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EML4551-2

Team 521: Energy Demand Reduction Project

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Abstract

Florida State University uses a great deal of electricity to operate, costing the school millions of dollars each year. Our team is assigned to reduce FSU's costs by focusing on energy usage campus wide. The heating, ventilation, and cooling (HVAC) systems account for more than 60% of the school's total energy use. Our team looked for ways to reduce both the peak demand and consumption on campus. Our sponsor instructed the team to focus the project scope to FSU's central utility plant (CUP). At the CUP, there's the greatest opportunity to make an impact.

The objective is to reduce the energy cost of the CUP by at least 15% and provide solutions that will benefit the university. The team considered a variety of initial solutions such as large battery packs, replacing conventional lights, and incentive programs among others.

The team picked the solution that would save the most money which is a stratified chilled water tank. Adding a thermal energy storage tank would reduce the peak demand by having some of the chillers running at night when the school is using less energy. The cost to build this TES tank is around $6.5M and the estimated savings are at least $400k per year. This gives a return on investment (ROI) between 10 - 20 years. TES tanks last over 50 years and do not lose efficiency over time like batteries and other storage methods.

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Disclaimer

Acknowledgement

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Chapter One: EML 4551C

1.1 Project Scope

The objective of this project is to reduce the energy cost of FSU's central utility plant by reducing the energy required to be supplied at peak hours or reducing overall electric consumption. The project description asks the team to design a system for saving FSU money at their central utility plant.

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Key Goals

The primary goal is to reduce annual utility cost of the C.U.P by at least 15%. The team's solution must have a Return of Investment (ROI) of 20 years or less and reduce peak demand charges by implementing energy storage technologies. Perform data analytics on FSU Facilities to aid in the generation of a current financial state to compare to our forecasted financial state, also perform multiple energy audits of the C.U.P. Formulate a professional executive presentation to be presented to FSU's decision makers and Trane which will include all findings and proposed solutions. The team will investigate all possible solutions to FSU's energy problem and propose a solution which will require minimal initial investment while providing maximum energy savings.

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Markets

Markets include medium to large corporate office buildings, colleges and universities, government buildings, healthcare, data centers, and other commercial real estate. Comfort cooling and heating is a necessity world-wide. The primary market will count as Florida State Universities

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Central Utility Plant with the secondary markets being other utility plants on FSU's campus and the formerly mentioned.

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Assumptions

The team has assumed that no physical prototyping is required, no hard budget on the final plan and no installation preventions. The project will only be applied to the Central Utility Plant, not to other places around FSU campus.

Stakeholders

The parties affected by the outcome of this project include our sponsors TRANE and Ingersoll Rand, our assigned adviser Dr. Juan Ordonez, the overseeing professor Dr. Shayne McConomy, FSU Facilities, Jim Stephens (Director of CUP), Florida State's President Thrasher, DN Stratified Tanks and the City of Tallahassee Utilities. These are all stakeholders in our Senior Design Project.

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1.2 Customer Needs

The team reached out to sponsors and potential customers to learn more about their needs for the project. We met with Jim Stephens and the Central Utility Plant at Florida State University to discuss the current system in place. Questions pertaining to current infrastructure, timeline, and expected results were discussed. The team also contacted the sponsor, Trane, to find out more about how they want the team to proceed and their expectations for us. Finally, the City of Tallahassee Utilities was contacted to determine how billing rates are structured for FSU.

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Table 1. Customer Needs table

Customer	Question	Answer	Interpretations
FSU Facilities	How can we reduce peak load consumption?	Find a way to store energy during non-peak hours and discharge it during peak hours	Energy is expensive during peak hours. If the plant can consume energy at low demand times and store this energy, money can be saved.
FSU Facilities	How can the solution be as aesthetically nice as possible?	Find a way in which our technical solution is pleasing to see for every student at campus	The final product can include an artistic element or a structure around it. The product is more than just functional but appeals to students/faculty that see it.
FSU Facilities	How much space do we have to work with?	The project can have the space that will be needed.	Based on the team project selection, it then can be established what amount of space can be used. It can either be in the CUP or near it or the satellites plants.

FSU Facilities	Are there any incentives or subsidies available to “green” projects and technologies?	That’s for you guys to find out.	Team will research available incentives for similar projects.
FSU Facilities	What brand of chillers does FSU have?	Trane	Any chiller modifications applies and comply to Trane’s chillers
FSU Facilities	How many chillers does FSU have?	21	About 20 percent of the chillers are excessive. Also, FSU has a lot of chillers and uses a lot of energy on them.
FSU Facilities	What is the maximum number of chillers needed on any given day?	80%	So, on the hottest of days, 16-17 chillers will have to be running at or near full load to meet the demand.

FSU Facilities	How much does FSU spend on Utilities per year?	Over 25M.	The national average says that 40% of total energy use is HVAC so if this holds true for FSU then that equates to 10M in HVAC related energy costs. It could be more or less once we obtain the data.
FSU Facilities	What steps are currently being taken to increase energy savings on main campus?	5 new chillers. Compressor overhauls on old chillers. Constant process optimization by Norman to make the loading and unloading of chillers most efficient.	FSU Facilities is always considering what to do in order to improve campus. The team can introduce new or expand in their plan for the project.

