Guidelines for Developing Solar Technology Commercialization Strategies

A Major Qualifying Project
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Abstract

This project aims to provide a guideline on how to commercialize a solar space heating technology, which is currently being developed by a fellow architectural major qualifying project team (MQP). Using Business Model Canvas and the Jerry Schaufeld's commercialization model as a referential framework the team looked into providing a guideline for a commercialization plan of a solar technology product for a broader solar market. Additionally, an engineering economic analysis was carried out to understand whether there is a potential for the product through the consumer point of view.

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1.0 Introduction

Current energy dialogue in the U.S. is centered on the solutions that reduce energy costs as well as the carbon pollution from the electricity and transportation sectors (SEIA, 2013). Heating and cooling buildings consume a huge chunk of available global energy. According to The World Business Council for Sustainable Development, buildings account for more than 50% of the world's energy consumption, with the resulting carbon emissions substantially more than those in the transportation sector (Roos, 2011). In the U.S. alone, approximately 44% of energy consumption is directly attributed to heating and cooling (SEIA, 2013). The residential, commercial, and industrial sectors in the U.S. spend over $270 billion annually on heating and cooling (Navigant Research, 2015).

Solar heating and cooling (SHC) technology can play a significant role in providing an economically viable and environmentally sustainable long-term solution to these essential heating and cooling needs (SEIA, 2013). SHC technologies have proven to have a wide range of applications and uses, including domestic water heating, space heating, swimming pool heating, air conditioning, process heating, steam generation, and air heating. (Siegel, 2016) SHC draws from an inexhaustible energy source – the sun. It has the potential to displace fossil fuels and electricity otherwise needed for heating and cooling.

Donor Ed Curtis envisions creating a super smart house (SSH). A zero-energy net consumption building, where the total amount of energy used will roughly equal to the amount of energy created on the site through renewable energy sources. Given the promise of SHC technology, Ed Curtis along with a fellow Architectural Major Qualifying Project (MQP) Team are currently re-innovating the design of the solar water heating system as a solar heating and cooling technology for Unity Homes. After they have finished making a final product a graduate qualifying project (GQP) team, consisting of graduate students will test the feasibility of the product and come up with a more in depth marketing strategy and profitability of the product. Meanwhile our MQP projects goal is to provide a guideline of a commercialization plan.

In the current market, just an innovative idea is not enough. There are sufficient innovative ideas and solutions, but they lack the directions and process models to enable them to help the world (Schaufeld, 2015). In Jerry Schaufeld's book *Commercializing Innovation: Turning Technology Breakthroughs into Products,* he looked at the disposition of the creative energy and output needed to achieve success in these efforts and realized that there might be a better way to focus on the commercial opportunity those ideas have. It is to understand how to turn those ideas into commercial activity.

This is why for the solar water heating system to have a potentially successful impact, using the business model canvas along with Jerry Schaufeld's commercialization model as a referential framework, the team looked into providing a guideline for a commercialization plan of a solar technology product for a broader solar market. Through industry analysis, this paper will also look into what the solar heating and cooling technology (SHC) market and broadly the solar market are like and the appropriate commercialization strategies to adopt for entering the solar market when the product is ready. Also, an engineering economic analysis was carried out to understand whether there is a potential for the product through the consumer point of view to understand whether there is a potential for such a product in the market.

2.0 Background

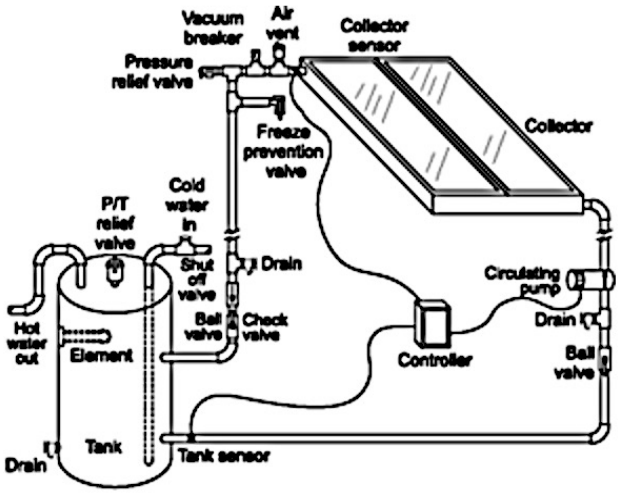
2.1. Emergence of Solar Thermal Heating Systems

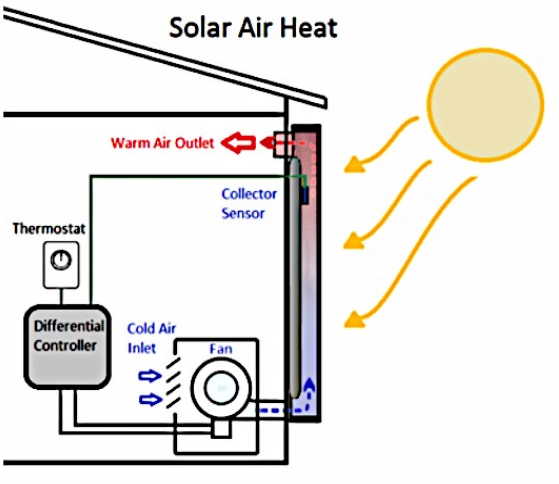
The first commercial solar water heater was patented in 1891. Inside the first five years, almost 30 percent of the homes in Pasadena, California, installed solar domestic hot water systems (Pahl, 2013). Although the solar hot water heating industry had spread to Florida by the 1930s, copper shortages due to use in ammunition and other military equipment during World War II (coupled with economic incentives offered by electric companies to switch to their hot water heaters) crippled the burgeoning solar hot water industry (Pahl, 2013). Copper was an important component in solar thermal heating system because of its certain favorable properties (Copper Development Association Inc, 2007). Copper has high heat conductivity, resistance to atmospheric and water corrosion, sealing and joining by soldering, and mechanical strength. It is still used both in receivers and primary circuits of heat exchangers in water tanks (Copper Development Association Inc, 2007).
It was almost more than a half century later when solar hit the mainstream market again, revitalized by the OPEC oil embargo and skyrocketing fossil fuel prices (Pahl, 2013). Federal and state tax credits of the early 1980s for renewable energy systems gave the solar industry a significant, if short-lived, boost (Pahl, 2013). Almost overnight, a huge number of companies sprang up all across the nation to serve a seemingly insatiable demand for a wide array of solar installations. Then, in 1986, the Reagan Administration pulled the plug on solar incentives. When all of Carter's financial incentives promoting renewable energy expired, Reagan administration chose not to renew it (Pahl, 2013). Today, motivated by consumer demand for environmentally friendly and economically sound technology, the solar industry is witnessing what many hope will be a full-fledged energy revolution (Pahl, 2013).

2.2. Development of the Solar Space Heating Systems

The Architectural MQP team's project focuses on designing a solar water heating system as a solar space heating system to minimize energy usage within single-family homes. SHCs trap the heat from the sun (solar radiation) and transfer the heat to water or air for use as thermal energy (SEIA, 2013). While both SHC systems and solar photovoltaic (PV) systems involve collector panels, they are very different technologies.

Figure 1: Image of General Solar Heating and Cooling Technology Designs.





Source: SEIA, Solar Energy Industry Association

Solar water heating systems are composed of three main elements: the solar collector, insulated piping, and a hot water storage tank. Even though there are many design variations, essentially the solar collector gathers the heat from the sun and transfers the heat to potable water (SEIA, 2013). The heated water then flows out of the collector to a hot water tank, and is used as required (SEIA, 2013). Though the Architectural team's system is based on these basic design elements, they are re-designing their system through active and passive design methods. To better understand the need for such a system and to determine how it can be optimized for a single-family home, they are conducting a research that focuses on the optimization of a home through passive methods. For this purpose, they are partnering up with Unity homes. Unity Homes emerged from the company Bensonwood Woodworking, a company that builds custom timber framed houses that incorporate sustainable design into every aspect of the building process. Unity Homes is working to address concern over inefficient energy usage in private homes by selling energy efficient homes to the general public. In collaboration with Unity Homes, they are also seeking to improve their home design by investigating both passive and active changes to their design.

Even though such a system should be considered a 'heating system or technology', given its solar components is also considered a solar technology. For this paper, the team decided to look into both solar and heating technology aspects of such a system. From now on the system will be referred as a solar space heating system for convenience.

2.3 What is Commercialization?

Commercialization is the process by which a new product or service is introduced into the general market (Staff, 2010). This involves understanding product design (PD), production process planning (PP), marketing (M), supply chain management (SCM), financial management (FM), human resources (HR), accounting and IT (AIT), and legal and regulatory management (LM) (XD). Commercialization ensures that the technology in question meets not only the performance and reliability requirements, but also the economic requirement (Balachandra, Nathan and Reddy, 2010). In the context of solar technology, commercialization is important as, without financial status, sustainable energy technologies will neither gain customer confidence nor benefit from the dynamism of the private economy. (Balachandra, Nathan and Reddy, 2010) Without a properly researched commercialization plan there is no way any product will achieve success in the current competitive market.

2.4 Commercialization Models

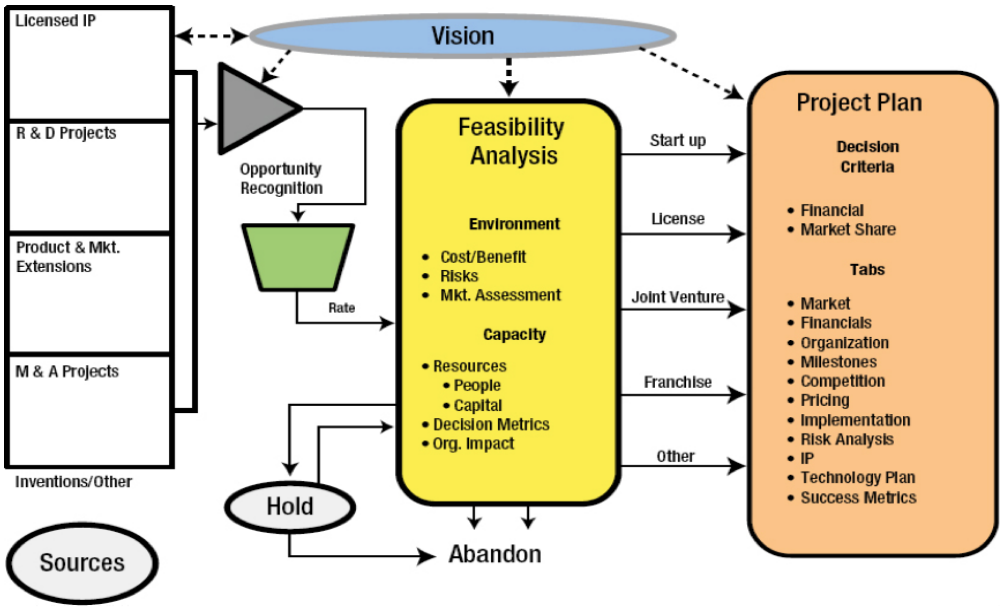
An important aspect of having a good commercialization strategy is to build upon a good commercialization model. Models are tools for delineating and understanding commercialization processes (Schaufeld, 2015). It helps break down complex process elements of commercialization so they can be understood in their own right (Schaufeld, 2015). An effective commercialization model should offer insight into more ambiguous environments, as a tool to evaluate how strategy shifts as the commercialization environment changes (Gans and Stern, 2002). For this very purpose one can't just use a commercialization model rigidly but follow it as a guideline. The models featured in this paper are the business canvas model and the commercialization model discussed in this paper is from Schaufeld's Book, Commercializing Innovation: Turning Technology Breakthroughs into Products.

2.5 Jerry Schaufeld's Commercialization Model

There are at least five separate sections to the generalized steps of the commercialization cycle. The number of steps will vary with the sectors, stages of growth, or the amount of capital required (Schaufeld, 2015). For example, the regulatory impact and government regulations of decisions in biotech or large capital equipment projects like a steel mill enlarges the model beyond a simple startup (Schaufeld, 2015). Schaufeld's framework also suggests considering the process of commercialization as a series of steps or gates. He dictates that each gate must be passed in order to move on to the next section. So how can a model be generalized that can be used as a foundation for more elaborate applications? Schaufeld with these concepts in mind explores a possible graphic model for portraying a cycle of commercialization. The model as shown in Figure 2 consists of the following sections.

- Sources of ideas
- Opportunity recognition
- Feasibility analysis
- Going-to-market methods
- Project plan

Figure 2: Jerry Schaufeld's Commercialization Cycle



2.5.1 Sources of Idea

For the entrepreneurial journey, discovering ideas worthy of becoming projects for successful commercialization is a critical part. (Schaufeld, 2015). According to Schaufeld, 'it isn't that there are not enough ideas but rather too many'. This is where the process begins to ensure that as many viable innovation sources as possible are considered that best match a given project (Schaufeld, 2015). According to Schaufeld, there are multiple sources to derive ideas. Some of the sources of commercialization mentioned in his book include Licensing, Research and development (R&D), Product and Market extensions and Mergers and Acquisitions projects.

2.5.2 Opportunity Recognition

There is an abundance of possible avenues an innovative idea or technology can go towards for commercialization. And this is where things get tricky, even though there are multiple paths, only a couple will result in success. This is why Schaufeld suggests that entrepreneurs and companies should use the funnel model, where ideas are constantly being drawn distilled into possible opportunities that are aligned to the overall vision of the environment they were meant to serve (Schaufeld, 2015). For the funnel model, the frequency and magnitude of the flow of ideas an organization can absorb are determined by its resources and capabilities (Schaufeld, 2015). The importance of a "flow" is that not all projects will equally succeed. So the rate (that is, the number and breadth) of idea flow must be considered in a way that a) allows for failure of some projects and b) is robust enough to satisfy the company's (or project's) appetite for new commercial ideas (Schaufeld, 2015).

2.5.3 Feasibility Analysis

Successfully passing this opportunity recognition is a signal for going onto the next step in the process, feasibility analysis. Conducting a feasibility analysis allows a company or entrepreneur to understand whether the product or business idea has a good chance of success in the market (Schaufeld, 2015). As obvious as it may seem, this step is repeatedly ignored or done in a peripheral manner (Schaufeld, 2015). The disregard for this step can have adverse effects on the overall project's probability of success (Schaufeld, 2015). Schaufeld's

framework considers six broad elements when conducting a feasibility analysis. These six considerations are economic, technical, operational, risks, legal and strategic.

Economic considerations reveal the underlying cost models, which are based on the bill of materials roll ups in the case of tangible products and, in the case of services (Schaufeld, 2015). They are only estimates but even as first order checks they help identify the feasibility of going ahead (Schaufeld, 2015). Materials considerations are usually bracketed by small and higher quantities. In established organizations, models of standard costs help normalize the accuracy of the estimates. Labor components also benefit from standard cost elements. There are also multiple external economic considerations such as the cost of money, Return on Investment (ROI) calculations, and of course the availability of capital as defined in the balance sheet or through the external capacity to borrow or raise capital through equity offerings (Schaufeld, 2015). ROI is a simple calculation of gains realized by an investment. ROI measures the profit or loss generated from an investment about the amount of money invested (Schaufeld, 2015). ROI also allows you to compare possible returns between investments (Schaufeld, 2015). In combination, these economic consideration tools aid in the decisions to go forward with the project.

Of all issues confronting the progress of new projects, the dynamics of technological considerations seem most intriguing (Schaufeld, 2015). Today, the rate of change of technological adoption is faster than any historical benchmarks before. Product lifecycles that were measured in yearly time constants are now presented in metrics measured in months (Schaufeld, 2015). The rate of change presents new challenges to markets and product development in that the changes can occur before the economic benefits of the product lifecycle occur (Schaufeld, 2015). This is why companies should ensure that before a product hits the market to have an understanding whether consumers are ready to adopt this technology and how long the technology will be relevant for.

