Alternative Power Source to Draw Underground Water

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Team 01

Concept Generation and Selection

Report 2

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Contents

1. Introduction

Babbitt Ranches is the producer of AQHA quarter horses and is home 730000 acres of land, with an additional 300000 acres deeded, located between Flagstaff Arizona and the Grand Canyon. In addition to raising livestock, Babbitt Ranches hosts a mining operation run by Cemex. Cemex, a global building materials company that distributes and sells cement, currently mines aggregate on Babbitt Ranches' property. This report will detail the problem that Babbitt Ranches and Cemex are experiencing, the concepts generated as solutions to said problem, as well as concept selection.

2. Problem Statement

Figure 1 is an aerial view of the Cemex mining site located on Babbitt Ranches' land. On this site is located a pump which is powered by a diesel generator. This pump draws water from underground to supply a high demand in various operations on the mining site. Both Cemex and Babbitt Ranches are currently looking for a new means of power for drawing water from this particular well, operated by Cemex. The current diesel generator operating the pump draws 0.3 m^3 per second from a depth of 520 m. Any alternative design would be required to supply enough power to operate within these constraints. The major problem with the current system using a diesel generator is the high cost of operation. Babbitt Ranches and Cemex are required to pay penalties for carbon emissions that the diesel generator produces. It has also become costly to maintain the supply of fuel with current fuel costs. The first priority for both Babbitt Ranches and Cemex is to lower the operating costs of their water pumping system. In addition, they have also expressed interest in mitigating their carbon emissions.

Figure 1: Courtesy-NASA

3. Concept Generation

To approach the solution the team researched various alternative methods for powering the Cemex pump at the specified flow rate and depth. Table 1 shows a list that was compiled of all of the ideas concerning the source or energy as well as design options that may utilize the power source. These ideas were compiled into four categories based on the natural resource in use.

Solar

The solar concept led to three ideas. The first idea the team had was an array of photovoltaic panels, which are able to produce the energy needed to power the pump. The footprint of such an array is not a problem because the client has indicated space is not a constraint for the design.

Solar irradiance can be focused by a solar concentrator and used to heat steam. The heated steam would be used in a Rankine power cycle where the solar concentrator acts as the heat generator.

An additional concept was a solar concentrator which would be used to heat the working fluid in a stirling engine. Stirling engines are simple, inefficient, and rely on temperature differences to generate energy. The solar concentrator would be focused on the hot part of the stirling engine. The cold part of the engine would be encased with a cooling fluid. Inside the stirling engine, the working fluid goes through cycles of expansion and contraction because of the temperature changes. The pistons move linearly and are attached to a system that translates the linear motion into rotational motion. The rotational motion would spin the magnets of an electric generator.

Wind

Also for the wind resource the team came up with three possible ideas. A large single wind turbine which generates enough power to power the generator of the pump was discussed. An alternative option would be an array of several turbines. Compared to one turbine, an array of turbines would mean smaller turbines but more space needed to set them up. Additionally, a vertical axis wind turbine. Vertical axis turbines are in their infancy relative to research, availability, and industry acceptance.

Geothermal

The geothermal resource had two ideas on the system set-up. A vertical loop, which would have one loop go far into the earth and back, and buried loops, which would have a loop buried less deep in the earth that coiled several times. Vertical loop systems require depths of about 50 meters to 70 meters. Holes are bored deep into the ground then pipes are run down into the holes (see Figure 3). Horizontal loops require a pit dug below the frost line of the soil (see Figure 2). Plastic pipes are laid in the bottom of the big pit. The pipes are laid out in a fashion that resembles a spring that has been smashed radially. With either vertical or horizontal loop layout, the system is a closed loop where the earth heats the internal fluid. The fluid is usually a type of glycol mixed with water. A pump returns the fluid to a compressor where the heat is then concentrated and used to run a heat-based power source.

