Solar Squad

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Problem Statement

What is the problem?

Historically, one of the major obstacles to more widespread adoption of solar panels as an energy source has been their high cost per unit power produced when compared to traditional sources of energy, such as petroleum, coal, and natural gas. A major factor in the high cost of PV panels is their relatively low efficiencies, with experimental averages ranging from eleven to fifteen percent efficiency in converting available sunlight into usable power (Pure Energies). Ultimately, the simplest conceptual solution to make solar panels more affordable would be to increase their efficiency per unit cost. Other than the material composition of the solar cells themselves, one of the better-established causes for low PV efficiency is a rise in temperature of the solar module when exposed to direct sunlight (Bücher et al.). In the words of a report by the German-based Fraunhofer Institute for Solar Energy Systems, "as is well known, the power output of a PV module decreases with module temperature increase for crystalline silicon modules" (which are the industry standard type of solar cells, as contrasted with amorphous silicon and organic solar cells, among others) (Bücher et al.). The drop in power output occurs according to the equation:

$V_{oc,\ measured} = \alpha*(25^oC - T_{panel}) + V_{oc,\ rated}$

where $V_{oc,measured}$ is the measured voltage output of the solar panel, $V_{oc,\ rated}$ is the expected output of the solar panel under standard conditions of 25°C and 1000 W/m^2 solar irradiance, T_{panel} is the calculated temperature of the solar panel, and α is the temperature coefficient for the solar panel (Surles et al. 2009). Thus, as α increases, we experience a drop in measured voltage output, which leads to a corresponding drop in power according to the standard relation p=iv, where the current i is assumed to remain fairly constant at lower voltage levels.

Who?

One of the major parties affected by the high cost of solar panels is the average homeowner. The high upfront cost of the panels and installation commonly causes homeowners to shy away from purchasing solar panels in favor of continuing to use the energy from their electricity provider. This in turn causes them to have to pay a higher hourly price for electricity. Likewise, energy providers are affected by the high cost of solar panels in the same way, albeit to a much lesser degree, and are less likely to purchase photovoltaics for their business as a result. Another party affected is any company which produces, markets, or distributes solar panels. Since the demand for solar panels by energy providers and homeowners is adversely affected by the high price of solar, producers and distributors of photovoltaic panels do not have as much business as they otherwise would, and so they see a smaller profit. If the price of PV cells was significantly decreased by increasing efficiency (through cooling PV panels), then all of these stakeholders would be better off.

Where and When?

It is evident upon close inspection that the problem of decreased efficiency as a result of a rise in temperature of PV panels is made more severe by warmer, sunnier climates. For instance, solar panels in the Mojave Desert are much more likely to benefit from any solution to this problem than are solar panels located in Seattle or Boston. Likewise, increased temperature of solar panels is a bigger problem in the summer months, when the sun shines for a longer period of time each day and the average temperature outdoors is much warmer than a corresponding average day in the winter months.

Why is it a problem?

According to a study by researchers at the National Technical University of Athens, a standard PV cell experiences a constant drop in power output of 0.45% per degree Celsius, which is consistent with other studies' estimates that range from 0.3% to 0.9% per ºC (Skoplaki and Palyvos 2008). Using the 0.45% drop in power per degree Celsius calculated from the aforementioned study and a 25ºC rise in temperature from the baseline temperature of 25ºC (A dark solar panel can easily reach a surface temperature of 50 degrees Celsius on an average summer day in full sun), that gives a 11.25% drop in power output, which is a reduction of .675 kW of power for an average residential 6kW system (Zhu et al.). To make up for a .675kW drop would cost approximately $560.25 in additional panels alone, and the total cost including everything would potentially be about $3,327.75 in additional installed cost (assuming a linear increase in installation cost) (Morris et al. 2013). The problem of high temperatures reducing efficiencies causes a large decrease in power output and is a problem that can be remedied to increase output and lower cost.

Significance: Why is this problem important?

According to the U.S. Department of Energy, solar panels are the most renewable form of energy today. However, they are not ubiquitous enough to replace or significantly deplete the use of fossil fuels. This is due to several reasons, including cost, availability, lack of awareness, lack of aesthetic appeal, etc., but a major issue has to do with the efficiency of solar panels. Most solar panels are only 11-15% efficient, which is extremely low compared with the maximum theoretical efficiency of 29.43% for undoped Silicon-based PV panels (Pure Energies and Richter et al. 2013). Therefore, there is a strong need for making solar panels more efficient.