Operational consideration explores operational readiness of an organization to embark on new projects centers on the current structure's capacity to absorb the requirements of the new ventures (Schaufeld, 2015). They fall into two broad categories— plant/equipment and human resources. Both of these categories are "long-lead" items and require months, if not years, for a company to acquire and absorb (Schaufeld, 2015). Operational issues include the capacity of the physical plant, equipment, people, and financial balance sheets to support the

proposed project(s) (Schaufeld, 2015). As early as the feasibility analysis is, it is common to explore future issues in a time-based format, commonly through charts or some other visual format (Schaufeld, 2015). The project management charts perform as an important set of tasks for commercial success by requiring the identification and quantification of long- lead items (Schaufeld, 2015). This falls into the category of capital expenditures (CAPEX), which have magnitude and exhibit long-time constants for delivery. Examples include purchasing buildings, hiring people, and buying machine tools. The planning of these aspects beforehand is important to the overall success of the project.

Risk factors are intertwined in all aspects of commercialization and commerce. Offsetting these risks at minimum entails weighing the rewards or the larger upside potential (Schaufeld, 2015). This potential is usually measured by the return on equity (ROE) of funds invested in the equity of the organization (Schaufeld, 2015). The biggest risk that an enterprise can face is not addressing the possibility that unforeseen, undesirable events occur (Schaufeld, 2015). The ability to frame and resolve risks beforehand is the backbone of good management practice. Risks come in different forms and aspects. Schaufeld covered four of the major kinds in his book. The mentioned risks are legal, regulatory, commercial and market, and financial. Legal risks include some very specific aspects such as Contractual, Intellectual Property and Governance. Commercial risk involves multiple elements that affect the sales transaction. Marketing influences such as branding, packaging, design, pricing, and distribution methods enter into this (Schaufeld, 2015). They each contain a certain degree of risk. Competitive pressures impact actual purchasing decisions (Schaufeld, 2015). It is an oversimplification to just refer these elements as competitions (Schaufeld, 2015). It is more complex than that.

The impact of regulatory change, beyond just rules imposed on every basic industry, has become even more significant. Regulatory issues pervade every aspect of modern business and it is compulsory to pay attention to them (Schaufeld, 2015). Regulatory bodies such as OSHA, FDA, Sarbanes-Oxley and more govern and set standards for board governance issues, each contains uncertainty of change, and thus risk (Schaufeld, 2015). Once again it becomes the domain of management to sort that out and to establish the priority of those that will impact future performance (Schaufeld, 2015). Many regulatory aspects are complex and seem to be in a constant flux of change. There are a group of specialists in each

area who serve as consultants to industry. They offer up-to-date information, as well as broad solutions gleaned from multiple clients (Schaufeld, 2015). According to Schaufeld financial risks is the top risk in any project. Although projects look at several possible channels for this vulnerability, weakness in the balance sheet that results in cash deficiencies tend to trigger maximum exposure to failure (Schaufeld, 2015). This is why it is imperative that all aspects of finance from funding to operational costs are strictly structured and followed.

A well-thought-out feasibility analysis offers direction as to how best to proceed to a viable commercialization outcome (Schaufeld, 2015). It also reveals a basic weakness in how some companies approach this. Organization have favored pathway to market but multiple alternatives should be constantly examined to see which path best serves the particular project (Schaufeld, 2015). A partial list is shown in Table 1.

Table 1: Alternative Commercialization Pathways (Schaufeld, 2015)

Alternative	**Attributes**
Startup	Allows separation from a parent organization and its brand. Offers the flexibility of a specific organizational model focused on the project. Risks include the uncertainty of new team and capitalization model.
Licensing	Offers a quick path for a new technology. Carries the financial overhead of a license fee, while relieving the cost of R&D and regulatory acceptance.
Joint Ventures	In many ways an attractive alternative in that it draws from multiple organizations. It loses the strength of the internal learning curves and poses the risk of mixing two diverse cultures.
Franchise	Offers an alternative project funding through fees and royalties. Carries the responsibility of providing quality and new products to sustain the franchise value.
M&A	Selling the project to another entity. Brings immediate liquidity but compromises the market preens of the new product.

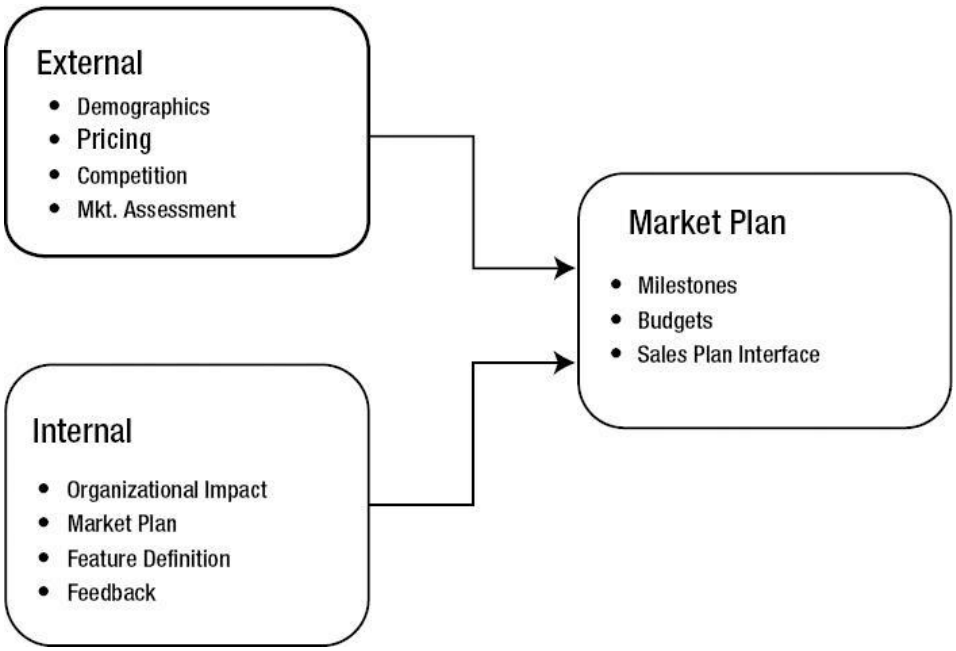
At this stage of the process, there are certain broad metrics that control decision-making. As the journey toward commercialization evolves and additional information becomes available, it may offer a point to review and even retrace the initial steps (Schaufeld, 2015). The advantage of this type of planning is that few expenditures of human and/or financial capital have been invested. Some of the early considerations include: Corporate vision, industry mores, human capital, financial resources, CAPEX and more.

2.5.4 Going-to-market Methods

Go-to-market strategy is the plan of a company, utilizing its inside and outside resources to deliver its unique value proposition to customers in order to achieve competitive advantage (Schaufeld, 2015). Go-to-market strategy starts with a situational analysis that describes the customer behavior and the market environment, as it currently exists (Schaufeld, 2015). It outlines the outside forces such as competitive and regulatory elements that can impact the success of the project (Schaufeld, 2015). The company defines a target customer audience and tries to understand their purchasing patterns in order to offer a strategy or approach as to how to overcome them (Schaufeld, 2015). As a result, marketing is a critical aspect in going-to-market strategy. Of all the functional disciplines, marketing probably has the most significant impact on the success of the outcome (Schaufeld, 2015). Through marketing a company derives valuable understanding of how a given product or service integrates into customer's perceived needs (Schaufeld, 2015). The results of a successful marketing and sales campaign translate directly into financial performance and overall project satisfaction (Schaufeld, 2015).

In the current times, the concept of commercial business is undergoing a major disruptive set of changes. The line between digital and traditional marketing is continuously becoming blurry. For marketers now it is less about digital marketing than marketing in a digital world. This is a significant increase and bears further consideration. According to Schaufeld, there is a need for commercial opportunities in a new context. Within the context of a new model of the marketing paradigm, a starting point is to look at the model from its organizational function, as shown in Figure 3.

Figure 3: Marketing Function



Demographics: In traditional marketing models, demographics are the focus of what the first contribution the marketing function adds to the success (Schaufeld, 2015). Demographics help define: Who are the customers? Where do they live? What do they buy? How do they make purchases? What are they willing to pay? The list of defining attributes also includes age, gender, marital status, purchasing power, and more. But Schaufeld suggests a dynamic model, which includes changes or trends marketing is undergoing. In this model the information is creatively synthesized into a demographic model of a hypothetical aggregate customer (Schaufeld, 2015). This information then can be used as the basis of the marketing plan and formulation of a brand strategy. The consumer's' psychographic individualities have a major part in developing a company's target market personas (Woolley, 2012). These individualities include: personality traits, lifestyle, opinions & attitudes, degree of loyalty, and events & occasions. "By segmenting the market based on these psychographic individualities you are able to be more niche in your advertising buys, maximizing exposure" (Woolley, 2012). Being able to understand when the company's target market will use the product/service, what they find most appealing about the product/service, what media they turn to for information and more, simply puts the company in a better position to succeed.

Pricing: Pricing is the process of determining what consideration a company will receive in exchange for its products or services (Schaufeld, 2015). It is one of the four Ps of marketing including Product, Promotion, and Place. The key influences on pricing include a bottom-up one driven by manufacturing and distribution costs, brand, product quality, and competition (Schaufeld, 2015). The second consideration is one of "what the market will bear" and rewards the most efficient producer and distribution channels (Schaufeld, 2015).
Proper pricing determination requires a sound strategy that embraces the market and its competitive forces, as well as the corporate requirements for profits and returns on their investments (Schaufeld, 2015). There are three ways a company can approach to help determine a strategic direction for pricing. These three approaches are, cost-based pricing, competition-based pricing and value-based pricing. Cost-based pricing is a method in which a fixed sum or a percentage of the total cost is added (as income or profit) to the cost of the product to arrive at its selling price (Schaufeld, 2015). It embraces the concepts of breakeven (BE) and experience curve (EC) impact (Schaufeld, 2015). Value-based pricing uses data based on the customer perception of value. Many customers use a simple metric of cost-benefit analysis for value (Schaufeld, 2015). Competitive pricing is setting the price of a product or service based on what the competition is charging (Investopedia, 2017). This pricing method is used more often by businesses selling similar products, since services can vary from B2B, while the attributes of a product remain similar (Investopedia, 2017).

Competition: The arenas of commercialization, pricing, and competition are intertwined. In the literature surrounding technology commercialization, the role of competition in the evolution of a commercial product is complete with supporters and detractors (Schaufeld, 2015). Every business has competition. Determining a project's competitive forces comprises several steps. The first step includes identifying who the competitors are. If there are other competitors, this means there is already an established market and opportunity for an entrant exists (Adams, 2010). They can be a totally new business, a new product, or even a new technology or even existing ones. They can be identified well before business opportunities are lost. Simple observations like their advertising, presence at trade shows, Internet sightings, patent searches, and simple dialogue with existing customers (Schaufeld, 2015). Only identifying them is not enough. Understanding the strengths and weaknesses of your

competition is critical to making sure your business survives and grows (Staff, 2016). Know what products they offer, how they distribute them, their annual reports (if public) or their SEC filings, their pricing schedules, who they identify as customers, and possibly their financial resources (Schaufeld, 2015). Checking their literature is a great starting point. The next step is dealing with them (Schaufeld, 2015). Competitors offer an opportunity to learn and innovate (Schaufeld, 2015). Observing how they go to market is a chance to improve that process. Sometimes the best strategy is to build on your own strength. Improving your customer service response function is an example (Schaufeld, 2015). Continuous internal improvement is a solid way to improve customer effectiveness and competitiveness (Schaufeld, 2015).

Market Assessment: Whether one is thinking of entering a new market or launching a brand-new product, conducting a marketing assessment is the critical first step for determining if there is a need or a potential customer base for your product (Blue Ocean, 2017) For assessing the market, the first essential step is to identify the industry where your product will fit in the best. It is important to know how an industry is defined. According to Michael Porter in his book *Competitive Advantage*, "an industry is best defined as "a group of companies engaged in similar production activities." (Porter, 1980, Pg. 32) Once a suitable industry has been determined, the next step is to analyze industry metrics using industry research reports. These reports provide data on market size, trends, life cycles and projected growth rates. It also includes comprehensive analysis of environment forces, market trends, entry barriers, competition, risks, opportunities and the company's resources and constraints (Blue Ocean, 2017.). This information can be used to narrow the potential market into a target market.

2.4.5 Project Plan

After all the following gates in the previous stages have been passed through, now is the time to take all that information and prepare a plan. Schaufeld asks his reader in the book "why plan?" It is that it can improve the probability of success of a project and promises to reduce losses and inefficiency (Schaufeld, 2015). Planning exists in the space between

project uncertainty and improved positive outcomes. The degree of formality, detail, and depth are also determined by the maturity of the organizational context in which the project exists (Schaufeld, 2015). Whatever the level of project planning sophistication employed, an overriding benefit of the process is the internal communication of goals, organizational interdependence, and measurable outcomes that are positive attributes of the process (Schaufeld, 2015). In this paper, for planning the commercialization strategy development, the business model canvas is considered to arrange the information.

2.5 The Business Model Canvas

The business model canvas is a visual chart with elements for developing new or documenting existing business models (Osterwalder & Pigneur, 2010). It focuses on describing a company's value proposition. The Business Model Canvas was created by Swiss business theorist Alexander Osterwalder and Belgian computer scientist Yves Pigneur, which since has been redefined for specific niches. Based on Osterwalder & Pigneur's book and tutorial video, it is clear that this model is designed to assist enterprises in describing their business model. The business model canvas specifies nine building blocks based on four central ideas, infrastructure, offering, customers, and finances.

2.5.1 Infrastructure

Under infrastructure, there are three blocks, key activities, key resources and partner network. For key activities, a company should consider the most important activities in executing a company's value proposition. Also, enterprises should consider, "Which ventures are essential to their distribution channels? And what kind of activities are fundamental to their revenue streams?" (Osterwalder & Pigneur, 2010). Typical activities could include research and development, production, marketing, sales and customer services. For example, for a company, which manufactures computer chips, key activities could include control of production and manufacturing, promotion of the product and packaging design. For vital resources, a company should consider the primary inputs that affect the value proposition. Essentially, they are the main components needed for the end product. Ultimately, the quality of the key resources will affect the sustainability and profitability of a company (Osterwalder

& Pigneur, 2010). The types of key resources can include physical, intellectual, human and financial assets.

The final aspect of this group is 'Key Partners'. A company usually decides to form partnerships to optimize operations and reduce risks. This block can point to suppliers and partners who can make the business model effective. Companies should consider “Which partnerships are critical to our business?”, “Who are our crucial suppliers?”, “Which of our suppliers and partners are sourcing our vital resources?" and “What type of partnerships would suit our needs?” (Osterwalder & Pigneur, 2010). There are four types of partners and partnerships to consider. The first is strategic alliances, where a partnership is formed between non-competitors. The second is co-opetition, where a strategic partnership is created in which there is a high risk from both companies. This partnership is usually formed when companies may be trying something new. The third type of partnership is joint-ventures. Joint venture is common with new enterprises and is beneficial when both companies can provide inputs to the business. The last partnership is buyer-supplier relationships. It is the most common type and ensures a steady supply of resources for a company. (Osterwalder & Pigneur, 2010)

2.5.2 Offering

According to Osterwalder & Pigneur, in their book, a company’s value proposition is what distinguishes itself from its competitors. In other words, it creates a case as to why a consumer should pick one product over another. Depending on the product it can have one or multiple value propositions. However, it is important that the product can solve a problem in a unique way. There are several elements of the value proposition a product can incorporate. Newness, performance, convenience and design are all qualitative features while price, cost reduction, and efficiency are quantitative elements. (Osterwalder & Pigneur, 2010)

2.5.3 Customers

The customer section of the business model canvas is made up of three aspects: customer segments, channels, and customer relationships. Companies are aiming their product toward

customer segments, i.e. customers or businesses. Customers can be segmented based on needs, demographic factors such as age and ethnicity or psychographic factors such as behavior, interests, and motivations. Once you can accurately match your value proposition you can obtain valuable revenue streams (Osterwalder & Pigneur, 2010). According to Cleverism, an organization can categorize consumers to specific groups if they watch the following characteristics:

1. The customer groups have a particular need which justifies the creation of a product to match this need.
2. The group needs a separate Distribution Channel to be reached.
3. The groups require relationships of different kinds.
4. There is a very clear difference in the level of profitability each group represents for the organization.
5. Each consumer group feels strongly enough to pay for a different version of the product or service, tailored to their preferences.