Figure 2. Horizontal Loop

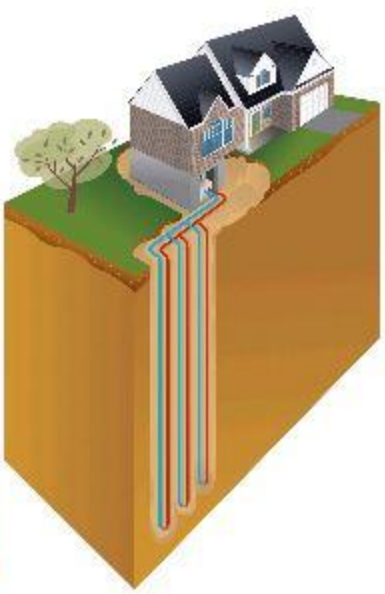


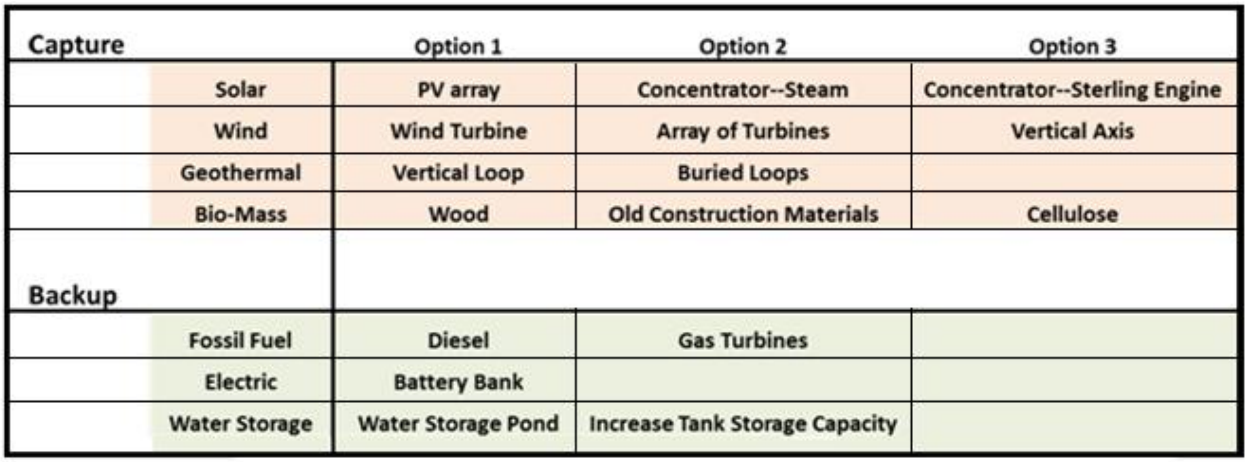
Figure 3. Vertical Loop

Biomass

The biomass resource had three ideas based on the expected available resources. The client CEMEX indicated that they are planning on having a landfill right next to mining pit, where people can bring their waste construction materials. Wood is a common construction material and potentially available most of the time in CEMEX's landfill. The main sources of biomass would be wood and old construction materials. Also, Northern Arizona has many ecological restoration projects where small diameter trees are cleared and burned in piles. These trees could be used for biomass.

The biomass could be processed into biodiesel, which means that the client could maintain their current system. Alternatively, the biofuels could be burned and used in a combustion chamber for part of the Rankine cycle.

Table 1 – Design Concepts



Capture		Option 1	Option 2	Option 3
	Solar	PV array	Concentrator--Steam	Concentrator--Sterling Engine
	Wind	Wind Turbine	Array of Turbines	Vertical Axis
	Geothermal	Vertical Loop	Buried Loops	
	Bio-Mass	Wood	Old Construction Materials	Cellulose
Backup				
	Fossil Fuel	Diesel	Gas Turbines	
	Electric	Battery Bank		
	Water Storage	Water Storage Pond	Increase Tank Storage Capacity	

Backup Power Source

The unreliable nature of wind energy and the cyclical nature of solar energy dictate the need for backup power sources. Table 1 also details concepts for backup systems that can supply power if the natural resource is unable to meet the demands.

Fossil Fuels

Fossil fuels are a reliable resource if alternative resources are not available. For the chosen system, there is a possibility that alternative energy production will not meet the client's needs. The client could maintain their current system but only use the diesel engine generator if the alternative energy source does not provide enough energy to run the pump. Another back up option for fossil fuels would be natural gas turbines.