Solar panels grow less efficient as they get hot. This is because as the temperature of the panels rises, the internal resistance rises, so the power output falls, because the electrical conductivity drops. They lose approximately 0.45% efficiency for every degree rise in temperature (Skoplaki and Palyvos 2008). Additionally, the lifetime of a solar panel is halved with every rise in temperature of 10ºC (Otth and Ross 1983). This highlights the need for a way to cool solar panels to bring their temperature down to a range where they are more efficient. The efficiency typically drops off after 25 degrees Celsius (Solar Panel Temperature), so temperatures around or below this would be ideal, as opposed to the average PV panel temperatures of about 50-55 degrees (Zhu et al.), which create a 12.5-15% drop in power output.

As was previously calculated, a cooling system which lowered the operating temperature of PV panels to the baseline temperature of 25ºC would potentially save up to $560.25 of PV panels and $3,327.75 of Balance of System costs (Morris et al. 2013). Any cooling system which costs less than these figures would save the consumer money, driving down the effective costs of "going solar." Such a cooling system would make solar more cost-effective for residential, commercial, and utility installations than an equivalent uncooled solar installation, potentially increasing the market penetration of PV panels in the energy sector by increasing affordability (Dubey et al. 2013).

Stakeholders

There are countless stakeholders within the realm of solar energy, but since we are focusing exclusively on the cooling of solar panels, the stakeholders within this problem space are utility companies, residential consumers, solar panel manufactures and distributors, and government regulators. Utility companies often times show on their websites and advertise that they are for solar (Georgia Power), but this is not the whole truth. They are for solar as long as they are still selling the energy they produce. Georgia Power "By law … doesn't have any competition. It is a regulated monopoly that sells electricity to 2.5 million customers"(Swartz, AJC). In this AJC article Swartz explains that in Georgia there is a company called Georgia Solar Utilities, a startup, and it wanted to "build a large solar farm and sell that electricity directly to customers as a utility". Georgia Power, seeing this as a threat, filed complaints with the Georgia Public Service Commission against Georgia Solar Utilities when they asked to be classified as a utility. Another more general case of utility companies campaigning against residential solar took place three years ago when top utility executives met in a private meeting of the utility industry's main trade association. Here they formed a plan to counteract the losses to utility companies from solar (Warrick 2015). An example of one of the measures against residential solar is a net metering surcharge. People who invest in residential solar for their homes make their money back by selling energy back to the grid. Some utility companies in Arizona have proposed to charge $50 a month to keep the solar panels connected to the grid which could make solar too expensive to some customers (Warrick 2015).

The next stakeholder is probably the most invested and involved in the problem space of cooling solar panels. That is the consumer, since the types of systems that we are envisioning that would get this cooling system are relatively small residential systems. There are numerous things a consumer would consider before installing a cooling system. These include cost, effectiveness, and cost efficiency. For cost, solar panels are already expensive and the total cost with installation can cost up to 4 or 5 times the cost of the panels themselves (RMI Morris et al.). Adding on more cost to this could definitely discourage a consumer from getting a cooling system, but if we can make the system cheap enough, the consumer might pay the extra up-front cost. This is especially true if it is effective enough to provide extra energy. If the cooling system can visibly increase efficiency, than solar distributors can easily market that system to consumers. Lastly, for the average solar consumer the decision will come down to one main thing, and that is cost effectiveness. If the cooling system can save more money than it costs, and make more energy than it uses, the consumer will likely invest in it.

The people and companies that produce and distribute solar panels would also have great interest in this. Their main goal is to sell as many solar panels as possible, and get as many homes fitted with solar panels as possible. The cooling system could create a selling point that would interest the panel companies. Their perspectives on the problem of efficiency are that it is a major disadvantage. Cost is the biggest reason that solar panels aren't in widespread use, and one cause of that is how inefficient they are. This inefficiency can be helped with a cooling system and that could become a selling point for the companies to use. Also when they are installing a new system, they would be the ones to install the cooling system as well.

The stakeholders that benefit and somewhat don't benefit are the government regulators. The regulators already have to regulate and make sure the systems are safe. They check for dangers to people and dangers to the grid, if it is connected to the grid, and with this addition of the cooling system they would have to check for more (FERC). This could potentially drive up costs of the permits and could create a problem for all the stakeholders. The solution to this is to keep it simple, and not have a massively complicated system, so permits would be affected. Government regulators could potentially benefit from the situation because if this is widespread then the industry could create standards for a cooling system and this would make the regulators job easier, since there would be some standard instead of just random cooling systems.