There are five main types of customer segments. The first is mass market. In this type the product or service it is meant for a wide population, which may mean it solves a common problem. The second type is a niche market. This refers to a customer segment with particular needs and defined characteristics. Therefore, these products or services are customized to the client's needs. The third type is segmented. This is when a company chooses different customer segments within a segment and creates different value propositions based on their needs. The fourth type is diversified segments. This is when an organization is able to serve multiple customer segments with different needs. The last type is multi-sided platforms and markets. This is when a service or technology allow more than one customer to have direct interactions. This is used when businesses serve mutually dependent customer segments. For example, Facebook allows a multitude of users to interact with the technology, similarly companies like Paypal and Ebay are considered multi-sided platforms.

The second box under customers is called channels. This is essentially how the business will target a customer segment. When selecting a distribution channel there are five elements that should be considered. The first is the market size and the number of customer segments. The second are the costs involved with each distribution channel. The third is

whether or not the product is standard or if you need additional distribution methods to reach a certain customer. The fourth element to consider is how much control will be required over the distribution channel. The last step is to take into account how long a healthy relationship will take to be created. (Osterwalder & Pigneur, 2010)

2.5.4 Finances

There are two elements within finances. The first one is cost structure. When building the business canvas model it is important to think about how the key resources and key activities of the company relate to the expenses of the business (Osterwalder & Pigneur, 2010). Next it may be beneficial if the organization can determine if their model is cost-driven or values-driven. As the names suggest, a cost-driven model will be focused on reducing costs while value-driven models are focused on the creation of a high value product or service. Furthermore, there are multiple characteristics of cost structures. The first characteristic is fixed costs. These costs remain the same whether an organization is producing one or one million pieces. Generally these costs are associated with renting facilities and manufacturing equipment. The second characteristic is variable costs. These costs are usually dependent on the volume of output a company produced. For example, common variable costs are delivery fees. Other variable costs can include labor, capital utility bills and raw materials. The third characteristic is economies of scale. This essentially means the higher volume the lower the cost per unit. This can be a huge cost reduction because the higher volumes spread the fixed costs, which in turn cause the cost per unit to fall. It is also possible for variable costs to be lowered through bulk ordering. These savings will eventually be transferred to the organization's customers leading to lower market prices. The last characteristic is economies of scope. This is when business can get a reduction of costs when businesses invest in multiple markets. This is based on product diversification, where different products use the same resource. This leads to less money spent on marketing and distribution. Economies of scope can be advantageous for a business in which processes are repeatable, costs are reduced and there is flexibility in the design of the product (Osterwalder & Pigneur, 2010). The second element under finances is revenue streams. This block is essentially about how the business will generate revenue. These streams need to be clearly defined and it may be

important for organizations to specify pricing as well. There are two types of pricing mechanisms, fixed pricing and dynamic pricing. Under fixed pricing products are generally standard and the price is dependent on product features and volume. Under dynamic pricing, organizations should consider the variables into producing the product as well as the market conditions. There are seven ways to generate a revenue stream. The first of these are asset sales. This is the most common and refers to a sale of a physical product from seller to buyer. The second is usage fee, a charge by a service provider to customer for use of the service. The third is subscription fee, where consumers bay for continuous access to the products of a company. The fourth way is lending, where organizations provide customers access to a product for a limited amount of time for a fee. The fifth way is licensing, where a product, service or idea is patented so holders can charge other companies a fee for it. The next stream is through brokerage fees. This happens when a company acts as a middleman between two other companies and charges a fee. Finally the last stream is advertising. Businesses can make money through advertising when they charge a fee for promoting another organization, product or service. In addition to the types of pricing and revenue streams, businesses should also consider "What benefits are customers paying for, how are they paying for it and what will encourage them to pay more for?" (Osterwalder & Pigneur, 2010).

2.6 Demonstrate Financial Trade-Off for Consumers

One of the keys to effective problem solving is knowing what kind of tool to use or analysis to conduct when solving the problem. Knowing the most effective strategy allows one to come up with the best solution and thus take proper decisions. Many problems are simple, and good solutions don't require much effort. Whilst other problems reside at a higher level of complexity. Economic problems almost always reside at higher level of complexity, which are considered to be intermediate and complex problems (Newnan, Eschenbach and Lavelle, 2017). Engineering Economic analysis is considered one of the most effective tools for these kinds of problems (Newnan, Eschenbach and Lavelle, 2017). Engineering economic analysis focuses on costs, revenues, and benefits that occur at different time periods (Newnan, Eschenbach and Lavelle, 2017).). According to Newnan, Eschenbach and Lavelle, for a

problem to be considered for engineering economic analysis it needs to have the following three criteria.

1. The problem is important enough to justify serious thought and effort.
2. The problem can't be worked in one's head, that is a careful analysis needs to be conducted.
3. The problem has economic aspects important in reaching the decision.

Whether a consumer will buy a solar thermal space heating system is a question that needs to be looked from the consumer's point of view for efficient understanding. So, the question now is, will I buy a solar thermal space heating system? This is a problem with enough complexity to require an engineering economic analysis since it satisfies all the beforehand mentioned criteria. It is an important decision which requires serious thought and effort because purchasing a solar energy system is not cheap. Just like purchasing a car, this is a significant economic investment for an individual. These systems cost on average thousands of dollars. Also, there are multiple alternatives in the market already to offer the same heating functions. This is why the benefits need to significantly out way the costs for a consumer to make the decision of purchasing the product. Therefore, a consumer must consider all the benefits versus the cost before making this significant purchase. In this paper, whether a consumer in Massachusetts will buy a solar space heating system was explored to obtain meaningful insight, into whether there is a market potential in the New England area.

3.0 Methodology

3.1. Secondary Research

Performing the analysis required conducting extensive secondary research. Secondary research can be defined as a method used for collecting data through secondary data collection. The process of secondary research involves collecting data from either the originator or a distributor of primary research or information that has already been gathered. There are many advantages of secondary data such as it is readily available and is economical. The information must be easily available, it should be relevant to the topic at hand, the margin of error and dependability of the source must be examined, and adequate data should be available.

Secondary research helped us obtain information on the solar industry as well as the different niche markets. In order to evaluate solar space heating systems and their marketing opportunities, the team first completed research on solar markets. This research contributed to the assessment of the current state and future trends of the solar industry, and opportunities for SHC technology. *IBISWorld* industry market research reports and solar business associations website such as *Solar Energy Industry Association (SEIA)*, *American Solar Energy Society (ASES), U.S. Energy Information Administration (EIA)* and more solar and energy associations were utilized for this paper. As a result, secondary research enabled a better understanding of the solar industry and key market trends.

3.2 Solar Companies Research

In almost every market there are going to be competitors who sell the same or similar product and/or service. In a market analysis, it is crucial to comprehend who your

competitors are. The understanding of competitors provides important information as to how to position your product and/or company. There are various steps and methods used in determining a market's competitors. The method opted for this paper was to research a myriad of solar companies in the United States in order to determine the competitive advantages of each company. These companies have already established the base for solar product expectations. Thus, a competition analysis was carried out on solar companies for the better understanding of their operating strategies.

This paper's research considered a list of ten solar companies. The marketing strategies of those 10 companies were analyzed and documented primarily through their official websites. The 10 companies considered are as follows: SolarCity, Sungevity, SunBugSolar, Vlvient, AstrumSolar, RGS Energy, Heliodyne, Apricus, Solect and CTech Solar. For this analysis, the team looked into these certain attributes. These seven attributes are price, quality, customer service, market share, reputation, marketing and new product innovation. In order to come up with a competitive analysis a basic profile for the potential competitors was developed. In order to do each company's website, customer reviews, and government reports to derive the information needed in order to weigh the competitors' attributes was reviewed. Then, their marketing campaigns were evaluated to see where and how they are marketing. To narrow the list down, the team looked at who the competition targeted and if they focused on a specific niche. This is important and can be very helpful when trying to identify what market a similar product could do well in.

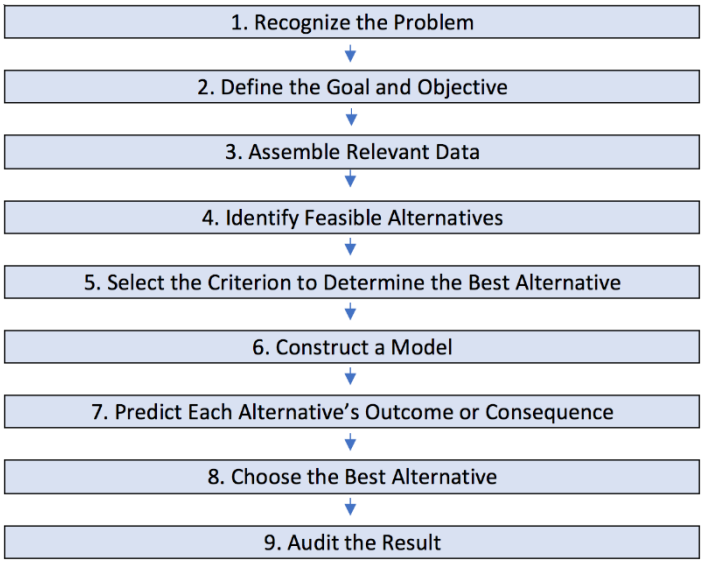
It was also vital to understand the company's product, how its product is similar or different and if there are any noticeable weaknesses to exploit. The team also looked at the

products in other markets they offered as well as new products they developed. For some companies where information was available the team gathered if they had any patents or IP on their product. For the public companies, the team looked at various financial ratios and profitability. The team also looked at their growth rate and their promotions, distribution channels, geographical coverage, and pricing. Along with all of this the team analyzed how big the company was, their objectives, mission statement and overall goals for the company.

3.3 Engineering Economics Analysis

Engineering economic analysis is an essential tool for decision making. And as discussed before, the decision to purchase a solar thermal space heating system is a significant one. By definition a decision problem needs to have at least two alternatives. If there is only one course of action available, there is nothing to decide (Newnan, Eschenbach and Lavelle, 2017). For this instance, the decision lies between a solar heating system and current traditional heating systems. This is not just any simple problem the team can give a quick thought and move on to take a decision. For this case, rational decision making is necessary. According to Newnan, Eschenbach and Lavelle, rational decision making is a complex problem that contains nine essential steps. These nine steps are represented in a sequential diagram in figure 4 below. It is common for a decision maker to repeat steps, take them out of order or skip the steps entirely (Newnan, Eschenbach and Lavelle, 2017). The sequential diagram is to show that are required and in a logical order, but the decision maker is still at digression as to how to use the process (Newnan, Eschenbach and Lavelle, 2017).

Figure 4: Sequential Diagram for Rational Decision Making Process.



3.3.1 Recognize the Problem

The very first step of rational decision making is recognizing what the problem is (Newnan, Eschenbach and Lavelle, 2017). In this project, given the current conditions whether a consumer will buy a solar thermal space heating system given the current heating alternatives was explored. In that regards, the problem being answered is whether a solar energy system is more profitable in the long term compared to traditional energy systems for heating from a consumer point of view.

3.3.2 Define the Goal or Objective

The goal or objective can be an overall or personal goal. A goal can be broad but an objective need to be narrow. This helps the decision maker to proceed the decision-making process with an acute purpose in mind. The objective as a consumer in this paper is to find the most profitable or savings providing heating energy source.

3.3.3 Assemble Relevant Data

For good decision making process, one must gather good information. This information can be in any form such as published papers, individual's knowledge or experience, surveys, market research etc. For this given problem, the two forms of information looked into were costs of purchasing a solar energy product and benefits of owning one such as incentives,

savings and more. Information was gathered through secondary research, as mentioned before, from government websites, solar consumer advice blogs and solar industry reports.

3.3.4 Identify Feasible Alternatives

Without the best alternative considered the result is always suboptimal (Newnan, Eschenbach and Lavelle, 2017). Luckily, there are plenty of alternatives currently in the market to be considered for space heating. The initial alternative is the new solar energy product and the other alternatives are the traditional heating sources in the market which are natural gas, propane, heating oil and electricity.

3.3.5 Select the Criteria to Determine the Best Alternative

The core task of decision making is choosing among alternatives (Newnan, Eschenbach and Lavelle, 2017). But how is the best alternative chosen? For that, what best means needs to be defined. There must be a criterion or set of criteria for judging among alternatives (Newnan, Eschenbach and Lavelle, 2017). These criteria are subjective to the decision maker and the nature of the problems (Newnan, Eschenbach and Lavelle, 2017). For this given problem, the best solution was decided upon is the alternative that maximizes profit or savings.

3.3.6 Construct a Model

In this point of the process, the previous various elements the objective, relevant data, feasible alternatives and selection criterion are brought together (Newnan, Eschenbach and Lavelle, 2017). Constructing the interrelationships between the elements is frequently called model building or constructing the model (Newnan, Eschenbach and Lavelle, 2017). For economic-decision making the model is always mathematical (Newnan, Eschenbach and Lavelle, 2017). For this problem, all the elements aided in the selection of the present worth analysis (PWA) model. This method is used for economic analysis to yield the same recommendation for selecting the best alternative among a set of mutually exclusive alternatives (Newnan, Eschenbach and Lavelle, 2017). Present worth analysis resolve alternatives into equivalent present consequences (Newnan, Eschenbach and Lavelle, 2017). The general formulae of a present worth analysis is given below.

To find P, Given F *(P/F, i,n)* $P = F(1 + i)^{-n}$

Here, P = A present sum of money.

F = A future sum of money. The future sum F is an amount, n interest periods from the present, that is equivalent to P with interest rate i.

i = Interest rate per interest period.

n = Number of interest periods.

It is most frequently used to determine the present value of future money receipts and disbursements (Newnan, Eschenbach and Lavelle, 2017). An example of such case would be determining present worth of an income-producing property, like an apartment. If the future income and costs are known, then a suitable interest rate can be used to calculate the property's future value. In present worth analysis, special care is given to time period covered by the time period associated with the task (Newnan, Eschenbach and Lavelle, 2017). This time period is usually known as analysis period, planning horizon, or project life.

3.3.7 Predict Each Alternative's Outcome or Consequence

A model and the data are used to predict the outcomes for each feasible alternative (Newnan, Eschenbach and Lavelle, 2017). As suggested earlier each alternative might produce a variety of different outcomes (Newnan, Eschenbach and Lavelle, 2017). But to avoid unnecessary complications, the decision-making process is based on a single criterion for measuring the relative attractiveness among various alternatives was assumed (Newnan, Eschenbach and Lavelle, 2017). To choose the best alternative, the outcomes for each alternative are stated in a comparable way. Usually the consequences of each alternative are stated in terms of money, that is in the form of costs and benefits (Newnan, Eschenbach and Lavelle, 2017). Resolving the consequences is done with all monetary and non-monetary consequences (Newnan, Eschenbach and Lavelle, 2017). In long term problems, like this one, costs and benefits take place in a longer period of time. The result may be cost at one point and benefits at others. For these kinds of problems, one error commonly assumed is that current situation will remain the same over long period of time (Newnan, Eschenbach and Lavelle, 2017). In reality, a market or circumstances never remain static. For this analysis, future energy market patterns and projections for the next 20-year period will be considered

3.3.8 Choose the Best Alternative

Choosing the best alternative may be simply a matter of determining which alternative best meets the selection criterion. But most economic solutions have market consequences, extra-market consequences and intangible consequences (Newnan, Eschenbach and Lavelle, 2017). Since the intangible consequences of possible alternatives are left out of the numerical model, they should be introduced into the process now (Newnan, Eschenbach and Lavelle, 2017). The alternative to be chosen is the one that best meets the choice criterion after considering both the numerical consequences and the consequences not included in the analysis (Newnan, Eschenbach and Lavelle, 2017). For simplicity of decision making process when carrying out the calculation, potential change in market conditions was built in the model. This way the decision is kept to picking the alternative which has the most positive present worth analysis value.

3.3.9 Audit the Result

An audit of the result is a comparison of what happened against the predictions (Newnan, Eschenbach and Lavelle, 2017). This step in the process the decision maker checks whether the decision analysis reasonably agrees with its projections (Newnan, Eschenbach and Lavelle, 2017). For example, if a machine was bought to save labor and improve quality? Did it? If that truly happened then the economic analysis was accurate can be used as a prime model for a similar problem in the future (Newnan, Eschenbach and Lavelle, 2017). This is a step of the process that given the nature of the project was not able to be carried out.