Natural gas turbines are efficient relative to diesel engines. The price of natural gas is expected to decline throughout the USA because of recent technological developments in fracking, the process where air, water, and other chemicals are pumped into the ground to break apart shale and release natural gas.

Electrical

Excess energy can be stored in deep cycle batteries. If the system produces more energy than needed, the energy could be stored. If energy is needed, the generator can run on energy from the batteries.

Water Storage

For water storage during off peak hours of the natural resource the ideas are to increase the capacity of water storage of the current system, such as installing an extra water tank. An extra water tank would allow the client to pump more water, so that if the pump is not running for some reason water is still available. Another alternative idea would be digging a water pit.

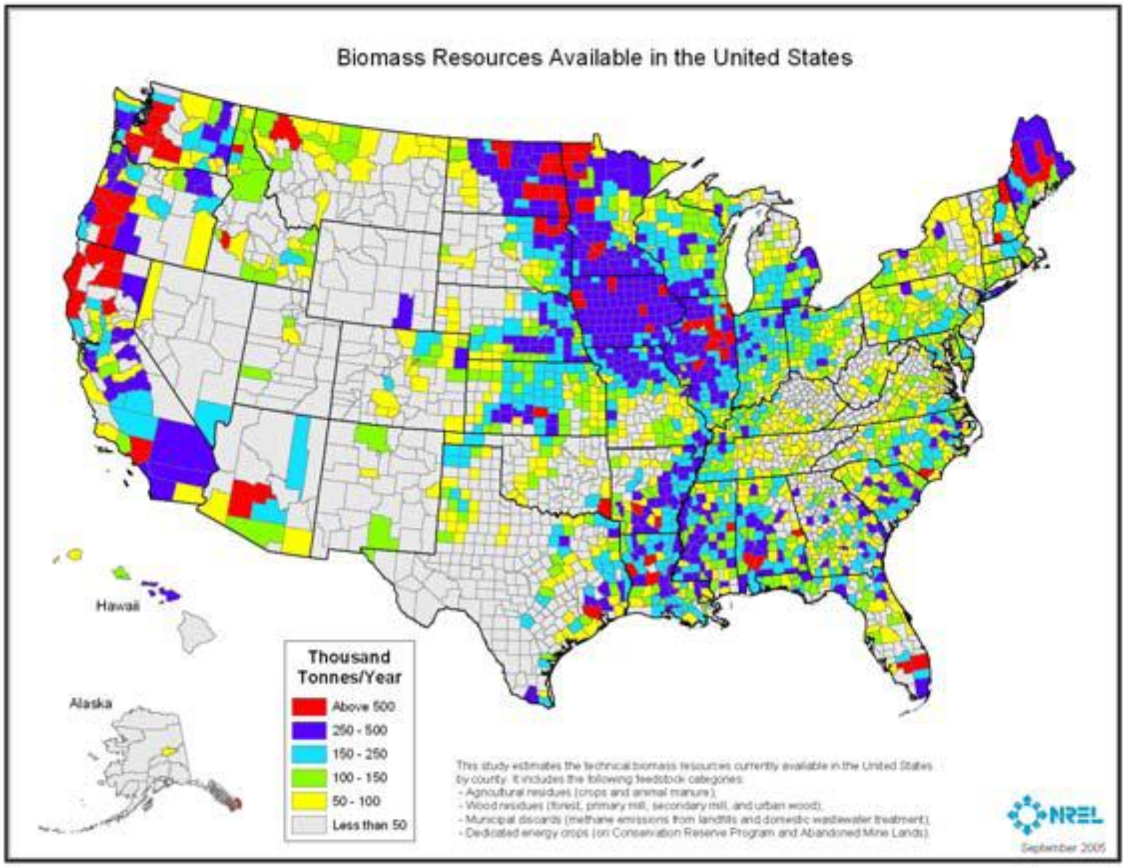
4. Concept Selection

Concept Refinement

Refinement of ideas generated through brainstorming sessions was crucial to determine the feasibility of each idea. The team analyzed each idea looking at different aspects such as expense of implementation, complexity of the system, and availability of the system for purchase.

