Cummins Energy Saving

Midterm Report I

Team Number: Team 2

Submission Date: October 31, 2014

Submitted To: Dr. Helzer, Dr. Shih, Dr. Gupta

Authors: Daniel Baker, Warren Bell, Daniel Carnrike, Kyle Fields, Marvin Fonseca

Table of Contents

Tables of Figures

Table of Tables

Abstract

The focus of this report covers the midterm report for the Cummins Energy Saving project. Cummins needs to reduce the power consumption at their technical center in Indiana by 10%. Team 2 has met with Roger England, the Cummins sponsor, and discussed the initial steps needed to make this a successful project. Weekly team meetings and biweekly advisor meetings have been held, and team members have established positions, project tasks, and resource allocations. Team 2 has completed a decision matrix selecting the optimal areas for implementing the proposed energy changes. Following this decision matrix, both a cost and energy analysis using MATLAB has been conducted for both solar panels and building insulation changes, in order to rank the most ideal energy savings ideas in terms of cost and efficiency. Currently, the team is working on touring the Cummins Technical Center in Indiana in order to gather information for proper analysis of design suggestions. Once this has been completed, Team 2 will use the gathered data to start work on a final report and design.

1 Introduction

Team 2 has been asked by Cummins to reduce the power consumption at their Technical Center in Indiana by 10%. In 2011, Cummins began to supplement some of its power sources in certain locations with solar panels and rerouting energy developed from their test cell dynamometers back into the grid. Also, they have been attempting to reduce power consumption by conventional means through light bulb replacements and light switch modifications. In order to solve this problem, the idea of solar panels and a grid monitoring system have been presented to assist in the consumption reduction. After further analysis, the optional grid monitoring system idea was scrapped due to the complexity of concepts involved. It was decided that Team 2 would focus resources into coming up with solutions to multiple areas of improvement for the Technical Center instead. Through the use of a decision matrix, the main areas of improvement that the team will work on are: solar panels, control valve (CVS) chillers, rerouting engine exhaust, and building insulation.

Team 2 will create a power consumption reduction plan for Cummins that is both economically and environmentally efficient. Part of the technical challenge is determining the feasibility of solar power for the location, as well as the cost effectiveness of the solar power. Additionally, there is a challenge in designing a way to reroute engine exhaust without interfering with the exhaust analysis that Cummins performs to study the emissions. It may also be difficult to determine the exact building insulation for the technical center. This report consists of additional background research that is imperative to the development of the solar panels and aforementioned areas of improvement. The report also details a project plan with the work breakdown and the criteria for design selection that helped narrow down the options to the final optimal designs.

2 Project Definition

2.1 Background research

Since 2011, Cummins has implemented solar cells as an alternative means of power in several of their facilities. Presently, the company has five solar arrays capable of generating up to 230kW. While this is an impressive feat, Cummins is looking to further capitalize on cleaner, more efficient sources of energy. As seen in Figure 1, the CTC has already made significant strides in lowering their total energy use, and this value is predicted to be around 60,000 MMBTU for the next four years[1].

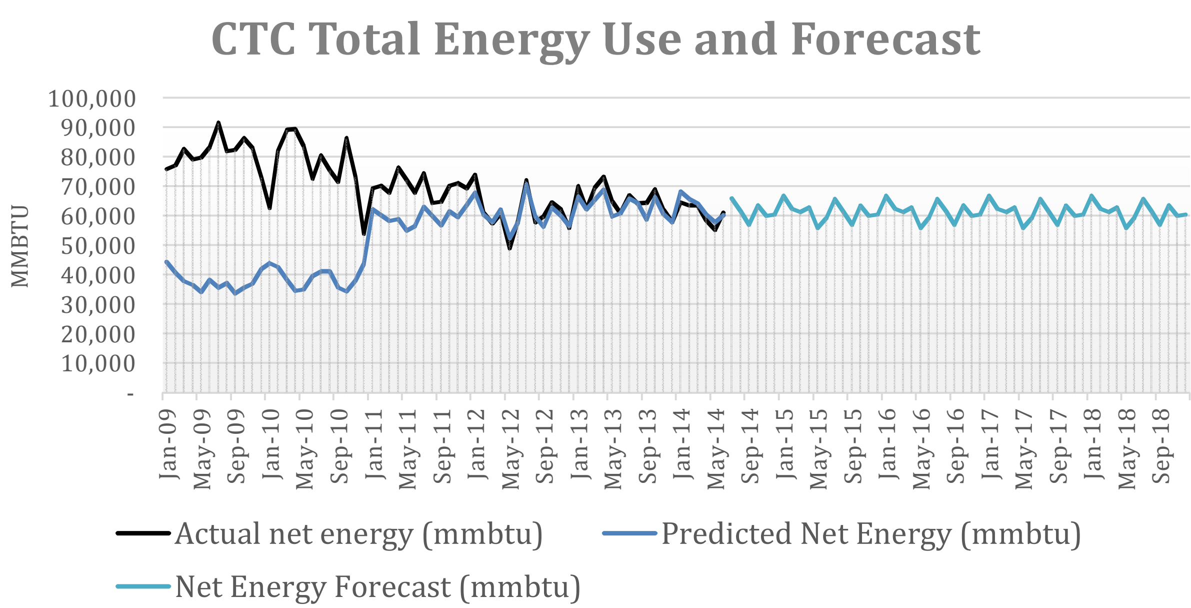

Figure 1- Energy Usage(2009-2018)

Florida State is in a unique position to assist in solving this problem with their Off-Grid Zero Emission Building (OGZEB). The OGZEB is a prototype used to test the feasibility of solar power in residential buildings. It consists of several rooms that are powered through solar energy, with the use of hydrogen powered appliances, high efficiency lighting such as sky lights, and recycled material insulation practices. The OGZEB building also has several power and temperature monitoring systems that analyze the conditions inside and outside the building. Though this is a residential application, the theory and techniques can be applied to an industrial setting. By utilizing the power monitoring systems in the OGZEB, Team 2 will have the ability to do the necessary research to solve the problem for Cummins[2].