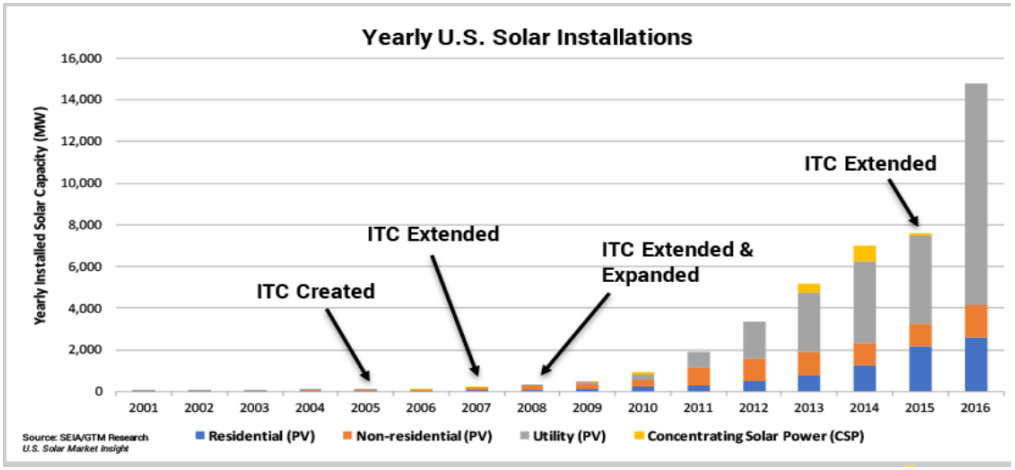
4.0 Findings and Analysis

4.1 Overview of the Solar Industry

"The solar power industry has experienced clear skies over the last five years." (IBISWorld 2016). In fact, in 2016 alone the solar power industry experienced growth of 18.5%. The performance has been dependent on the price of solar generation, strong government support and falling panel prices. Currently, almost thirty states have mandated renewable portfolio standard (RPS). Under the program utilities are required to generate renewable energy along with their other energy sources. Because of these recent trends, solar power plants have been built at a high rate over the last five years.

The solar energy market in the United States is thriving at this point in time. "GTM Research" and "The Solar Foundation-SEIA", track trends and trajectories in the solar industry that demonstrate the diverse and sustained growth across the country (Association, 2016). According to the SEIA's graph below, the amount of solar installations in 2000, the toddler year, were at just a few hundred. Fifteen years later the number of installations in the year 2015 alone was just over 7,000. The solar industry has become more stable and showed consistent growth beginning in the year 2006. This is mostly due to the Solar Investment Tax Credit (ITC), which has provided industry stability and growth since its initial passage in 2006.

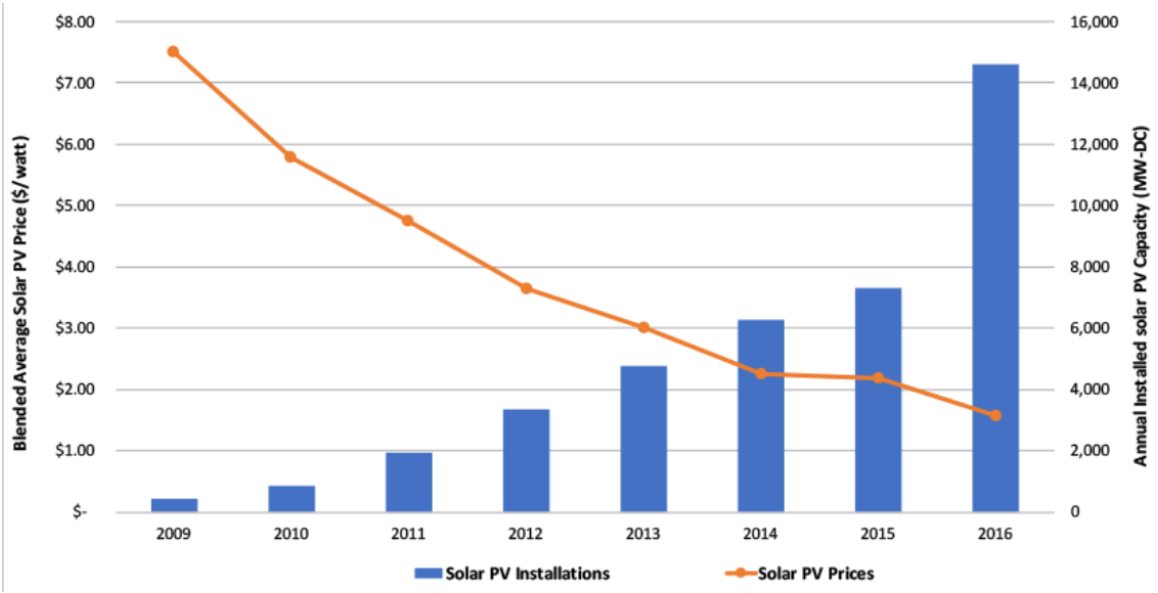
Figure 5: Overview of the Yearly U.S. Solar Installation Over the Last Sixteen years.



Source: Solar Energy Industries Association, 2017

The cost to install solar has dropped by more than 60% over the last 10 years, leading the industry to expand into new markets and deploy thousands of systems nationwide.

Figure 6: Drop in cost of solar installation over 8 years.



Source: Solar Energy Industries Association, 2017

4.1.2 External Drivers

There are several key external drivers affecting the industry's performance. First, the price of natural gas and steaming coal, the two competitors of solar power. Coal currently generates the largest share of US electricity, therefore a rise in coal prices will cause consumers to seek substitute energy such as solar energy (EIA, 2016). Also, there are major environmental concerns that come with coal power, the biggest being coal plants are the nation's top source of carbon dioxide, the primary cause of global warming. At the same time, while coal prices peaked in the last five to ten years, its price is expected to drop over the next five years. This can be because of a decreased demand and the phasing out of coal

power to natural gas and renewable sources. Natural gas has been a popular option because of the rapid demand for energy and its comparatively low environmental impact. The "Energy Information Administration" says that the volatility of natural gas prices is very high. For example, the need for heat during the winter or the lack of heat, can cause fluctuations and change the demand for natural gas on a large scale. This makes it a very risky market. According to industry research, natural gas prices are just expected to rise over the next five years, which means demand may shift towards renewable resources.

The second key external driver is the tax credits offered for energy efficiency. This initiative offers incentives for industry operators, as well as commercial and residential properties who generate solar energy. Under the solar Investment Tax Credit (ITC) residential, commercial and utility investors in solar energy property can claim a thirty percent federal tax credit. This initiative has helped annual solar installation grow by over 1600 percent since it was implemented in 2006. In 2015, a multiyear extension was put in place ensuring the policy's existence through 2021. This provides certainty for companies to develop long-term investments in the industry. In fact, according to the Solar Energy Industries Association (SEIA), they expect the twenty-seven gigawatts of solar energy installed total in the US after 2015, to be over 100 gigawatts by 2020. In addition to this, the 210,000 Americans employed in solar energy now is expected to double to 420,000, all while creating $140 billion dollars of economic activity in the same time period.

The last external driver is the price of semiconductor and electronic components. These components are essential in the production of solar panels and major purchase costs for industry operators. Hence, as semiconductor and electronic pieces decrease in price, so does the cost of solar panels leading to increased profits by solar energy generators. Over the last

decade there has been a steady decrease in the price of semiconductors. The price continues to fall because computing capacity is growing exponentially every year and manufacturers are able to create more powerful chips using less and less silicon. Since chip production has become less inexpensive there has been an increase in competition which will continue to lower prices on semiconductors.

4.1.3 Barriers to Entry

Although the solar power industry has great potential, every industry has obstacles to entering the market. The first barrier are the industry's high capital costs. In order to set up the necessary infrastructure and generate solar power a large amount of capital and investments are required. This may scare new entrants from the market, but the government's tax incentives has helped lessen the initial costs. The second barrier, cited by IBIS World, is the industry's participants. According to IBIS, finding operators and experts in the industry is tough and may be a problem for new entrants. They say that new U.S. companies without expertise from overseas, where solar output has been high, will have a tough time navigating and operating in the industry.

The third barrier of entry is competition. Currently there is competition in the solar power industry with an increasing number of entrants. While solar companies compete within their market they also compete with other industries. Solar power companies must compete with traditional power plants, who offer and natural gas and coal services, as well as other green technology companies such as hydroelectricity and wind power. Demand fluctuates depending on consumer preference and costs play a big factor in the decision. Often times consumers will prefer the traditional method because it is less expensive. Because solar power is a source of intermediate power, as it can be switched on and off to meet demand, its biggest competitors are sources of energy that do the same. These sources include wind farms and power stations fueled by natural gas and oil. Seeing as they serve the same reason, their industries are often competing to be the least expensive technology to produce power.

4.1.4 Government Assistance

State and federal tax credits have been key drivers in the increase of investment in solar systems. Government assistance has increased under the Obama administration because of the emphasis on renewable energy and energy independence, and stable under his administration in the last few years. The solar Investment Tax Credit (ITC) has been one of the most significant federal policy mechanisms to support the deployment of solar energy in the United States (U.S.). This credit provided business certainty to project developers and investors, driving growth in the industry and job creation across the country. According to IBIS World, tax credits, which will expire in 2023, will continue to stimulate downstream demand, which will benefit industry revenue. As a result, the US government will likely remain a crucial driver of performance. However, given the change in administration, the future of renewable energy including solar energy is uncertain. The new administration is a big supporter of traditional energy sources such as coal, natural gas, oil and more. As a result, there may be no new policies or improvement of policies to further the effort of renewable energy. Given that, the burden for propelling of solar energy in the future might lie on the state level.

State rebates and other incentives for solar installations have increased in recent years. Arizona, California, Connecticut, Florida, Hawaii, Maryland, Oregon, Pennsylvania, Vermont and Wisconsin have all provided rebates in recent years. Notably, California introduced a thermal program as part of its California Solar Initiative, which has quickly increased the number of solar water heater installations in the state (SEIA, 2017). The program offers cash rebates of up to $2,791 for single-family homes and rebates of up to $500,000 for multifamily and commercial properties.

4.3. Competitive Strength Assessment of Solar Companies

By utilizing the competitive strength assessment tool, the top potential solar companies within the solar industry and the qualities all the companies value were obtained. Detailed calculation is attached in Appendix A. This competitive strength assessment allowed to rank the top seven attributes over ten companies, weighting the importance each company assigned. Once a full list of companies was ranked, a strategy was devised on how to

incorporate all the strengths found within each company in the company that is going to come from the solar space heating system.

Understanding what a company does really well and not do well, allowed in the identify which attributes are more important than the others. Table 2 ranks the attributes overall prioritized by every company. The top three priorities by solar companies seem to be providing good price to consumers, customer service and quality of product. While marketing seems to be the least prioritized attribute.

Table 2: Solar Companies Weighted Attributes Ranked

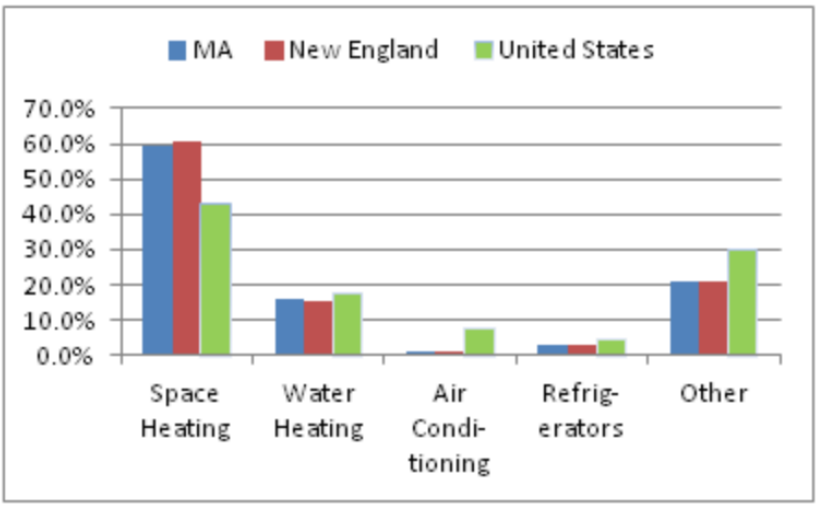
Attributes	Weighted Rating
Price	14
Customer Service	11
Quality	10.4
Market Share	6.15
Reputation	5.5
New Product Innovation	2.75
Marketing	2.55

This assessment also revealed that SolarCity is the biggest potential competitor. Due to the fact that it is such a large organization, they have been able reduce the cost of their product and provide financial options for the customers. SolarCity's scale is its biggest strength, which would also make them the ideal company to be partnered with. Since, they own a big market share and customer satisfaction that will be easy to latch onto and utilize their deep pockets to help the innovation needs of this project.

4.4. Overview of Household Heating in Massachusetts

Historically, space heating is the largest component, fifty-nine percent (59%), of a Massachusetts's household energy expenditure (EIA, 2016). Given Massachusetts's cooler weather, it is understandable, how residents in this state spend 16% more than the rest of the country on heating.

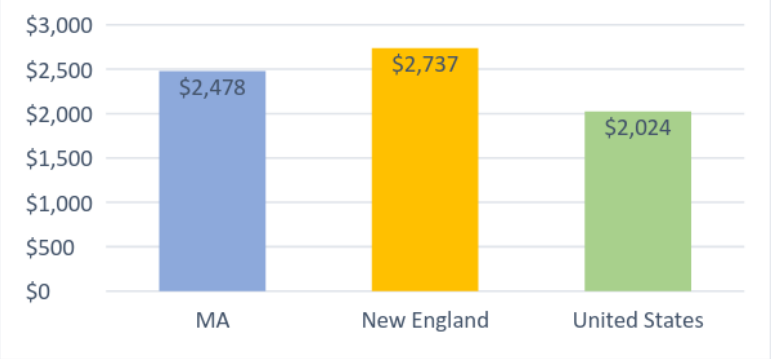
Figure 6: Average Household Energy Costs by Usage Type.