According to the U.S. Department of Energy's report entitled, *Geothermal Technologies Program, Arizona,* the San Francisco Volcanic Field is one of several largely untapped geothermal resources in Arizona. It has not actually manifested any attributes of a good geothermal power source on the surface, but it has very similar geology to areas in other states with high temperature geothermal resources. The problem with this option as a power source is the immense initial cost of heavy research into the geothermal resource and implementation of a power harnessing system. Large corporations such as Arizona Power Service Company are currently looking into geothermal resources elsewhere in the state, but the value of the geothermal attributes that the San Francisco Volcanic Field may hold is largely unknown. This lack of data combined with huge potential costs for such a system to harness geothermal energy has led to this idea not being pursued.

The National Renewable Energy Laboratory created a report entitled, A Geographic Perspective on the Current Biomass Resource Availability in the United States, which looked into various forms of biomass for locations across the United States. When compared with the nation, Northern Arizona has very small amounts of crop residues available for biomass consumption. Methane and manure were also viable options as Babbitt Ranches has a large amount of livestock. Unfortunately, as stated in this report, manure that is deposited on fields and pastures produces an insignificant amount of methane. Ponds and holding tanks proved to be much more effective to capture the energy in manure. Logging residues, such as unused portions of trees that are cut, are also not very high for Northern Arizona. Urban wood residues such as waste from construction are an option for the site, but gaining enough quantity to supply the power needs of the pump would be very difficult. Figure 4 below from the report displays the overall lack of biomass availability in Northern Arizona.



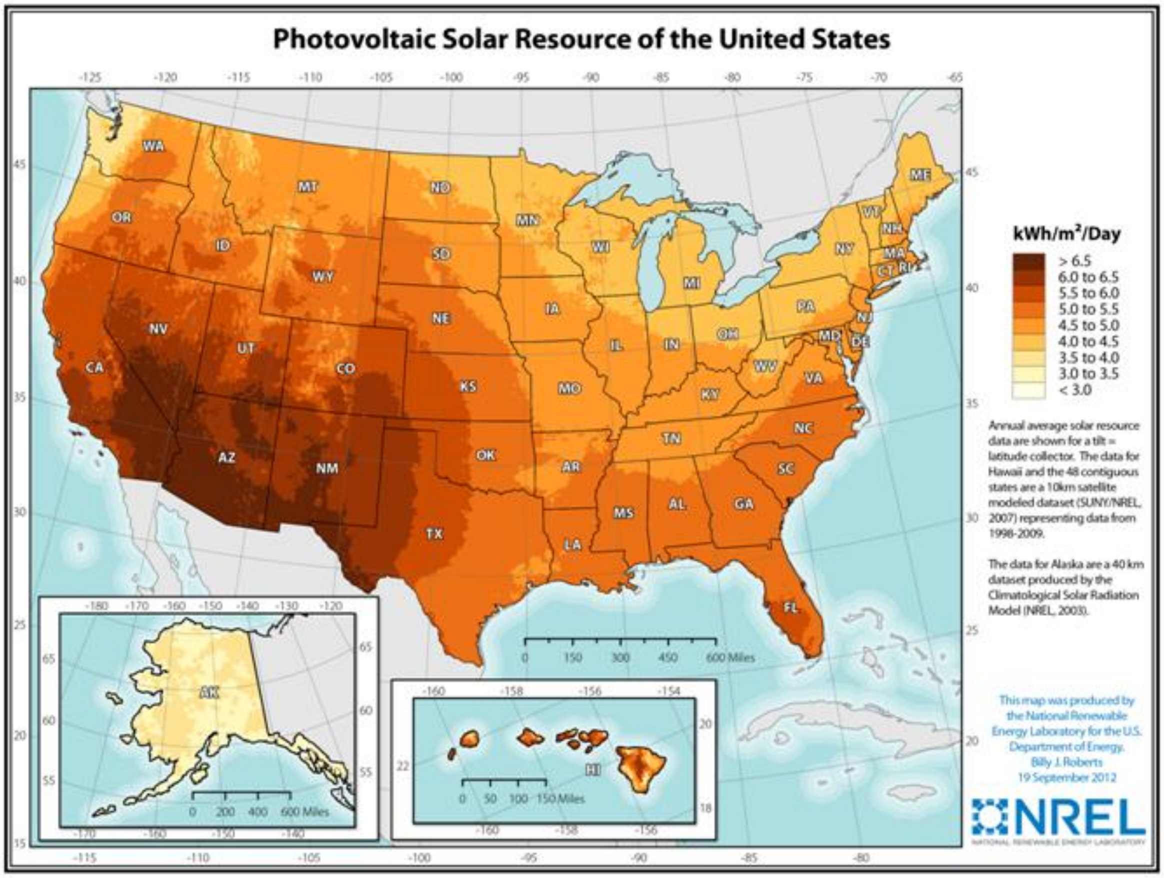
This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:
- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and domestic wastewater treatment);
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands).