2.1.1 Energy Audit

An energy audit is the practice of surveying a facility in order to identify different opportunities to reduce energy consumption and optimize the efficiency of energy usage[3]. To achieve this final goal, the use of energy management is critical; which consists of organizing financial and technical resources and personnel to maximize energy efficiency. Energy management also consists in keeping and maintaining records of energy usage and the performance of all machinery or appliances. An appropriate record keeping method can help to determine the areas in which the efficiency is under the standards of the facility. Depending on the building, the approaches to improve the efficiency of the energy usage can vary, and are often subject to the areas that consume the most energy. In most cases, the HVAC (heating, ventilating and air conditioning) is the source of major energy consumption in manufacturing facilities mainly due to heat generation from machinery and processes.

2.1.2 Solar Panels

A solar panel, or module, is a series of interconnected silicon cells joined together to form a circuit. In greater numbers, the amount of power produced by these interconnected cells can be increased and used as an electricity production system[4]. For this project, the main focus will be analyzing the feasibility of implementing photovoltaic cells on the roof of the technical center for energy generation. Photovoltaics cells are designed to supply energy to commercial or residential buildings. The efficiency of these cells can go up to 19% and have a life time of 25 years. These cells need to be in arrays because each cell can only produce a limited amount of energy. Each package of solar panels may include the cell, a DC/AC converter, a solar tracker, and a battery. The theory behind the energy generation of these cells is the photovoltaic effect which consists of converting the energy of the Sun coming to Earth in the form of photons to electrical energy. This is done when the photons interact with the material's surface on the cells and excite the valance electrons, breaking them free and making them jump to the conduction band enabling the use of the electrical energy. The movement of electrons will produce a current and through ohm's law, if the current is supplied across a resistor, a voltage can be developed. The first usage of these modules was in the aerospace industry in 1958.

2.1.3 Insulation

Thermal insulation refers to the reduction of heat transfer between objects that are in thermal interaction. This can be accomplished by different ways from a specific process to the implementation of a different material. The capacity to insulate a material is measured in thermal conductivity (k). This property is proportional to the heat transfer. In other words the lower the thermal conductivity, the lower the heat transfer will be across the material.

Most insulators work by slowing down the heat transfer from the exterior to the building or vice versa. This can be done by increasing the thickness of the insulator, changing the insulator material, or adding reflective barriers to decrease the radiation coming from the outside to the building.

The thermal conductivity (k) is measured in watts per meter per kelvin. As the thickness of the insulator material increases, the heat transfer decreases because thermal resistance increases. The main application for insulators is present in buildings. In order to maintain an acceptable temperature in a building by heating or cooling, a large portion of the total energy consumption is needed. When a building is well insulated, the owner can see major savings in energy usage, it also helps to provide a more uniform temperature throughout the building reducing the temperature gradient in all directions.[5]

2.1.4 Engine Testing

To measure the power of the Cummins QSK23 and other tested engines Cummins implements dynamometers. Dynamometers or "dyno's" for short can be categorized into 2 types, inertial dyno's and absorption dyno's. An absorption dyno directly absorbs power from the prime mover (usually driveshaft) and converts it to heat which is generally dissipated into the ambient air.[6] Here is an area where Team 2 plans to improve overall plant efficiency by harnessing this heat or possibly the energy before it is converted to heat and use a DC to AC converter to run this power back into the grid or use the heat if it will be more cost effective.

In most dynamometers power is not measured directly and must be calculated from the product of either torque and angular velocity or force and linear velocity. Conversion factors must be implemented to get the result in relatable units.

2.1.5 CVS Chillers and Chilled Water

Chillers are used to cool water that is used for air conditioning and cooling machinery. In any industry, chillers are always a major power consumer. In order to reduce energy consumed by the chillers it is recommended that Cummins use absorption chillers. Absorption chillers use hot water to power the generator used to cool water down. Using an absorption chiller as opposed to a mechanical chiller is beneficial because absorption chillers require low maintenance; they have a high reliability, and are relatively quiet and vibration free.[7]There are three types of absorption chillers: single effect, double effect, and triple effect chillers. In the case of the Technical Center, it will be more prudent to use a single effect chiller as it will be able to use low pressure waste heat to power the chiller efficiently. A double or triple effect chiller will require too much pressure and heat to be a feasible energy saver. Figure 2 depicts a flow chart of a single effect chiller. Notice the coordinate system only relies on pressure and temperature change. This is because the absorption chiller is not using electrical power to generate a cooling effect.

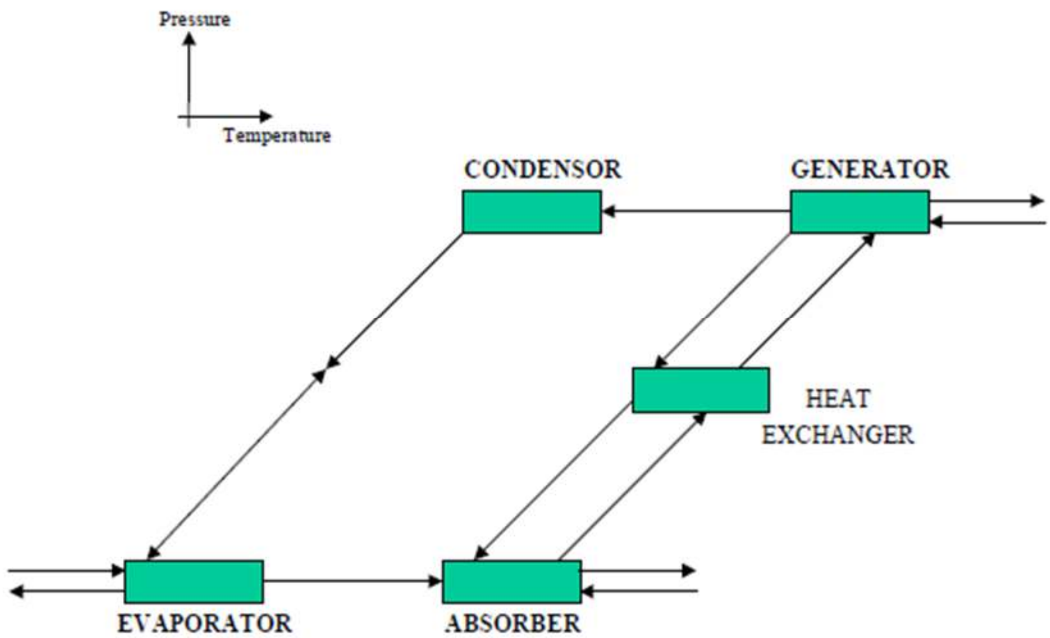

Figure 2 - Absorption Chiller Cycle

2.2 Need Statement

The Cummins Technical Center in Columbus, Indiana is looking to reduce their power consumption by 10%. While Cummins has already made great strides in reducing power consumption in their company, they believe there is still more work to be done. Cummins has asked Team 2 to look at the efficiency and feasibility of solar cells as well as rerouting power from dynamometers back to the grid. Additionally, Cummins would like a method to monitor the power grid in order to reroute power and eliminate waste.