Source: U.S. Energy Information Administration (EIA)

According to the U.S. Energy Information Administration (EIA), Massachusetts households also spend 22 percent more on energy than the U.S. average, paying about $2500/yr, which is slightly less than the six state New England region average, as shown in figure 7. About 59% of Massachusetts resident's total average household energy expenditure is spent on space heating specifically. (EIA, 2016)

Figure 7: Total Average Household Energy Expenditures

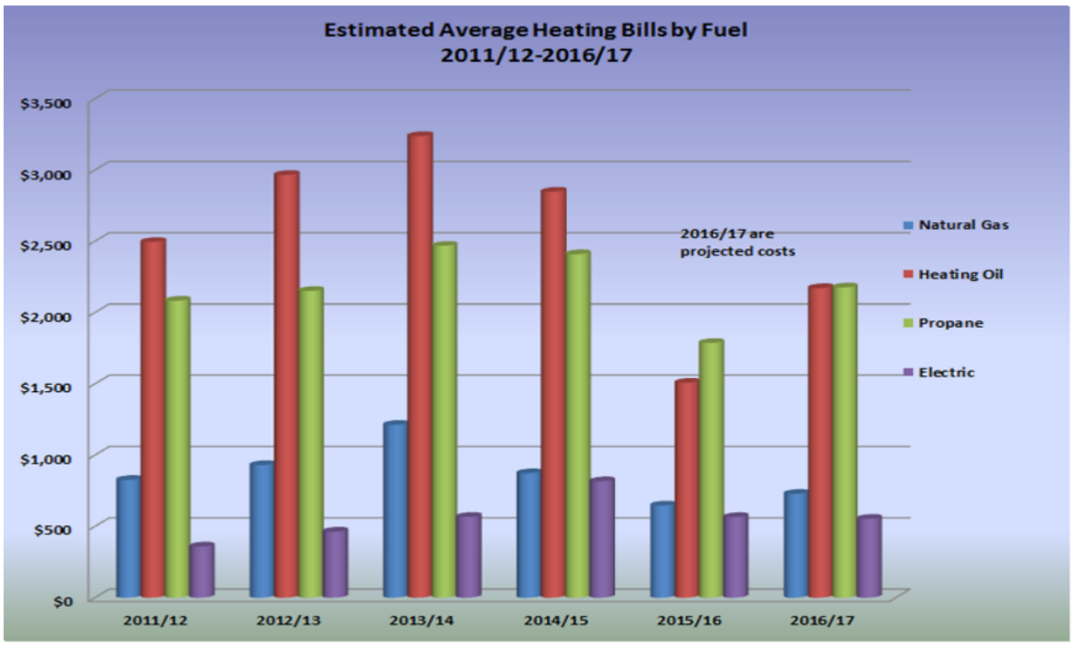


Source: U.S. Energy Information Administration (EIA)

The Department of Energy Resources (DOER) in Massachusetts tracks energy prices and consumption, including those associated with the cost of heating homes during the winter (EIA, 2016). DOER has analyzed weather forecasts and the projected prices and consumption based on predictions for previous winters (October-March) for the major heating fuel sources

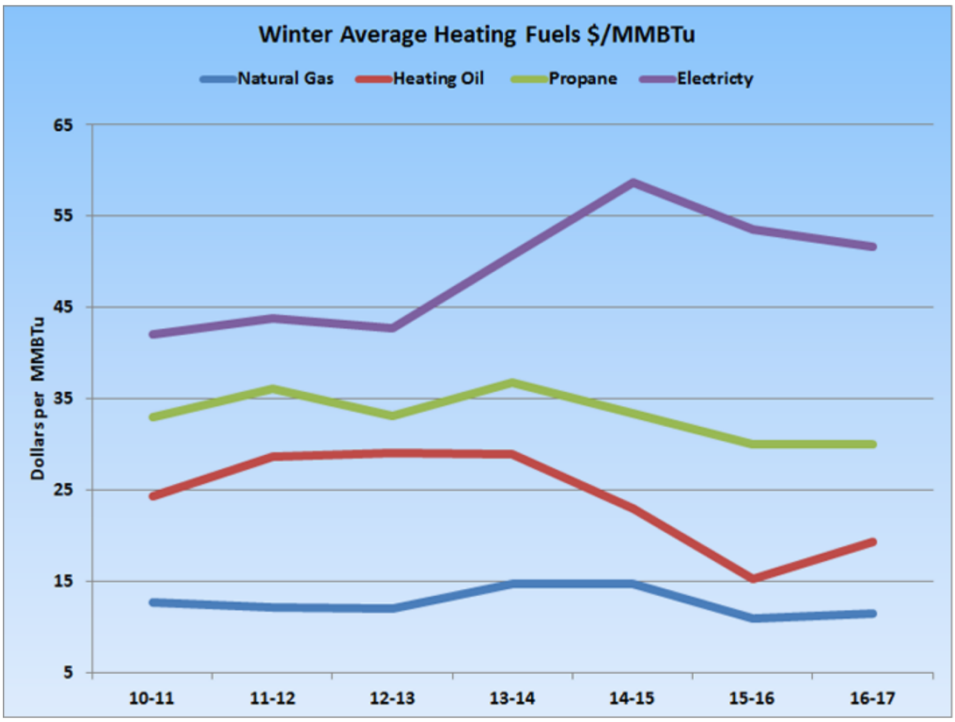
(natural gas, heating oil, propane, electric heating) to provide the following heating season cost projections for 2016/2017. According to DOER heating expense estimates for an average residential customer was: $728 for natural gas; $2,171 for oil; $2,176 for propane, and $553 for electric heating (EIA, 2016). Figure 8 shows costs associated with the average household usage by fuel type and is a useful comparison year to year for any one fuel type. However, it should not be used to compare one fuel type to another because it is not normalized for factors that affect fuel usage such as size of household or square footage (EIA, 2016). From figure 8, it may appear that electric heat is a lower cost alternative to other fuels but electric heat is generally used in smaller spaces such as apartments and condos and is actually more expensive both on a square foot basis and based on a comparison of energy delivered (EIA,2016). As shown in figure 9, based on energy intensity of heating fuels by prices per Millions of British Thermal Units (MMBTU), electricity is actually the highest cost fuel compared to other heating fuels (EIA,2016).

Figure 8: Estimated Average Residential Winter Heating Bills by Fuel



Source: *U.S. DOE/EIA; Mass. Utility Filings, DOER SHOPP surveys*

Figure 9: Measuring Energy Intensity of Heating Fuels by Prices per Millions of British Thermal Units (MMBTU).



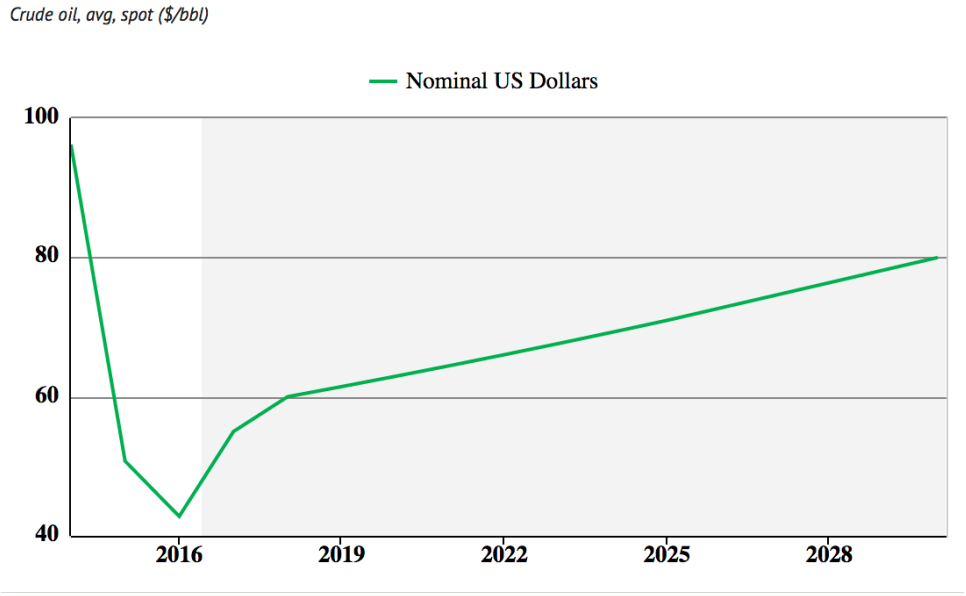
Data source: U.S. DOE/EIA; utility filings; and DOER analysis

4.4.1 Factors Affecting Future Projected Heating Costs for Different Heating Fuels.

Heating Oil

In the United States, households that rely primarily on heating oil for heating purposes are most prevalent in the Northeast region (EIA, 2017). Reliance on heating oil is highest in the Northeast, where about 22% of households use oil for space heating, down from 27% five years ago as an increasing number of homes switch to using natural gas and electricity for space heating (EIA,2017). The current high heating bill from heating oil reflect higher crude oil prices. The U.S. EIA estimates that the cost of Brent crude oil spot prices will average $43/ barrel this winter, an increase of about $9/barrel (22 cents/gallon) from last winter (EIA,2017). The increase in crude prices is attributed to the gradual tightening of global oil supplies. According to World Bank Oil forecast, the price of oil will only be going higher in the future. The forecast is shown in figure 10.

Figure 10: World Bank Oil Price Forecast.



	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
Nominal US Dollars	55.0	60.0	61.5	62.9	64.5	66.0	67.6	69.3	71.0	80.0

Source: (Knoema, 2017)

Propane

Propane is impacted by higher crude oil and natural gas prices, as these are the fuels used to make propane (EIA,2017). As a result of higher crude oil prices, propane prices are expected to rise about 7% this winter of 2016/17. EIA expects that households using propane for heating in the New England area are expected to spend an average of $346 (21%) more this winter of 2016/17, with average prices that are about 7% higher and consumption that is 13% higher than last winter (EIA,2017).While supply issues that have occurred in past years such as the prolonged cold weather throughout the U.S. during the winter, or late season crop drying in the Midwest resulting in high usage of propane stocks are not expected to reoccur, rising exports to international markets could impact available supply and drive up prices.

Natural Gas

Natural gas is the primary heating fuel for nearly half of all U.S. households (EIA,2017). . EIA expects households heating primarily with natural gas to spend $116 (22%) more this

winter of 2016/17 compared with last winter (EIA,2017). The increase in forecast expenditures compared with last winter is driven by comparatively similar increases in price and consumption. Residential natural gas prices are forecast to be 11% higher than last winter of 2015/16, at an average of $10.37 per thousand cubic feet (Mcf). This price level would be the highest since the winter of 2010-11 (EIA,2017).. Consumption is also forecasted to be 10% higher than last winter of 2015/16 (EIA,2017).. This increase in consumption is based on a return to temperatures that are closer to normal following last winter's El Niño weather pattern that resulted in winter temperatures that were 15% warmer than the previous ten-year average nationally (EIA,2017).

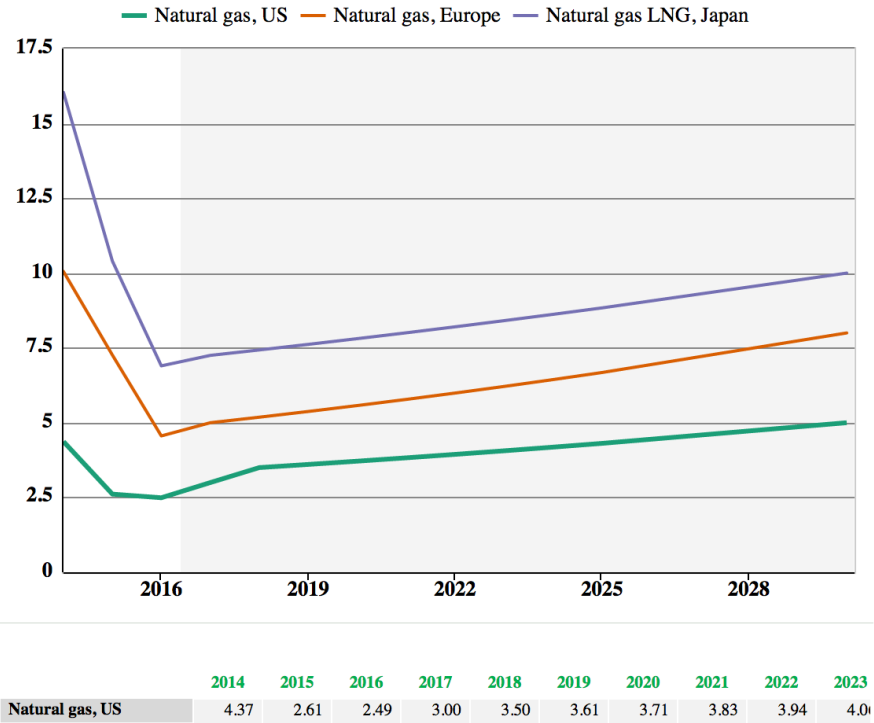
Although, forecast residential natural gas prices are 11% higher than prices last winter, Henry Hub spot prices are expected to average $3.16 per million British thermal units (MMBtu) ($3.26/Mcf), which would be 53% higher than last winter. The Henry Hub is a natural gas distribution hub for pipeline located in Erath, Louisiana that serves as the official delivery location for futures contracts on the NYMEX (Investopedia, 2007). Due to its importance, it lends the name to the pricing point of natural gas future contracts on the New York Mercantile Network (NYMEX) and the OTC swaps traded on Intercontinental Exchange (ICE) (Investopedia, 2007).

Higher natural gas prices reflect falling natural gas production during 2016 and increased use of natural gas for electricity generation. Changes in spot prices do not quickly translate into changes in delivered residential prices. The rates utilities charge for delivered natural gas can be set by state utility commissions a year or more in advance and reflect the cost of natural gas purchased over many months (EIA,2017). Also, residential prices include charges to cover utility operating costs and the cost to transport and distribute natural gas that are not directly linked to wellhead prices (EIA,2017). According to World Bank, the price of natural is expected to slowly increase in the future. However, it will still be at a price lower than Europe and Japan. The forecast is shown in figure 11.

This year, additional capacity will be available to deliver natural gas from the Marcellus region in Pennsylvania to New England with the expected November 2016 start-up of the Algonquin Incremental Market (AIM) Project. This expected incremental pipeline capacity has helped lower expected prices for natural gas delivered to Boston during the peak

winter months by about $1/MMbtu compared with expectations from a year ago (EIA,2017). However, pipeline constraints still exist in the Northeast, particularly into the New England market, contributing to significant basis differentials between New England prices and Henry Hub futures prices (EIA,2017). These constraints could contribute to day-to-day price volatility during periods of cold temperatures (EIA,2017).

Figure 11: World Bank Natural Gas Price Forecast.



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Natural gas, US	4.37	2.61	2.49	3.00	3.50	3.61	3.71	3.83	3.94	4.0

Source: (Knoema, 2017)

Electricity

Among U.S. households, 15% in the Northeast primarily rely on electricity as their heating source. In past years, electricity prices in New England have been affected by constrained fuel supplies. The region's power industry has become more reliant on natural gas for electricity generation. Natural gas currently supplies 50% of total generation in New England, compared with 37% in 2005 (EIA,2017). This increased reliance on natural gas can put generation fuel supplies in competition with natural gas used for space heating during cold spells. Winter electricity prices on the New England wholesale electricity market have

generally tended to be higher than prices at other times of the year, and occasional price spikes have occurred.

Generally, high crude oil prices and increased consumption is leading to higher residential heating bills. This also depends on the form of heating fuel a consumer is using. But there seems to be a trend of higher heating bills regardless of the fuel source. The pattern seen within all the heating sources suggests that the overall fuel prices are going to increase.

4.5 Consumers' Financial Trade-Off Analysis

As already outlined in methodology, the team used an engineering economic analysis among for the solar space heating system and different heating fuel source alternatives to see whether a potential exists for consumers to adopt this system. For that very purpose, the team identified alternatives which were the following respectively.

- A Solar Space Heating System
- Heating Oil
- Propane
- Natural Gas
- Electricity

4.5.1 Cost of Solar Space Heating System Installation and Maintenance

Since the Architectural teams' solar space heating system is still in the making and specific building cost doesn't exist, the cost of the entire solar energy product is being calculated from existing solar energy heating system market data. For accurate calculations, we first looked at what are the exact factors that impact the cost of solar panel installation and then find correct numerical figures for those factors. When it comes to solar thermal system installation cost, the biggest cost lies in the equipment. This equipment includes the entire system consists of solar collectors, storage tanks with heat exchangers and other installation materials. Not all solar systems are created equally, and more efficient equipment comes with a higher price tag. More efficient, higher-quality equipment comes with benefits that may be worth the added cost, such as better heating control and longer warranty. While equipment

costs make up a significant portion of your solar energy system price, the cost of permits and labor to install the system are also important factors. Considering all these factors the gross cost of a residential solar space heating system ranges from $10,000 to $20,000 (Energysage, 2017). But the investment is worthwhile since solar space heating systems generally are highly durable, with warranties of 10 years and expected operating lives of over 20 years (Energysage, 2017). For analysis, the team is considering the entire life-span of a system as the analysis period. One of the costs often overlooked but smart consumers consider when buying a long-term investment product is maintenance cost. Solar space heating system requires moderate annual/periodic inspection and maintenance to ensure efficient operation. Maintenance is generally provided by the installer and/or the manufacturer. Other times a solar space heating system owner can also get a qualified contractor, who can conduct annual maintenance inspections and cleaning independently. Maintenance cost in solar market varies a lot, but according to National Renewable Energy Laboratory, a widely agreed upon figure for solar space heating system operation and maintenance cost is 0.5 – 1 % annually of the total initial installation cost (NREL, 2016). Another cost that even the keenest consumers overlook is the disposal cost. Disposal cost is the cost to replace or remove any system specially a solar one once it reaches the end of its life cycle. Now numbers for neither a disposal or scrap cost for a solar thermal heating system are easily accessible. Currently, when early-generation green technology is being replaced, much of it finds its way into landfill or incinerators (Tahiri, 2014). It is possible, through innovative technologies still being developed, in the future there will be a recycling or another form of disposal initiative for these systems; but for now, the team is neither considering a scrap or disposal cost for solar systems.