Figure 4: Biomass Resources Available in the United States

Natural gas pipelines through Arizona unfortunately run miles away from the construction site. The nearest pipeline that could be routed from was would provide too large of a cost to implement. However, transporting canisters of natural gas on trucks could very well be a means of supplementing the mains source of power.

While natural gas and diesel could be very useful as a backup or supplement to the primary power source, a battery backup system would not work. For the very large amounts of power required for the operation, any battery would be extremely large and far too expensive in order to meet power demands.

The National Renewable Energy Laboratory also has reported a map, shown below in Figure 5, that displays the solar resources for photovoltaic panels in the United States. The region just above Flagstaff sees 6 to 6.5 kWh/m^2/Day on average, making solar PV, as well as a solar concentrator with a stirling engine, a very good option for the design.


Photovoltaic Solar Resource of the United States

Annual average solar resource data are shown for a tilt = latitude collector. The data for Hawaii and the 48 contiguous states are a 10km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2009.

The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy. Billy J. Roberts 19 September 2012

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Figure 5: Photovoltaic Solar Resource of the United States

Wind data acquisition systems have recently been in place near the site which will provide very useful information on the availability of wind as a viable resource. Very large benefits of wind turbines as well as PV panels are that these two technologies are heavily increasing in production and demand. This means that the availability of these technologies to adequately provide power for the design requirements is extremely good. There are also benefits of implementing multiple systems to meet the power requirements, which could be very effective in the design.

Concept Evaluation

To further analyze the three options that proved most viable, solar PV, wind turbines, and stirling engine, the team established evaluation criteria, shown in Table 2 below, that would be assigned to the systems attributes. A perfect performance level for the new design would cost less than $100,000 initially, which is less than what the client currently pays annually. A perfect performance level for the design would also output at least 100 kW of power, which is estimated to provide enough power to the pump, leaving extra to be used for other Cemex operations.

Table 2 – Evaluation Criteria

Performance Level	**Criteria Metrics**		
	Value	**Cost $**	**Power (kW)**
Perfect	**10**	**<100,000**	**>100**
Excellent	**9**	**<200,000**	**>90**
Very Good	**8**	**<300,000**	**>80**
Good	**7**	**<400,000**	**>70**
Satisfactory	**6**	**<500,000**	**>60**
Adequate	**5**	**<600,000**	**>50**
Tolerable	**4**	**<700,000**	**>40**
Poor	**3**	**<800,000**	**>30**
Very Poor	**2**	**<1,000,000**	**>20**
Inadequate	**1**	**<1,500,000**	**>10**
Useless	**0**	**>2,000,000**	**<10**

Based on these criteria, ratings were assigned to each idea in the decision matrix, shown in Table 3 below. Initial estimates of power output by each idea singularly reached 50 kW. Initial estimates of cost of the designs gave: $305,000 for a PV array, $380,000 for a wind turbine, and $1,100,000 for a sterling engine and concentrator.

