Solar Size: Project Experience Report

Tristan Brown-Hannibal
Karlee Fidek
Kaden Goski

Version	Date
1	April 8, 2022

Purpose and Problem

Solar panels are a type of power generation many companies and individuals are looking into. It could be the case that many people want to install solar panels for the goals of combating climate change. This is a goal that all members of our team believed in. More concretely though, it is known that people want to offset their costs of doing business. Power costs can be a large portion of a business's expenditures. This was highlighted to us in our meeting with Greenwave Innovation. They pitched an idea of a way to meet currently unmet consumer solar panel demand.

Among their initial pitch, they mentioned a few things that they thought were openings for a product. One of them was that overgeneration was not accounted for enough when trying to size solar panel installation solutions. Overgeneration not being accounted for means that the less than optimal solar installation could be purchased.

Overgeneration is an aspect of solar panel generation. If solar panels generate more than the consumption needs of a building, they can send that energy back into SaskPower's power grid. SaskPower will then compensate the seller. In Saskatchewan the value of overgeneration is a half-credit or 7.5 cents/kWh. This means that overgeneration is not as valuable as merely offsetting power consumption that would otherwise be used, though just because it is less valuable, doesn't make it valueless.

Looking at averages does not provide much insight into overgeneration. For example, if it were extremely sunny for one day in a week, but normal overcast for the rest of it, the average might be below the user's consumption data, even though there was overgeneration. Looking at the average output of panels can hide the fact that overgeneration occurred and result in over estimation of the return.

In this case, the problem is that potential solar users and potential customers are not provided with enough information to make a good choice deciding which solar installation to purchase, which may make them hesitant.

As a group we thought we could address any concerns by simplifying the process in a few ways. These are:

- Giving clear and concise information about power outcomes when customers install solar panels at their business, taking in consideration unique factors about that location and overgeneration.
- Suggesting an optimal solar panel installation given different types of solar panels.
- Showcase what customers stand to gain from an optimal installation monetarily.
- Create a calculation to show how much power an inputted solar panel installation produces.

Initial Vision & Plan

Customers

The first step in planning our solution was defining exactly who our north star customer was. We had two main options; we could focus on residential customers or we could focus on industrial/business customers.

To us, residential customers were noble customers. Being able to convince a regular person to go green aligned well with our ‘why’ which was trying to save the environment and limit climate change - an extremely scary and real problem. It aligned well because changing the attitude of a regular person is important in normalizing and standardizing the green way of thinking.

Industry customers as a north star were a more financially sound customer base. If we were to focus on industry partners, we believed that the product would have more monetary value. However we were not sure about this, so in the initial meetings with Greenwave we asked who their target customers were. They indicated that most of their business is from industrial partners.

In the end, we weighed the pros and cons and decided on industrial customers, primarily because we thought Greenwave could give better insight into that realm of customer. However, we did not completely neglect residential customers, our carryover customers, as we included domain specific information in the app that would help non-informed users understand the process.

Envisioned Requirements

There are a few things that we thought our tool should accomplish concretely. Firstly, we thought we would utilize Greenwave’s database to get customer consumption data. This would require user accounts to verify that anyone who uses the tool has permission to access the data.

Next, the tool should gather specifications about the user such as potential panels, financial considerations, location data, and time frame. Using this data in combination with a historical irradiance API, the application could calculate periods of overgeneration and undergeneration.

With this historical data, we could utilize the panel options provided, calculate the optimal solar installation, and give graphical information about it including insights about return on investment and generation.

Form

After understanding our goal, customers, and requirements, we considered what application type to utilize for implementing the tool. Three main options were brainstormed:

- Making a standalone web application, separate from Greenwave's services
- Integrate a web app into Greenwave's services
- Make a mobile application

We decided on making a standalone web app as it had less restrictions and we could more clearly distinguish our work compared to others.

Technologies

With a web app decided, we needed to pick the languages we were going to write our application in. As a group, we were interested in learning a new front-end language framework. Specifically, the two that we looked closest at were React and Vue. We created a decision matrix to test these two against each other. They were both attractive options, but in our research, we found it easier to understand Vue's documentation. Therefore, we felt that the learnability was higher and learnability was important for our project.