Existing Solutions

The problem of solar panels losing efficiency as the temperature increases is not a novel one. The researchers and people who work with solar panels have known about this problem and have worked on ways to fix it. Some of these technologies have been worked with before (David's TLUG info). These existing technologies include heat film, water-cooling, and heat pipe. The heat film has recently been discovered by researchers at Stanford that block some thermal radiation while still preserving efficiency (Stanford Engineering). This is a type of glass that goes on the panels that reduces the temperature on the solar panel and increases its life. Water-cooling is the most common and comes in many forms, but it is mostly spraying water on the panels when they get hot. The heat pipe is a pipe that runs under the panels and can move the heat and use it elsewhere like in a solar water heater. The focus of the rest of these explanations of the solutions will be about the heat film and the water-cooling. For the heat film the main reason it hasn't become widespread is because of cost and a lack of marketing. Since this is a relatively new technology, it will take a while for the cost to come down to be affordable to the average consumer, and the other problem is with marketing. Zhu, one of the authors of the Stanford paper said that this "has substantial commercialization potential" (Stanford Engineering). This heat film is also still being researched. The other solution is water-cooling, water-cooling is cheap and effective but the reason it hasn't become extremely widespread is lack of knowledge and subsequent desire for solar cooling. If people don't know about the benefits, they can't adopt them. To fix this, solar companies need to sell solar systems that already include a cooling system, and they will need to justify the cost. There are existing solutions to these problems but none are easy or cheap enough to be implemented on a big scale. That is where we come in.

Why is it still a problem?

The problem of solar panels losing efficiency with rises in temperature is fairly well-known among PV cell researchers, but most scientists working on the efficiency of PV cells have attempted to improve the solar cells themselves, rather than work on this particular problem. Another related challenge to implementing a cost-effective cooling system is that any kind of active cooling system (including water, pipe, and air cooling systems) inherently requires an input of energy (Zhu et al.). If the input energy required is too high (as has been the case with some cooling systems designed in the past), then the cooling system will wind up costing more money and energy than it saves, making it more of a problem than a solution (Zhu et al). For our solution to be a success, we must ensure that any system that we design does not fall into this trap, so we must keep in mind that we cannot exceed the cost saved by using fewer PV panels. Another challenge is that while this problem has long been acknowledged by PV researchers, most solar panel installers are not installing existing solar panel cooling systems, perhaps because of issues such as lack of market readiness, lack of awareness, and high costs of existing systems. All of these issues have contributed to the low market penetration of solar cooling systems.

Proposed Work

Goal

Our long term goal is to improve the efficiency of current photovoltaic cells. We have decided to focus on the cooling of solar panels. After evaluating many different directions and problem spaces, we feel this is the area we can be the most successful. There are already multiple post-production methods of temperature regulation and our purpose is to find the one with the most potential and improve upon it. If we are successful in finding a cost effective solution, we will be able to increase the electricity produced by a single solar cell. We can then focus our project on expanding our solution to an array of solar panels. Ideally, in the coming years, we want installers to distribute the systems on a large scale, and thereby increase the total amount of clean energy produced from solar. We also hope that we can extend the lifespan of solar panels by decreasing the harsh effects of high temperatures. This would make panel owners' investments significantly more profitable and encourage more people to invest in solar energy.

Objectives

1.) Establish Partnership with ESCEX Sustainable Energy/ Fujikura Ltd.

