Energy Savings

Table 23 below provides a summary of the energy savings attributed to the Solyndra photovoltaic system.

Table 23 – Solyndra energy savings calculations

PV Avg. Power Output (kWh/yr)	Electricity Cost ($/kWh)	Total Savings	Savings (lbs of CO_2/yr)
687,796	0.068	$46,770	962,914
With Future Proposed Carbon Tax			
687,796	0.1762	$121,190	962,914

- The average power output
- 1.4 lbs of CO_2/kWh (Referenced in Lori Farley's Thesis Report 2008)
- The current electricity rate, as provided by the owner, is $0.068/kWh. However, in order to show an even greater potential savings, an analysis was completed involving the proposed carbon tax on energy. The idea of the carbon tax is to place an environmental tax on carbon dioxide and greenhouse gas emissions. Implementing this tax is a means of slowing the climate change by reducing such emissions and forcing energy companies to produce cleaner energy. It is estimated that a tax between $0.1027-$0.1137/kWh will be placed on electricity produced by coal (for an average of $0.1082) (Carbon Tax, 2009).

Payback

In the case of the Solyndra system the total cost for purchasing and installing is $2,608,900 and the total savings provided by the system is $46,770. Dividing these numbers produces a payback period of **55.8 years**, which is quite unreasonable from a cost perspective for a data center.

As mentioned in the energy savings section above, it is highly probable that a carbon tax will be instituted in the near future. By implementing the carbon tax, the saving for the photovoltaic system increases to $121,190. Such a savings decreases the payback period to **21.5 years**, which is still unreasonable.

Economizers | Mechanical Influence

Research

Economizers are a type of mechanical mechanism that aid in reducing energy consumption by recycling energy produced within a system or utilizing outdoor environment temperature differences (Fontecchio, 2008). In the more recent years, economizers have become more commonly utilized within mechanical systems of data centers on either the chillers or computer room air handling units (CRAHs) due to the ability to save a substantial amount in operating costs.

The typical design of economizers for data centers includes several filters located within the ductwork that connects the outdoor environment to the indoor environment. In order to ensure proper operation of economizers, it is necessary to have good controls, valves, dampers, and maintenance procedures (Economizer, 2009), as well as necessary to monitor the outdoor air conditions to maintain appropriate humidity levels. Otherwise, without proper operation and monitoring, the true savings of the economizers could not be reached.

There are several types of economizers used in the industry; however, data centers typically operate with either air-side economizers and/or water-side economizers. The following sections provide further detail on both the air-side and water-side economizers.

Air-Side Economizers

The idea of air-side economizers is to more efficiently prevent overheating of a building space using 100% recirculated air. The cool outdoor air is directly circulated in the building space, while the warm return air is rejected to the outdoors. Figure 21 below provides a diagram of an air-side economizer (Intel Air Side Economization Study, 2008). This process is most efficient when the outdoor air temperature is sufficiently cool and the amount of enthalpy in the air can be reasonably controlled, thus not necessary to additionally condition the air. Mild climates, such as San Francisco, are the optimal geographic region to utilize the economizers and achieve the best reduction in HVAC energy costs. However, temperate climates, such as Chicago, New York City, and Washington, D.C., can also be positively impacted by the economizers.

