Supplemental Materials

for

Taking the Power Back: Designing a Replicable Neighborhood Grid

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Project Team:
Rishi Gupta
Deanna Rice
Anavat Siamwala

Faculty Advisors:
Professor Lindsay Davis
Professor Lorraine Higgins

Liaison:
Australian Energy Foundation

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Supplemental Material A: CHP

Another consideration for microgrids to increase their efficiency is the usage of combined heat and power (CHP) or cogeneration. This utilizes the waste heat created by generators to power the HVAC (Heating, Ventilation, and Air Conditioning) system of a building, resulting in less of the total energy being wasted. This reusage drastically increases the overall efficiency of a microgrid's generators, since waste heat is where energy is commonly lost.

Supplemental Material B: Comparisons of Key Features between AC and DC systems

Impact Factors	AC Distribution System	DC Distribution System
Transmission of Power over Short Distances	There is a significant power loss in line hence AC system is less efficiency	It has better efficiency hence good for power transmission for short distant
	More number of conductors required for specific amount of power transmission	Less number of conductors requires for specific amount of power transmission
Stability and Synchronization	External disturbances effect on stability, real & reactive power can manage microgrid stability independently & synchronization between DGs and utility grid is required	DC distribution system is free from stability and synchronization problem where the voltage sag is directly consequences of real power flow over power line
Reluctance	Reluctance is present in AC line	DC line is free from reluctance thus capable to transmit more power
Frequency (50 Hz or 60 Hz) / Health Concerns	Monitoring of AC system is required as it fluctuates continually	Frequency monitoring is needless as DC has zero frequency
	Line inductance and switching introduces transient stability concern	Absent of transient stability concern
	Electromagnetic interference produces health concern	There is no electromagnetic phenomena is DC system to produce health concerns
Resistance	In AC system, the line resistance is high	It has minimum line resistance
Susceptance	A huge concern of charging current and over-voltage problem	Those problems do not exist in DC system
Analysis	The analysis of AC system requires dealing with complex numbers, hence it is tough	DC system analysis has only real numbers i.e. simpler
HVDC (High	It is suitable for HVDC transmission	It is not suitable for HVDC transmission

Voltage Direct Current) Transmission		
Long Distance Power Transmission Ability	AC power can be transmitted over long distances	Inappropriate of this application
Reactive Power	Need to monitor reactive power continuously	Reactive power is absent in DC system
Skin Effect	Need bigger cross sectional area conductor due to skin effect	No skin effect on DC system so small cross sectional area conductor will work
Corona Effect	More Corona losses on AC line	There are tiny losses from Corona effect in DC line
Protection System	Simpler, cheaper and matured protection system	The protection system is complex, expensive and not matured enough
Maintenance	Maintenance is easy & inexpensive	Maintenance of DC substation hard and expensive
Transformer	Voltage level is adjustable using transformer	Transformer is not applicable in DC system
Capacitance/ Inductance Effect	Power losses on lines during no load/open circuit	No capacitance/inductance effect
Telecommunication Interference	AC system has telecommunication/wireless network interference	DC system has no telecommunication/wireless network interference
Efficiency	Less due to too many conversions	More due to less conversion
Noise and Danger	More noisy and more danger	Less noisy and less danger
Conversion Losses	DC to AC conversion loss is less	AC to DC conversion loss is more
Peak Voltage	Higher (1.4 times) than nominal value	Same as nominal value
Control Method	Direct Power Control in AC systems	Indirect power control in DC system
Blackout / Voltage Sag	During blackout/voltage sag AC system is affected	During blackout/voltage sag DC system is unaffected
Variable-Speed Drives	It is hard to obtain variable speed control	It is easy to obtain variable speed control

Supplemental Material C: Advantages and Disadvantages of Energy Generation Methods

Type	Description	Advantages	Disadvantages
Solar Panel (PV)	Panels consisting of photovoltaic cells which convert sunlight into electricity	Renewable	Currently inefficient
		Decreasing prices due to market growth	Variable output
		No fuel requirement	Weather dependent
Small Wind Turbine	Blades which convert rotational motion into electricity	Renewable	Weather dependent
		No fuel requirement	Variable output
			Location dependent
Hydrogen Fuel Cell	A chemical reaction converting hydrogen and oxygen into water and electricity	Can be renewable	Very expensive
		Capable of CHP (Combined Heating and Power)	Low efficiency
		High peak power	
		No greenhouse gas emissions	
Internal Combustion Engine	Standard generator that uses a combustion reaction to move pistons to create rotational energy	Reliable output of energy	Nonrenewable
		Simple mechanism	Noisey
		Capable of CHP (Combined Heating and Power)	Particulate and greenhouse gas emissions
		Widely implemented	