4.5.2 Benefits of the Solar Space Heating System

The benefits one reaps from a solar space heating system is roughly based upon the amount of energy a household uses on heating. The cost associated with solar space heating system may not be justified for small household with small energy usage. While for larger households which have large energy consumption, there might be potential for massive savings on bills by getting such a system. Energy usage for heating is can vary from household to household, depending on energy usage habits, number of household members

and what form energy source they use (EIA, 2016). This is why the team looked into aggregate energy consumption and prices used by Massachusetts household for heating. In Massachusetts, 59% of total average household energy expenditure is spent on heating as seen in figure 6. This roughly equals to $1475. Overall, by adopting a solar space heating system, all the money that an individual would have spent on heating would become potential savings, since there are no bills. There is however, an annual operational and maintenance cost associated with it, but looking at market data that seems to be minimal compared to annual heating bills.

The money that consumers save by not spending on heating bills can be considered as savings. The team is going to consider this savings over the entire analysis period of 20 years. Now an individual will definitely not have the same savings every year. It is unwise to assume that the energy market will stay static over the course of next 20 years. The savings amount will fluctuate depending on the market fluctuation of the heating fuel source or inflation. Now the exact percentage change for the aggregated heating energy every year projected over 20 years can't be determined for sure. But as explained above in the section 'Factors Affecting Future Projected Heating Costs for Different Heating Fuels', it is known that the general trend for energy bills are going up. Many analysts and traders also believe that heating bill increases could be on the way because of those different energy market trends (EIA, 2017). Now being optimistic customers, it is considered that the aggregate increase in energy cost per year is going to be only 2.5%. As a result, the savings are going to increase by 2.5% every year for next 20 years. Now, it is also being considered that the consumer is going to hold on to this savings by storing in a savings account or certificate of deposit for present worth calculation purposes. Since, present worth analysis provides a basis for assessing the fairness of any future financial benefits or liabilities, considering that the consumer is going to keep the savings in a savings account or certificate of deposit, allows gaining the current worth of a future sum of money or stream of cash flows for given a specified rate of return. Every bank and credit union offers a different return on annual savings interest. So, an average was taken of what the national rate is on a 12-month certificate of deposit (CD) for deposits under $100,000 for simplicity. Since the savings are going to be annual, the team also wanted an annual rate of return rate. According to the

Federal Deposit Insurance Corporation (FDIC) calculations, the national rate of return for a 12-month certificate of deposit (CD) for deposits under $100,000 is 0.24%.

Another benefit of adopting a solar system are all the government subsidies and rebates. These incentives allow an individual to own these systems at a lower cost that original. The incentives are designed to lower the burden on consumers, so that they can have less financial burden on them and ultimately allow consumers to earn their investment back. In Massachusetts, there is no sales tax on solar products, as a result there are no additional cost on equipment purchase. There is a Massachusetts rebate program MassCEC's Residential and small scale solar hot water program that provides rebates for the installation of any solar hot water or space systems at home across the state, within 45 days of installation. Homeowners are eligible for a base rebate amount of the lesser of $4,500 or 40% of the installed cost (Massachusetts Clean Energy Center, 2017). This is a cost that can be deducted off of the installation cost.

4.5.3 Present Worth Analysis of Solar Space Heating System

For present worth analysis (PWA), all the costs and benefits numerical data are summarized in Chart 1 and Figure12 displays the cash flow diagram of the data analysis.

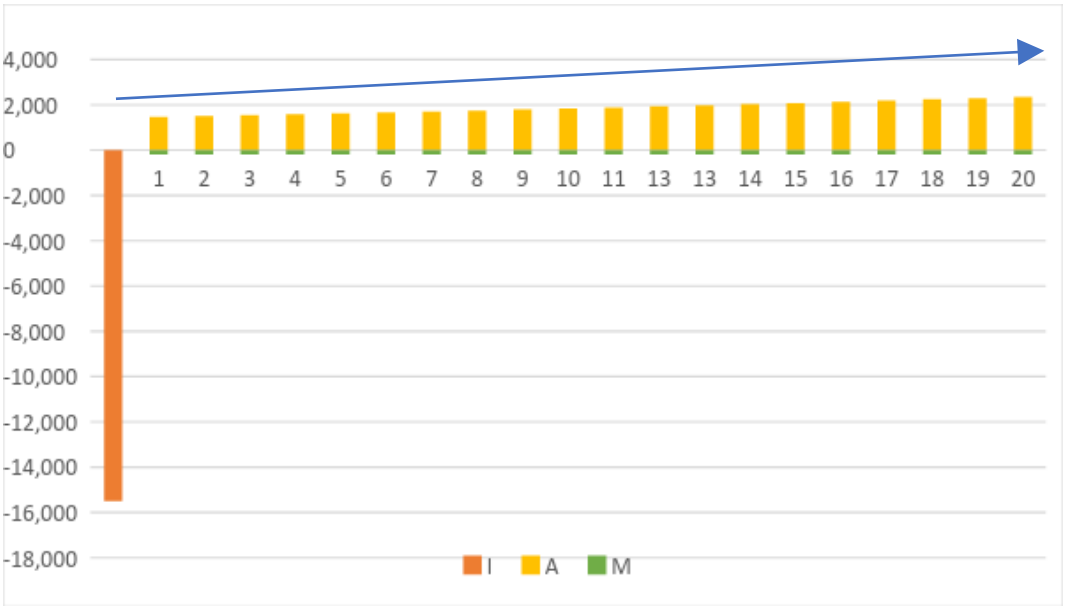
Chart 1: Summary of Cost and Benefit Numbers

Cost		
Equipment & Labor	$20,000	One Time Payment
Operation & Maintenance (M)	$200	Annual
Benefits		
Savings (S)	$1,457	Increases 2.5% annually
Rebate	$4,500	One Time Payment
Annual Interest (i)	0.24%	Certificate of deposit (CD) rate of return

In figure 12, 'I' represents the initial investment for the cost of the system. It is going to be the difference between equipment & labor, and rebate from the MassCEC program. It is $15,500. 'A' represents the incremental savings data, Year 1 starting at $1457 and then increasing 2.5% every year. 'M' represents the operation & maintenance expenditure which is going to be a constant $200 every year. present worth for the solar space heating system

was calculated using a gradient series present worth formula. Detailed calculation is attached in Appendix A. The present value of the system is $15,573.

Figure 12: The Cash Flow Diagram of Solar Space Heating System PWA over 20 years.



Present Worth Analysis of Traditional Heating fuels

The Department of Energy Resources (DOER) estimates heating expenses based on the average price of fuel; consumers' expected fuel usage; and anticipated weather conditions. For 2016/17 winter for an average residential customer heating bill was: $728 for natural gas; $2,171 for oil; $2,176 for propane, and $553 for electric heating. Chart 2 represents consumption and expenditures from last five years. Accurate data of Massachusetts heating bill projections for the next 20 years is not readily available. However, the heating bill of the last five years is available. Using this data, the average change in expenditure percentage for each respective heating fuel is determined (as seen in Chart 2). It is then used to project next 20 years of heating bills. For year 1 bill, the bill of 2016/17 is considered for every heating source and since, there is no installment cost, the initial cost at year 0 is zero. There is also no rate of return used for these calculations because, since the bill is not going to be in any form of savings, there is no interest.

For heating oil, the average change in expenditure percentage over the last five years is 3%. Therefore, it can be used to determine that for the next 20 years, the heating bill on an average is going to increase 3% every 5 years. For propane, the heating bill on an average is going to increase 2% every 5 years. While for natural gas, the heating bill on an average is going to increase 0.3% every 5 years. And for electricity, the heating bill on an average is going to increase 13% every 5 years. The projected figures considering the future average bill increases for each heating source is represented in figure 13 to 15 through cash-flow diagrams.

Detailed calculation of present worth analysis for heating oil, propane, natural gas and electricity are attached in Appendix B, C, D and E respectively. The present value of each heating source over the next 20 years is summarized in table 3 below.

Table 3: Present Worth Value of Heating Sources

Heating Oil	**-$45,413.27**
Propane	**-$44,843.10**
Natural Gas	**-$14,560**
Electricity	**-$13,409.69**
Solar Space Heating System	**$15,573.**

Chart 2: Massachusetts Winter Heating Bill Based on Fuel Source.

Heating Oil							
	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	Average Change in Expenditure % over 5 years
Consumption (Gallons)*	627	736	807	895	674	807	
MA EIA Wtd Price ($)	$3.98	$4.03	$4.01	$3.18	$2.24	$2.69	
Expenditures	$2,495	$2,965	$3,237	$2,847	$1,508	$2,171	
Annual % Change in Expenditures		19%	9%	-12%	-47%	44%	3%
adjusted US EIA consumption based on MA Vs. US HHD Difference							
*estimated consumption							

Propane							
	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	Average Change in Expenditure % over 5 years
Consumption (Gallons)*	608	683	708	759	631	718	
MA EIA Wtd Price ($)	$3.43	$3.15	$3.49	$3.18	$2.83	$3.03	
Expenditures	$2,083	$2,151	$2,468	$2,409	$1,786	$2,176	
Annual % Change in Expenditures		3%	15%	-2%	-26%	22%	2%
adjusted US EIA consumption based on MA Vs. US HHD Difference							
*estimated consumption							

Natural Gas							
	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	Average Change in Expenditure % over 5 years
Consumption (therms)*	677	769	824	855	593	693	
MA EIA Wtd Price ($)	$1.22	$1.21	$1.47	$1.02	$1.09	$1.05	
Expenditures	$826	$930	$1,212	$873	$646	$728	
Annual % Change in Expenditures		13%	30%	-28%	-26%	13%	0.3%
adjusted US EIA consumption based on MA Vs. US HHD Difference							
*Based on gas utility company fillings with the Massachusetts DPU							

Electricity (Heating Only)							
	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	Average Change in Expenditure % over 5 years
Consumption (kWh)	2398	3173	3271	4071	2909	3403	
Avg c/kWh	14.97	14.6	17.322	20.05	19.42	17.65	
Expenditures	$359.00	$463.28	$566.74	$816.26	$565.00	$553.00	
Annual % Change in Expenditures		29%	22%	44%	-31%	-2%	13%
*MA Utility Fillings with DPU							

Figure 12: Cash Flow Diagram of Heating Bill from Heating Oil Over 20 years.

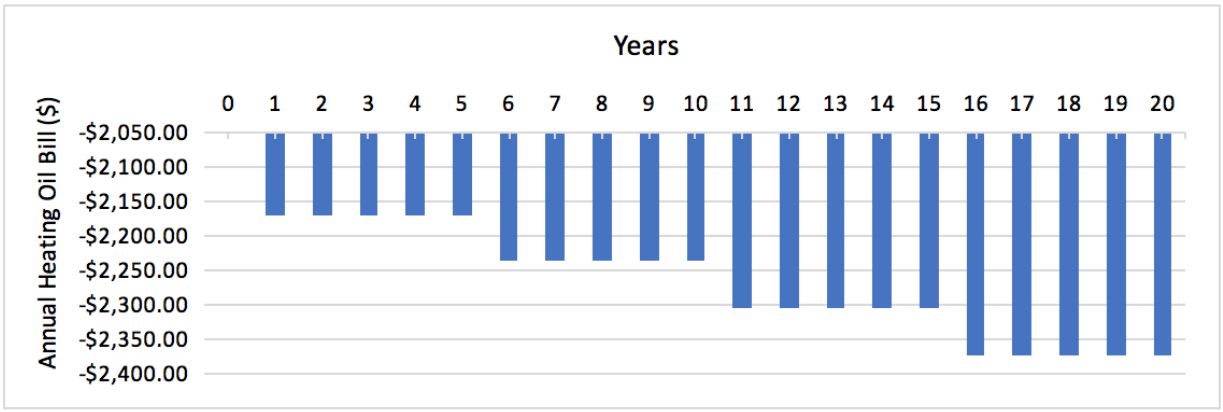


Figure 13: Cash Flow Diagram of Heating Bill from Propane Over 20 years.

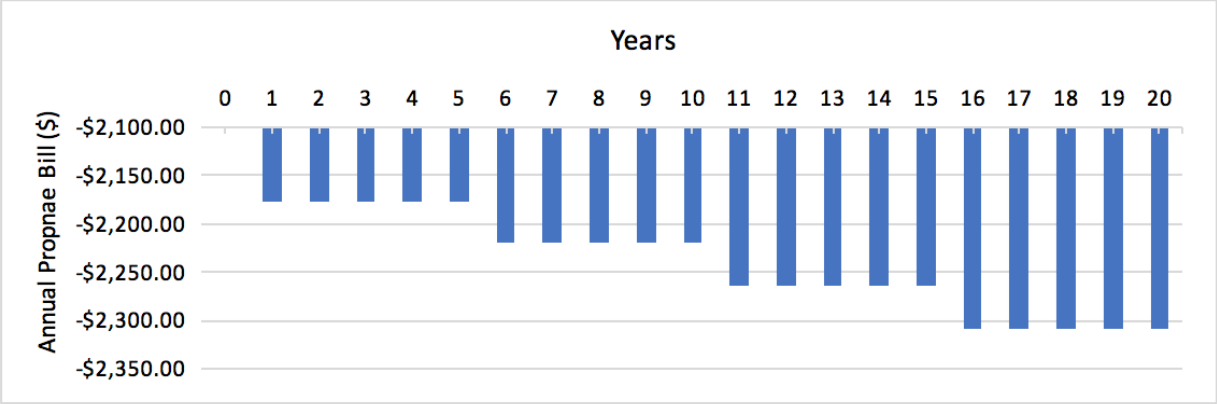


Figure 14: Cash Flow Diagram of Heating Bill from Natural Gas Over 20 years.

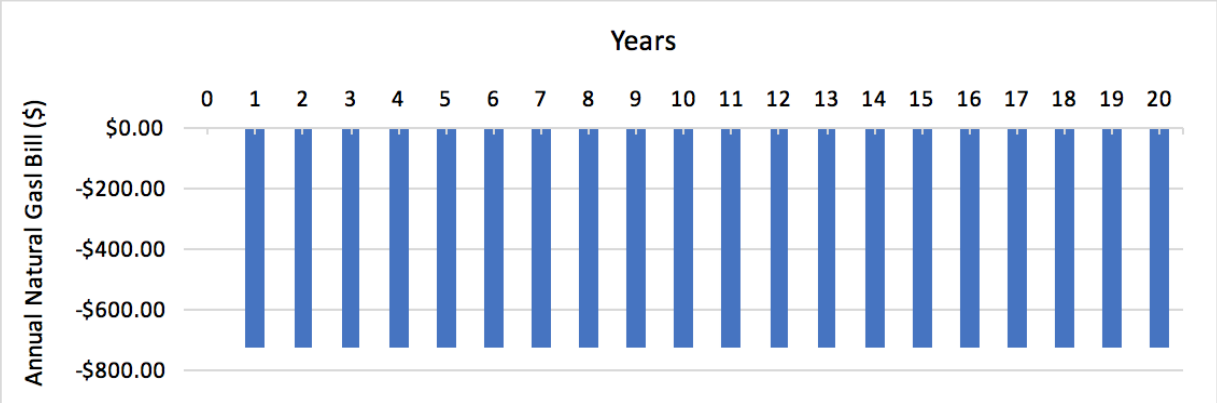
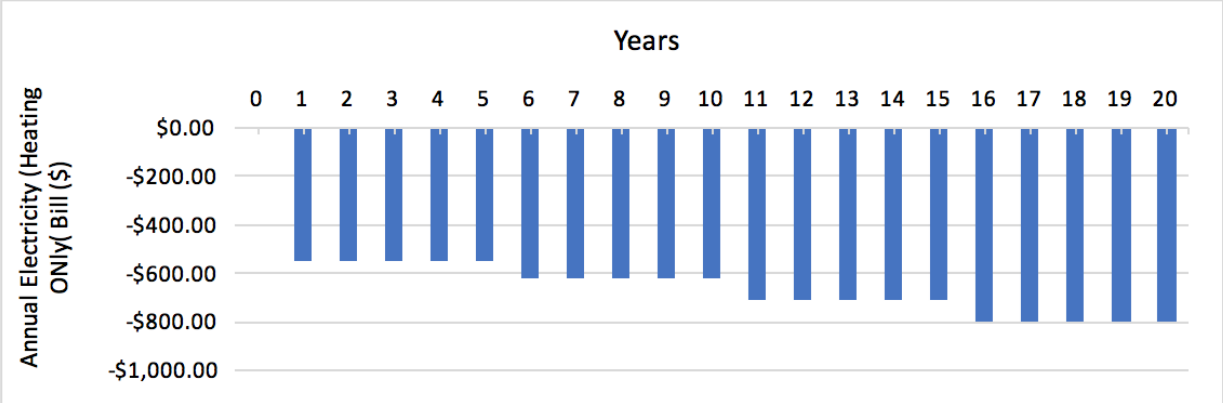


Figure 15: Cash Flow Diagram of Heating Bill from Electricity Over 20 years.