“Cummins needs to reduce their energy usage in order to save money and reduce their environmental impact.”

2.3 Goal Statement & Objectives

2.3.1 Goal Statement

The goal of the project is to, “Review current Cummins Technical Center (CTC) electrical usage and devise a plan to decrease it by 10% and design a monitoring system.”[8]

2.3.2 Objectives

- Analyze feasibility of implementing solar panels for energy generation based on weather, altitude, and longitude conditions.
- Measure electricity consumption.
- Evaluate current processes.
- Create a Pareto chart to show opportunities to reduce electrical consumption based on capital invested.
- Decrease the energy consumption by 10%.
- Come up with creative ideas for potential areas of improvement.

2.4 Constraints

The project must be completed under the following constraints:

- Any methods applied for reduction in power consumption must be cost effective for potential capital invested.
- The monitoring system must cost less than $2,000, our allotted budget for a working system.
- Any power saving ideas (e.g., Solar Panels) should apply to weather conditions for Columbus, IN.
- Solar Panels must be able to fit on the roof of Cummins Technical Center.
- Insulation must meet federal and state regulations.

3 Design and Analysis

Due to the nature of the project, the following design areas are theoretical, and are based off of educated assumptions. Each of these design areas will have subsections of electrical and mechanical components which are subject to revision until the team knows what processes Cummins has in place at their facility in Columbus.

3.1 Function Analysis

The function analysis section contains a breakdown of the different designs that were developed. This section is broken down into the four different designs and their associated design and performance specifications.

3.1.1 Solar Panels

From the average insolation calculated, solar panel dimensions were derived from the constraint of the roof in order to calculate the total area of the solar panels allowed. As shown in Table 1, the dimensions of both roofs and usable area are presented. Team 2 has not been able to travel to the facility and take direct measurements, so measurements were approximated using satellite imaging of the two technical center roofs. From Table 1, the amount of useable roof area was found to be $2{,}125\ m^2$.

Table 1 - Roof Dimensions

	Width (m)	**Length (m)**	**Area (m^2)**	**% Useable**	**Useable solar area (m^2)**
Roof 1	35	35	1,225	100	1,225
Roof 2	90	100	9,000	10	900

3.1.1.1 Design Specifications

The design specifications for the required solar panels are described in the following section. These design specifications were calculated with the average insolation of $556\ \frac{W}{m^2}$. The average insolation was calculated by a MATLAB program team 2 developed. The MATLAB code takes into account equations that were derived[9] and computes the necessary values. This code can be seen in the appendix.

Table 2 - Annual CTC Energy Usage

Annual Energy Used	759,640 GJ
Annual Energy Cost	$17,935,949.50

As shown in Table 2, Cummins' current yearly usage is approximately $759{,}640\ GJ$[12], so the annual saving goal would be $75{,}964\ GJ$.

3.1.1.2 Performance Specifications

Table 3 shows the different specifications Team 2 have developed in order to reduce the energy consumption by 10%. As stated before, Team 2 has not visited the technical center so measurements are based off of background research conducted and are accurate to the limited constraints.

Table 3 - Performance Specifications

Performance Specifications	**Solar Panels Estimate**
Solar Panel Area	$2{,}125\ m^2$
Energy Per Day Seen	9.18 GJ
Efficiency	19%
Energy Per Day Collected	1.7442 GJ
Annual Energy Generated	636.633 GJ
LCOE	85 USD/MWh
Annual Cost Reduced	$15,031.61

Table 3 depicts the constraints developed in order to make a feasible energy savings option and the calculations can be found in the Appendix.

3.1.2 Insulation

Table 4 - Insulation Design Specifications

Material	Thermal Resistance	Types	Green	Fire Resistant
Fiber Glass	2.2 to 2.7	High, Medium, Low Density	20% to 30% Recycled	Yes
Mineral Wool	3.7	Blanket and loose fill	75% post-industrial recycled	Yes
Cellulose	3.2 to 3.8	loose fill or spray	82% to 85% recycled	No
Plastic Fiber	3.8 to 4.3	High, Low Density	----	Yes
Closed Cell Foam	5.6 to 8	Spray, Foam board	-----	No
Closed Cell Foam modified	9	Foil	----	Yes

3.1.2.1 Design Specifications

Table 4 above lists several alternative insulation options for Cummins. The table shows the thermal resistance, what type of insulation, how 'Green' each material is, and whether or not it is fire resistant.

3.1.2.2 Performance Specifications

The reason for updating insulation is based mainly on the thermal resistance of the current insulation installed at the facility. A higher thermal resistance means a greater savings in heat because less is transferred to the outside. The types listed gives one an idea of how feasible it will be to install in the facility, this is based on work involved as well as cost of each material. A "green" material may result in tax reductions due to the environmentally friendly nature of the material. This could be done through the 'green point' system or following government standards for green initiatives.

3.1.3 Engine Testing Exhaust Gases

Cummins currently tests 96 engines at a time. For ease of calculations we will assume these all to be QSK23 due to the fact we have specs for this engine and it is currently being tested within the

CTC. These specs are listed below and using these design specifications, performance specifications were made. Finalizing with annual and per second energy not being captured and cost analysis.

3.1.3.1 Design Specifications

The design specifications are limited to constraints of the engines shown in Table 5.

Table 5 - Engine Specifications

Engine Type	In-line, 6-cylinder
Displacement	1,404 CU inches, 23 liters
Bore and Stoke	6.69 x 6.69 inches
Aspiration	Turbocharged/ charge air cooled
Oil System capacity	54.8 U.S QT, 52 liters
Unaided Cold State Capability	18°F

Once Team 2 visits the CTC it will be able to further optimize its calculations by gathering more relevant diameters, materials, velocity, temperatures, and pressures. Once this data is gathered Team 2 will be able to generate more in depth designs to harness any wasted heat and energy. In this section assumptions are made to start the design process. The volume flow rate[12] was determined to be: $\dot{V} = 0.001348\frac{L}{s}$.