Supplemental Material D: Advantages and Disadvantages of Energy Storage Methods

Type	Description	Advantages	Disadvantages
Li-Ion Battery	Standard battery which stores electricity as chemical potential energy	Reliable	Flammable electrolytes
		Well known/established	Variable lifetime depending on discharge
		High energy density	
		Fast charge-discharge cycle	
Hydrogen	Hydrogen gas stored in an appropriate tank	Virtually no standby losses	Very expensive
		Good for long term storage	Low efficiency
		Potentially large storage	Highly flammable gas
Flywheel (Kinetic Energy Storage)	Electrical energy is converted into high speed rotational energy	High efficiency	Limited time for discharge
		Fast charge-discharge cycle	High standby losses over the course of a day

Supplemental Material E: Evaluation of Energy Monitoring Systems Based on Background Research

System Name (Company)	Other Information	Monitor Energy?	Control and Allow Energy Transactions ?	Communication System	Includable Hardware	Capital and Installation costs for software (AUD per household)*	Capital costs for total package with included hardware (AUD per household)
MicroEM (Greensync)	Peak Response Unit may allow for autonomous energy transactions	Yes	Yes	3G/4G Cellular network	-Greensync's Peak Response Unit -Selectronic Inverter -Fronius solar inverter	To be Determined from Company Questions	To be Determined from Company Questions
Ubi (Mondo Power)	Ability to Control Household Appliances	Yes	Yes	Wifi	-6kW solar cells per home -10 kwH lithium ion battery per home based on Yackandandah microgrid. Unsure if monitoring system has to be purchased with this package.	$830	$30,823
Reposit system (Reposit Power)	Not compatible with Tesla Powerwall 2 or Sonnen batteries.	Yes	No	Wifi	Smart controller energy monitoring box per home	$329	Not Applicable
xGrid (Power Ledger)	Deals directly with the main grid and has to coordinate with consumers and main grid's energy distributor	Yes	Yes	Wifi	Not Applicable	To be Determined from Company Questions	Not Applicable

Microgrid plus system with Powerstore (ABB)	Compatible with Communal battery storage	Yes	Yes	Wifi	-Powerstore Power conversion system (inverters) -Lithium ion batteries ranging from 365 to 7380 kWh.	Varies from $2-3 million for total system, household cost depends on no. of participating homes	To be Determined from Company Questions

Supplemental Material F: Community Electricity Retailer

Another key financial governing component of the Yackandandah grid that was considered for Halpin Street's neighborhood grid is the community electricity retailer. Under current Victorian law, a community electricity retailer is required to help control and facilitate electricity transactions between homes in a microgrid. The community electricity retailer in the Yackandandah microgrid is responsible for purchasing electricity into the neighborhood grid from the National Energy Market (NEM) or the main grid when households are consuming more energy than the system can provide, conversely the community electricity retailer is also responsible for selling surplus energy back to the main grid. Mondo Power's ubi software will be used by the community energy retailer to create a fair credit and debit system for energy generation and consumption, establish a fair price for electricity when trading between homes, and evenly distribute the cost of 'top up' or excess electricity purchased from the NEM among homes in the Yackandandah neighborhood (McGowan, 2018). Another financial aspect the community electricity retailer is responsible for is to offer a low interest financing option for residents to purchase microgrid components. However, to operate based on these responsibilities, the community electricity retailer must possess a certain amount of financial resources. As such, new particiting homes on the Yackandandah neighborhood microgrid are required to pay a 100$ membership fee(*ibid.*). Community electricity retailers were considered for Halpin St. once the interests and financial resources of the residents were further analyzed since it is required by law. Having a community electricity retailer would allow for an external regulator to control the street's financial details on energy transactions and reduce the amount of financial planning the residents must undertake to successfully control the neighborhood microgrid.