In order for our project to have any chance at being successful, we realize that it is imperative that we find a researcher/researchers who are interested in working with us on implementing our solution. While we are from from naive about the reality of the problem space we are entering into, we do understand that the likelihood of us making a significant impact is drastically increased if we can find someone to partner with who has the knowledge/resources to help us obtain our goals. A partner is important to the success of our project because it will provide our group with a larger communication network, thus opening us up to possibilities that we would otherwise be unaware of. This includes, but is not limited to, things like alternative design ideas and/or further critical analysis and refinement of our solution. In addition a partner provides us with a reliable source for us bounce ideas off of which is crucial in devising a technological solution such as ours. A partner could also serve as our most valuable critique by letting our group know if we have strayed too far off topic or if our current goals are to lofty and unattainable. In these ways and many more, we believe setting up a partnership is an essential step for our team to take in the coming months. We currently have two contacts with whom we are networking, in hopes that we can join efforts with their respective companies and reap the benefits of partnership. The first of these contacts is Jay Cutting, who is the Technical manager at ESCEX Solar. As the technical manager for ESCEX, Mr. Cutting can help us to refine our solution in order to conform to current solar cell technology. In addition Mr. Cutting can also provide us with invaluable insight into the current solar market, allowing us to design an appropriate solution which not only fits the available technology, but also meet the demands of the public. While Mr. Cutting can advise us on commercially implementing our solution, our second potential partner can help our more with the technical development of our cooling system. Randeep Singh has a PhD thermal science and is currently employed by Fujikura Ltd. (a Japanese based power company) where he is the manager of its electronics division. Mr. Singh was referred to us by Dr. Akbarzadeh who wrote a paper on solar panel cooling, using a system very similar to the one we have in mind (Akbarzadeh). Dr. Singh has expressed his interest in helping us to achieve our goal which bodes very well for the future of our project. With these two valued partners we believe we will not only have a much better chance of making a viable solution, but also a much better chance of taking our solution out into the world in order to make a real world impact. If we are unable to acquire these two partners we believe that it will be much harder for us to obtain our overarching goal. From talking to our facilitator and other Grand Challenges faculty it has been noted many times that the vast majority of teams that went on to be successful did so because they were able to partner with an organization on campus or nearby campus. In rare cases it was mentioned to us that long distance partnerships were enough to get teams through the inevitable struggles that come with implementing a solution to a wicked problem. Given the information from these sources, and our own intuitive knowledge of the scope of our particular problem, we believe that without a partner it will be extremely difficult for us to be successful in designing a system to regulate the temperature of traditional photovoltaic cells. While this is no easy task even with a partner, having that mentorship/support will drastically increase our chances for success.

In order to accomplish the objective of partnering with these two potential partners we will first need to come up with a strong pitch for why we will be a valuable partner. In other words we want to be sure that we have a well thought out solution before we pitch the idea of partnering with these companies in order to maximize the chances that they agree to get on board with our project. We will go about preparing our pitch by using the resources we have at both GTRI and the grand challenges faculty to critique our solution and pitch before we take our ideas directly to our potential partners and ask for their support. By proceeding in this manner we hope to refine our solution ideas, as well as, practice composing and performing a professional pitch to a company. Once we are satisfied with the caliber of our pitch we will go to both our contacts and discuss the idea of them partnering with us for the duration of our project. One thing we will be sure to consider prior to having this discussion is what kind of relationship we want to have with each of these partners. Because both of these companies and contacts have very different expertise and knowledge we will want to discuss how we want each of these partners to coexist with our overarching project. For this reason it will essential to establish a finite yet flexible relationship with our contacts and to incorporate this into our pitch. By performing the above steps we believe that we will maximize our chances to foster a healthy and lucrative partnership with both of these prestigious companies.

Our aim is to establish contact with an organization with expertise in the fields of solar energy and/or methods of cooling equipment to their optimum temperatures of operation. The two companies we have identified are working in the area that we wish to, so they would have people with the knowledge we are seeking. We have an idea for the sort of cooling system that we want to design, but it would be helpful to get some expert opinions on our project ideas before we implement them or even design a prototype or run an experiment. While it is beneficial to fail and learn from our mistakes, it could save us a fair amount of time, money and other resources, if someone were to point out the missing link in our idea and show us why the idea would not work, rather than us spending time, effort and other resources in an endeavor that was bound to fail. Furthermore, if we can find an organization that is focusing its efforts on a similar project, we might be able to collaborate our efforts towards a mutual goal. It is also possible that we are able to identify a group that has worked on a similar project, but hasn't completed it. Despite our lack of technical know-how, it is possible that an injection of our manpower and creativity might be able to propel the project to success. Discoveries may have been made since the time the project was first attempted and now that gives us the ability to complete the project. If the companies we are currently aiming to partner with are either unable or unwilling to aid us, we can search for other resources. In the unlikely event that we are unable to identify any groups that are working on a similar problem space, we would be greatly aided by establishing a partnership with a laboratory so that we would have access to their technical knowledge as well as their resources and equipment for any experiments that we may run down the line. They would also be able to help us in following proper convention while conducting the experiment to reduce our experimental error. Overall, the anticipated benefit of finding a partner for our project would be compensating for our lack of technical knowledge as well as allowing us access to to equipment and technology that would augment our experiments and research.