3.1.3.2 Performance Specifications

Facilities currently reuse exhaust gases exiting the engines, but they must be analyzed prior to recirculation. Cummins suggested that there may be efficiency losses of 15-20% in this process. A potential design that more efficiently captures these exhaust gases post-analysis phase will also need to be in line with Cummins' emissions standards. The proposed implementation would also need to be cost effective for Cummins to use it.

Table 6 - Engine Testing Performance Specs.

Variable	Value	Assumptions	Source
P	650 kW	At 2000RPM, QSK23	Cummins Dimensions
N	96 engines		Cummins
Max Power	62.4 MW	All engines running, Average engine QSK23	
P_harnessable	6.24 MW	10% available for use (allows for pipe losses)	Cummins said 10-20%
Annual E_harness	197,000,000 MJ		
Practical Annual E_h	100,000,000 MJ	Engines run 50% of time	
Energy gen available	$1,932.50	6.957 cents/kWh	US Dep. Energy

3.1.4 Absorption Chillers

Due to the inability to measure any of the chiller use at the CTC, all values are estimated using an analysis for absorption chillers from the department of mechanical engineering at Anna University.[10] The numbers on the tables below are directly from the study; however they are good assumed values to show the benefits of the absorption chillers.

3.1.4.1 Design Specifications

However when looking at Table 7 it shows the power consumption of the VARS and VCRS and in this case the VARS is superior only needing 26% of the power a VCRS needs.

3.1.4.2 Performance Specifications

Table 7 - Power Consumption of VARS and VCRS

Unit	Power data (kW)	
	VARS	VCRS
Refrigerant pump	1.5	
Solution pump	7	
Compressor power		335.5
Cooling water pump	37	30
Chilled water pump	37	37
LT hot water pump	5	
HT hot water pump	5	
Cooling tower fan	15	10
Total power input	107.5	412.5

3.2 Cost Analysis

The following section is a breakdown of cost analysis for each idea generated. This section will describe the initial cost of installment and overall cost.

3.2.1Solar Panels

The average insolation as stated earlier in the report was $55^{6}\frac{W}{m^2}$. The average insolation was needed to calculate how much energy was produced per year; $E = 34^{4},95^{4},87^{5}.3\ \frac{kWhr}{year}$. The annual energy generated by the solar panels, was calculated with equations found in reference 9. Some assumptions that were made in order to calculate the energy was; 4.21 hours of useable sunshine per day for Columbus, Indiana[13]. Table 8 shows the different assumptions made to generate the levelized cost of energy.

Table 8 - Assumptions made for Solar Panel Cost

Initial Investment	$950,000.00
Annual Cost of Maintenance	$10,000.00
Lifetime (Years)	25
Interest Rate	10%

The initial investment cost was estimated to be $950,000 because of the solar panel costs[14], battery system needed, installation fees and a safety factor for any unforeseen costs. The annual cost of maintenance was based on a group of people to maintain the solar panels throughout the year. Also, a safety factor if some solar panels were damaged throughout the years due to weather. The average lifetime years were estimated from background research. The interest rate was an average from banks around America. The levelized cost of energy was $L.C.O.E = \frac{¢0.033}{kWhr}$ and was calculated with equations found in reference 9. The average cost of energy[15] was found to be $\frac{¢6.95}{kWhr}$ which was taken as an average of all energy distributors in America and their individual cost for industrial buildings.

By installing solar panels at Cummins Technical Center, the payoff will be immediate. Once solar panels were installed and the total amount of energy generated by the solar panels would be used to power the building. Energy generated from solar panels would save Cummins from buying that energy from the grid and have a total savings of $23,974,363.83. The amount of savings were found by multiplying the average cost of energy by the amount of energy generated from the solar panels.

3.2.2 Insulation

The total cost of implementing insulation is given by a fixed installation cost of $50,000. It will take Cummins about two and a half years to make a return. This was calculated by calculating the heat flux of each insulation material. To calculate the heat flux the difference between the outside and the inside temperature of the building was calculated and then divided by the thermal resistance values of the material given in Table 4. Multiplying the heat flux by the average energy cost for industrial facilities for each material will provide the savings generated by each material. The total savings will be equal to the difference between loss in the insulating material Cummins is currently using (asphalt) and the new materials shown in Table 4.

Table 9 - Cost Analysis for Insulation

Material	Cost (per ft^2)	Total Cost for the roof	Total Saving per year
Fiber Glass	0.42	$9,606.66	$18,331.76
Mineral Wool	0.625	$14,295.62	$18,352.97
Cellulose	1.25	$28,591.25	$18,448.09
Plastic Fiber	1.5	$34,309.50	$18,596.58
Closed Cell Foam	2.2	$50,320.60	$18,955.43
Closed Cell Foam modified	2.3	$52,607.90	$19,068.17

3.2.3 Absorption Chillers

Table 10 shows the average initial cost of the Vapor Absorption Refrigeration System (VARS). As table 10 shows, VARS is 124% more than the Vapor Compression Refrigeration System (VCRS)[10]. Table 11 shows the annual cost to run the chillers and again the VARS is better in the respect that it is 80% cheaper to run than the VCRS. While the numbers for the CTC will be different, the idea is still the same. By replacing the chillers Cummins will benefit greatly when using the exhaust gases to heat the water, it will take the chillers almost completely off the grid. The amount of savings that Cummins could save would be 80% of the cost right now.