Supplemental Material G: Consent Preamble

We are a team of students from Worcester Polytechnic Institute in the United States. We are interviewing residents of Halpin Street to assess the interests and desires of this community in the development of the Halpin Street microgrid, as well as evaluating available resources and power consumption patterns.

Our research and this project is sponsored by the Australian Energy Foundation (AEF). You will be asked about your home's electricity supply and consumption, and your expectations and interests for this project. Your participation in this interview is completely voluntary and you have the right to skip any question or end this interview at any time. The process should take no more than ten minutes.

By completing this interview, you affirm that you are at least 18 years old, that you are the first to complete this interview for your household, and that you consent to have your responses included in our research. We may use your input responses in our final report, but we will not be disclosing any of your specific financial information. You will also be given the right to review any section containing such information prior to its publication (for logistical reasons, this requires you provide us with an email address). If you have any further questions or concerns regarding the project or interview, please do not hesitate to contact us at gr-B19AEF@wpi.edu.

Supplemental Material H: Halpin St. Neighborhood Grid Summary for Resident Interview Questions

The Halpin St neighborhood grid is a community-led project for trading renewable energy on Halpin Street. The goal is to generate energy through a series of solar panels on separate roofs, then trade the energy produced among neighbors, with the appropriate cost structure to encourage generation and local trading. Creating this system (called a neighborhood grid) would also require a system for storing the excess solar panel energy in a distributed set of batteries or in a shared neighborhood central battery. The project would enable a group of residents to spend less on electricity, buy more efficient and smaller solar and battery systems, and lower their environmental footprint.

Supplemental Material I: Initial Questions on Financial and Technical Features of Microgrid Products offered by Australian Energy Technology Companies

Introductory note in email:

We are a group of students from Worcester Polytechnic Institute (WPI) seeking information on products for microgrids by your company for our research project. Our project is to aid in the design and development of a neighborhood microgrid in Halpin St Brunswick West, outside of Melbourne. We have compiled a list of questions focusing on the technical and financial aspects of your products, which should take no longer than 10 minutes to answer. The responses may be shared be with residents in the Halpin St. community and members in the AEF(Australian Energy Foundation).

The Halpin Street neighborhood microgrid is a community-led project for trading renewable energy on Halpin St.. The goal is to generate energy through a series of solar panels on separate roofs, then sell excess solar to other neighbors, with the appropriate cost structure to encourage generation and local trading. This would also require a system for energy storage through a distributed set of batteries or a shared neighborhood central battery. The project would enable a group of residents to spend less on electricity, buy more efficient and smaller solar and battery systems, and lower their environmental footprint.

We greatly appreciate your input on this matter, if you have any further questions about the specifics of the project please do not hesitate to contact us at gr-B19AEF@wpi.edu.

Greensync Specific Questions:

Technical

1. Are the MicroEM software and Peak Response Unit systems installed as part of a package with solar panels,lithium ion batteries, and inverters for neighborhood microgrids?
2. Can the peak response unit autonomously trade and purchase electricity from other homes in a neighborhood microgrid depending on how much energy has been stored or generated?
3. Are there applications to access MicroEM monitoring data on smartphones, tablets, laptops etc.?

Financial

4. If yes to question 1, what is the capital and installation cost of a sample package per household?
5. What are the capital and installation costs of the MicroEM software with the Peak Response Unit?
6. Are there applications to access MicroEM monitoring data on smartphones, tablets, laptops etc.?
7. Does Greensync have a system to pay upfront for system maintenance and installation costs, and have monthly charges for consumers based on their energy consumption?
8. Were the Mooroolbark Microgrid trials partially funded by government incentives or grants? If so, which ones?

Ovida Specific Questions:

Technical

1. Is Ovida able to install solar panels and energy management systems in a residential neighborhood microgrid for non-tenanted homes?

2. If yes to question 1, is Ovida's energy management system able to display energy generation(from their solar panels) and storage data(from their lithium ion batteries) to homeowners through applications on smartphones ,tablets,laptops etc.?
3. If yes to question 1, Does Ovida's energy management system for microgrids allow for to trade and purchase electricity between other homes?
4. Is Ovida able to install inverters and lithium ion batteries when installing a microgrid system for a neighborhood?