We knew we would need a graphing solution, so we also looked into tools that helped achieve this. We worked through a similar problem of comparing chart tools. We compared Apex Charts, Charts.js, and D3.js. D3.js was by far the most powerful, but required a great deal of learning as every chart was custom built. We liked the look of Apex Charts the most, and once again thought it had the easier documentation to follow.

Outcome and Deviations

Purpose and Problem

The purpose and problem that our application addressed changed a little bit throughout our project. We pivoted to focus solely on return on investment calculations and optimization rather than including a calculator that allowed users to input all variables and see what that may produce. This was done in part from feedback by Greenwave and in order to streamline our project and focus on usability, both for potential customers and Greenwave. It allowed us to create a technical yet user friendly application.

We also were not able to get connected to Greenwave's database information. Instead, they provided us with an example .CSV which contained consumption data from a building they monitor.

Stakeholders

The stakeholders and target customers did not change from our initial targets. Our focus was industrial customers with a knowledge base in the app to provide support to any residential or inexperienced users.

Timeline

The actual timeline of our project lined up closely to how we had planned it in our original Trello Kanban and Gantt chart. We spent the first semester exploring and researching solar power and data sources, solidifying our technology stack, building our initial solar model, and getting the web application up and running. This all went smoothly and allowed us time to set up return on investment calculations and optimization in the second semester.

Our second semester timeline involved improving the solar model calculations, setting up return on investment calculations and graphs, and a comparison of different solar panels and configurations to determine optimized installations. All of this was done in order as written with documentation and meetings throughout. We met all of our original goals except for the real-time data processing which would have included forecasting and day-of data processing. This was dropped as real-time data sources were prohibitively expensive.

End Product

The end product we created accepts inputs under a few different categories. Firstly, it requires the user to enter latitude and longitude data, select a location from a map, or enter an address. This is so the historical solar data can be retrieved for that specific area. Next, the consumption data for that location is required to be uploaded in CSV format.

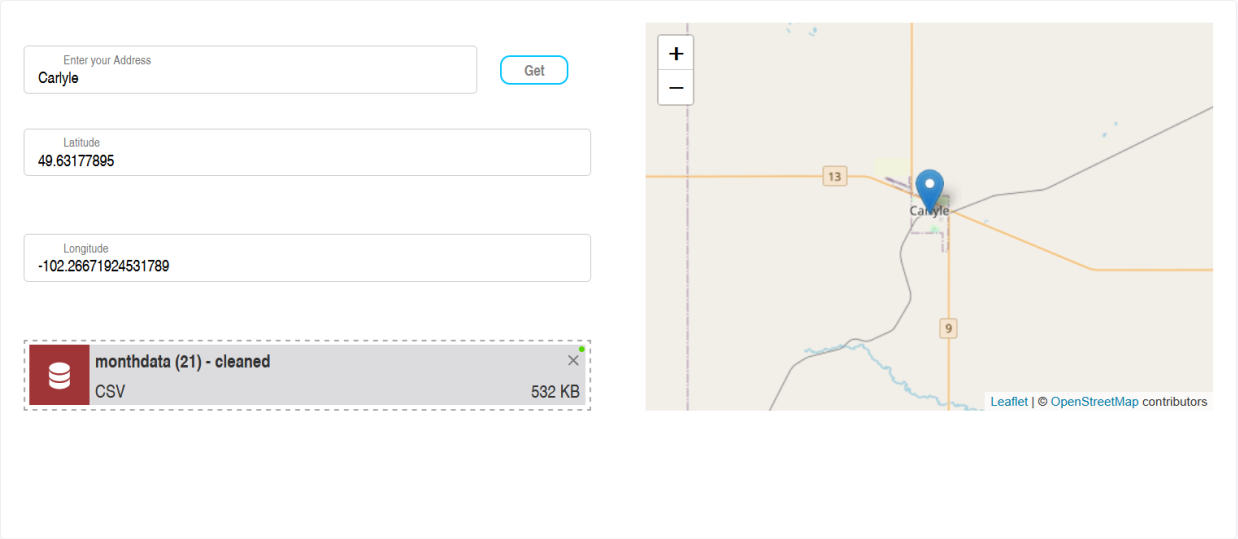

Figure 1. Location and Consumption Inputs

Next, the users must specify details relating to their options for solar panels. The application provides three default solar panels, but the user is free to add or remove panels if needed. The solar panel information consists of: name, module efficiency, panel area, cost ,and wattage. This information will alter the estimated solar production.