Table 10 - Annual Cost of VARS and VCRS

Unit	Operating costs ($)	
	VARS	VCRS
Refrigerant pump		
Total use (kWh/y)	13140	
Annual cost ($)	1428	
Solution pump		
Total use (kWh/y)	61320	
Annual cost ($)	6665	
Compressor power		
Total use (kWh/y)		2938980
Annual cost ($)		383345
Cooling water pump		
Total use (kWh/y)	324120	262800
Annual cost ($)	35230	34278
Chilled water pump		
Total use (kWh/y)	324120	324120
Annual cost ($)	35230	42277
Cooling tower fan		
Total use (kWh/y)	131400	87600
Annual cost ($)	14283	11426
LT hot water pump		
Total use (kWh/y)	43800	
Annual cost ($)	4761	
HT hot water pump		
Total use (kWh/y)	43800	
Annual cost ($)	4761	
Total annual operating cost ($)	102359	471326

Table 11 - Initial Cost of VARS and VCRS

Unit	Initial cost ($)	
	VARS	VCRS
Machine cost ($)	278478	112041
Cooling tower ($)	22826	19565
Cooling water pump ($)	5435	4348
Chilled water pump ($)	3913	3913
LT hot water pump ($)	1848	
HT hot water pump ($)	1848	
Total initial cost ($)	314348	139868

3.3 Evaluation of designs

3.3.1Criteria, Method

Table 12 - Cummins Important Energy Users Decision Matrix

Revision date: 8/18/2014		Significance threshold: 220						
Rating of Importance to EnMS		10	5	10	5	10	10	
Significance Category	Important Energy Users Energy subsystem / function	Primary Energy Consumption (MMBTU)	Cost (Currency)	Greenhouse Gases (MTCO2)	Ability to Influence	Ability to Measure	Regulatory Requirements	Total
1	Engine Testing (Diesel)	9	9	9	9	3	9	390
2	Facilties boilers (NG)	3	1	3	3	3	3	140
3	Test Cell Fans/Pumps (Electricity)	3	3	3	9	9	1	220
4	Test Cell, include Dynos (Electricity)	3	3	3	3	9	1	190
5	CVS Chillers & Chilled Water (Electricity)	3	3	3	9	9	1	220
6	Process water (Electricity)	3	3	3	3	9	3	210
7	Engine testing (NG)	1	1	1	3	3	9	160
8	Miscellaneous (Electricity)	1	3	1	0	9	0	125
9	Office (Electricity)	1	3	1	1	9	1	140
10	Compressors (Electricity)	1	3	1	1	9	1	140
11	Hybrid Test Cell, Cold Cell, Altitude Test Cell (Electricity)	1	3	1	1	9	1	140
12	Applied Lab (Electricity)	1	3	1	1	9	1	140
13	HTG Pump, Air Handlers-main aisle, Emergency Generator (Electricity)	1	3	1	3	9	1	150
14	Waste Heat Recovery Cells (NG)	1	1	1	1	1	3	70
15	Lighting (Electricity)	1	1	1	1	9	1	130
16	Walesboro Noise Facility (Electricity)	1	1	1	1	3	1	70

The criteria used to select these design ideas is by analyzing their scores in separate categories. These categories are based on how much energy is being used, the cost of the energy being used, the emissions of the areas of improvement, the ability to make realistic changes and measure them, and the stringent requirements of regulations. Looking at the final score it becomes apparent the highlighted areas are the largest energy consumers. With that knowledge it was possible to determine where to focus energy saving ideas. Table 13[12] describes each criterion in detail to explain each score in shown in Table 12[12].

Table 13 - Decision Matrix Criteria

Primary Energy Consumption: the Energy used in the subsystem converted to primary energy in MMBTU		**Ability to Influence:** the level of opportunities for reductions in energy use and / or GHG emissions for that subsystem	
9	Greater than **30%** of site total	9	**High** - Opportunities for improving efficiency and consumption will substantially decrease GHG
3	Greater than **5%** but less than **30%** of site total	3	**Medium** - Opportunities for improving efficiency and consumption may decrease GHG
1	Less than **5%** of site total	1	**Low** - Opportunities for improving efficiency and consumption will have little or no decrease on GHG
Energy Cost: the cost of the energy in the subsystem in local currency		**Ability to Measure:** the level of availability of accurate, reliable data	
9	Greater than **$1 million**	9	**High** - Metered data available
3	Greater than **$100,000** but less than **$1 million**	3	**Medium** - Some metered data available for calculating subsystem use
1	Less than **$100,000**	1	**Low** - No metered data available
Green House Gases Emissions: GHG emissions generated by the energy used by the subsystem		**Legal and other Requirements**: energy use subsystems that are regulated or subject to other requirements for energy use or emission limits	
9	Greater than **30%** of site total	9	Extensive regulatory application
3	Greater than **5%** but less than **30%** of site total	3	Few or limited impact requirements
1	Less than **5%** of site total	1	Basic, few requirements

4 Methodology

To complete this project within the deadline, Team 2's first priority will be to gather pertinent information. First and foremost, Team 2 will be researching the Technical Center through the Cummins sponsor Roger England and plant liaison Mike Hayes. It will be important to understand the priorities of Cummins and ensuring that the company gets exactly what it needs. The Off Grid Zero Emission Building will be another valuable resource to research grid monitoring systems and how to achieve energy savings through environmentally friendly means. By visiting the OGZEB, Team 2 has developed an efficient procedure for measuring the power consumption of facilities by imitating the OGZEB electrical monitoring system. After gathering information and visiting the OGZEB Team 2 conducted several brainstorming sessions thinking of any and all possible energy savings ideas. These ideas will be updated throughout the year but originally about 12 ideas were listed as shown previously in section 3 of this report. From these ideas, Team 2 created a decision matrix and separated each idea into 5 aspects that were ranked according to criteria previously established by Cummins. From this decision matrix, the top 4 major areas of interest were selected. Team 2 then split up these 4 main foci between the 5 team members as stated below in the resource allocation.

Every two weeks, Team 2 plans to talk with its advisor, Dr. Ordonez, to provide updates and gather insight on how to move forward. Each step forward will be documented weekly on the website by Marvin Fonseca, the webmaster. Once Team 2 obtains the necessary information to proceed, they will create a draft of the overall energy saving plan.