Table 3 - Decision Matrix

Criteria	**Units**	**Design Option**					
		Solar (PV array)		**Wind (Turbine)**		**Stirling engine**	
		Raw Score	**Value on Scale**	**Raw Score**	**Value on Scale**	**Raw Score**	**Value on Scale**
Cost	**$**	**305000**	**7.9**	**380000**	**7.2**	**1100000**	**1.8**
Power	**kW**	**50**	**5**	**50**	**5**	**50**	**5**
Total			**12.9**		**12.2**		**6.8**
Normalized total			**0.40**		**0.38**		**0.21**

The decision matrix shows that the stirling engine was the least effective solution relative to the others. A stipulation to this rating is that stirling engines are much less complicated that the other design, which could prove very desirable. The solar PV array and wind turbine were equally viable options from the design matrix.

Conclusion

During this phase of the design project it became increasingly obvious that the scope and complexity of this project was not completely understood. This is directly related to the limited communication with the client and the groups misunderstanding of the expectations for the final design of this particular project. These shortcomings should be resolved over the course of the following week, where several meetings and/or information exchanges are scheduled.

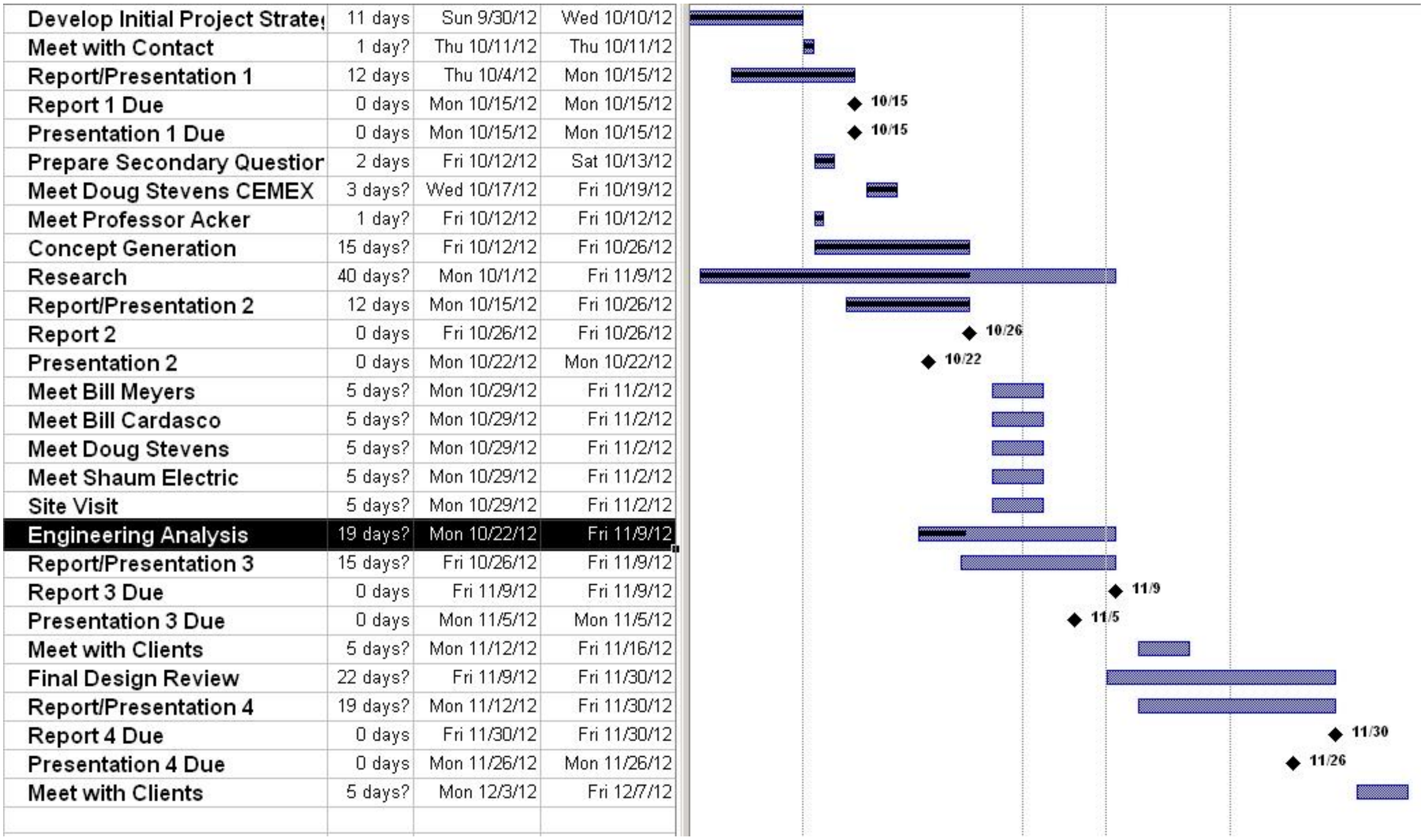
The concept generation and selection analysis suggested that implementing either a wind turbine(s) or solar array would be the most feasible option. After gaining a better understanding of the project's complexity and feedback from the presentation, it is realized that more information about the current system is necessary. In addition, an engineering analysis needs to be performed on the pump, of which the new system will be designed around. This, too, will be possible as more information is received during the next week.