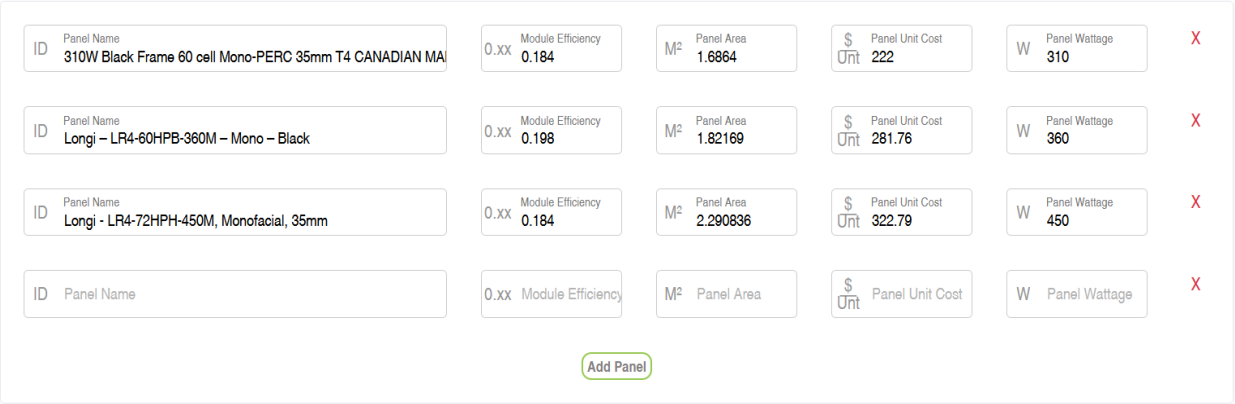

Figure 2. Solar Panel Specification

Financial and roof details are requested in the next section. The available roof area is the maximum amount of space available to install solar panels, specifying the upper bound limit of how many panels can be installed. The roof direction is the direction the panels will be installed. The financial details include any loan interest rate, the total value of available grants, and the cost of a kWh.

The roof details will change the estimated power generated and the financial details will move around the math on the return value.

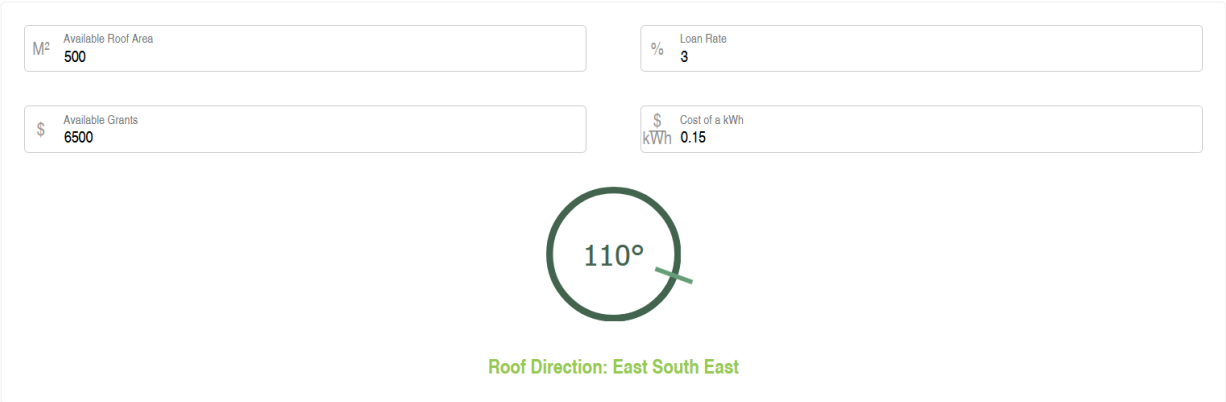

Figure 3. Roof & Financial Inputs

The final input a user needs is the analysis dates. The analysis dates consist of the start and end date. The analysis dates will alter the estimated generation value as different times of the year receive different amounts of sunlight.