4.1 Flow Work

The flow of work for each area of design will be as follows:

4.1.1Solar Panel

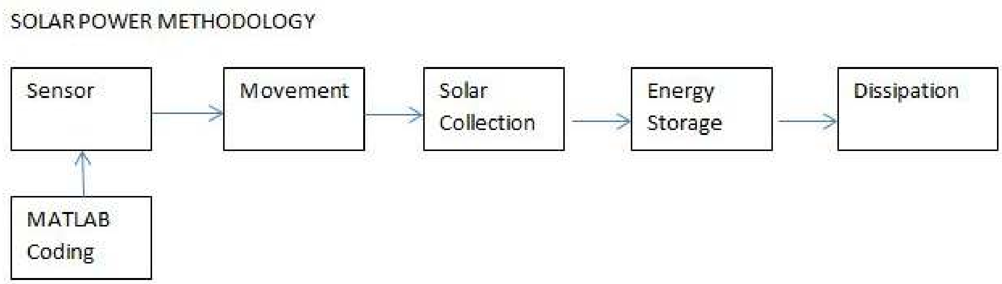

Figure 3 - Solar Power Flow Chart

4.1.2Insulation

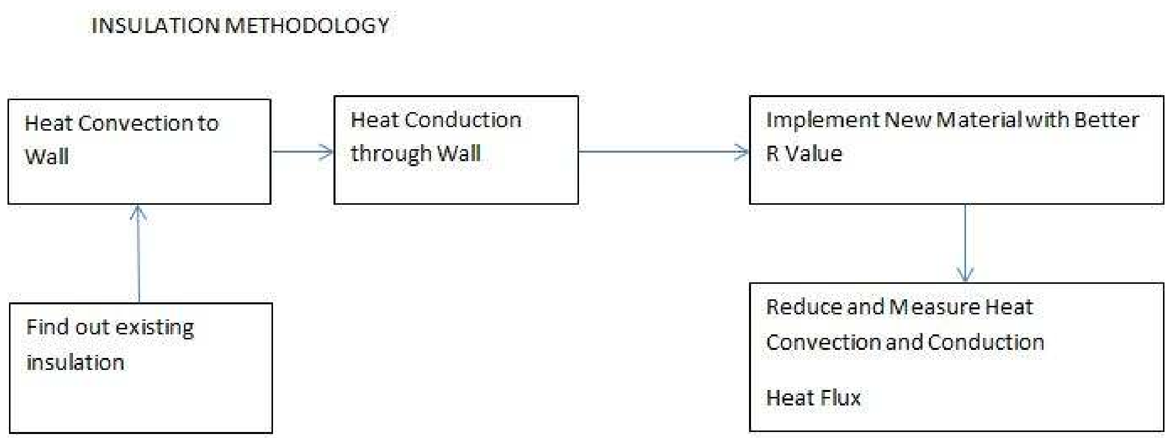

Figure 4 - Insulation Flow Chart

4.1.3 Engine Testing

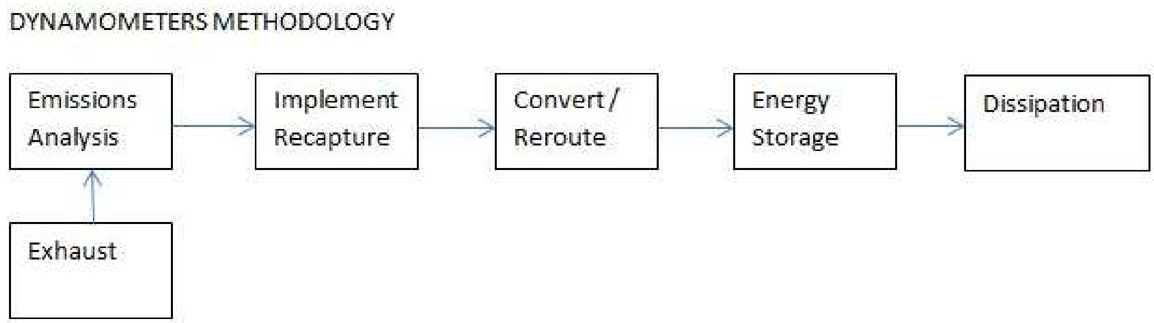

Figure 5 - Engine Testing Flow Chart

4.1.4 Chillers

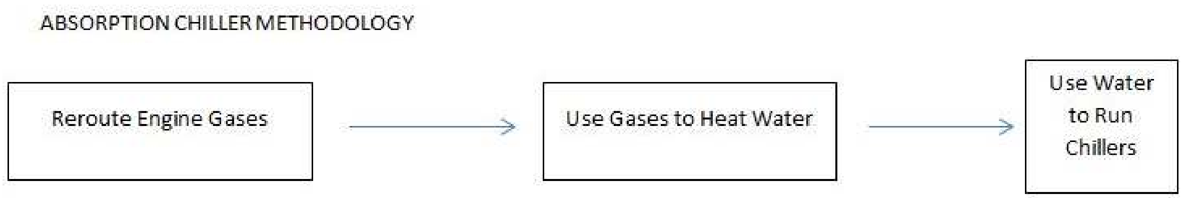

Figure 6 - Chiller Flow Chart

4.2 Schedule

A schedule is important for the completion of the project. In order to finish the project in a timely manner, a Gantt Chart has been developed for scheduling and organizational purposes. The Gantt Chart displayed in Figure 7, depict varying tasks that were described by Team 2 as important to the overall project. Figure 7 is a description of tasks that are required to be completed before the conclusion of the fall semester. The Gantt Chart can be found in the Appendix.

4.2.1 Classroom Assignments

Table 14 displays the required assignments and their individual due dates linked with the senior design course. These assignments are relevant to the completion of our project because each deliverable allows for the instructors and teaching assistants to see our progress in an official report.

Table 14 - Class Deliverables

Assignments	**Due Date**
Project Plan and Product Specifications	10-Oct
Initial Web Page Design	17-Oct
Midterm Presentation	14-Oct
Midterm Report I	24-Oct
Peer Evaluation I	28-Oct
Midterm Presentation II	11-Nov
Peer Evaluation II	25-Nov
Final Web Page Design	25-Nov
Final Design Presentation	2-Dec
Final Report	5-Dec

4.3 Resource Allocation

In order to maximize our time efficiency, the work breakdown structure will be broken up into sections that allow each member of the team to contribute to the technical aspects of the project. Since the team selected 4 areas of improvement for the facility to implement, the work breakdown is given to each member according to member interest and background knowledge. In this way, each member will be responsible for a different design aspect of the energy savings plan for Cummins.

Daniel Baker: He will create a budget for the prototype/prototypes we plan to implement. Additionally, he will also create and forward a travel budget to Cummins. This travel budget will be used to fly to Indiana and walk through the Cummins Technical Center to gather the information for the final draft of the energy saving plan for 20 days. He will be responsible for looking into the possible energy gains in CVS chillers and chilled water.