Observing the present worth analysis of the solar space heating system versus the

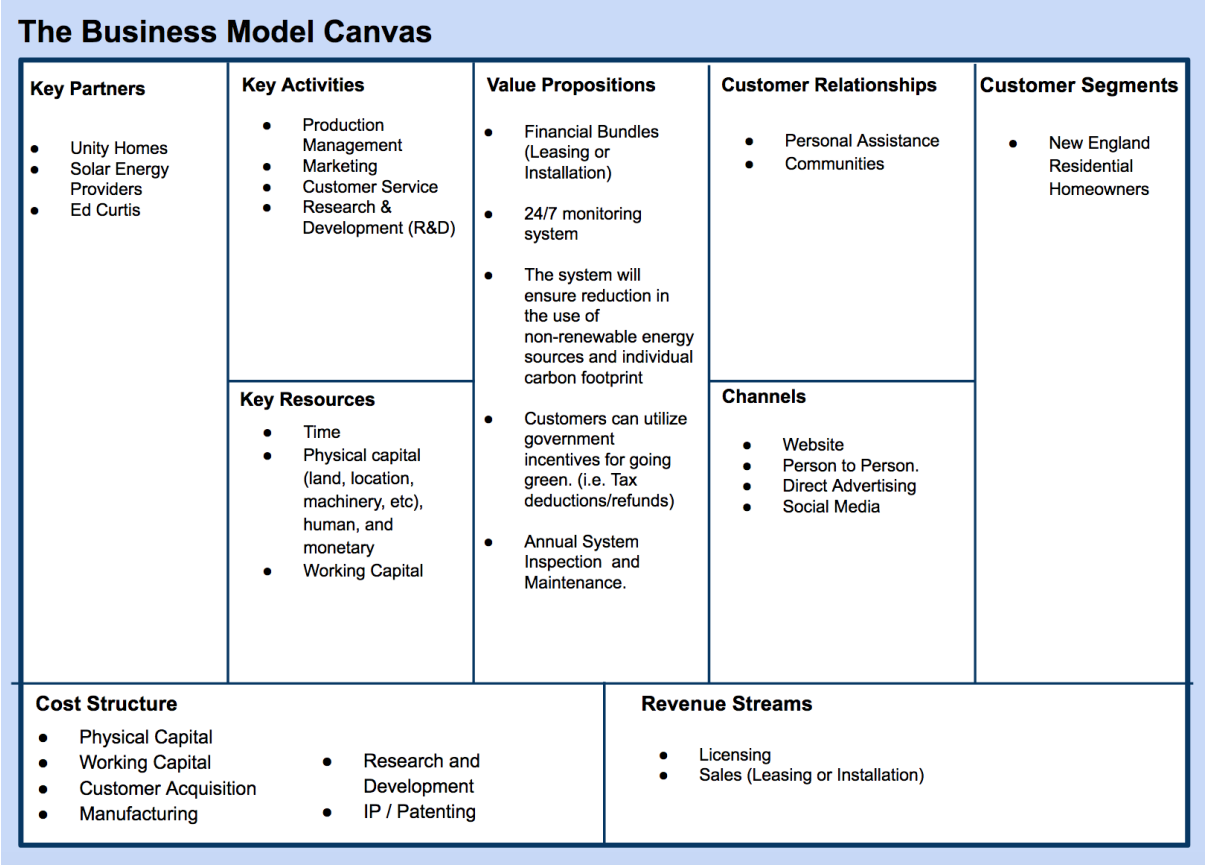
several heating systems over 20 years, the solar space heating system is clearly the best investment. Since, consumers have an opportunity to save over time instead of constantly paying bills, the savings interest allows for profit. However, this profit is still very much based upon what the heating bill price will be from the market. Even though past data was used to project the potential future bills, market conditions are very susceptible to change. In the past, there have been some drops in certain heating fuel prices such as heating oil and natural gas. The price percent change used for the calculation takes that into account. But future market projections for every heating source seems to be rising over the next 20 years. As a result, this might increase heating bill and might make it more profitable to own a solar space heating system.

However, the current fuel price projections might change given the market, policy and regulation changes that might come under the new president's administration (Lipschultz, 2017). President Trump, is a huge supporter of increasing the production of fossil fuels like coal, crude oil, and natural gas (Lipschultz, 2017). He wants to bring more federal land under crude oil and natural gas drilling. He also proposes to lift regulatory restrictions on crude oil and natural gas exploration and production (Lipschultz, 2017). These changes could potentially reduce prices of these important heating fuels, which might change the current profit estimated from a solar space heating system. Since, currently there are no predictions or data on it, no estimation can be made for sure. But the intangible benefits that a solar space heating system is still going to remain intact. Some of these benefits include protection from the instability of the energy market price changing your heating bill, the system produced clean power reducing pollution, possibility of being off the grid and more. Taking into consideration the monetary and intangible benefits, the solar space system for some consumers will be highly beneficial in Massachusetts.

4.6 Business Model Canvas

In the business model canvas, the team outlined the guidelines as to how the project should approach commercialization strategy for a solar space heating system taking into account the solar technology element and heating aspects component of the product. Figure 16 outlines the guidelines visually on the model canvas, while detailed explanation is provided below.

Figure 16: The Business Model Canvas for Solar Space Heating System



4.6.1 Key Partners

Ed Curtis: One of the biggest partners in the development of this project has been Ed Curtis. He has raised seed money as initial funding to pursue the development of a solar space heating system. Without Ed Curtis and his drive and vision of this project, the project would not even exist. He is mentoring the entire project throughout the different aspect of the project development such as designing, building and testing of the system prototype, commercialization and business potential and more. Ed Curtis will be considered as the co-founder of company or venture that will come about from the project since it was the instigator of the product idea and the project.

Unity Homes: Currently, a key partner could be the company Unity Homes. Unity Homes is a company that aims to build custom timber framed houses that incorporate sustainable design into every aspect of the building process. They are already collaborating with the architectural team to re-innovate the design of a solar water heating system to be used within a New England Home. Unity Homes' zero-net energy homes would benefit immensely with the solar thermal water heating system. The team believes there are two types of partnerships with Unity Homes that could be beneficial. The first is a joint venture partnership. In this type of partnership both partners have an interest in developing a new business. When customers are looking to purchase one of the many different style homes offered by Unity Homes, the solar thermal heating system can be packaged into the home to make it even more efficient and environmentally friendly. The second type of partnership is a licensing partnership. In this case, SSH would license their patents, designs and other intellectual property. It would allow them to tap into Unity Home's existing production. In exchange for a small percentage of the revenue, distribution and marketing systems could be made available. This key strategic partner makes sense because prospective users of Unity Homes are already environmentally conscious consumers. As a result, they are more likely to adopt and purchase a renewable energy sourced heating, ventilation and air conditioning (HVAC) system, which will be cost effective, and pollution reducing. This is also a great place to start the product and see how well the consumers respond to it.

Solar Service Providers: Another strategic partner would be licensing the product to other solar service providing companies such as SolarCity, Solect etc. Doing so will be advantageous in many ways. With solar energy growing rapidly in the last decade trying to enter the market as a startup is going to be a challenge. However, these solar companies are already established in the solar market, which have logistics, supply chain and resources in place. They also have pre-existing recognition and customer base. The general operating model of these companies is that first they determine upfront how qualified a building or property is for solar energy generation and then create a customized design and installation. Most of this installation is meant for providing electricity for different individual's needs. However, if the team partners with them, these companies can now market the product the 'solar space heating system' as an add-on feature. If customers also want their heating and

cooling needs to be taken care of by solar energy, this will be an add-on they would consider. Not only will they have their electricity needs taken care off but also heating and cooling. The system will also cost less being integrated with a PV (photovoltaic) installation than buying the system a new.

There are several reasons why a company would want to partner or have a working relationship with Worcester Polytechnic Institute (WPI). Using the technical and innovative resources that are available to the students it makes it possible to perform tasks from research, building prototypes, to creating a product. Since, the project was conceived and continued at WPI, it will continue to devote resources for further improvement of the system and its processes. Partnering with WPI allows for the product to consistently be worked upon and improved by project teams. Through all of the technical and innovative resources WPI offers such as being able to obtain IP, labs and tools to build, professors for advice, the support of the WPI community it makes it possible to develop a product/ company and sustain it.

4.6.2 Key activities

Key activities are crucial for the business to deliver on its value proposition and to make the rest of the business work. Depending on the strategic key partner and business strategy chosen, key activities will be determined. If selling through a third party is part of the business model, then a key activity would be making sure channel management is effective. Product driven businesses would include ongoing learning about the users and new techniques to build a better product. If the focus is providing multiple segments for the customer, key activities would consist of maintaining expertise in each segment, and creating/ acquiring products and services that are a good fit. Infrastructure-driven businesses such as electric utility would include infrastructure working on reliability and making it more efficient.

There are four major key activities that will affect the success of the solar space heating system. The first key activity for this will be production management. There are different areas under product management. The most crucial area is selecting the right product and the right design for the product. This is important because the combination of the

right product and design may dictate if your product will be successful within an industry. Another vital aspect is quality and cost control. The product should be continuously improved upon in quality while also continue to reduce in costs to stay competitive in the market. In it also important that the product process in efficient. Ideally, a lean manufacturing process that minimizes all waste maximizing efficiency and lowering cost should be implemented. More specifically, lean manufacturing involves never ending efforts to eliminate waste or any activity that consumes resources without adding value (Mind Tools, 2016). A great system to use for the production of the solar space heating units is the "Zero Defects" system. According to Chandana (2013), Zero Defects is a term developed by Philip Crosby refers to quality management for a product where waste is eliminated and defects are reduced. Essentially, Zero Defects ensures quality standards and reducing defects to as close to zero as possible in projects (Chandana, 2013).

The next key activity is marketing. In order for the company to grow and for consumers to hear about the value a product could provide it must be marketed well. Under the marketing department there are several functions, research, product development, communications, sales support and strategy. The business should have full knowledge of the market the company is in as well as about the customer and potential competitors. The marketing department may also be involved with pricing when the product is developed as they know the competition and market best. After the product is developed it is marketing's responsibility to get the product out there through press releases, advertisements, e-mails etc. In addition to this, marketing may also work closely with sales, to provide them with potential leads. The reason marketing will be such a major key activity is because the solar aspect of the system. According to EIA (2017), many American consumers are aware that solar is a clean form of energy but aren't entirely aware of the benefits and potentials of such a system. The fuel heating systems already occupy the current consumers' houses and this is what they are used to. Fuel companies have spent billions of dollars over a one-hundred-year period to effectively brand their supposedly unique kind of fuel. This is why marketing will need to work extra to market both why pick a solar system and then additionally why pick a solar heating system over the current options.

The third key activity is sales and customer service. This activity is crucial for a company in the solar industry. They may increase sales by showing customers what the value

propositions of the produce are. Often times a customer may have certain specifications requiring a dedicated sales representative. Customer service representatives will be key when solving customer complaints or to offer technical help. For example, customer service and sales reps could be involved in the installation as well as maintenance of the system. This additional activity will allow the system to differentiate itself from the other solar technologies in the market.

The last key activity will be continuous research and development (R&D). This will be one of the most vital activities for progression. One of the main responsibilities of this activity will be to keep an eye on innovations and trends within the industry. It will be important to keep an eye on the competition and innovate the product with the needs and the demands of the market as necessary. The solar industry is in a constant form of innovation as new forms of solar technology keep emerging to make solar systems cheaper, more efficient and compact. Now that this industry is competing with fossil fuels on a cost per kW-hr basis, the innovation is getting even more important. As a result, to stay viable in the market, R&D will always need to be on top of the game to keep the system potentially desirable in the market. Given, the fact that WPI is the hub of this project, R&D will be a strong activity since there is a potential for teams to keep working on the system.

4.6.3 Key Resources

Key resources are assets that are strategically placed in order to have a more targeted result than the competitors. The business model canvas suggests that there are three core business types: these types include product, scope, and infrastructure. These types tend to have similar key resources. The key activities truly drive the accrual of the key resources.

Product-driven businesses have a product that is proprietary, a product that is different than its competitors. Product-driven businesses usually acquire key resources such as key talent in critical areas of expertise. Product-driven businesses accumulate intellectual property related to their product.

Scope-driven businesses create synergy around a certain customer segment. A scope-driven business would solve a certain need for a company. An example of a scope-driven

business would be if a company started a business to take care of all the IT needs for an organization. Scope-driven businesses usually have key knowledge about their segment, repeatable set of processes, and infrastructure such as service centers.

Infrastructure-driven businesses achieve economies of scale in specific repeatable areas. Infrastructure-driven businesses are typically telecommunication business, or companies that work within their infrastructure, like retailers would focus on retail. Infrastructure-driven businesses key resources are various types of virtual and physical infrastructure. Infrastructure driven businesses produce at scale with little differentiation in order to add to their revenue stream.

Since, the architectural team is developing a solar space heating system the business canvas model's key resources will fall under a product-driven business. The product that is being developed potentially has IP potential that will differentiate itself from the competitors. As mentioned in the background, key resources often fall into four groups, physical, intellectual, time, and human and financial resources. In order to develop a product within the solar energy industry it will be necessary to have access to physical capital such as land or a manufacturing facility. Intellectual resources such as IP and patents can also be considered as a solar energy company's key resources. The key resources are the resources that give the product its value proposition, it is the parts of the product that will ultimately drive the revenue stream. This is why it will be important to pick the right key partner who can be a vital source of these key resources. Finally, in order to fund the business financial capital is also necessary primarily for the large initial costs. The initial seed money has been financed by the WPI Entrepreneurial Trust but as the project moves forward, larger investments will be needed for the product to come into fruition. This is where finding bigger investors and funding will be key. A common way start-ups go about to attain that large amount of money is to either find an angel investors or venture capitalist. But for this project finding the right person will be key since it being developed under the WPI roof. But since the system is being developed under an academia umbrella, another form of funding could be federal grants such as 'The Small Business Innovation Research (SBIR)' or 'The Small Business Technology Transfer (STTR)' grants. The SBIR and STTR programs are two of the largest sources of early-stage capital for technology commercialization in the United States (SBIR, 2017). The Technology Program Office administers the Small Business Innovation Research (SBIR)

Program and the Small Business Technology Transfer (STTR) Program (SBA, 2017). Through these two competitive programs, U.S. Small Business Administration ensures that the nation's small, high-tech, innovative businesses are a significant part of the federal government's research and development efforts (SBA, 2017).

4.6.4 Value proposition

A solar space heating system will be very beneficial to the customer because it will allow them to save money. The system is being developed with the aim that it will reduce the cost of monthly utility bills for heating. The system may also provide luxuries such as heating the floors in a home, heating a driveway, and even heat the outdoor patios and stairs. On average in New England, people spend almost 60% of their energy bill on heating. Solar systems have the potential to provide these features for a home all on renewable energy that a lower cost. Along with saving monthly utility bills having renewable energy systems allows the customer to utilize government incentives. Federal and state subsidies and rebates allow an individual to own these systems a lower cost that original. Overall, the value that is being provided is savings, convenience and efficiency.

However, the product does more than just save the customer money it also helps diminish the indoor and outdoor environmental footprints wherever the system is installed. Since the system uses the sun as the main source of energy, utilizing this daily source of energy helps preserve the natural resources that cannot be replenished so easily. Installing a such a system will help decrease the natural resources such as coal, natural gas, and helps reduces fracking and the consequences that come along with its process.