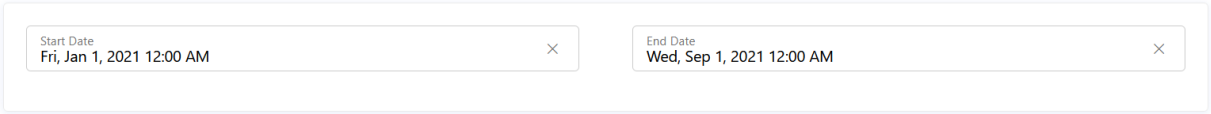

Figure 4. Analysis Period Inputs

After receiving the inputs, the application creates a summary of its calculations. The first data showcased are statistics about the calculated optimal solar installation. These include the total return value of the installation, the breakdown of value between overgeneration vs. full-credit, the total amount of power generated, and a monthly breakdown of power generated.

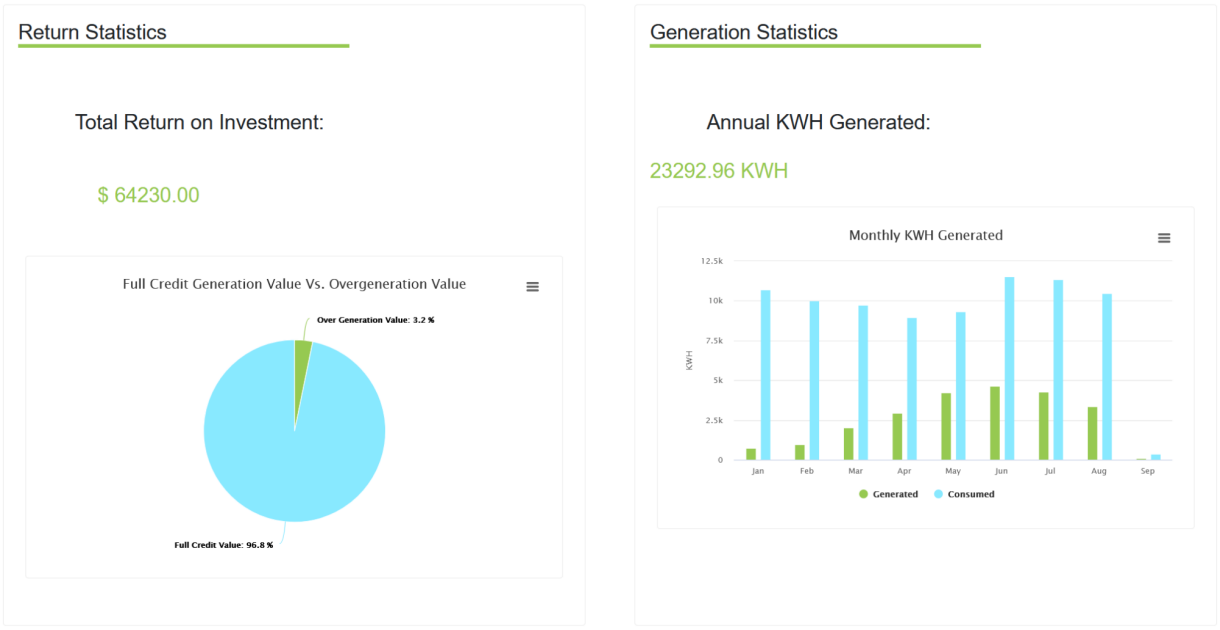

Figure 5. Summary Statistics Outputs

The summary page also indicates the optimal solar panel setup for the user, using their inputted solar panel options.