Solar arrays and wind turbines would naturally seem like the obvious choice when designing a system where little knowledge of the system is present. This is due to the decreasing cost of these systems, their availability and their increasing efficiencies. However, though they may seem obvious, they may not be the best choice for this particular situation. Battery backups, for reserve power supply are inefficient for this problem, and the closest grid access would cost millions to access. This being said, and many other examples like it, show that it is necessary to do a site analysis, a pump analysis and finally, an engineering analysis of the system and potential solutions.

The group will move forward with the selections derived from the concept generation but will not rule out other potential design options, until all of the necessary analysis has been finalized.

5. Gantt Chart

The updated Gantt chart detailing the project schedule can be seen in Figure 6 below:



Develop Initial Project Strate	11 days	Sun 9/30/12	Wed 10/10/12
Meet with Contact	1 day?	Thu 10/11/12	Thu 10/11/12
Report/Presentation 1	12 days	Thu 10/4/12	Mon 10/15/12
Report 1 Due	0 days	Mon 10/15/12	Mon 10/15/12
Presentation 1 Due	0 days	Mon 10/15/12	Mon 10/15/12
Prepare Secondary Questior	2 days	Fri 10/12/12	Sat 10/13/12
Meet Doug Stevens CEMEX	3 days?	Wed 10/17/12	Fri 10/19/12
Meet Professor Acker	1 day?	Fri 10/12/12	Fri 10/12/12
Concept Generation	15 days?	Fri 10/12/12	Fri 10/26/12
Research	40 days?	Mon 10/1/12	Fri 11/9/12
Report/Presentation 2	12 days	Mon 10/15/12	Fri 10/26/12
Report 2	0 days	Fri 10/26/12	Fri 10/26/12
Presentation 2	0 days	Mon 10/22/12	Mon 10/22/12
Meet Bill Meyers	5 days?	Mon 10/29/12	Fri 11/2/12
Meet Bill Cardasco	5 days?	Mon 10/29/12	Fri 11/2/12
Meet Doug Stevens	5 days?	Mon 10/29/12	Fri 11/2/12
Meet Shaum Electric	5 days?	Mon 10/29/12	Fri 11/2/12
Site Visit	5 days?	Mon 10/29/12	Fri 11/2/12
Engineering Analysis	19 days?	Mon 10/22/12	Fri 11/9/12
Report/Presentation 3	15 days?	Fri 10/26/12	Fri 11/9/12
Report 3 Due	0 days	Fri 11/9/12	Fri 11/9/12
Presentation 3 Due	0 days	Mon 11/5/12	Mon 11/5/12
Meet with Clients	5 days?	Mon 11/12/12	Fri 11/16/12
Final Design Review	22 days?	Fri 11/9/12	Fri 11/30/12
Report/Presentation 4	19 days?	Mon 11/12/12	Fri 11/30/12
Report 4 Due	0 days	Fri 11/30/12	Fri 11/30/12
Presentation 4 Due	0 days	Mon 11/26/12	Mon 11/26/12
Meet with Clients	5 days?	Mon 12/3/12	Fri 12/7/12

Figure 6: Gantt Chart

6. References

Doug Stevens – Cemex

Bill Cardasco – Babbitt Ranches

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