The biggest potential problem of this outcome is simply that we are unable to identify any partners willing to work with us, however, this seems unlikely, because, as mentioned earlier, we do have two companies that we are in contact with. We are hoping to avoid this problem by designing our pitch with substantial evidence not only for establishing the problem, but supporting our idea as well. We are also trying to be able to show actual data gathered from experiments, prototypes, etc., to backup our case. We will also try to highlight the corporate benefits of our project, so that we are able to appeal directly to their commercial interests. If they are unwilling or unable to work with us, at the very least we will be able to identify a laboratory on campus that will be willing to help us along the way. We might not be able to cooperate with people actually working in a similar problem space, because they may not be willing to share their intellectual property with us. Another long-term problem might be that if we do work with a partner, and our project is successful, they may force us to sign over the rights to the product in exchange for allowing us to use their resources. However, this problem is considerably far away, and only applicable under the assumption that our project is successful.

2.) Identify parts/materials & design cooling system using professional contacts and research

In order for our project to be successful we first had to narrow down our focus to examine one single type of cooling method for solar panels. this took quite a bit of back and forth discussion as we started with four methods each with its own pluses and minuses. While these methods are all viable ways to regulate the temperature of solar panels, our group had to examine which of these methods we believed we could take and improve upon in order to substantially impact the efficient cooling of commercial solar panels. After many meeting discussing the pros and cons of each method we finally settled on going after a refrigerant based cooling method. Our primary reasoning behind this choice was that not very many people have attempted this method because it is slightly more complicated than traditional water cooling, so we feel as though there is a substantial amount of room for innovation. On another note we also chose this avenue of investigation because were able to make contact with one of the pioneers of this cooling method, and thus decided that it would be worthwhile to further pursue this particular cooling process. Now that we have settled on what our direction will be moving forward our next objective is to begin working on establishing a list of the parts/materials and cost of these fundamental resources that we will need to begin work on a prototype. One of the central goals of our project is to keep our cooling system as cheap as possible and to do that we intend to use only those materials that an average homeowner would have access to through their local hardware store. While we envision our initial design being slightly more complex we hope to work towards a solution that is simplistic in design as well as materials. In order to compile this list we will first go through an arduous drafting process with both of our partners where we work towards ideating a solution which improves upon current refrigerant based cooling technology. Once we and our partners our satisfied with the practical and mechanical aspects of our design we will begin experimenting with materials starting with the cheapest and most available and scaling up to more expensive materials only when absolutely necessary. We will undoubtedly go through several phases of design, material choice, building, and testing but by starting with a strong conceptual solution and working from least to most expensive materials we hope to minimize the time it takes to develop a solution.

Choosing the right materials is essential to the success of our project because one of the things that we want to set our solution apart from similar cooling systems is the simplicity of our materials. The reason why we are putting such a huge emphasis on easy of assembly and fundamental simplicity of our materials is that currently one of the largest margins of cost in the solar industry is installation. For this reason we believe it is paramount that our solution has a minimal impact on the solar installation market and contributes very little if any to the cost of installation. On a similar note we also want our cooling system to be as functionally simple as possible because we believe that consumers should have the option of fixing their own cooling system if need be as opposed to sending an inordinate amount of money for a solar installer to come out to their house and perform the necessary repairs. Currently because of the complexities associated with solar installation the cost and time it takes to get a part fixed is much too high. This problem is one that our team hopes to be able to help alleviate by increasing the availability of the materials used. There are several steps that we will need to take in order to properly identify the right materials for our project. To start with we will need to see what kind of resources we have access to at the invention studio here on campus, as this will most likely become our primary work space for the majority of our project. Once we have assessed the materials in the invention studio our next step will be to talk to our partners and purchase any additional essential materials. While it is likely that we will need to purchase additional materials as the project progresses for starters we believe we can maximize how far our dollar can go by using the resources at hand and only purchasing those things which are absolutely vital to our success.