FSU Facilities	Are there any OEM's (Original Equipment Manufacturer) that FSU will not buy from? (i.e. Cooling Towers, Thermal Storage Tanks, Batteries, HVAC Equipment)	No, there are no OEM's that FSU will not buy from.	The team is not restricted from considering implementing any equipment to improve energy efficiency and reduce costs.
FSU Facilities	Does FSU have any predetermined budget for increasing energy savings?	No. However, the solution that delivers the most savings with the least initial investment and minimal risk is preferred.	Budget is relative to risk and ROI. if a project is twice the price but 5x the savings then that is a better solution. If fsu can budget the money for it.
FSU Facilities	Can we have access to FSU's GIS (geographical information system) data?	Yes	The data from the geographical information system at FSU is available. This means the equipment and its information are

			known and can be analyzed for savings.
FSU Facilities	What amount of our current equipment is used normally in a day with a lot of energy demand?	FSU currently has 21 chillers in its facilities. In a day with a lot of demand, FSU uses 80 % of their facilities	In theory, FSU Facilities never reaches full capacity, since it is good engineering practice to have equipment support if something goes wrong.
FSU Facilities	What is an acceptable ROI for our proposed solutions?	7-10 years. Preferably 7.	7 -10 years. Preferably 7.
FSU Facilities - Trane	What particular device is the one with most power consumption?	Chillers/Boilers	This is where we will focus for maximum energy savings

Trane	What would you consider to be a successful project?	The team proposes a solution that Trane will be able to sell to FSU.	Come up with a feasible solution that FSU will be swayed to invest in.
City of Tallahassee Utilities	What is the cost structure in Tallahassee as it pertains to billing rates?	Email sent. Waiting for response.	Waiting for response.

From the answers provided by the customers, the team constructed an interpretation of needs which conveys information in more engineering terms and describes needs and not wants. The main takeaways from the interpreted needs so far are that comfort heating and cooling consumes the most energy at Florida State's utility plant, Florida State is concerned about return on investment, and there are a wide range of possibilities to save money at a central utility plant.

1.3 Functional Decomposition

Having identified the project direction through the established customer needs, the Energy Demand Reduction Plan was decomposed into a sub-set of functions to better identify ways to approach our end goal. The diagram in Appendix B (Figure 1) shows the resulting functional decomposition flow chart.

The overall goal of the system is to reduce the cost of energy expenditure, which would translate into saving money. The sub-systems establish two paths to approaching this problem. The sub-systems, which are Reduce Consumption and Reduce Demand, correlate to each other but can be worked as two separate approaches as well.

Reducing the Energy Consumption goes hand in hand with Reducing Peak Demand. If the consumption is reduced, the peak demand will reduce as well since they are directly correlated. In order to achieve this, different functions were identified and divided resulting in three separate levels: building level, plant level and user level. In the building level many possible solutions are already available to us, ranging from appliances to the infrastructure itself. In the plant level, an assessment of the current HVAC equipment will be needed beforehand in order to decide. Better equipment at the CUP will mean better efficiency in distributing and storing energy. Regarding user level, consumption will not change if the users aren't aware, which is why incentives can be formulated for the users in order to change their consumption behaviors.

Reducing the Peak Energy Demand will reduce the costs of the electric bill. This happens because the utility company must be able to supply the peak demand which stresses their generation plants, making them produce power less efficiently resulting in extra charge. It is possible to reduce the peak demand by finding solutions that generate power on campus to alleviate demand during peak hours and/or energy storage systems that can store energy during off-peak hours and release during peak hours.

Table 2. Functional Decomposition Cross Reference Table

F.D. Cross - Reference Table							
	Reduce Consmption (Wh)	Reduce Peak Demand	Improve Building Efficiency	Current HVAC Equipmen	Efficiency at User Level	Research Energy Generation	Research Energy Storage
Replace Inneffiecient Appliances	X		X				
Improve building infrastructure	X		X				
BAS Systems	X		X				
Replace Current Equipment	X			X			
Improve current equipment	X			X			
Add New Equipment	X			X			
Devise Incentives Programs	X				X		
Create Marketing Plan	X				X		
Utilize Renewable Resources		X				X	
Utilize Non-Renewable Resources		X				X	
Introduce Innovative Ideas		X				X	X
Utilize Thermal Storage		X					X
Utilize Electrical Storage		X					X
Conduct Energy Audit	X	X	X	X	X	X	X
Conduct Feasibilty Tests	X	X	X	X	X	X	X
Realize Cost/Benefit Analysis	X	X	X	X	X	X	X
Establish Budget	X	X	X	X	X	X	X
Apply Aesthetic Design	X	X	X	X	X	X	X

1.4 Target Summary

Assessing the customer needs provided critical information regarding the possible functions of the project. The targets and metrics were assigned to the functions to provide better and clearer goals for the project. The information required to establish critical targets was gathered though our sponsor, FSU's C.U.P., and group research. The team transformed the interpreted customer needs into the most basic components of functionality. These components answer the question what the plan must do. Next the team acquired numbers from sponsors, advisors, and our own research to attach to the basic functions of the project. Finally, the team determined a method for validation of the targets. Below is the target summary which includes the targets the team thought were most important, a full targets table is shown in appendix C.

After careful consideration, the team arrived at the conclusion that our four mission critical targets are reduce peak demand, reduce overall consumption, the return on investment (ROI), and saving money. The metrics for these targets are: percentage of kilowatts, percentage of watt hours, years, and percentage of money, respectively. The testing method that will be used are statistical software's, such as Microsoft Excel and Minitab, to optimize the data and produce forecasts. Resources needed to validate our solutions are any OEMs of any existing technologies we plan to suggest as well as the OEMs of the components we plan to use in our innovative solutions. We plan to utilize existing research and development (R&D) and apply it to our collected data.

1.5 Concept Generation

The team utilized crap shoot, a morphological chart and forced analogies to come up with a wide range of 100 concepts. Using these brainstorming methods, the team was able to achieve a higher spread of ideas that view the problem from multiple angles. A morphological chart was used to understand ideas at a system level, forced analogies helped diversify the ideas, and crapshoot was used to bounce ideas off of teammates to imagine new ideas. Also, the team incorporated starbursting, where questions are the focus of brainstorming without worrying about the answers, along with crap-shooting to communicate ideas.

Starbursting:

- How can FSU generate Energy at a cheaper cost than that supplied by Tallahassee Utilities?
- How can we incentivize faculty and students to be more mindful of their Energy consumption on campus?
- What existing technologies can be used to accomplish peak demand reduction and/or greater energy efficiency?

- How much space is available on campus to implement a large structure for generation or energy storage?
- What ideas can be used in collaboration with each other?
- What resources exist that can be used to make aesthetic designs?