Financial

5. If Ovida is able to install the components mentioned in question 3, does Ovida's PPA also apply for the energy management system and these additional components when installing a neighborhood grid?
6. What is the average electricity generation cost rate from solar panels installed under Ovida's PPA?

Mondo Power Specific Questions:

Technical

1. Does the Ubi software allow for electricity trading between consumers connected together in a microgrid? If yes, does the system have the ability to automate purchases or transactions?
2. Does Mondo Power install a hardware monitoring unit that sends data to the Ubi software system?

Financial

3. Does Mondo Power install the Ubi software as part of a package with solar panels, lithium ion batteries, and inverters? If so, what is the average cost of such a package per household?
4. What is the average capital and installation cost of the Ubi software per household?
5. Does Mondo Power have a system to pay upfront for system maintenance and installation costs, and instead have monthly charges for consumers based on their energy consumption?

ABB Specific Questions:

Technical

1. Is ABB able to install their Microgrid Plus Control system for residential homes in a neighborhood microgrid setting in the Victorian region of Australia?
2. Is the Microgrid Plus Control system only compatible with ABB's powerstore central battery storage system?

3. If yes to question 1, is ABB's Microgrid Plus Control system able to display energy generation(from their solar panels) and storage data(from their lithium ion batteries) to homeowners through applications on smartphones ,tablets,laptops etc.?
4. If yes to question 1, does ABB's Microgrid Plus Control system allow for consumers to trade and purchase electricity between other homes?
5. Is ABB also able to install solar panels as part of a package with the Microgrid Plus control and powerstore battery systems?

Financial

6. What is the average capital and installation cost of ABB's Microgrid Plus control system?
7. Does ABB have a system to pay upfront for system maintenance and installation costs, and instead have monthly charges for consumers based on their energy consumption?

Power Ledger Specific Questions:

Technical

1. Is Powerledger's xGrid system able to allow for energy trading between homes in a neighborhood microgrid setting (where homes are connected together on a separate grid)?
2. Does Powerledger need to install a hardware measuring unit to measure energy transactions being sent to and from households?
3. If yes to question 2, are the houses also able to monitor their energy generation(from their solar panels) and storage data(from their lithium ion batteries) through an application on smartphones ,tablets,laptops etc.
4. Are households able to view their energy transactions and purchases through an application on smartphones,tablets,laptops etc.?

Financial

1. Can individual households purchase the xGrid system?
2. If yes to question 1, what is the capital and installation cost of the xGrid system per household?
3. If no to question to 1, is the area's energy distributor able to purchase the xGrid system and distribute the charges of the system to households accordingly?

Supplemental Material J: Objective 3

User and Task Analysis:

- What your users' goals are; what they are trying to achieve
    - We plant to utilize these points while decision making in Halpin Street as a model for the users and their needs
- What users actually do to achieve those goals

    - In our case, these groups would need to first consider their current energy consumption, then evaluating the personal cost of conventional and solar systems. Next, the need to see the cost each other household bears, and finally the collective decrease in price when collectively utilizing the energy system in the neighborhoods
- What experiences (personal, social, and cultural) users bring to the tasks
    - In this case, we will need to understand the thoughts of each individual and their input of the extent to which they want to be involved with the project. Another is whether they will be willing to house generation or storage systems.
- How users are influenced by their physical environment
    - This will need to be determined once we arrive as well because we do not know how they are influenced by their environment other than the fact some homes are better suited for solar panels than others.
- How users' previous knowledge and experience influence:
    - How they think about their work
    - The workflow they follow to perform their tasks

Generally, this analysis before drafting the how-to guide and provides an outline as to what you would be including in your guide. It begins with understanding who your intended users are and understanding what they want out of the medium. From here you define clear goals for the user and find the tasks in order to complete that goal. The tasks are defined by the procedural types. There are four main procedural types to be included in the outline under the required content to help to understand the structure of each user goal. These consist of:

Procedure Topics- Most of the documentation should be procedural where it is a series of step by step instructions.

Concept Topics- Each concept topic is meant to help choose a procedure or directly help perform one.

Workflow Topics- These are the overarching goals of the project that have subcategories of procedures.

Troubleshooting Topics- These are general overviews of potential troubles that should be documented and given a solution to help guide the user.

Here is our application for the residents who would be utilizing the how-to guide to designing their neighborhood grid.