If this project is to be successful in the solar industry there needs to be a variety of financial bundles. These financial bundles allow the customer to figure out a payment plan that suits them the best. Financial bundles include anything from leasing, financing, or buying the product. Incorporating these bundles will allow the customer realistic payments that will be a smaller if the company were to buy off the grid. If the grid can offer a customer fifteen cents a watt, applying the system to their home could save them three cents a watt, charging them twelve cents a watt. This is now a reduction on their utility bills on top of the

tax benefits, the customer will only see savings. In order to compete with the industry, the system needs something that will make it different from the rest and what would separate would be through additional features and customer service. Such an additional feature could be an inbuilt 24/7 monitoring system. This monitoring system will allow the customer to have a detailed update on their system to track how much money they are saving through a monthly report. This will allow consumers to track how efficient their investment is, it presents a transparency for the customer in order to build customer satisfaction. This also adds more value to the system because such monitoring systems are not a regular add-on to solar systems in the current market. Scheduled annual system inspection and maintenance will also keep the customer at ease that their systems are being taken care off.

When going over the value proposition for a product it is very important to analyze whether or not it actually has a relative advantage over the competitors or not. There are a couple ways in doing so, first an industry analysis of the competitors. Doing so reveals what each competitor is doing during their operations and from this data can be gathered to see what processes work well or each competitor and what does not work as well. Often the websites have a customer section where the customer has provided feedback on the job the competitor has done this will expose the strengths and weakness or what the customer likes or doesn't like. Another way of assessing the value proposition is to survey and ask customers if they were having this type of product what extra features or main features does the product need to have in order for the product to be worth purchasing.

4.6.5 Customer Segments

The system is being targeted to residential, single family homes in the New England area. This form of business is known as B2C (business-to-consumer). B2C essentially is one company engaging in commerce directly with the consumer. The reasoning behind this is because the solar space heating system is essentially a heating system. By design the system has insulated containers filled with heated water that is holding all of the energy inside of it. This heated water can be used for multiple purposes, however would be the most beneficial to New Englanders because of the heating capabilities. In the warmer parts of the country

such as the south and west the need for an efficient heating system diminishes. Eventually as the product grows and revenue increases the goal is to expand farther north to Canada and west to the colder states where heating is more of a need. However, the initial step won't be B2C, it will be B2B. It would be in the architectural team's best interest to engage in B2B (business-to-business) commerce as they are more likely to achieve low costs and increase profit margins according to Frank Goppel, Business Development Director for Solect.

4.6.6. Channels

In the current market, reaching your customers effectively is vital for the success of your product. This is why a multi-platform marketing strategy needs to be used which uses different platform such as direct advertising, social media, online website, community outreach and more. The website will allow the customer to get a whole 360 view of the ins and out of the product, how the product will be delivered, and how the installation process works. The website will also hold information such as a background to how the product came to be, who is involved with the product from partners to investors, as well as customer reviews stories, and pictures. The website will use Google camps to locate the home and give rough estimates on how much sun is usually generated in the area to give an estimate on price and savings. The website should also allow the customer to have an interactive modeling program to give an idea of what the house will look like and possible locations where the system can be installed. Other channels will be used such as face to face selling, direct advertising through phone call/mail/newsletter, trade shows, and also through social media. Face to Face selling and direct advertising allow us to sell the value proposition and what makes us different from the competitors more efficiently, it allows us to answer any questions right then and there to help diminishes any doubt. This also allows for more direct communication and transparency to build trust between us and the customer. Trade shows allows for the product to be seen from vendors and customers from all over. This allows for connections to be built and maybe future partnerships. Trade shows allow for more national exposure and to also see what else is going on in the industry. However, through these multi-platform channels, one thing will remain constant, the image of the product. The product

should be marketed as a system which is a utility bill saving and environmentally conscious alternative to traditional fuel heating options. The burden will lie between both WPI and its key partners when it comes to this system, since key partners have the resources and WPI has the image to brand this system.

4.6.7 Customer relationships

Having a strong customer relationship is very important in the solar heating industry. As a solar energy business, dedicated personal assistance should be a top priority. It is vital that potential customers talk face to face with sales representatives so that they get the system that works for them best. Also, personal assistance is necessary during the installation and for after sales services. The way they grow is by great customer reviews and spread by the word of mouth. Therefore, it is essential to implement personal assistance, dedicated personal assistance and a community based customer relationships. These will allow for the best customer relation and employee to customer communication but also customer to customer communication in order to build a community. The team will be collaborating with the key partners such as, Unity Homes and other solar service providers working more towards reaching the customers. Nevertheless, the approach the key partners take to reach the customers will need to be discussed earlier on. A big aspect of lack or doubt about solar technology acceptance is from lack of knowledge or familiarity. Thus, the key partner chosen to conduct business with have to be on board with the idea of doing solar outreach, education and support to individual consumers or communities about the benefits (monetary and environmental) of solar technology. This will enable the solar thermal heating system to gain more traction and acceptance among consumers. Professor Van Dessel and his team will primarily be sources of R&D support and enhancement for whoever delivers the product. The creators of the finished the system would benefit most from using the architect team as R&D support. This would allow Professor Van Dessel and his team to completely focus on the innovation of their product and work towards growth for the company.

4.6.7 Cost Structure

The costs associated with this business are going to consist of physical capital, benefits for the employee, materials to build, R&D, and working capital. These are going to be costs that take away from the total revenue. It is going to cost capital for the physical cost such as a building and the machinery for manufacturing floor. Working capital will be necessary to conduct day-to-day operations. Money is also going to have to be invested in research and development in order to grow the product.

The WPI cost for a provisional patent is not very much, approximately $650. According to the Director of Intellectual Property and Innovation at WPI, Todd S. Keiller, after the first year, the cost will increase from anywhere from $8-12 thousand to convert and protect the patent around the world. The total cost for a U.S. patent runs around $25 thousand. For a worldwide patent, it depends on the countries chosen, but this can range anywhere up to a couple of hundred thousand dollars.

Once the solar water heating system acquires property patent, the technology can be licensed to the key partners. Licensing, will put more responsibility on a partner because they will be taking on most of the cost structure and operational finances, while earning royalties from the license use and also sales. The partners will inherit physical capital, working capital, customer acquisition, and the manufacturing costs. Utilizing the key partners in this way, the team will be able to use Unity homes and other solar providers' customer base and marketing strategies without investing serious capital into doing it on their own, which would happen for a start-up company. Also, Unity homes and the other solar providers can now use the technology in order to manufacture and integrate the system to their existing systems and needs.

4.6.8 Revenue Streams

There are many ways in which revenue can be generated. Revenue can be produced through asset sales, licensing, leasing, and installation fees. For success of the product, a recurring revenue stream needs to be created. A recurring revenue stream is earned from consistent ongoing payments rendered to the company for either delivery of the value

proposition or after sales care for the customer. The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are two of the largest sources of early-stage capital for technology commercialization in the United States, as mentioned in the business model canvas (SBIR, 2017). With granted funding from SBIR/STTR and a possible partnership with the key partners such as Unity Homes, production can commence and can be in the market right away. And with their existing customer base the team can start selling products and achieve revenue through sales. However, if partnering with other solar companies, the biggest revenue stream will come from licensing the product to them. Acquiring revenue from licensing is defined as "income earned by a company for allowing its copyrighted or patented material to be used by another company (Staff, "Licensing Revenue", 2010). Once the solar space heating system is complete they can file for a patent which gives them the right to exclude other from making, using, or selling the specific design of the solar space heating system. Since solar companies don't always manufacture their own equipment, the team could supply companies with the system and acquire revenue through licensing. Essentially, they are charged for being able to sell the finished product. This entire revenue stream, however, is completely contingent on receiving the patent for their intellectual property.

5.0 Conclusion

Throughout all of the research the team has done on the solar industry and on heating alternatives, trends started to present themselves. The main motivator that drives consumers to purchase any heating system is the monetary savings regardless the heating source. Yes, customers like the fact that their home is more environmentally friendly but that is not what drives the sales. However, the initial cost of these systems is rather expensive even with rebates and tax cuts. Even with the current conditions compared to the traditional heating fuel sources in the market if a consumer can afford that initial investment, they are eventually going to get a good rate of return in the future. Thus, there is a potential for such a space heating system in the current market. To capture this potential, the Architectural team will have to build a system which will be affordable for consumers but also provide the quality which will meet their demand. Nevertheless, a big think to look out for will be change in governmental policies in both the solar industry and traditional heating fuels. Sudden change in policies might make any given source more desirable to consumers changing the potential for a solar space heating system.

While for commercialization plan of the system, the team recommends that if the architectural team has any proprietary intellectual property to patent it. IP is going to be extremely important down the road because this is going to ensure proper revenue streams. Once an IP is obtained, it's recommended that they license the IP to different solar companies. This will be the easiest way to access the market without the biggest capital investment. However, If the system has no IP, the team suggests partnering with Unity homes where as the home is being built the system can be incorporated specific to their house platforms.

When it comes to commercialization of a product of a renewable energy, it is not straight up a technical or business challenge. Multiple factors come into play for the successful idea of commercialization. We feel that any discipline may follow the steps in this report to commercialize their own solar technology. We had to understand what drove consumers to buy such products and how we can use that to the advantage of marketing our system. We also had to understand how solar is currently being marketed and how government policies dictate consumer willingness. And even though we were able to touch

upon different aspects, and derive general trend and patterns, there is definitely potential for more in depth analysis. When the design team does finalize on a product, much detailed feasibility analysis should be carried out to understand the true potential for the success of this system.

5.1 Interdisciplinary Nature of MQP

Our MQP team had to partially work with another MQP team with a different major, there were various interdisciplinary perspectives in this project. Since we were the business team and they the engineering team, there were couple of barriers in our communication. To communicate effectively with the architectural team, our team had to tap into our knowledge of science and technical elective courses such as physics, chemistry manufacturing engineering and more to understand their design vision and goal for their project. Our group internally also came from two different sets of disciplines. One member being an industrial engineer and the other three being management engineers. As a result, we got to bring different approaches through the methodology of our paper, to research and derive insight.

This paper looked into the potential for a solar space heating system and provided guidelines for commercialization research the broader aspects of solar and heating market trends. Since, we looked into a broad market, even though we used tools that we learned in our undergraduate career, our team recognized that for effective commercialization strategy recommendations, other disciplinary of entrepreneurship, consumer psychology, knowledge of basic science, politics and marketing needed to be considered in combination to ours. An example of such an interdisciplinary thought process to combine different disciplines was understanding whether the solar space heating system is something a consumer would want. From our research, we learned that what drives consumer to buy a heating system is monetary gain, as a result we chose to carry out an economic analysis. For this analysis methods learned in the course of ECON 1110 Introduction to Microeconomics, OIE 2850 Engineering Economics and BUS 2080: Data Analysis for decision making were combined.

Another way we considered our knowledge of different disciplines from our elective classes was in the building of our Business Model Canvas, where we approached the whole

modelling from an entrepreneurial point of view, and was built upon taking into consideration of governmental policies, external market factors, IP process and more that we learned from entrepreneurial courses such as ETR 1100 Engineering Innovation and Entrepreneurship and BUS 3010: Creating Value Through Innovation courses. Overall, our team brought our individual knowledge from both our core and elective courses, to create a holistic interdisciplinary approach, which considered different elements in commercialization to provide a guideline for commercialization strategy for a solar space heating system.

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Appendix A: Competitive Strength Assessment Calculation

Competitor Factors	Weighting
Price	25%
Quality	20%
Customer Service	20%
Market Share	15%
Reputation	10%
Marketing	5%
New Product Innovation	5%
	100%

Competitive Ratings
10 = Very strong/best in class Performer
5 = Average performer
1 = Extremely weak Performer

Competitor Rating

Competitors	Price	Quality	Customer Service	Market share	Reputation	Marketing	New Product Innovation	Total Score
Solar city	8	7	9	6	10	7	6	**53**
Sungevity	9	6	8	5	7	4	10	**49**
SunBugSolar	5	5	8	4	8	8	9	**47**
Vlvient	2	7	3	5	7	6	8	**38**
AstrumSolar	4	6	7	4	6	5	7	**39**
RGS Energy	3	4	4	2	5	7	2	**27**
Apricus	6	3	1	4	2	2	3	**21**
Heliodyne	8	4	5	3	3	3	5	**31**
Solect	7	4	6	5	4	4	4	**34**
CTech Solar.	4	6	4	3	3	5	1	**26**
Total Attribute Score	56	52	55	41	55	51		

Weighted Rating

Competitors	Price	Quality	Customer Service	Market Share	Reputation	Marketing	New Product Innovation	Total Score
Solar city	2	1.4	1.8	0.9	1	0.35	0.3	**7.75**
Sungevity	2.25	1.2	1.6	0.75	0.7	0.2	0.5	**7.2**
SunBugSolar	1.25	1	1.6	0.6	0.8	0.4	0.45	**6.1**
Vlvient	0.5	1.4	0.6	0.75	0.7	0.3	0.4	**4.65**
AstrumSolar	1	1.2	1.4	0.6	0.6	0.25	0.35	**5.4**
RGS Energy	0.75	0.8	0.8	0.3	0.5	0.35	0.1	**3.6**
Apricus	1.5	0.6	0.2	0.6	0.2	0.1	0.15	**3.35**
Heliodyne	2	0.8	1	0.45	0.3	0.15	0.25	**4.95**
Solect	1.75	0.8	1.2	0.75	0.4	0.2	0.2	**5.3**
CTech Solar.	1	1.2	0.8	0.45	0.3	0.25	0.05	**4.05**
Total Attribute Score	14	10.4	11	6.15	5.5	2.55	2.75	

Appendix B: Solar Space Heating System Present Worth Analysis using Geometric Series.

$$P = A + (A - B)\left[\frac{1-(1-i)^n(1+i)^{-n}}{i-g}\right] \quad \text{where } g \neq i$$

$$P = -15{,}5000 + (1457 - 200)\left[\frac{1-(1-0.25)^{20}(1+0.0024)^{-20}}{0.0024-0.25}\right]$$

$$P = \$\,15{,}573$$

Appendix C: Present Worth Calculations of Heating Fuels

C.1 Present Worth Calculations of Heating Oil Bill.

Year	Bill (B)
0	
1	-$2,171.00
2	-$2,171.00
3	-$2,171.00
4	-$2,171.00
5	-$2,171.00
6	-$2,236.13
7	-$2,236.13
8	-$2,236.13
9	-$2,236.13
10	-$2,236.13
11	-$2,303.21
12	-$2,303.21
13	-$2,303.21
14	-$2,303.21
15	-$2,303.21
16	-$2,372.31
17	-$2,372.31
18	-$2,372.31
19	-$2,372.31
20	-$2,372.31
Total	**-$45,413.27**

C.2 Present Worth Calculations of Propane Bill.

Year	Bill (B)
0	
1	-$2,176.00

2	-$2,176.00
3	-$2,176.00
4	-$2,176.00
5	-$2,176.00
6	-$2,219.52
7	-$2,219.52
8	-$2,219.52
9	-$2,219.52
10	-$2,219.52
11	-$2,263.91
12	-$2,263.91
13	-$2,263.91
14	-$2,263.91
15	-$2,263.91
16	-$2,309.19
17	-$2,309.19
18	-$2,309.19
19	-$2,309.19
20	-$2,309.19
Total	**-$44,843.10**

C.3 Present Worth Calculations of Natural Gas Bill.

Year	Bill (B)
0	
1	-$728.00
2	-$728.00
3	-$728.00
4	-$728.00
5	-$728.00
6	-$728.00
7	-$728.00
8	-$728.00
9	-$728.00
10	-$728.00
11	-$728.00
12	-$728.00

13	-$728.00
14	-$728.00
15	-$728.00
16	-$728.00
17	-$728.00
18	-$728.00
19	-$728.00
20	-$728.00
Total	**-14,560**

C.4 Present Worth Calculations of Electricity (Heating Only) Bill.

Year	Bill (B)
0	
1	-$553.00
2	-$553.00
3	-$553.00
4	-$553.00
5	-$553.00
6	-$624.89
7	-$624.89
8	-$624.89
9	-$624.89
10	-$624.89
11	-$706.13
12	-$706.13
13	-$706.13
14	-$706.13
15	-$706.13
16	-$797.92
17	-$797.92
18	-$797.92
19	-$797.92
20	-$797.92
Total	**-$13,409.69**