Beau Bell: He will be responsible for research and technical analysis of diesel testing consumption, dynamometer control and analysis, and looking into utilities enhancement programs for a duration of 21 days.

Daniel Carnrike: He will be responsible for research and technical analysis of Solar Panel technology, possible avenues for geothermal and green energy, latitude and longitude location coordinates for a duration of 14 days.

Kyle Fields: He will be responsible for research into possible energy gains in AC ventilation design for 9 days, compressed air leak study for 9 days, research into pumps and valves, and oversight for entirety of the project. He will assist the other group members in their respective design categories as needed.

Marvin Fonseca: He will be responsible for looking into energy audits and practices, handle website updating daily, and researching insulation/fabrication techniques for 14 days.

5 Conclusion

Following the completion of the Product Specifications and Project Plan report, Team 2 has made significant strides in narrowing down design implementation suggestions for the energy savings options that Cummins requested. The cost effectiveness of the solar panels has been estimated based on calculations made using prior knowledge in MATLAB code as well as Excel in order to find the feasibility and cost savings, respectively. Additionally, the cost effectiveness of replacing the building insulation has also been estimated in the same manner. Likewise, cost analysis for the absorption chillers has been based on an ideal Vapor Absorption Refrigeration System study. On the administrative side of the project, Team 2 has come up with a Gantt Chart and resource allocation for each team member that will help the project stay on schedule. The team has met at the OGZEB house and learned that the design of the prototype grid monitoring system would be too overly complicated and ultimately unhelpful to this design project. Team 2 is finalizing the travel budget and plans on visiting the CTC in Indiana November 13th-14th, and the results of this trip and the subsequent tweaks to the designs mentioned in this midterm report will be presented in the Final Report that was shown in Table 14. From there on, the data collected from the facility will allow the team to have accurate data for the final design of the energy savings plan and an accurate calculation of the cost effectiveness of the proposed changes for the technical center, along with any other ideas that are suggested by the sponsor while the team is visiting. The team also plans to continue meeting with the advisor Dr. Ordonez for support in the design of the solar panels and general guidance in the other design suggestions. Additionally, Team 2 will have staff meetings to ensure that the work being done is productive and will help ensure that deliverables are completed in a timely and satisfactory manner. Further work will be required to finalize the actual cost of implementing these designs. Problems may arise in the ability to implement these designs due to feasibility, innovation, and funding. The team is also tasked with coming up with as many design suggestions as possible, and this leads to complications since there is not a singular design that must be selected as best among other designs. This unique project requires that Team 2 creatively design new and unique ways for Cummins to save 10% of their energy consumption, and through the visit to the facility, the team will be better equipped to handle the task.

6 References

1. "Cummins Explores Solar to Help Power Facilities." Cummins, n.d. Web. 22 Sept. 2014. <http://www.cummins.com/cmi/navigationAction.do?nodeId=201&siteId=1&nodeName=Cummins+Looks+at+Solar+Power&menuId=1050>

2. "Off-Grid Zero Emission Buildings." *FSU*. N.p., n.d. Web. 25 Sept. 2014. <http://esc.fsu.edu/currentProjects.html>

3. Kutz, Myerq. "Energy Audits." *Mechanical Engineers' Handbook*. 3rd ed. Vol. 4. Delmar: Mcgraw Hill, 2005. 272-301. Print.

4. "What Are Solar Panels Made Of?" *Solar Power World*. Web. 10 Oct. 2014. <http://www.solarpowerworldonline.com/2013/05/what-are-solar-panels-made-of/>

5. "Insulation. – Department of Energy" Web. 30 October 2014. http://energy.gov/energysaver/articles/insulation http://energy.gov/energysaver/articles/insulation-materials

6. "Dynamometer Review." *Engineers EDGE*. Web. 17 Oct 2014. <http://www.engineersedge.com/industrial-equipment/dynamometer-review.htm>

7. "Absorption Chillers." *New Building Institute Advanced Design Guideline Series* (1998): 1-97. Web. 15 Oct. 2014. <www.newbuildings.org>.

8. "Senior Design Project Definition – Decreasing Electricity Usage at Cummins Technical Center." *FSU*. Web. 10 Oct 2014. <Senior Design Project Definition>

9. Vieira, Da Rosa Aldo. Fundamentals of Renewable Energy Processes, Third Edition. Kidlington, Oxford, U.K.: Academic, 2013. Print.

10. Murugavel, V., and R. Saravanan. "LIFE CYCLE COST ANALYSIS OF WASTE HEAT OPERATED ABSORPTION COOLING SYSTEMS FOR BUILDING HVAC APPLICATIONS." *Department of Mechanical Engineering, Anna University* (2010): 1-9. Web.

11. "Use Low-Grade Waste Steam to Power Absorption Chillers." *U.S. Department of Energy: Energy Efficiency & Renewable Energy* (2012): 1-2. Web. <manufacturing. energy.gov>.

12. Fridley (2014). Georgia Tech Training [PowerPoint Slides]. Retrieved from < https://www.dropbox.com/home/Senior%20Design>

13. "Sun Hours/Day Chart". *Big Frog Mountain: Alternative Energy Sources*. Web. 25 October 2014. <http://www.bigfrogmountain.com/SunHoursPerDay.html>

14. “SolarWorld SW 250 Mono,250 Watt Solar Panel”. *GoGreen Solar*. Web 22 Oct 2014 <http://www.gogreensolar.com/products/solarworld-sw-250-mono-250-watt-solar-panel-pallet-of-30>

15. “Electric Power Monthly with Date for August 2014” *Independent Statistics & Analysis; U.S Energy Information Administration*. Web. 24 Oct 2014. < http://www.eia.gov/electricity/monthly/pdf/epm.pdf>

