Honors Thesis

Advisor: Dr. Richard Balling

Seawater Air-Conditioning Potential in Port-au-Prince Bay

Background and Significance:

As my culminating design experience, I am part of a civil engineering group designing a skyscraper. Several factors we considered in the skyscraper design are creative approach, response to site, sustainability, and functionality. In trying to meet these goals, our group identified an HVAC system called seawater air-conditioning (SWAC).

The location for our skyscraper will be Port-au-Prince, Haiti. Haiti is located south of the tropic of cancer. Summertime temperatures average 95 degrees Fahrenheit and wintertime temperatures average 72 degrees Fahrenheit (Weather Channel 2013). Demands on the heating, ventilation, and air-conditioning (HVAC) system will consistently require cooling rather than heating due to the warm summers. A reduction in the need of energy for cooling dramatically decreases the cost for HVAC in Haiti, improving the profitability of our skyscraper design.

A typical air conditioning system uses a condenser to condense a refrigerant, heating it up. This refrigerant is then cooled down by passing through a set of coils, turning into a liquid. The refrigerant is then passed through an expansion valve where it quickly evaporates into a cold low pressure gas. This gas is then used to absorb heat from the air by running through another set of coils exposed to air that will be blown into the air-conditioned room. Larger HVAC systems may use the refrigerant to cool water in a chiller unit and then use the water to cool air in a similar way, running water through coils to absorb the heat. Water is then used to dissipate the heat from the refrigerant by sending it to a cooling tower. Energy-using parts of this system include compressors, pumps, and cooling towers.

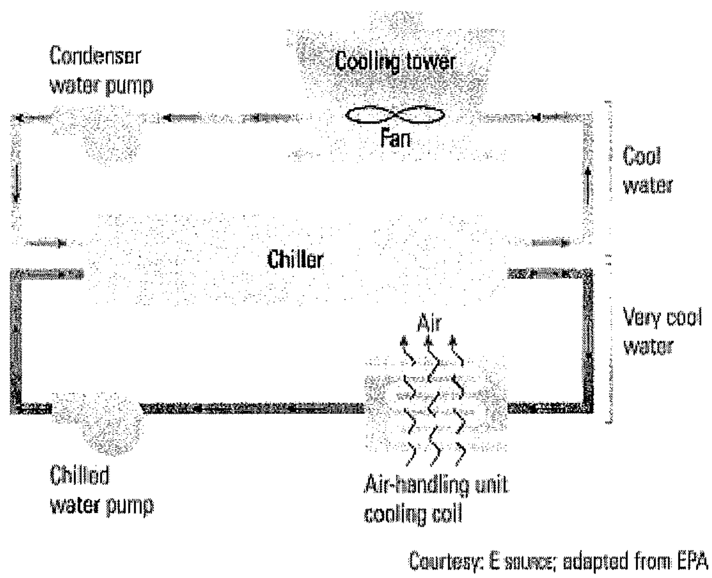

Figure 1: Large Capacity HVAC (Energy Star 2008)

The SWAC system is meant to provide cooling through a less energy intensive process than condensing and expanding gases. SWAC harvests cold seawater to provide the cooling for a building. Seawater is often deep in the ocean, about 1000 m. The cold seawater is pumped to a heat exchanger where it acts as a heat sink. Fresh water is pumped in, and, without mixing with the salt water, transfers its heat to the saltwater and cools down. Then, the cold fresh water is distributed inside the building to cool it and the seawater is returned to the ocean.

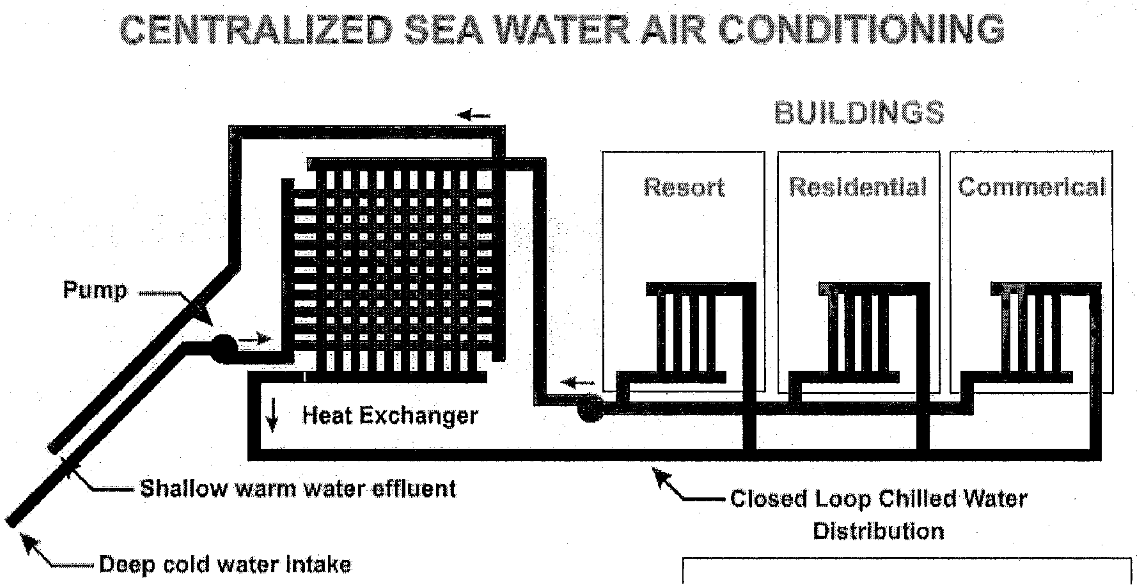

Figure 2: SWAC Cooling Process (Makai 2008)