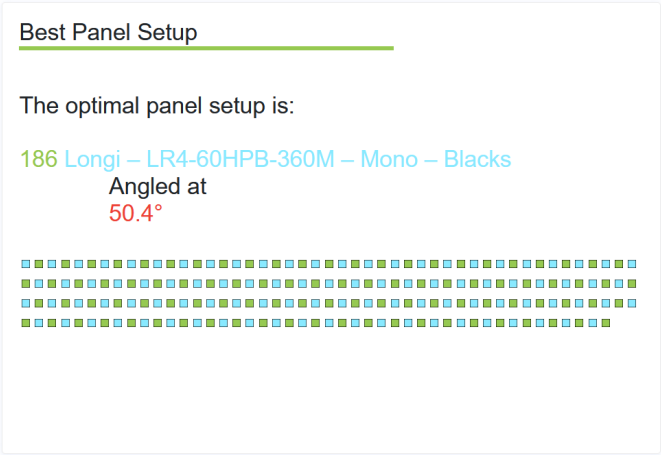

Figure 6. Summary Statistics Outputs

The summary page also breaks down the cash flow of the installation over a 20 year period. The cash flow in figure 7 highlights the individual contributing factors of the purchase. These include capital cost, maintenance cost, interest cost, value of power saved, and remaining balance. Each of these can be toggled off or on. Figure 8 also shows the remaining balance, but cuts out the individual contributions, leading to a cleaner look.

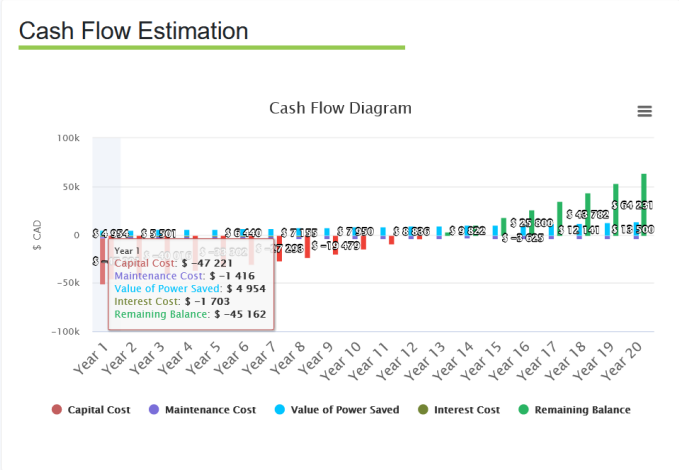

Figure 7. Cash Flow Breakdown

Figure 8. Yearly Remaining Balance

The final summary output provided is an hour by hour comparison of consumption data vs. estimated power generated. This graph showcases the analysis period, quickly allowing a user to visualize what the general ‘trend’ of solar power generation will be.

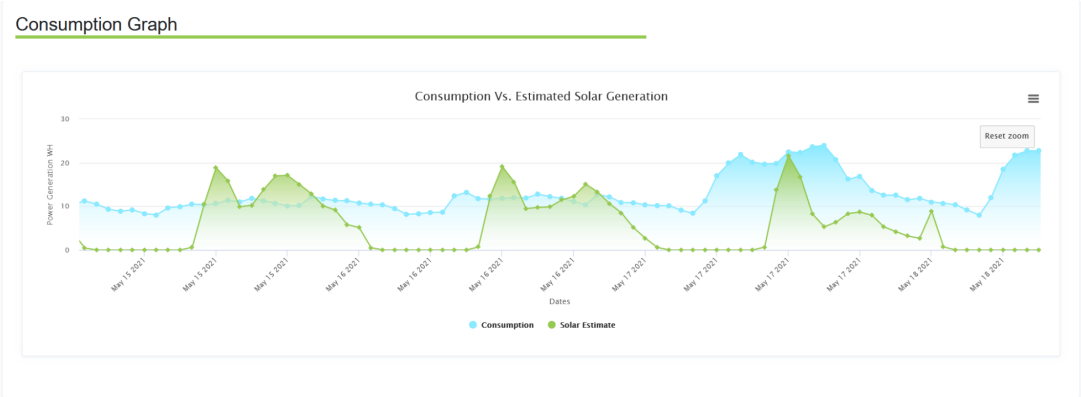

Figure 9. Comparison of Consumption vs. Estimation

Lessons Learned and What Went Well

Research and Complexity

From the beginning of our project, we had to research in order to learn, understand, and implement the model and calculations associated with solar power. It quickly became apparent that the black box of solar power and photovoltaic panels was something that we had to delve deep into to understand the basics.