Table 3. Morphological Chart

Reduce Peak Demand	**Reduce Need for Electricity**	**Increase efficiency of appliances/buildings**	**Other energy sources**
Thermal Storage	Student Incentives	Replace/Improve chillers	Waste compost
Store energy as potential	Requirements for Energy use	Centralize vs personal units	Convert exercise motion to energy
Solar panels	Use sunlight to light buildings	SunBlanket	Natural Gas
OnCampus Power Plant	Fewer People	Intelligent Appliances	Wind turbines
Thermoelectric generation	Reduce or stop consumption in big consumption buildings (AME, Mag lab)	Reduce usage of appliances across campus	Plants (bamboo)

Forced Analogies:

- Sloth is like a power plant because it attempts to use the least amount of energy for operation as possible.
- A Camel is like an energy efficient plant in that it can make a small amount of sustenance go a long way.

- Reptiles are like solar panels because they like to sunbathe
- Sleeping is like Energy storage during off peak hours because Energy is being stored at night to be used during the day

High Fidelity Concepts

1.) Stratified tanks for chilled water storage (DN Tanks is a preferred manufacturer). Stores thermal energy to pump chilled water through HVAC system to alleviate the consumption of energy from HVAC systems. In Florida chilled water will be vital in lowering the consumption of air cooling. Essentially, by having chilled water tanks, you can run chillers through the night to "charge" the tanks and during the next day "discharge" the tanks. This alleviates some of the load on the entire chiller plant system.

2.) Implement large battery packs which can be charged by various methods (can be from the grid) during off peak hours to be discharged during peak hours. The amount of power that will be needed to be stored will come from the grid, and that will be used in peak hours to offset FSU peak demand. The technology of the battery must be efficient and reliable, and it must store at least the amount of energy that it is needed in order to offset this consumption.

3.) Implement smart speed bumps. Use the kinetic energy in the cars driven around campus to actuate a piston or rotate a gear. Use this forced motion to induce a current in a coil. This acts as a generator and is supplied by cars driving over the "smart" speed bumps. This is renewable and the amount of energy generated is proportional to the number of cars, speed of cars and conversion of energy from kinetic to electric.

Medium Fidelity Concepts

1.) Replace lightbulbs with LED lights. LED lights require a larger initial capital investment but are much more efficient than standard incandescent light bulbs that are currently in use around campus. The LED lights require less energy to operate, this reduces overall consumption and offsets peak demand since lights are frequently used during this time period. All incandescent lights that can be replaced will be replaced by high efficiency LED lights

2.) Burn natural gas to generate energy to then store in batteries which will be discharged during peak times. Natural gas is a cheap commodity that can be burned on campus to generate energy to offset the peak demand.

3.) Incentive programs for reduced energy usage. This will encourage students to be more aware of when they are using energy and will lead to a reduced usage. Some incentives will be a lowered tuition rate, priority to football games, etc.

4.) Collect rainwater for irrigation and other grey water needs to reduce the amount of water utility needed from the city. (maybe rainwater could be used in cooling towers – heat rejection loop (only applicable at COE since main campus does not have cooling towers, they utilize the aquafer)

5.) Build a sunshade big enough to encompass the entirety of campus, effectively blocking all the sun's rays. This would lower temperatures on campus reducing stress on cooling systems.

A full list of the one hundred concepts can be found in Appendix D.

1.6 Concept Selection

Following the team's concept generation, the next task was to select the best solution from the 100 concepts. We accomplished this by evaluating our concepts and criteria with AHP, House of Quality, and Pugh Charts. It is important to note that the team decided to leave two medium fidelity concepts out of the analysis, LED lights and collecting grey water. Replacing lights with LED's was eliminated because the University is currently pursuing this project and rainwater collection was eliminated because the team was told to focus on electric utility.

The team utilized an AHP Chart to determine the ranking (or relative weights) of our criteria with which we use to evaluate our possible solutions. These criteria are the customer requirements obtained by the team earlier in the semester. The way that the AHP allows us to obtain the relative weights of each criteria is by comparing each criterion to one another and giving the comparison a "score" from 1-9, translating to how much more important one is to the other. Once this is done, the scores are normalized as a percentage and the percentages are averaged to find the weights of each criterion. This chart provides the team with actual data describing how much more or less important each criterion is than another, rather than simply stating that one is or isn't without providing a value to represent this relationship.

The criteria that we are using to evaluate our concepts are peak demand reduction, consumption reduction, return on investment, aesthetic design and reliability. Upon completion of our AHP chart, the team was able to conclude that return on investment was the most important criterion and reliability was a close second. The other three criteria were fractions of the top two and aesthetic design was deemed the least important of all. For the actual weights of each criterion, the teams AHP chart can be viewed in appendix E.

The team used the House of Quality (HoQ) to assist with translating the customer requirements into technical requirements and seeing how well the two correlates. To accomplish this task, first the team had to realize the customer requirements, which can be seen on the left of the house. Next, we translated the general customer needs technical requirements by being more specific. For example, one customer need was the solution we selected must be visually appealing. The team then translated this need to at least 75% of FSU's students, faculty, and staff would be pleased with the change we initiated. Next, we ranked the importance of each customer requirement on a scale of 1 – 5, with 1 being least important and 5 being the most important. Moving along, we identified relations between our technical requirements by comparing them against one another and determining if there was a positive or a negative correlation between our technical requirements, which can be seen in the roof structure of the house. The middle of the house highlights the relationship matrix, where customer requirements are compared to the technical requirements. To the right of the house, we completed a competitive assessment of our 3 high fidelity concepts to determine how well our concepts meet the customer requirements. Lastly, the bottom of the house depicts the raw score, relative percentage, and importance rank, which helped the team decide which requirement should be prioritized.

After completing the HOQ, the team concluded stratified tanks for chilled water storage would accomplish our customer needs the most. From our competitive assessment, stratified chill water tanks ranked the best for meeting our customer's requirements. The first choice was followed by installing battery packs and discharging them during peak hours. This concept was ranked fair when it came down to fulfilling the customer requirements reducing overall energy consumption and serviceability. We also concluded that reducing peak demand should be prioritized, followed by a close second place of saving a minimum of $100,000 a month.