This process can save as much as 90% energy use compared to a typical HVAC system. 90% savings in energy means a 90% savings in operation cost. These savings come from the fact that SWAC doesn't need the compressor and cooling tower. This can be a great source of savings in building operating cost. While the SWAC system requires a higher initial cost than a typical HVAC system (from the long pipe systems required to harvest the water), it quickly catches up to typical HVAC systems through low operation costs. Associated with this savings is the scale of SWAC. As more square footage is cooled, the system becomes more efficient. The pipes pump more water, maximizing the use of built pipeline. Thus we can see that SWAC is more suitable for large cooling needs.

The SWAC system also eliminates the need for the refrigerants of typical HVAC systems. Refrigerants are known to deplete the ozone layer. Thus the SWAC system not only saves energy, but eliminates the use of some environmentally harmful substances.

Statement of Intent:

I'm looking to assess the ability of businesses or home owners in the Port-au-Prince bay to use a special HVAC system called SWAC. In particular, I want to assess the feasibility of the SWAC system for the skyscraper my group designed in our culminating design experience. As part of this analysis I want to find what areas of the bay seawater can be harvested from. These are areas that are at such a depth that it is consistently cool. This water must be pumped to the coast which requires pipes and pumps. I look to establish an initial cost based off of distance for the pipe and pump as well as the actual cooling system. Finally I want to establish a minimum square footage to be cooled to make the system economical in each area of the bay.

Methodology and Procedures:

In terms of overall format, the outcome of the paper will be a triple bottom line analysis of SWAC in the Port-au-Prince bay. This will include summary results of the impact the SWAC system will have on people and the planet and detailed results of profit. Several key points of economic information are needed to complete this research including comparison initial and operation costs of typical HVAC systems, locations where cool seawater can be harvested, initial cost of the SWAC system, operation cost of the SWAC system, and detailed geographic information in the Port-au-Prince harbor.

My first major area of research will be to find a cost for installing and running a typical condenser-type HVAC System. These will be based on a square foot basis of a building. The annual utilities cost will also be calculated based off of square footage. I plan on using a US government based resource to do this. All costs will be given in dollars.

The second major area of research involves what areas of the Port-au-Prince bay have cool enough water to use. Preliminary research says that 1000 meters under the ocean surface will typically provide cold enough water for a SWAC system. However, SWAC systems have been installed in some lakes which aren't even 1000 meters deep. This provokes interest as to how deep the seawater actually needs to be. There is an existing Argo program that has 3000 free drifting floats around the world that measure ocean temperatures down to 2000 meters. Contact will be made with FFRHX for their data.

The initial cost of the system is the third area of research. While companies are willing to provide a cost estimate for individual SWAC projects, they can't provide the analysis I'm seeking. I must understand how much each element of the SWAC system costs in order to do an analysis of the Port-au-Prince area. Leading companies or organizations in SWAC technology will be contacted as well as published articles analyzed concerning this. These include Makai Ocean Engineering, Honolulu Seawater Air Conditioning, LLC., and Capital Cooling Group.

Finally, completion of the economics portion of a triple bottom line analysis will come by creating a map displaying economically advantageous areas for SWAC. Time valued analysis comparing traditional HVAC systems to SWAC will be performed. Only areas that will use ½ the energy of traditional HVAC systems will be considered. Because SWAC costs can be mitigated by cooling larger areas, this ½ energy standard can be met by increasing the size of facilities to be cooled. Thus, conceivably a map could be formed showing a range of sizes of cooling areas in the Port-au-Prince bay that are economically advantageous. A program called ArcMap will be used to display this information. Information will be provided so that less advantageous cooling areas than ½ the energy can be calculated in the area.

Preliminary outline:

I. Abstract

II. Introduction

A. The high energy cost of HVAC systems

B. The need for improvement in Haiti

C. SWAC system superiority

D. Thesis: This paper determines the applicability of SWAC systems in Port-au-Prince bay by comparing its cost with typical HVAC systems and then presenting the size of area that needs to be cooled in each part of the bay to make SWAC economically meaningful.