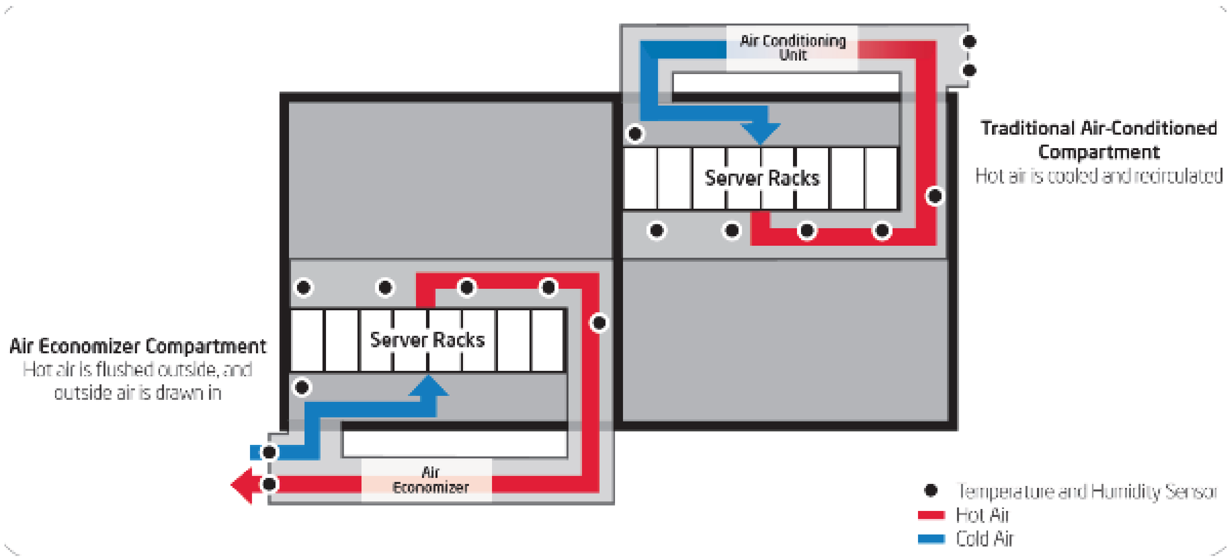

Figure 21 - Air side economizer

There are several disadvantages to using air-side economizers. First, in comparison to a conventional cooling system, the economizers require additional outdoor air louvers, return duct, and exhaust duct. All of these items require a significant amount of space, especially the louvers, and cost. Second, the controls of this mechanism tend to be quite complex. Lastly, since the economizers have a direct impact on the computer rooms, there is little room for error with the design. (David R. Pickut, 2008)

Water-Side Economizers

Water-side economizers, placed on chillers, allow cooling towers to produce chilled water when weather conditions permit. Opposing air-side economizers, this process is most efficient in temperate climates, such as Chicago, New York City, and Washington, D.C., and somewhat efficient in mild climates, such as San Francisco.

Currently, the most common type of this economizer is the plate-and-frame heat exchanger; see Figure 22 (Plate & Frame Heat Exchangers, 2008) to the right. This type of economizer pre-cools the chilled water prior to flowing into the chiller's evaporator. As long as the outdoor wet-bulb temperature is at least 10°F less than the design return chilled water, there will be a heat transfer from the return chilled water to the condenser water loop from the cooling tower. Therefore, the chiller loading and energy consumption can be reduced as a result of lowering the temperature of the water entering the evaporator. Further, if the wet-bulb temperature decreases low enough, the cooling tower could solely serve the cooling load while the chillers are turned off. Please see Figure 23 below for a diagram of this system. (Heating and Cooling, 2008)

Figure 22 - Plate-and-frame heat exchanger

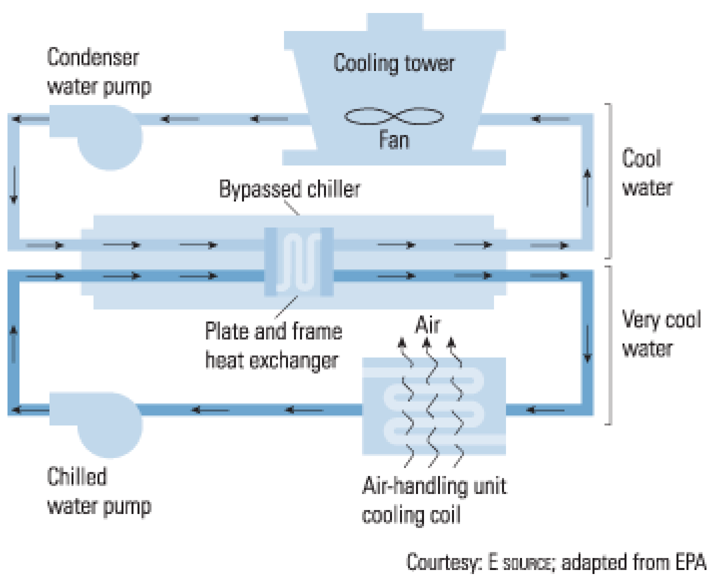

Figure 23 - Water side economizer system

Comparable to an air-side economizer, there are several disadvantages to a water-side economizer. First, this device requires an additional heat exchanger, piping valves, and controls which take up additional space and cost. Further, adding a heat exchanger increases pumping costs due to the added pressure loss. Second, the controls tend to be complex in comparison to a conventional system. Last, water-side economizers can be quite tricky and difficult to operate when the weather conditions are sub-freezing and/or freezing temperatures. (David R. Pickut, 2008)

Comparison and Selection

In comparison, air-side and water-side economizers are quite similar in regard to their advantages and disadvantages. Most importantly, in terms of proper climates, both systems could be utilized on MADC5, with water-side being slightly more ideal. However, the most significant difference involves the need for louvers for air-side economizers. Due to the extremely large size of MADC5, the size of louvers required to operate air-side economizers would be too large for the building. On the other hand, in order to utilize water-side economizers, the only requirement would be to purchase plate-and-frame heat exchangers for each of the chillers, a total of eight per phase.