The team used a Pugh chart to help compare concepts against each other for different criteria. The important criteria were return on investment (ROI), reliability, reduction of energy demand, reduction of energy consumption, and aesthetically pleasing design. Once the important criteria were determined, the team set a datum for the initial comparison. The current infrastructure and system used by Florida State's central utility plant was used as the starting datum since any concept selected should be better than what is in place now. From the first Pugh chart, the team eliminated concept 8, a giant sunshade, since it contained the most minuses and included a minus in reliability which the team deemed to be one of the most important criteria.

For the second Pugh chart concept 2, battery storage, was chosen as the datum because of its high plus to minus ratio and other concepts such as the speed-bump generator and solar panels incorporate this technology. The team eliminated concept 5, burning natural gas on campus, because it compared negatively against battery storage. For the third Pugh chart concept 1, thermal storage using DN tanks, was selected to be the datum because it had the most pluses and fewest minuses in the second Pugh chart. The third Pugh chart illustrated to the team that concept one compared the best to the other concepts based on the important criteria. The team decided to combine concept 1, thermal storage using DN tanks, and concept 6, incentives for using less electricity, because concept 6 is at no additional cost to the team and aids in reducing electric demand and consumption.

The charts mentioned above provided the team with an obvious winner for our concept selection. Stratified chilled water tanks are the best means of achieving the desired goals of this project while meeting the expectations of our customers/sponsors. The team would like to note that moving forward, we will also be investigating possible social experiment type incentive programs that could achieve consumption and demand reduction at little to no cost to the university.

DN tanks is a manufacturer of stratified chilled water tanks. Stratified chilled water tanks work by "charging" the tanks at night and "discharging" the tanks during the day. At night the chillers of the utility plant will run and store the chilled water in the tank effectively charging the tanks. During the day, the campus will utilize the chilled water from the thermal storage tank instead of having to run the chillers. The tank will cool down at night and heat up during the day. Since the chillers will be running at night to cool the stratified tank, the electric demand during the hottest hours in the middle of the day will be less, resulting in a cheaper utility bill. Also, with chillers running at night the ambient temperature is lower, resulting in a higher efficiency for the chillers which means they require a less amount of energy from the grid to do the same amount of work. This means the DN tanks not only reduce electric demand by moving the chillers operation time to at night, but also reduce electric consumption by operating the chillers at a higher efficiency.

Incentive programs that the team considered ranged from a student/faculty level to a utility company level. Incentive programs are cheap ways to reduce electric demand and/or overall consumption. Incentives that the team initially considered were at the person and building level. An example of a personal level program would be small tuition discounts for students who use the least amount of electricity. Other possible incentives include a fire marshal tax discount to the university since a large body of water will be accessible on campus or a rate discount from the utility company since the university will be putting less stress on the system.

1.7 Bill of Materials

The team's solution requires Florida State University to purchase one stratified chilled water tank. This stratified chilled water tank purchase includes geographical preparation, the tank, the diffusion system, and installation. The sponsor for this project, Trane, guided the team to a manufacturer of stratified chilled water tanks that has worked closely with Trane on similar projects in the past. The manufacturer that Trane prefers the senior design team to use is DN Tanks. The size of the tanks is dependent on information at the Central Utility Plant such as peak length time and peak demand.

The line item is considered complete when Florida State University has received the stratified chilled water tank proposal from the senior design team. The proposal will consist of all the line items mentioned in the bill of materials. The project is deemed complete when the demand reduction solution has been proposed to Florida State University that contains all the line items. Other tasks that need to be accomplished to consider the project complete are level 1 and level 3 energy audits.

Once the team selected thermal storage through stratified chilled water tanks as the solution to Florida State University's problem of reducing peak electric demand, Trane recommended the team to contact the stratified chilled water tank manufacturer DN Tanks. DN Tanks' sales representative, Guy Frankenfield, instructed the team to find out more detailed information from Florida State's central utility plant. Once this information is transferred to DN Tanks, then Guy Frankenfield will respond with the tank size. Once the tank size is known, material cost and labor cost are easily determined. Additional costs the team needs to consider is for an aesthetically appealing design, such as the University of Central Florida's red brick theme to match the campus buildings, and location of the tank. Depending on the location, prices for installation vary. A tank in the ground under the football field costs more to install than an above ground tank on the side of the road.

Table 4. Bill of Materials Table

Bill of Materials for DN Stratified Chilled Water Tank				
Component	Vendor	Unit Cost	Labor Cost	Project Cost
Geotechnical Site Evaluation	DN Tanks	$ -	$ 95,000	$ 95,000
Site Preparation	DN Tanks	$ -	$ 500,000	$ 500,000
The Tank	DN Tanks	$ 5,000,000	$ -	$ 5,000,000
Piping	DN Tanks	$ 500,000	$ -	$ 500,000
Delivery	DN Tanks	$ -	$ 100,000	$ 100,000
Instrumentation	DN Tanks	$ -	$ 50,000	$ 50,000
Installation	DN Tanks	$ -	$ 225,000	$ 225,000
	Total	$ 5,500,000	$ 970,000	**$ 6,470,000**

DN Tanks charges their customers one time, meaning the purchase includes everything from delivery to installation. Since our project only requires one purchase, unit cost was not applicable. Instead the team estimated costs within the tank such as the pipping, tank, diffusor system, delivery, installation and included these in the bill of materials to pre-estimate the cost of the tank.

1.8 Spring Project Plan

The team predicted the required work to complete the project in the spring semester. The figure below shows a Gantt chart which illustrates the timeline of the project. The first step is to meet with high-level City of Tallahassee Utility employees to acquire a detailed analysis of the electric rate structure. Next the team wants to meet with the engineers at the central utility plant on Florida State Universities campus to determine detailed equipment usage and analyze the systems data such as length of electric peak and water temperatures of incoming and outcoming flow from chillers. The team is continuing to pursue incentive programs and possibly an electric generator as a speed bump which will require a feasibility analysis and testing. Since these additional solutions to reduction of energy demand are not in the main scope, they are not included on the Gantt chart, but will take some time from the team in the spring semester. The main milestone for the spring semester in the level 3 energy audit which the sponsor Trane desires in a twenty-page report with ASHRAE guidelines. The level three energy audit was broken down into component parts such as cost and savings analysis, dynamic model of energy use, and identifying situations that cause load profile shifts. The final three objectives are engineering design day, finals, and graduation.