III. Background

A. How conventional HVAC systems work

B. How SWAC works

C. Examples of SWAC systems

D. Conditions in the Haiti area

IV. Explanation of Methods

A. Cost for conventional HVAC

1. Refrigerant cooled air systems

a. Installation cost based on floor area

b. Operation cost based on floor area

c. Time-value economic analysis

2. Water cooled air systems

a. Similar to SWAC

b. Installation cost based on floor area

    1. Water-air interface, pipes, pumps etc. form base cost

    2. Cooling towers

    3. Compressors

c. Operation cost based on floor area

d. Time-value economic analysis

3. Building Size Spreadsheet

    a. Input a range of floor areas in rows

    b. Input installation and operation cost based on area beside each row

    c. This spreadsheet is replicated for each ¼ segment of shore

B. Geographic mapping of thermoclines

1. Geographic Excel spreadsheet

    a. Input depth of thermocline in Port-au-Prince Bay

    b. Input associated coordinates

    c. Input coordinates of ¼ mile segments of shoreline

2. ArcMap development

    a. Present map of necessary thermocline depth in the bay

    b. Overlay contour line showing critical depth onto map of the bay.

    c. Give sample distances from the shore to nearest critical thermocline depth on map

3. Excel Spreadsheet Development

    a. Calculate shortest distances to critical thermocline depth from shore.

b. Beginning and ending coordinates of each shore segment form a row on a new spreadsheet

c. Associated distance to critical thermocline depth placed to the right of shore segment coordinates on spreadsheet

C. Cost of SWAC System

A. Initial cost

1. Base system of standard HVAC system for large buildings

2. Pipe system

a. Standard pipe size with variable flow

3. Pumps

4. Heat Exchanger

B. Operation cost

1. Cost to run pumps in seawater pipe

    a. Energy first, and then derived cost

2. Cost to run pumps in freshwater pipes

3. Maintenance on system

4. Time-value economic analysis

D. Map Creation

A. Update Triple Bottom Line Analysis Spreadsheet

1. Alongside conventional HVAC columns are SWAC columns.

2. Include energy required for pumps

    a. Takes into account flow resistance, distance, and elevation

3. Based off of energy and source for conventional HVAC (based off of regional energy price) make a cost for SWAC in each ¼ mile shore segment for each size of building
4. Distinguishes at which point a 50% reduction in cost is achieved and updates Geographic Spreadsheet with this information
5. In ArcMap provide a scale of colors for minimum required building size
6. In ArcMap update coordinates on coast with these colors

V. Discussion of results

A. What sizes of buildings can be served?

B. How big must they be in the actual city of Port-au-Prince

C. What kinds of buildings can be served and is this useful to the city?

D. Could neighborhood coordination be achieved to reach greater areas of service?

E. Is SWAC technology easily available to Port-au-Prince?

F. Do Haitians care about air conditioning?

A. Conclusion

A. Restate topic of research

B. Recommendations for Port-au-Prince bay

E. Bibliography

Preliminary Research:

The Port-au-Prince bay is very shallow, most of it being 100m deep. This makes the likelihood of a thermocline being in the bay very low. Most likely pipes will need to extend the 30-40 miles from Port-au-Prince city to the island's shelf. This makes providing Port-au-Prince city with SWAC limited to very large cooling needs. However, what exactly these needs are is unknown.

Qualifications for me to be investigator:

I am a Civil and Environmental Engineering student in my senior year. I've had experience dealing with energy cost analysis from my junior level Environmental Engineering class. I wrote a paper entitled "Ice Storms and Power Outages in Tahlequah" for my class paper. Similar to this SWAC project, I investigated costs related to power and gained experience in time-value analysis. One of the more complex parts of this project involves understanding how flow through the pipes will affect power needed in the pumps. This becomes easy as analyzing pump systems is taught as part of standard Civil Engineering course load. Finally, for analyzing my results and making recommendations, I have unique access to a team member that served a two year church mission there.

Qualifications of faculty advisor:

My faculty advisor is Dr. Richard Balling in the Civil and Environmental Engineering Department. He teaches a structures class, but understands a broad range of topics due to his research into Greenplex technology. These include energy efficient technologies and time-value analysis. He also has good connections with other engineering faculty that could help me with the fluids and ArcMap portions of this research.

Schedule:

July 5: Contact FFRHX about water depth in Port-au-Prince bay

July 15: Contact Makai Ocean Engineering, Honolulu Seawater Air Conditioning, LLC., and Capital Cooling Group about 1) Price and diameter of pipe 2) price and type of seawater pumps 3) Price and type of freshwater pumps 4) Price and diameter of freshwater pipes

August 1: Get ArcMap data for Port-au-Prince area

August 15: Determine coordinates of ¼ mile segments of coast and start Geographic Spreadsheet. Hopefully depth information of bay will have been received and allow distances and depth information for pipes to be included.

September 1: Create Building Size Spreadsheet. Find cost of conventional HVAC and include in spreadsheet.

October 1: Determine energy requirements for SWAC based off of building size, length of pipe, and change in depth of pipe. Include in Building size spreadsheet and link to Geographic Spreadsheet. A unique Building size spreadsheet must be made for each ¼ mile segment of coast.

October 15: Create ArcMap maps to demonstrate results. First shows where thermocline is and second shows size of buildings.

November 1: First draft of paper complete

December 1: Second draft complete

January 1: Final draft complete

Expenses:

Detailed ArcMap of Port-au-Prince Bay:$15

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