7 Appendix

7.1 Gantt Chart

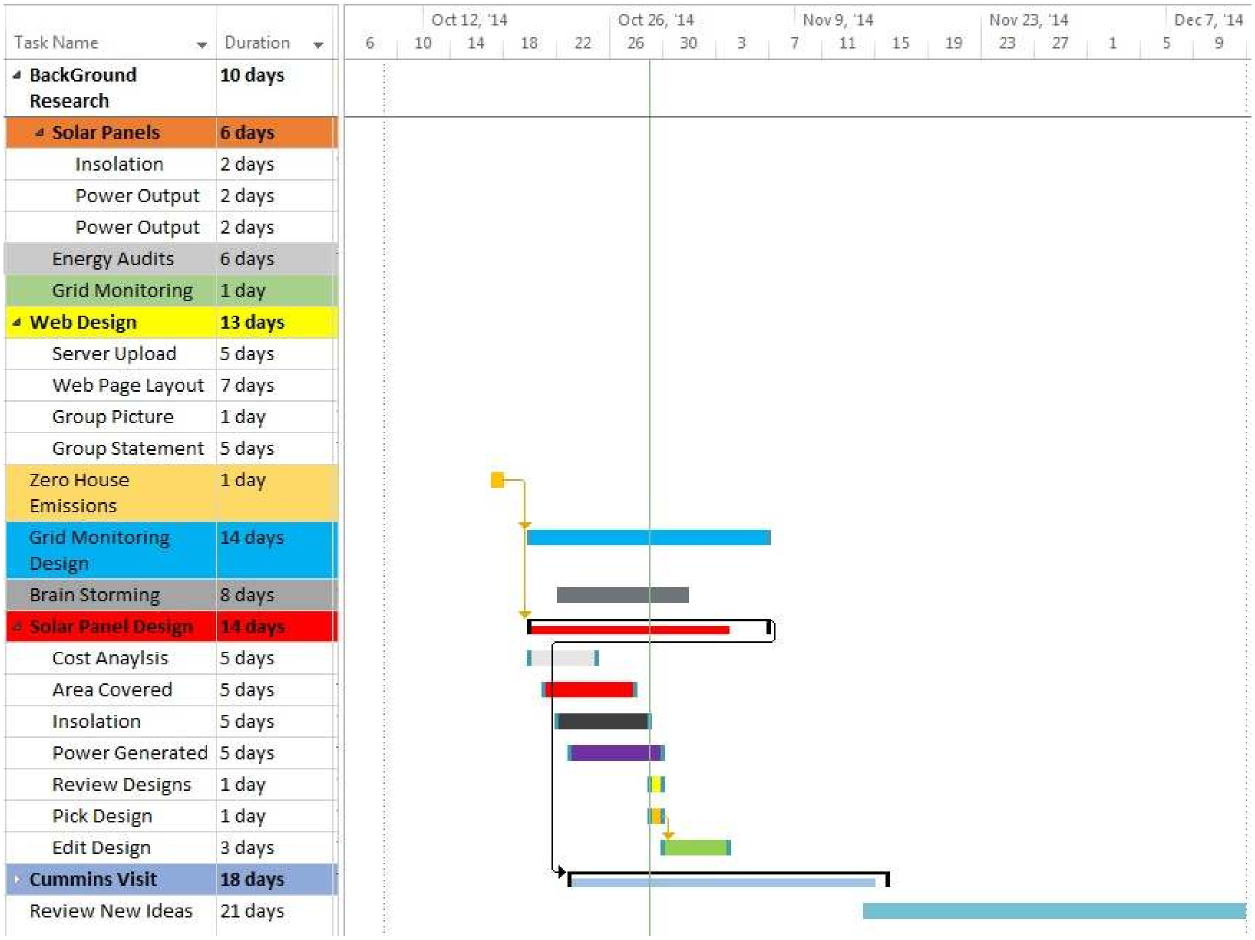

Figure 7 - Gantt Chart

7.2 MATLAB Code for Solar Panels

```
%Team 2
%Senior Design  Solar Estimates

clc
a = 0.14;
h = .192; % km above sea level
AM = 1.5; % Air Mass Index [100 units]
I_o = 1365; % Outside Atmosphere W/m^2
ALPHA = zeros(1,100);
time_day = zeros(1,100);
zenith = zeros(1,100);
azimuth = zeros(1,100);
Insolation = zeros(1,100);
azimuth_y = zeros(1,100);
azimuth_x = zeros(1,100);
ratio = zeros(1,100);
%%%% Solar Time throughout the day
day =  input('What day of the year is it = ');
sunrise = input('What is sunrise solar time = ');%solar
sunset = input('What is sunset solar time = ');


zeta = 180; % directions that the solar panels face

%%% Coordinates for Indiana
lamda = Coordinate_Time(39,12,4.49298); % lattitude
W = Coordinate_Time(85,54,13.0428); % Lonigtude
elevation = lamda;

%%% Average Insolation Equation
I_local = I_o.*((1-a.*h).*(0.7.^(((AM).^0.678))) + (a.*h));

declination = 23.44.*sind(360*((day-80)/365.25));

for i=1:100

    time_day(i) = sunrise + ((sunset-sunrise)/99)*(i-1);
    ALPHA(i) = 15.*(time_day(i) - 12);
    zenith(i) = acosd(sind(declination).*sind(lamda) + ...
        cosd(declination).*cosd(lamda).*cosd(ALPHA(i)));
    azimuth_y(i) = sind(ALPHA(i));
    azimuth_x(i) = (sind(lamda).*cosd(ALPHA(i)) - ...
        cosd(lamda).*tand(declination));
    ratio(i) = azimuth_y(i) ./ azimuth_x(i);
    azimuth(i) = atan2d(azimuth_y(i), azimuth_x(i));

    if ALPHA(i) > 0 &&  ratio(i) > 0
        azimuth(i) = 180 + azimuth(i);
    elseif ALPHA(i) > 0 && ratio(i) < 0
        azimuth(i) = 360 + azimuth(i)  ;
    elseif ALPHA(i) < 0 && ratio(i) < 0
        azimuth(i) = 180 + azimuth(i);
```

```
    elseif ALPHA(i) == 0
        azimuth(i) = 180;

    end

    Insolation(i) = I_local.*(cosd(elevation).*cosd(zenith(i)) + ...
        sind(elevation).*sind(zenith(i)).*cosd(azimuth(i) - zeta));

end

Sun = mean(Insolation); %% Calculationg the Mean Insolation

%%% Plots
plot(time_day,Insolation)
xlabel('Time (Hr)')
ylabel('Insolation')
title('Insolation in Day')
grid on
```