Our expected goal is not to design an entirely new method of cooling; we do not possess the technical knowledge to undertake a large research problem like that. We are aiming to identify a pre-existing method of cooling that we can improve upon in order to make the cooling process more efficient, so that we can maximize the benefits realized in applying this to solar panel systems. The term ‘improve’ is open to interpretation. Possible improvements would be to:

- Increase the cooling at the same monetary cost or energy input
- Reduce the cost of the existing system
- Redesign the system so that it doesn’t require an expert to install/repair/perform upkeep operations, which would make the process of having such a system considerably easier for the customer
- Redesign the cooling system to a ‘one-size-fits-all’ type of system, so that every individual customer does not require an expert to review his/her photovoltaic system and install a customized cooling system.

In order to maximize these improvements, it is vital that we identify the right materials. Since we want our system to be commercially viable and easy to maintain, it is also important to identify low-cost, yet effective materials. We can measure the effectiveness of the materials we identified based on the benefits we realized through our system. Carrying out a cost-benefit analysis to measure the trade-off between power and monetary input versus savings will allow us to determine how successful we were at meeting this objective.

The biggest problem in this objective is that people seem to have worked in a similar problem space in the past, conducting research (Akbarzadeh) (Moharram), but there isn’t a solution that has gained popularity. It seems unlikely that we would be able to make a breakthrough discovery. That is why our aim is to discover how we can improve an existing method. Another potential challenge to this might be that the materials that solar panels are currently made of are tough to cool with existing methods, requiring either a revolution in the types of cooling or the material composition. Altering the material composition of solar panels would require technical skill as well as time that we do not possess. Additionally, such a venture would serve a different purpose than what we are trying to achieve, and it might defeat one of our goals - reducing the cost of solar panels (if the material used were to prove more expensive). In order to accomplish this objective, we must identify a cooling method which can be improved to bring about a marked rise in efficiency of the panels. We must also make the best use of materials available to us in order to ensure our system is inexpensive and easy to install and maintain.

3.) Build refrigerant based cooling system

Once we have successfully accomplished our first two objectives our next logical step will be to address designing our prototype of our refrigerant based cooling device. The reason why this this objective is so important is that without completion of this step our project has no substance and we cannot claim any results or achievement. It is also important to build a prototype in order to confirm our research and thought process with respect to the cooling method we chose in the previous objective. With this prototype we will be able to prove that our idea works or contrarily we will discover that we need to make slight adjustments/look at the problem from a different angle in order to accomplish our goal. No matter the outcome of our prototype it will an invaluable learning experience for our team, allowing us to concretely gauge how good our problem solving has been so far, and what adjustments we need to make moving forward. In addition to the previously mentioned reasons, building a prototype is also important because it demonstrates the fact that our team can move from a conceptually idea to a concrete solution. This task is very difficult and most likely the most challenging thing we will have to do in order for us to complete our project; however, we are optimistic that with the direction we have chosen, as well as, the on/off-campus resources we have that we will be able to create an effective design. If we are unsuccessful with this step of our project we will be greatly hindered in our ability to succeed within this problem space. The consensus of our team is that while failure is certainly an option when it comes to a task as difficult as making a prototype, we believe that if we utilize the partners we hope to create and the many on campus resources that we can make our idea become a reality. If despite these efforts we are still unable to build a prototype then one option we would be willing to pursue, that Dr. Wynes mentioned to us, was the possibility of performing a research paper instead. This research paper would be a comprehensive review of all cooling methods to date and would detail their comparable efficiencies and other relevant research data. That being said we do believe that we can accomplish our goal of regulating solar panel surface temperature via a refrigerant based cooling system.

In order to complete this specific objective there are several actions we will need to complete before we are able to successfully build a prototype. The first thing we will focus our attention on is compiling a list of all the functions that we see as essential to a successful cooling system. With this list in hand we will be able to look at the cooling method we have chosen to look at and compare our list of desired deliverables with the list of things that the given cooling can do. With this compare and contrast established we will be able to more clearly see the flaws in conventional cooling methods. With these drawbacks highlighted we will move into an extensive brainstorming phase where we will enlist the help of our facilitator/partners with the purpose of coming up with a unique design for a viable refrigerant based cooling method which builds upon the previously existing method. Once we have an idea we believe will work we will go through an extensive critique and revision period where we will reform and refine our idea until we are finally ready to take our conceptual design and attempt to construct it with the resources available in the invention studio. An additional step within this process is making sure we are trained or can get someone to operate the necessary equipment within the invention studio that it takes to build our prototype. This prototype construction will undoubtedly take a great deal of time and will require patience and adaptability on our part. Most likely during this time will have to make some sacrifices and compromises but ultimately we will come away with an efficient and viable design to cool traditional photovoltaics.