The major focus in January is meeting with key employees at FSU's central utility plant, Trane, and City of Tallahassee Utilities to acquire data needed for the level 3 energy audit. The major focus of February is starting the energy audit and researching incentive programs to save money on electric utility charges. The major focus of March is the level 3 energy audit and the dynamic simulation of the energy load. The major focus of April is finalizing the level 3 energy audit and presenting the results to Trane and FSU's central utility plant engineers. Once all of these milestones are completed then the team will graduate May 2nd, 2020.

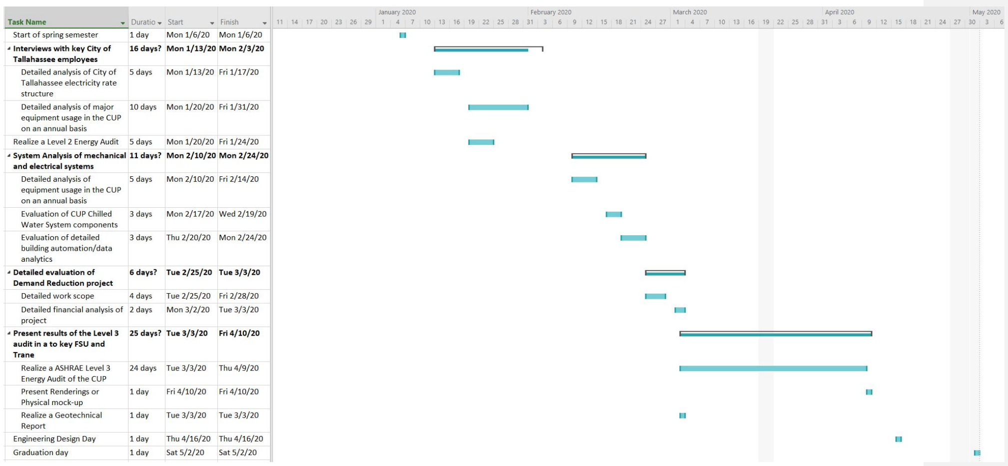

Figure 1. Gantt Chart

Appendices

Appendix A: Code of Conduct

Mission Statement

The senior design team 521 is committed to uphold engineering standards by creating an efficient work environment that supports creativity, commitment and communication. We are committed to providing the highest-quality service to the best of our abilities, to uphold and exceed our client's expectations while maintaining safety standards.

Roles

Each team member will be held to a certain standard and has been assigned a role in the project that best fit their past experiences and abilities. For other duties the freest team member at the time will complete the task. Weekly action items will be created as a team and from this list, each team member will claim an action item to complete by the next meeting. The team leader will decide who will work on which action items (if a tie breaker is needed or if certain action items go unclaimed). For the sake of consistency, primary roles have been assigned to each team member in order to have permanent type of tasks.

Edgardo Cordero - Project Manager

Responsible for team management, schedule coordination and communication amongst team members and stakeholders. Responsible for editing and final submission of each assignment, the project manager will also be responsible for managing budget and keeping track of deadlines.

Alec Schoengrund – Mechanical Design Engineer

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Deleted: Lead Mechanical Engineer

Responsible for most of the mechanical aspects of the project. Responsibilities include review of mechanical designs, coordination with mechanical departments, and cost analysist. The lead mechanical engineer will also oversee documentation of the project.

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Mira Meyers – Quality Control Engineer

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Deleted: Lead Industrial Engineer

Responsible for the industrial engineering aspects of the project. Responsibilities include invoking the principles of Six Sigma, conducting a cost benefit analysis, providing support with software such as Minitab and MATLAB, and conduct research to provide possible solutions to reduce energy usage.

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Steven Decker – HVAC Engineer

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Deleted: Sales Engineer/Industry Specialist

As the member with the most experience in the field, responsibilities include minor project management, energy auditor, financial analysis and research. The member is also responsible for providing specialized support to each team member regarding technical information.

Juan Villalobos – Energy Auditor

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Deleted: Lead Electrical Engineer

Responsible for electrical aspects of the project. Responsibilities include presenting solutions based on the data collected and analyzed, review of electrical designs, research of new electrical technologies, coordination with the ECE department, support with MATLAB, Multisim and other software.

Deleted: Matlab

Keaton Zargham - Data Analyst

Responsible for acquiring/discovering useful information, modeling power system data, informing conclusions and supporting decision-making with the direct help of the adviser.

Communication

Primary communication will take place through the GroupMe application. Other forms of communication include text messages, email and Basecamp chat. Time conflicts should be resolved by selecting the time that works for the most amount of people. Team members are expected to reply to important communications within 24 hours.

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Dress Code

Business casual is expected for most meetings that will regard professional interactions and presentations. A change in the dress code must be requested within 48 hours of the meeting and any change will be notified to all members. Weekly meetings dress code adheres with the FAMU FSU dress code policy and business formal for presentations.

Deleted: Business formal for the most important meetings and presentations and for weekly meetings no dress code is required, i.e. casual attire.

Attendance Policy

The team will meet on a weekly basis, every Friday at 10:30 AM, to do weekly progress updates and discuss any upcoming action items for the following week. In addition, there will be a weekly optional meeting every Wednesday at 2:00PM to discuss progress and seek assistance from one another. The meeting location will be at the FAMU-FSU College of Engineering in the industrial senior design lab, unless otherwise specified prior to the meeting. Every team member is expected to be in attendance for Friday meetings. Scheduling is established based on every member school schedule. Time conflicts were found around the members schedule for various

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days of the week, and Friday was chosen as the least conflicting with each of the member's agendas. When deemed necessary, meetings will be scheduled with external parties, such as stakeholders. One member of the team will be designated to communicate with the external party and determine their availability. Next, said member will send a Microsoft Outlook calendar invite to all members of the team and the guest. Location will vary based on who the team is meeting with.