- User-driven design
    - The idea of user-driven design is to organize based on user needs instead of what it is expected by conventional documentation to allow for accessibility for the specific user.

Ex: The user needs are determined once we are on through their answers from the survey, interviews, and interactive media.

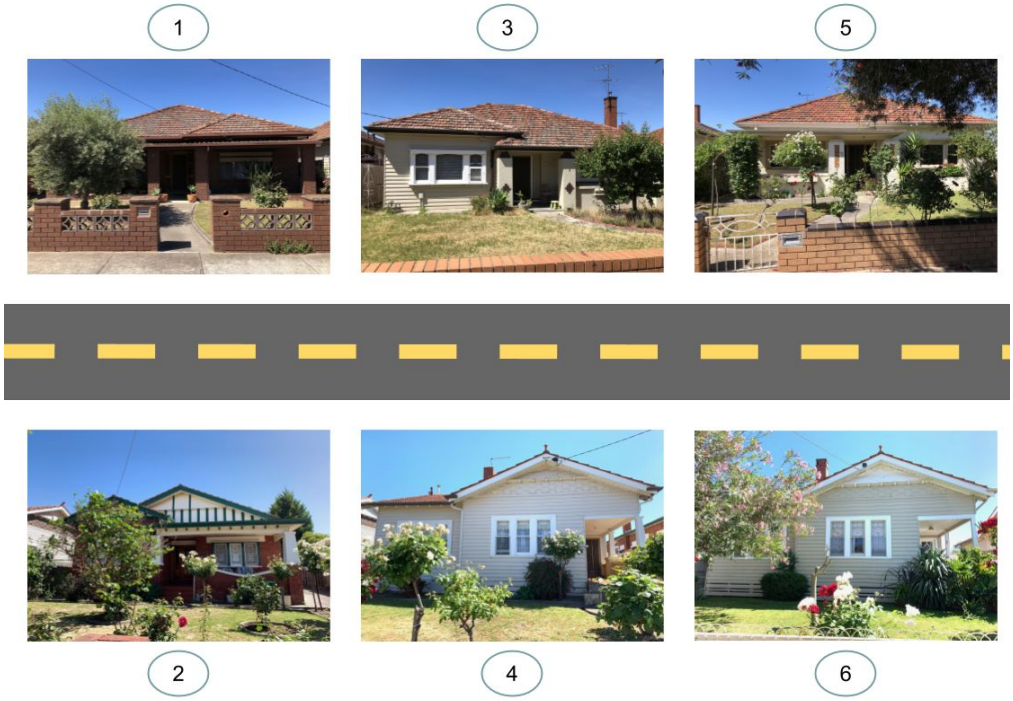
- Simple, Concise Wording
    - We do not want a lengthy text that is difficult to read for our users. This can be influenced by a variety of options. Below is a series of steps to be taken into consideration when writing a how-to guide.
    - Present Tense: It is common practice to talk in the present tense because it emphasizes the "who" and "what" of the action. This is to just provide clarity for the user.
      Ex: Solar panels are a source of renewable energy generation.
    - Active Voice: Active voice is encouraged wherever possible because it empathizes the result of action instead of the
      Ex: Turn on the power button (active). The power button is on. (Passive)
    - Second Person: Using 'you' whenever possible to provide clarity.
      Ex: You select the 'help' button on your screen.
    - Declarative Sentences for Points of Information: This allows background information or other points of information to be embedded within a procedure.
      Ex: The solar panel is initially placed on top of a roof.
    - Imperative Mood for Describing Tasks: "Use the imperative mood in all text that instructs the reader what to do or how to perform a task" ("Runstorm lecture notes", 2019).
      Ex: Place the solar panel on the roof.
    - Parallel Structure: Using similar syntax throughout the document just provides simplicity and professionalism.
      Ex: Lists containing the same structure at each point such as a verb than a noun for each.
    - Position of Modifiers: A Position Modifier changes the meaning of the word and if put into a different location it may cause different meanings as well. This will be avoided by having multiple teammates read through the document.
      Ex: The concept of a neighborhood microgrid is described in the novel. The concept of a neighborhood microgrid is described as a novel.
    - Infinitive Lead-Ins to Procedures: Every procedure needs a lead-in that explains the purpose of the procedure for the reader.
      Ex: The purpose of this section to understand how to turn off wifi on your phone.
    - Nominalization: Nominalization is using a noun form instead of the verb/adjective form. This is meant to be avoided in technical writing because it limits the direct, concise, and understanding of topics.