This is our overarching objective - designing the system itself. While our first system will be a prototype, it is still an important goal to measure the potential for our project's success. After designing our prototype, ideally we would install it on a photovoltaic system and be able to gather data comparing the amount of money and energy we put into our system as opposed to how much money and energy our system saves. For our product to have commercial viability, the savings need to outweigh the costs. At a more basic level, an anticipated outcome is to ensure that our system works at all. If our prototype is able to bring about some change in temperature, we have made a start. The effort required to improve upon it would be gauged by the data mentioned above. Also, if the data is stacked heavily against us, it is a sign letting us know that we need to either modify our problem space, or go back to our second objective where we search for different materials and/or methods in order to set ourselves up for success.

A major problem in building a prototype is that none of us have prior experience putting together a complex system such as this, so we have a large technical gap to overcome. It likely requires a proper lab and extensive equipment to put together such a system successfully. Therefore, in order for us to successfully complete this objective, we need to complete our first objective and establish contact with a corporate and/or academic partner that will help us bridge our technical gap and supply us with the equipment we require. Since this objective also involves gathering data to gauge the successfulness of this prototype, we need to identify a photovoltaic power system we can test our prototype with. Another Grand Challenges team is working on obtaining a solar panel, so hopefully we are able to collaborate with them in order to gather data to measure the effectiveness of our system. If we are unable to do so, our Grand Challenges grad student partner, Matt, is conducting research with solar panels as well, and he would be willing to allow us to carry out our experiments using the panels he has access to. We could also purchase our own panel to test, but the ideal situation would be to test on a rooftop solar panel system, because that is the audience we are targeting currently. It might be hard to find someone who would allow a few college students to install something they designed on a solar system that cost them a lot of money. However, this problem is far in the future, so we can currently ignore it and focus on designing the prototype itself.

Research Team

Our team will be comprised of six students. These six students will be the current members of our Grand Challenges team. We spent the second half of first semester and entirety of this semester researching general information about solar panels as well as current cooling methods.

All the students on our team are well-informed about the problem space. Each person on the team has more specialized knowledge in the area they have spent the majority of time researching. However, there is always a need for more current and relevant information. Therefore we will continue our research and exploration of the problem space as we continue with our project.

Our team needs strong leadership. We will need individuals that are well-versed in interviewing, media presentation and other modes of communication. This is important to the success of the team. By dividing the workload into different areas of expertise, we can ensure the completion of assignments to a high quality of work.

We have yet to find an individual who has agreed to be our team advisor. We are hoping that our current Grand Challenges facilitator, Matt, will agree to continue advising us. He has given us invaluable advice and helped us find a direction with achievable potential. We also hope to contact Georgia Tech Research Institute in the coming weeks and seek potential partners as we continue forward with our project.