This led to an overwhelming feeling that we knew next to nothing on the topic and it would be impossible to decipher what we needed to do. Fortunately, we learned that handling complexity in research such as this is something that is best done one step at a time. We found some great resources that enabled us to implement our own solar model using a variety of

equations and methods. It is important to focus on the small steps rather than the big picture, just as was done with the project MVPs.

Utilizing New Technology

Our project stack largely consisted of technology that was new to all of us. Our project largely consisted of Vue.js, Highcharts, Laravel, and Python. While we had some experience with Python, the rest of the stack was completely new to us. This meant that we had to learn as we went, following tutorials and making mistakes along the way.

We found out early that it might not have been the best idea to try and learn new frameworks and technologies especially for the base of our program with both Laravel and Vue.js. However, the project timeline allowed for some breathing room and we spent the first term learning and applying the new frameworks and technologies. This went very well and by the second term we knew how to use everything. We enjoyed learning along the way and learned that it was acceptable to base a project on new technologies as long as you have time to adapt and overcome any challenges along the way.

Scrums

Accountability and continual progress were integral to ensuring we met deadlines and produced the application that we envisioned. We had weekly team scrums on Fridays which provided us with time for discussions and feedback on each person's individual work. This acted as a push off to ensure we all got our own work done. We also had our weekly/bi-weekly scrums with our project advisor, Dr. Timothy Maciag. These were important to ensure that we were on the right track and to get outside feedback when needed.

We also had intermittent meetings with our project mentor, Dr. Kin-Choong Yow, and business partner, GreenWave Innovations, when necessary. These focused on presenting our advancements and answering any questions that they had. They also acted as valuable feedback points and provided clear guidance to meet our project purpose and vision.

Feedback and Adaptability

As our project was done in partnership with Greenwave Innovations, we looked to them for our project idea and general direction. Due to miscommunication on our end and theirs, we ended up needing to pivot fairly dramatically from a custom solar panel installation calculator to an optimized solar panel installation solution with a focus on return on investment. This was done in the second term, so we did not have much time to stop and think about it.

We were understandably challenged by this, however we did not let it bring us down. We set to work on creating an optimized solar panel installation algorithm that focused on return on investment and within two weeks were back on track with a working MVP. This was a great learning experience that showed us how things work in the real world. There are

miscommunications and misunderstandings and recovering from them is a matter of focusing, working hard, and continuing on the way forward.

Frameworks

The surface level answer to what we learned from this project is related to our frameworks. We used two new technologies in the process of creating this project. As we used them, we learned about two exciting and relevant tools. Both Vue and Laravel are currently very popular tools in industry. Being able to have experience working with these tools could lead to job opportunities.

The downside is that we spent a lot of time grappling with the code instead of designing and making a product. As we developed, it took additional time looking at tutorials and documentation trying to find a way to achieve our tasks. It also led to more refactoring, as mistakes in design were made frequently and had to be rectified. Overall, we may have still picked Vue and Laravel but using an unknown technology is something we will consider in more depth for future projects.

What Will We Take With Us Going Forward

When planning for and implementing projects in the future, we will ensure we clearly define our expectations and goals; integrate weekly scrums and pair-programming from the beginning; and accurately account for the time required to learn new technologies.

While we had a good understanding of the product we were hoping to create, we could have documented our goals in more detail to avoid misunderstandings between ourselves as a team and with our company advisor. In the future, we will aim to always verify that each person has the same understanding regarding any new information. We believe this will save us time when we are working on projects in the future. Clearly defining our clients expectations regarding their involvement with our future projects will also help us to account for any time that will be needed to research industry related knowledge.

We found that we were more productive and gained a more cohesive understanding of our project and application when we began having weekly meetings and pair-programming sessions. In future projects, we will aim to include weekly meeting and pair-programming sessions into our schedule from the beginning of the project. We recognize the value they provided and believe they will lead to successful future projects.