Ex: Interference is the nominalization of interfering. It causes to interfere to become a noun within a sentence, taking the action away. This is avoided because it removes the doing portion meant to guide others.

Here are the seven standing elements:

- EPPO topics are self-contained meaning they can be standalone and function on their own without the rest of the document. They tend to be made up of three elements- concept, reference, and task.
- EPPO topics have specific and limited purposes to have clear and defined boundaries of the topic covered in that section. Allowing the reader to go to a specific page and find the information they desire quickly.
- EPPO conforms to a pattern meaning they have a beginning, middle, and end that oversees the general information in a patterned story form.
- EPPO topics establish their context, this is meant to help the reader understand early whether or not they are in the correct location for the information they are looking into. This tends to be a heading with a short description of what is being explained below.
- EPPO topics assume the reader is qualified to a degree. This does not mean the reader knows everything, only that they know enough background to have a basic understanding of the topic they looked into within the guide.
- EPPO topics stay on one level. This is meant to have a topic stay on a single level of abstraction so topics are not becoming too broad and stick to the original purpose.
- EPPO topics link richly, following the bottom-up navigation method, providing quality, not quantity.

Supplemental Material K: Interactive Poster for Residents



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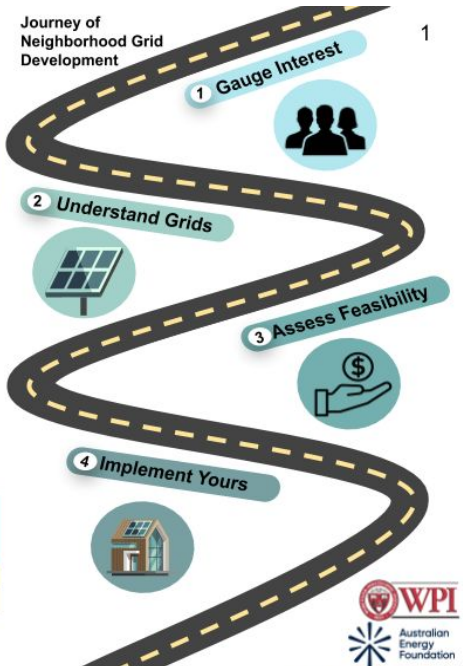
Supplemental Material L: Additional Resident Pamphlet Pages



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Making it Advantageous

- Saving immediately and optimizing energy usage
- Buying in bulk allows for a cheaper price and producing your own energy saves money
- Storing energy together to use in peak pricing hours to save money.
- Saving money by buy collectively renting an electric car to share

For ‘Unsure in Participating’ and ‘Not Interested in Participating’ categories:

Take Action- Your Next Steps

Next to this poster is a street view of Halpin Street. We are asking you to take the stickers from your pamphlet and place the corresponding sticker onto your home if you are going to help the environment and take action to help your community.The corresponding colors and their actions are listed below.

- Installing a Monitoring System
- Installing Solar Panels on Your Home
- Neighbourhood Battery
- Community Electric Car

- Independence from electrical companies
- Lowered electrical costs through community collaboration
- Reduced environmental footprint

For ‘Interested in Participating’ and ‘Somewhat Interested in Participating’ categories:

Supplemental Material M: Contributions

	Primary Contributor
Abstract	Deanna
Introduction	Deanna
Background	
Replacing Conventional Energy	Deanna
A Beginner’s Guide to a Microgrid	Rishi/Anavat
Microgrid Pilots	Anavat
Halpin Street Neighborhood Project	Anavat
The Australian Energy Foundation and its goal for a zero-carbon Australia	Deanna
Moreland’s Energy Plans	Deanna/Anavat
Regulations Applicable to the Halpin Street Neighborhood Grid	Anavat/Deanna

Methodology	
Objective 1	Rishi
Objective 2	Anavat/Rishi
Objective 3	Deanna
Results	
Objective 1	Rishi
Objective 2	Anavat/Rishi
Objective 3	Deanna
Recommendations and Conclusion	Anavat/Rishi
Roles: ● Author-Illustrator - Deanna ● Analyst - Anavat ● Project Manager - Rishi	