Attendance will be tracked using the meeting minutes for every meeting. In order to have an excused absence, it is the primary responsibility of the member to communicate to the team at least 24 hours in advance. Failure to attend any mandatory meeting will result in an internal disciplinary action, as set forward in the team's code of conduct.

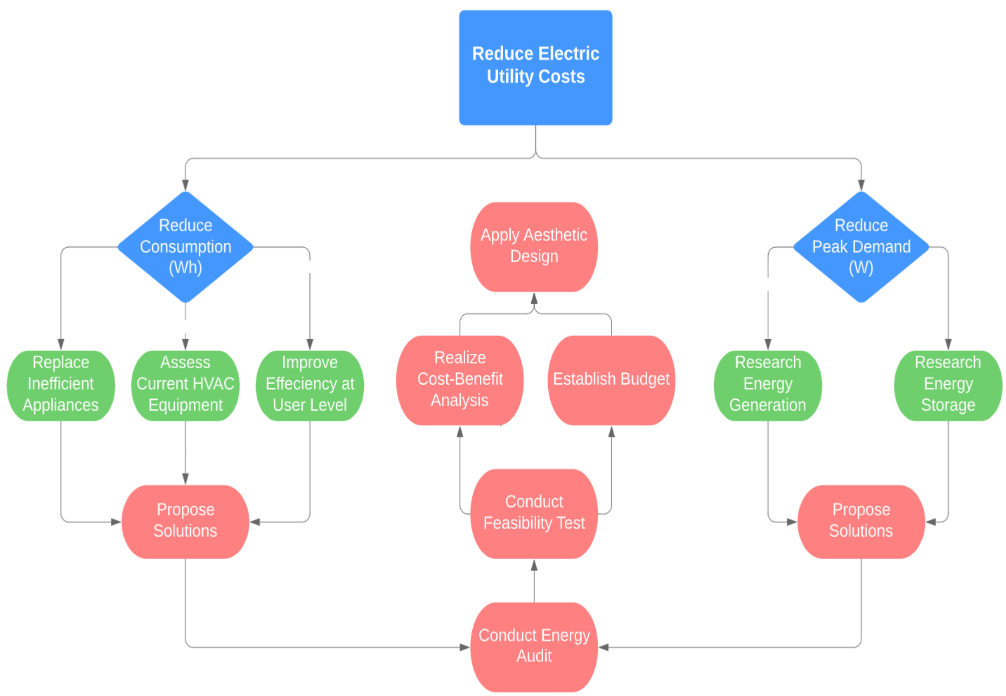
Statement of Understanding

By signing this document, the members of Team 521 agree all the above and will abide by the code of conduct set forth by the group.

Name	Signature	Date
Steven Decker		
Mira Meyers		
Keaton Zargham		
Juan Villalobos		
Alec Schoengrund		
Edgardo Cordero		

Appendix B: Functional Decomposition

Table 5. Functional Decomposition chart



Appendix C: Target Catalog

Table 6. Target Catalog Table

Function	Target	Metric
Reduce peak demand	≥ 10	% (kW)
Reduce consumption	≥ 10	% (Wh)
Available space for solutions	Space needed ≤ Space available	m^2
ROI	7-10	years
Save money	≥ 10	% (money)
Establish initial capital payment	< 10 million	$ (money)
Aesthetically pleasing design	75% of public is satisfied	Survey (1-5 stars)
Improve utility appliance efficiency	≥ 10	% (kW) using energy audit
User level efficiency improvement.	≥ 5	Efficiency ratio: (%)
Research energy generation solutions to offset peak demand	≥ 10	% (W)

Research energy storage solutions to offset peak demand	≥ 10	% (W)
Assess current HVAC equipment to find fixable inefficiencies to reduce peak demand		% (Wh)

Table 7. Target to function link, key table

Function	Target number that the function affects
Apply aesthetic design	7,3
Cost Benefit Analysis	4,5,8,9
Establish budget	4,5
Conduct Feasibility Test	3,4,6
Conduct Energy Audit	1,2,8
Replace Inefficient Appliances	8,2,5,4
Access current HVAC Equipment	1,2
Energy Generation	5,1,2,4
Energy Storage	5,1,4
Reduce Consumption	5,2,4
Reduce Peak Demand	5,1,4

Appendix D: Concept Generation

1. Replace existing lights with LED lights which will reduce consumption and not give off any heat.
2. **Install solar panels on all roofs to reduce consumption.**
3. **Install solar panels on available unused FSU land ownership. (this is cheaper than installing on roofs).**
4. Reduce energy needed for reheat by connecting water loop used to cool solar panels to the AHUs which will also increase the profitability of the solar panels.
5. **Install thermal storage tanks to offset the peak demand.**
6. **Install innovative smart speed bumps around campus that will generate energy when cars drive over them (like a piston in a car engine, will transfer up-and-down motion into rotational motion which we can turn into electricity).**
7. **Introduce incentive programs for students and faculty to reduce individual consumption.**
8. Student/Faculty ID cards needed to "turn on" rooms (dorms and classes).
9. Lights connected to motion sensors.
10. Room thermostats connected to occupancy sensors, motion sensors, and/or ID cards.
11. If natural gas is a consistent price, and electricity is more expensive during peak, then maybe we can have a power plant on campus where we burn natural gas to produce our own energy during peak times.
12. Burn natural gas to produce energy to store in batteries which will be discharged during peak times.
13. **Implement large battery packs which can be charged by various methods (can be from the grid) during off peak hours to be discharged during peak hours.**
14. Replace old AHUs with newer more efficient AHUs.
15. Replace old VAVs with newer more efficient VAVs.
16. Update/reinsulate ductwork to reduce amount of heat loss in the ducts.
17. Replace old Chillers with newer more efficient Chillers.
18. Replace old Boilers with newer more efficient Boilers.