Timeline

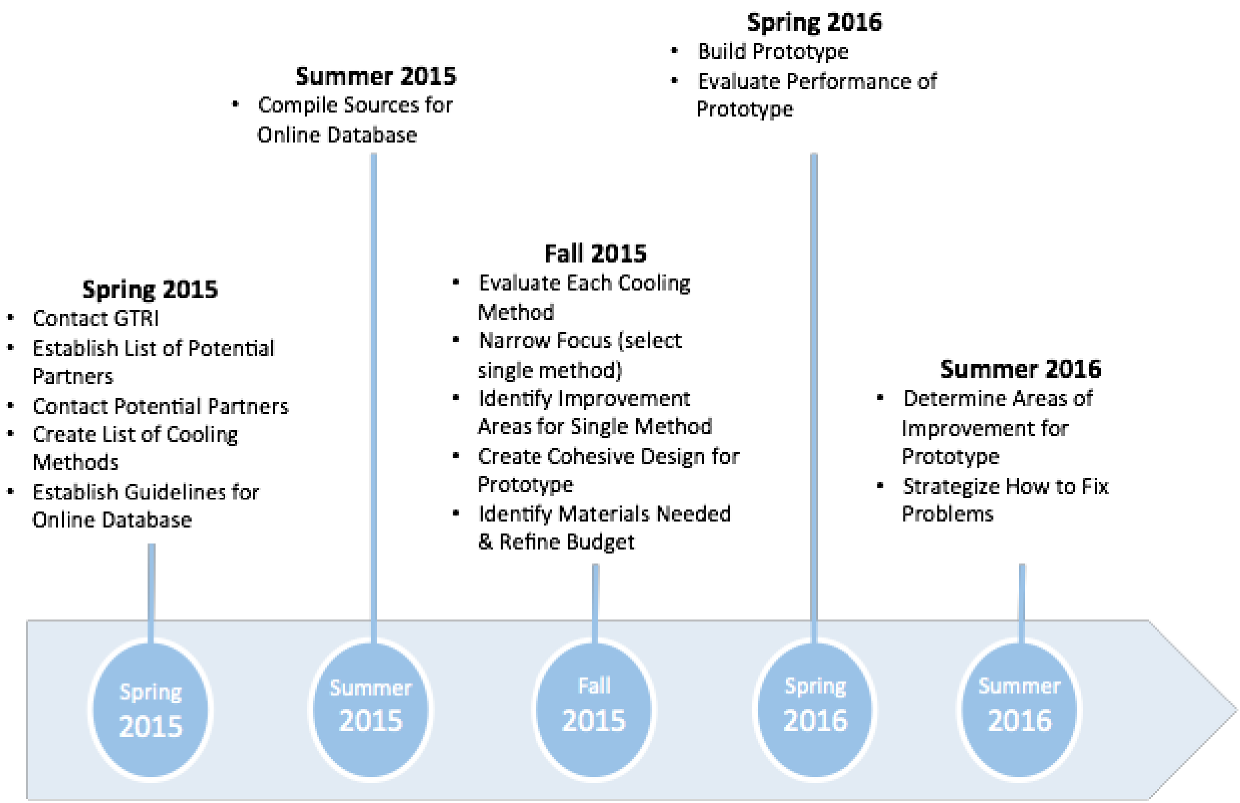

Figure 1. Estimated timeline to complete proposed objectives.

Budget

Materials and Supplies:

Material	Estimated Cost
Photovoltaic Panel	$200
Multimeter	$20
Piping & Tubing	$30
Water Pump	$25

At the current time, we do not anticipate there being a service cost or travel expense. This is subject to change as our solution develops.

The materials are needed in order to further our experimentation and aid us in reaching our two year goal of completing a functioning prototype. We anticipate (like any science based project) have a lot of trial and error. Possessing our own materials would significantly simplify that process and allow us to spend a greater amount of time experimenting and making adjustments to our system as needed. It would also allow us to test any assumptions quickly and facilitate the process.

This is a rough estimate of the materials we will need. By no means is this a final or exact budget. It is simply a rough idea of the materials we anticipate using in the coming months. This budget will be revised significantly as we further develop our experimentation and solution.

Expected Outcomes and Future Direction

When this project is completed we hope to have a functioning prototype that regulates the temperature of a standard photovoltaic cell. After the second year of working on this project (Summer 2016), we hope to have our initial prototype. This prototype will be both tangible and show potential for improvement. We define “potential for improvement” as a functioning system that runs automatically without human interference. A successful first prototype would be a cooling system that decreased the temperature of the photovoltaic panel by even a minute temperature change. However, this is an extremely ambitious goal and is not completely reasonable. A more reasonable goal for the end the second year of the Grand Challenges program would be to have a clear prototype design, list of needed materials to create the prototype and estimated budget for the prototype. This goal would give our team potential as we approach another year working on developing a cooling system. We would also have a clear direction moving forward. Our direction would be focused towards building and improving the prototype. Beginning with a single photovoltaic cell, we hope to expand to an array of panels. This is a long term goal that is currently outside of the scope of our next two years of the project. As of now we will be focusing on developing a cooling system for a single photovoltaic cell.

There are many organizations we can look to for funding that are affiliated with Georgia Institute of Technology. Our primary focus will be developing a partnership with Georgia Tech Research Institute (GTRI). Currently researchers are working with solar panels at GTRI. It would be in our best interest to seek materials and advice from the researchers there, because it is conveniently located. At the current stage of our project there is no need to seek funding outside of local/ on-campus resources. The current scope of our project is small (a single photovoltaic panel) and therefore the scope of our finances shall also remain local. We hope to purchase or acquire a photovoltaic cell in the coming year for experimentation. This will be an investment for our team that we hope the Grand Challenges Program or GTRI will be willing to assist us in the purchase of a full size panel. This investment will aid in the experimentation and the continuation of our progress.

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