As a result, after talking with several mechanical engineers and evaluating the two devices, it was determined that water-side economizers would best suit MADC5.

Constructability Analysis

Fortunately, it is not a difficult task to implement water-side economizers with the existing mechanical design since the economizers can attach to the existing headers with the chillers. One economizer per chiller would be installed in a parallel arrangement to allow the use of either the economizer or chiller at a lower kW depending on the conditions. In order to complete the installation, there is additional material required for connecting and routing pipes, however this does not require a significant amount of extra time, therefore not extending the project schedule. The following page, Figure 24, illustrates a simple schematic drawing of one of the two chiller plants with the water-side economizers.

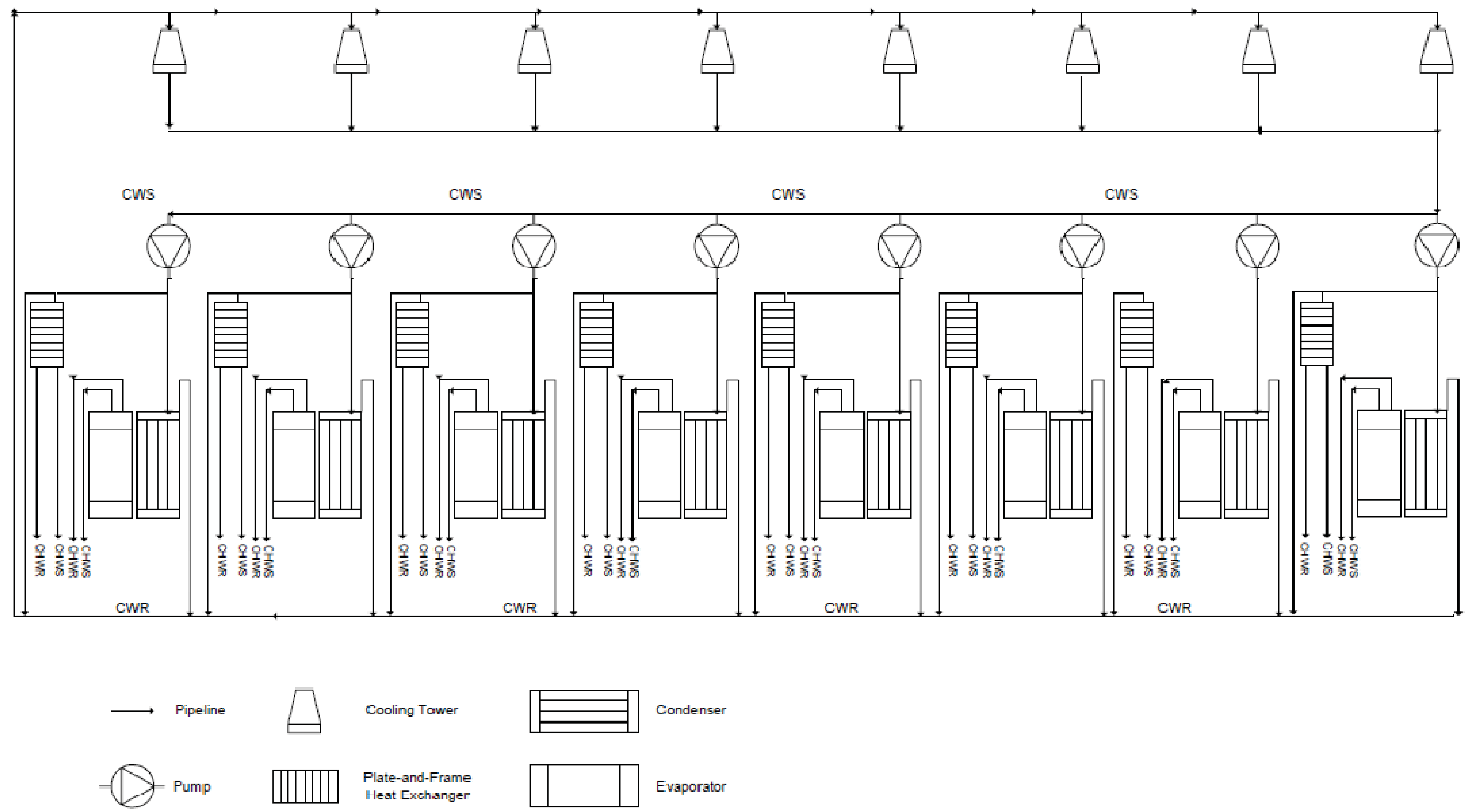

Figure 24 - Schematic of Chiller Plant with water side economizers

Cost Analysis

Equipment Selection and Cost

In order to properly size the water-side economizer, or plate-and-frame heat exchanger, it was required to analyze the given parameters for the chilled water pumps and cooling towers. The following performance data assisted with this process:

Table 24 - Water side economizer product data

	Hot Side	Cold Side
Flow Rate (gpm)	2160	3240
Inlet Temperature (°F)	58	43
Outlet Temperature (°F)	46	50.99
Pressure Drop (psi)	3.54	7.78

As a result of analyzing the above data and consulting Steve Wandishin at The Morin Company, LLC, it was determined that the optimal heat exchanger is a Tranter SUPERCHANGER® Plate and Frame Heat Exchanger (cut sheet can be found in Appendix F). The SUPERCHANGER® allows for the separation of hot and cold fluid by a plate which provides the most effect means to transfer heat from one fluid to the other. Fluid travels throughout the devise in a counter-current direction enabling the hot liquid to become cooler and the cold liquid to become warmer, as shown in Figure 25 on the left.

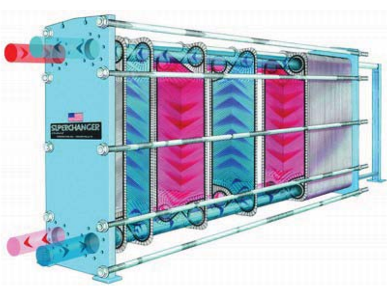

Figure 25 - Tranter SUPERCHANGER® Plate and Frame Heat Exchanger

Each SUPERCHANGER® costs approximately $47,000, plus any additional costs for connection and routing materials. Since there are sixteen chillers for the entire building, it is recommended to ultimately purchase sixteen heat exchangers. However, as the owner has determined to build out Phase 1 of MADC5, it would only be necessary to purchase eight heat exchangers for a total cost of **$376,000**.

Energy Savings

According to Michael Kjelgaard, P.E., author of Engineering Weather Data, the energy savings attributed to implementing water-side economizers can be determined by the following formula (Kjelgaard, 2001):

Savings = Cooling Load * Cooling Plant Efficiency * Electricity Cost * Load Hours

**Savings value does not include tower fan and pumping cost. In addition, the cooling load is assumed to be running at 100%.*

Please see Table 24 below for a summary of the energy savings attributed to water-side economizers.

Wet Bulb Temp.	Cooling Load (tons)	Cooling Plant Efficiency (kWh/ton)	Electricity Cost ($/kWh)	Load Hours (h)	Savings per Chiller	Total Savings	Savings (lbs of CO_2/Plant)
24°F	840	0.5	0.068	803	$22,934	$183,472	4,704
With Future Proposed Carbon Tax (+$0.1082 (Carbon Tax, 2009)***)***							
24°F	840	0.5	0.1762	803	$59,425	$475,400	4,704

Figure 26 - Water side economizer energy savings data

- For the cooling plant efficiency, since a majority of the savings is directly related to the chillers, the efficiency rating was based on the chiller efficiency of 0.5.
- The current electricity rate, as provided by the owner, is $0.068/kWh. As mentioned in the solar energy system analysis, the carbon tax would be $0.1082.
- Load hours are the number of hours per year when the outside air temperature is below a user defined "economizer on" temperature. When the temperature is below the defined value, the cold outdoor air would be utilized to cool the water as opposed to using mechanically chilled water from the chillers, thus saving electricity costs. For the MADC5 data center, energy savings will be calculated for a wet bulb temperature of 24°F, which is the typical operating temperature. Please see Appendix F for all of the weather data provided by the mechanical engineer.
- 1.4 lbs of CO_2/kWh (Referenced in Lori Farley's Thesis Report 2008)

Payback

The most important aspect, especially to the owner, of installing a newer, efficient technology is to evaluate the payback period of the device. In the case of the water-side economizer the total cost for purchasing and installing eight is $376,000 whereas the total savings provided by the economizers is $183,472. Dividing these numbers produces a payback period of **2.05 years**, which is quite reasonable.

As mentioned in the energy savings section above, it is highly probable that a carbon tax will be instituted in the near future along with a steady increase in energy costs. By implementing the carbon tax, the saving for eight chillers escalates to $475,400. Such a savings decreases the payback period to only **0.79 years (9.5 months)**.

Conclusions and Recommendations

Thin-Film Photovoltaic System

The push for environmentally-friendly energy sources has created an ever growing market for solar energy systems. Since it is such a new technology and constantly redesigned and improved, the installation cost per Watt is quite high. As a result, the energy savings are much less than owners would hope, creating an extreme payback period. However, solar energy systems are not about the short-term investment, but rather the long-term and how it can help save the environment.