19. Collect rainwater for irrigation and other grey water needs to reduce the amount of water utility needed from the city. (maybe rainwater could be used in cooling towers –heat rejection loop (only applicable at COE since main campus does not have cooling towers, they utilize the aquafer)
20. Collect food and other natural wastes produced on campus to be used as biofuel to produce energy. Some sort of compost might give off gases that could be burned for energy for the wastes that can't be burned directly.
21. Capture wind energy via appealing small to mid-size wind turbine(s) on top of select buildings that might receive consistent breezes.
22. Install a small nuclear power plant on one of the many FSU owned land parcels.
23. Install a fun and interactive "Hamster Wheel" type of fitness station on campus (I.e. Stationary Bikes) that will produce energy and show the user how much energy they have produced – this could tie into our incentive idea.
24. Instead of recycling the campus's paper products, we could burn all of it to produce energy which we could store in our batteries to further offset peak demand.
25. Build a sunshade big enough to encompass the entirety of campus, effectively blocking all the sun's rays.
26. Buy smart power strips that will turn off connected appliances after works. We can put them in locations with computers that are locked after hours.
27. Reduce the number of allowed plug loads in faculty offices.
28. Thermostats that will adjust the temperature based on occupancies in the room.
29. Replace old VFDs (variable frequency drives) with more efficient ones to ensure the set fan speed is accurate.
30. Ensure that all doors have no gaps to reduce the need to dehumidify as often.
31. Invest in shades for all windows on campus to reduce the heat load from outside.
32. Rebuild buildings that have poor infrastructure.
33. Investigate dorms that allow every room to have their own window unit, this way all dorms would have one central control.
34. Remove all light switches from all buildings. Install motion detectors that will only detect human loads and then turn on lights.
35. For classes that take place during the day, tell teachers to only use the sunlight to light up the room.

36. Use energy from the opening of doors on campus
37. Generate power in drains from the flow of wastewater
38. Generate power in pipes with the flow of water and/or steam
39. Pressure plates on sidewalks or areas of high student traffic to generate power
40. Methane plant from human waste
41. Dictate HVAC controls to only run at efficient temperatures
42. Admit fewer students
43. Reduce elevator access to only those who need it
44. Turn Power off to student's dorm rooms based on their class schedule, ensures they go to class.
45. Make a rule that restricts the wattage of a lightbulb to under 60 watts.
46. Run the pumps at a lower speed.
47. Ensure all units are Energy Star certified.
48. Invest in thermostats that automatically adjust the temperature inside based on the temperature outside. The goal would be to reduce the difference and in return, you save energy.
49. Remove all washers and dryers from all dorms. Instead, have one central washing/drying place accessible to all students on campus.
50. Install low-flow showerheads in all dorms on campus.
51. Instead of using the heat of HVAC to reduce humidity in the buildings, invest in Energy Star dehumidifiers.
52. Consider having classes outside to get advantage of sun light
53. Optimize gym equipment to generate small amounts of power
54. Install photochromatic tint on all windows around campus which will transition between transparent and opaque with the amount of sunlight that is received.
55. Unplug all appliances on campus during breaks when students are away.
56. Install energy generation buttons on chairs in classrooms so whenever a student sits down, they generate power.
57. Use DN tanks to store chilled water.

58. Create an (Amish club) - Amish don’t need electricity.
59. Install more fans in buildings where they fit so that circulation will be better, and buildings can be cooled to higher temps.
60. Instead of doing virtual parking permits, give students solar panel parking permits that will power campus.
61. An innovative door mats idea that will harness energy from people walking on them.
62. All water fountains will be replaced with mechanically operated well pumps.
63. All lights will be replaced with candles during the winter months to reduce energy spend and help heat the buildings.
64. An innovative hat idea that has solar panels in the bill which will charge small electronics.
65. Cook food over a bonfire every Friday, to save energy on cooking appliances
66. Install grills around campus to urge people to cook without electricity.
67. All FSU vehicles that are electric convert to gas powered so batteries don’t need to be charged
68. Remove all dishwashers on campus and start only handwashing
69. Build a hydroelectric dam to generate energy
70. Close buildings for a few hours at night.
71. Raise the temperature of all buildings to 74-75 during the heat of the day (3 hours) where people will not notice a difference.
72. Only allow football games to occur during the day, so there won’t be a large demand on electricity.
73. Get a competition going between dorms on campus and give incentives for energy reduction.
74. Have every car that enters a parking garage tow a bucket of water to the top to store as potential energy.
75. Start charging students for football tickets “Green Charge” to offset peak.
76. Add entry counters at football games to generate rotational energy
77. Regulate the use of the turbines in the AME building to reduce peak demand
78. Shut down the mag-lab, for energy cost savings

79. Bamboo power. (bamboo grows 3 feet a day, it will grow and push a weighted ceiling upwards and after a week we will harvest the bamboo. This will lower the weighted ceiling harnessing energy and we will sell the bamboo)
80. Add batteries on outlets to store energy when they are not being used
81. Freeze the pool at the leach (at night), to store energy as chilled water
82. Store heat exhausts from appliances in silicon thermal generators
83. Install enough plants inside buildings to consume the CO2 produced by occupants. This will reduce the amount of outside air required.
84. Steam generator to use heat from other equipment to move a steam piston and salvage the electricity.
85. Put solar panels on floor under transparent walking layers inside buildings to absorb energy used to produce light
86. Transition FSU academia to a paper only policy to reduce computer use
87. Change all dorm rooms to have communal bathrooms to use a central water heater and wastewater pump system
88. In dorms, do not allow students to have television sets in their individual rooms. Only allow one TV in the lobby for all students to use.
89. Don't use electric fans use bladeless fans. They only move air and produce heat. Use the air flow from the cooling system instead.
90. Remove humidity from air to make the HVAC system work easier. Huge Damp-rid in the HVAC system.
91. Get rid of all windows.
92. Thermoelectric generator. Uses a temperature difference (Heat from other equipment) to create a potential difference (voltage)
93. Harness vibrational energy in the stadium during football games when crowd cheers and stomps.
94. Replace all electric paper towel dispensers with manual ones, which can reduce consumption of energy
95. Have a daily onion squeezing contest doing the peak demand hours. The juice from onions can be converted to methane, which then can be used to generate electricity.