Even though we recognized that learning a new technology would require extra time, we did not accurately estimate the amount of time it would actually require. In the future, we will make sure we do not underestimate the amount of time it will take; if anything, we will allocate extra time for learning the new technology to ensure we have enough time. We also think that it would be useful to do combined knowledge acquisition, so that we all gain the same understanding of the technology.

Advice for Future Groups

Ensure your team has a clear and uniform idea regarding the desired outcome and goals of the project. If each team member has varying understandings of what needs to be accomplished, time may be dedicated to working on features that do not meet the project vision. Varying expectations may also result in an incohesive end product. In order to avoid issues with mismatched understandings, it is a good idea to document a list of features that should be included in the end product. Each feature should be described in as much detail as possible to outline the expected functionality and purpose. Once the features have been documented, team members can refer to the document to ensure they are implementing the feature as desired.

It is helpful to meet as a group as often as possible. Consider scheduling a weekly meeting that will act as an informal scrum. Even though you may not have accomplished a large amount in one week, the meeting will allow you to make sure everyone has something to work on and will keep everyone on track and accountable for the work they have been assigned. The purpose of the meeting can be adjusted as needed; for example, one week it may be a short meeting used to check-in with each other whereas another week it may be used to discuss any issues or struggles someone has encountered. Either way, a weekly meeting will be more beneficial than one may realize.

When you are developing the application, take the time to do some pair-programming especially if your team is using a new development environment or multiple team members are working on interconnected components. While it is not realistic to perform all development in pairs, working on interconnected components with each other will allow for open discussion regarding the best way to connect the components. It will also foster a better understanding of how the individual components work and are implemented. Pair-programming will be very helpful when using a new language or environment because team members may have gained different knowledge and insight that other team members need to understand in order to work on interconnecting components. Pair-programming may also lead to quicker solutions because one team member may provide a perspective or implementation approach that the other team member would not have thought of.

Closing Remarks

Project Definition and Communication

After deciding on a project idea, ensure you can clearly indicate what problem you are aiming to solve and how your proposed solution is different from tools already available in the market. If both questions cannot be answered, the idea may need to be reevaluated or modified. Once you have a finalized project idea, document your vision for the project, project goals, and plan. Also, begin to complete the project initialization and planning documentation as soon as possible. The documentation process will force you to explore all aspects of your project early on and should help you gain a better understanding of your overall project or expose any issues

you may encounter. In the end, you want to have a very clear understanding of your project and what you hope to develop as an end product. A well-defined expected end product will be easier to break down into increments and MVPs.

Do Not Be Afraid to Change

If you have concerns or doubts about your project idea after starting to work on documentation, do not be afraid to consider changing your project idea. While it may seem like it will be a setback, changing your project idea in the early stages is not a big deal, especially if it results in a better project idea and end result. That being said, ensure you remain on top of your documentation so that you can still meet deadlines. If you feel like you want to change your project but do not have other ideas, ask your mentor. They may have topic suggestions that they believe will make interesting projects. You can also consider reaching out to companies to see if they have any upcoming projects that you could help out with.

Clearly Define Expectations When Working With a Company

If you reach out and agree to a project with a company, ensure that you clearly define your expectations for guidance, help, and knowledge transfer on their end. The project you are working on with the company may very well not be your area of expertise. However, you will most likely require industry-related knowledge in order to complete the project. In which case, you want to ensure that the company will provide you with the industry-specific knowledge you need to complete the project otherwise you will spend a lot of extra time doing industry research. Being provided with the knowledge as opposed to having to research it on your own will allow you to spend more time developing. If you can spend more time developing then you can implement more features and functionalities as well as produce a better overall product.

Acknowledgements

We would like to acknowledge and thank Dr. Timothy Maciag and Dr. Kin-Choong Yow for their guidance, feedback, and support throughout the completion of our capstone project. Dr. Timothy Maciag provided invaluable insight into people-centered design aspects of our application such as suggesting the inclusion of explanations regarding industry specific knowledge resulting in a more user friendly interface. Dr. Kin-Choong Yow encouraged us to explore project options beyond our initial idea leading to the selection of our current project. We would also like to acknowledge Greenwave Innovations for suggesting our project idea and providing sample consumption data for testing purposes.