
0.5000
2.0000
3.0000
4.5000

Appendix C:
Merchandise Sales

Products Purchased At Snow Sports Specialty Stores

Season	Apparel	Equipment	Accessories	Total
2010/11	$631,484,569	$652,994,205	$733,501,741	$2,017,980,515
	31.3%	32.4%	36.3%	100%
2009/10	$582,547,354	$561,816,248	$632,370,255	$1,776,733,856
	32.8%	31.6%	35.6%	100%
2008/09	$598,726,870	$523,832,218	$585,355,794	$1,707,914,882
	35.1%	30.7%	34.2%	100%
2007/08	$664,251,136	$563,733,716	$624,826,402	$1,852,811,254
	35.8%	30.4%	33.7%	100%
2006/07	$622,598,729	$563,622,139	$586,422,337	$1,772,643,206
	35.1%	31.8%	33%	100%
2005/06	$579,172,886	$617,690,007	$599,325,160	$1,796,188,053
	32%	36%	32%	100%
2004/05	$546,487,808	$622,995,217	$562,564,919	$1,732,047,944
	32%	36%	32%	100%
2003/04	$513,937,507	$641,456,028	$556,509,695	$1,711,903,230
	30%	37%	33%	100%

Figure 1: Annual Breakdown of Snow Sport Related Purchases [SnowSports Industries America, website]

Products Purchased Online

Season	Apparel	Equipment	Accessories	Total
2010/11	$325,164,341	$140,526,198	$186,524,403	$652,214,942
% of online market	49.8%	21.5%	28.6%	100%
2009/10	$298,729,338	$132,439,566	$166,220,158	$597,389,063
% of online market	50%	22.2%	27.8%	100%
2008/09	$278,791,332,	$115,219,427	$152,503,267	$546,514,025
% of online market	51%	21%	28%	100%
2007/08	$258,847,926	$113,166,387	$119,732,372	$491,746,685
% of online market	53%	23%	24%	100%
2006/07	$189,418,120	$64,408,888	$83,635,678	$337,462,685
% of online market	56%	19%	25%	100%

Source: SIA SnowSports RetailTRAK - August 1, 2010 to March 31, 2011

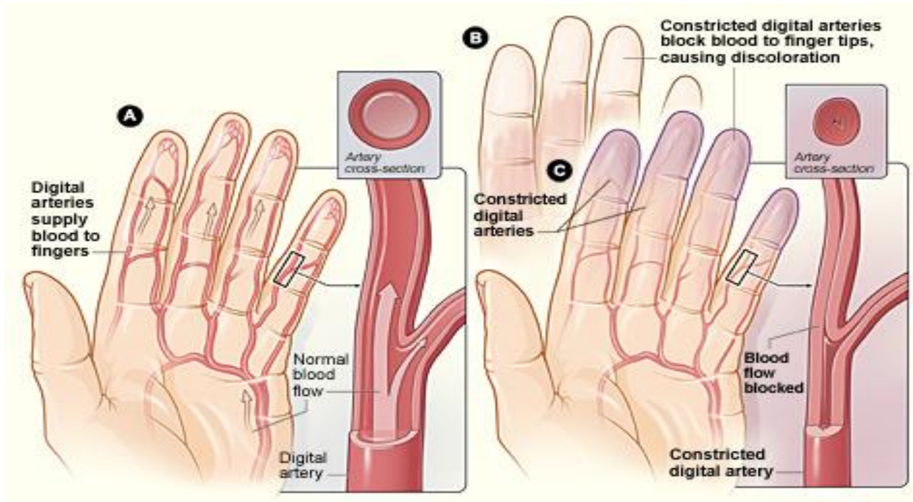
Figure 2: Percentage Breakdown of Online Snow Sport Product Sales [SnowSports Industries America, website]

Appendix D:
Competitive Analysis Breakdown

Factor	Solar Heated Gloves	Strength	Weakness	Competitor: Gerbing's	Competitor: ThermoGloves	Importance to Customer
Price	These gloves are relatively expensive at $400. However, this is a one time only price as there is no need for additional battery purchases.		✓	Fairly cheap gloves, costing $200 per pair. Also, their overall price continues to increase as batteries are purchased.	Cheap at $100 per pair. Price could continue to grow with the purchase of more batteries.	★★★★
Quality	As a smaller company, SPG has the capabilities of ensuring each glove is of high quality.	✓		Very high quality gloves.	High quality gloves.	★★★★★
Selection	As a start-up company, SPG has a limited number of products available.		✓	Offers a variety of gloves including sizes for both male and female and various patterns.	Offers a variety of sizes but have only one main design so equally selective to the SPG gloves.	★★
Durability	Leather exterior should allow gloves to be stronger and more durable than nylon counterparts.	✓		Gloves are high quality, but they are made of less durable materials which may lend themselves to more tears.	Made of polyester which is less durable than leather so may not be as durable.	★★★★★
Reliability	Due to their reliance on weather, the gloves are not able to produce heat during night or poor weather conditions.		✓	When batteries are fully charged, these gloves produce heat reliably regardless of weather.	When batteries are fully charged, these gloves provide heat consistently.	★★★
Appearance	Our gloves have an extremely unique appearance and are eye-catching.	✓		Gloves are available in 3 different colors so they are able to appeal to a variety of consumers.	Gloves are black and white and appeal to a broad-spectrum of clients.	★★
Warmth	SPG is able to produce up to 132.1 degrees F. when the weather is at optimal conditions and uses Aerogel, a highly insulative material.	✓		Uses 7.7W of power which enables them to reach temperatures of 135 degrees F. Also, they use Thinuslate™, a less insulative	Offers three levels of warmth reaching a max temperature of 111 degrees F. Insulation is not as effective as that of either	★★★★★

				material than Aerogel.	company.	
Renewability	The solar panels allow them to use renewable solar energy to power the glove.	✓		Lithium batteries must be frequently recharged and are a non-renewable resource.	Lithium batteries must be recharged and are a non-renewable resource.	★★★★
Company Reputation	SPG is still relatively unknown in the market as it is a brand new company.		✓	Gerbing's is currently one of the foremost glove companies, and they offer other clothing items.	Thermo-glove is well-known and is already being sold with many glove distribution companies.	★
Weight	This product does not require batteries so it is able to remain extremely lightweight.	✓		These gloves weigh 3.3 pounds per pair so they are fairly heavy for the average consumer.	Fairly lightweight gloves, but slightly heavier than the SPG gloves.	★★
Eco-friendly	Rechargeability and use of solar energy makes them highly environmentally friendly.	✓		Due to their reliance on lithium batteries they are worse for the environment.	Lithium-polymer batteries are fairly environmentally friendly but are still less green than solar panels.	★★★
Longevity	Gloves stay heated for as long as they receive sun exposure.	✓		Can only last two hours at full power.	Must be recharged after 5 hours of use.	★★★★
					highest=	★★★★★

Appendix E:
Raynaud's Disease Portrayal



[What is Raynaud's?, website]