96. We will build a large reflective cone that will direct the sun's rays to an element that will produce steam energy.

97. Renegotiate with the city of Tallahassee for a lower rate since FSU is the reason Tallahassee is on the map.

98. We will have batteries that are distributed to citizens of Tallahassee where they will be charged on their meter and FSU will reimburse them for more than it cost them to charge it. And FSU will off load the batteries during peak times.

99. Insulate all buildings from the outside to prevent heat from entering the building. Huge blanket

100. Priority (Dorms, football tickets, etc.) for least used energy on campus (mainly for freshman)

Appendix E: Concept Selection (AHP, Pugh and HOQ Charts)

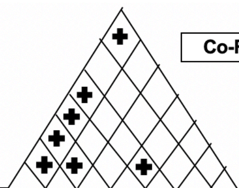
Table 8. AHP Chart

	Peak Demand Reduction	Consumption Reduction	Return on Investment	Aesthetic Design	Reliability
Peak Demand Reduction	1	5	0.33	7	0.20
Consumption Reduction	0.2	1	0.14	5	0.11
Return on Investment	3	7	1	9	1
Aesthetic Design	0.14	0.20	0.11	1	0.11
Reliability	5	9	1	9	1
Sum of Columns	9.34	22.20	2.59	31.00	2.42

Table 9. Normalized AHP Chart

	Peak Demand Reduction	Consumption Reduction	Return on Investment	Aesthetic Design	Reliability	Criteria Weights
Peak Demand Reduction	0.11	0.23	0.13	0.23	0.08	**0.15**
Consumption Reduction	0.02	0.05	0.06	0.16	0.05	**0.07**
Return on Investment	0.32	0.32	0.39	0.29	0.41	**0.35**
Aesthetic Design	0.02	0.01	0.04	0.03	0.05	**0.03**
Reliability	0.54	0.41	0.39	0.29	0.41	**0.41**
Sum of Columns	1.00	1.00	1.00	1.00	1.00	

Table 10. House of Quality chart



Co-Relationships

Customer	Requirements		IMPORTANCE	Operating Factors: Save a minimum of $100,000 per month	Reduce peak demand by 7430 KW monthly	Reduce consumption by 4470 MWh monthly	Return of Investment must be 7-10 years	Service life for more than 10 years	Efficiency greater than 90%	Pleases at least 75% of the FSU students, faculty,	Competetive Assesment: Stratified tanks for chilled water storage	Install Battery packs which can be discharged during peak hours	Implement smart speed bumps
Ergonomic Features	Reduce peak demand	1	5.00	3	9	3	0	0	0	0	G	G	F
	Reduce overall energy consumption	2	3.00	3	3	9	0	0	0	0	G	F	G
	Save money	3	5.00	9	3	3	9	1	1	0	G	G	F
	Durability	4	4.00	1	0	0	1	9	0	0	G	G	F
	Serviceability	5	3.00	1	0	0	1	3	3	0	G	F	F
	Reliability	6	4.00	0	3	3	0	3	9	3	G	G	F
Aesthetic Features	Visually appealing	7	1.00	0	0	0	0	0	0	9	G	G	F
	Raw score			76	81	69	52	62	50	21			
	Relative %			18%	20%	17%	13%	15%	12%	5%			
	Importance Rank			2	1	3	5	4	6	7			

Relationship Key:
Strong = 9
Moderate = 3
Weak = 1
No Correlation = 0

Co-Relationship Key:
Positive +
Negative -

Competetive Assesment key:
Good = G
Fair = F
Poor = P

The importance ranking is scaled on a scale from 1-5, with 1 being the least important and 5 being the most important.

Table 11. Key for PUGH charts

Symbols	Relationship	Value
+	Better than baseline	1
0	About the same	0
–	Worse than baseline	-1

Table 12. PUGH Chart 1

Criteria	(DATUM)	DN Thermal Storage Tanks	Battery Storage	Speed Bump Generators	Burn Natural Gas on Campus	Incentive Programs	Giant Sunshade	Totals	Rank
		Alternatives							
Return on Investment	0	+	+	+	−	+	+	4	3
Reduce Electric Demand	0	+	+	+	+	+	+	6	1
Reduce Electric Consumption	0	+	+	+	0	+	+	5	2
Aesthically Pleasing	0	−	−	−	−	0	−	-3	5
Reliability	0	+	+	+	+	0	−	3	4
	# of Pluses	5	3	3	2	3	3		
	# of Minuses	0	1	1	2	0	2		

Table 13. PUGH Chart 2

Criteria	Battery Storage (DATUM)	DN Thermal Storage Tanks	SpeedBump Generators	Burn Gas	Incentive Programs	Totals	Rank
		Alternatives					
Retrun on Investment	0	+	−	−	+	2	1
Reduce Electric Demand	0	+	+	−	−	2	1
Reduce Electric Consumption	0	+	0	−	+	2	1
Aesthically Pleasing	0	−	−	−	+	1	4
Reliability	0	+	−	−	−	1	4
	# of Pluses	4	1	0	3		
	# of Minuses	1	3	5	2		

Table 14. PUGH Chart 3

Criteria	DN Thermal Storage Tanks (DATUM)	Battery Storage	Speed-Bump Generator	Incentive Programs	Totals	Rank
		Alternatives				
Retrun on Investment	0	−	−	+	-1	2
Reduce Electric Demand	0	−	−	0	-2	3
Reduce Electric Consumption	0	−	−	0	-2	3
Aesthically Pleasing	0	+	0	+	2	1
Reliability	0	−	−	−	-3	5
	# of Pluses	5	3	2		
	# of Minuses	0	1	2		

References

There are no sources in the current document.