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The Techno-Economics Comparison of Various Solar Cooling Methods (Part-1)

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Abstract:
The fast growing demand for refrigeration and air-conditioning around the globe has led to a dramatic increase in electrical demand and higher CO_2 emissions. Traditional vapour compression cooling systems increase electrical operating cost and the emission of greenhouse gases, when hydrofluorocarbons (HFCs) are used as refrigerants.

Solar-powered cooling systems are playing a vital role in the Heating Ventilation & Air-Conditioning (HVAC) industry, as well as in process cooling. Since these systems are driven thermally, rather than electrically, they reduce operating costs and one's carbon footprint.

This two-part article investigates and compares the viability and performance of alternative space conditioning systems applying various solar powered cooling technologies in today's market.

Introduction:
The International Energy Agency (IEA) has report the percentage of energy consumption by residential and commercial buildings is relatively high. These buildings consume about 40% of the energy in developed countries, with approximately 50% of that energy being utilized by HVAC systems.

As the world faces increasing energy requirements in developing countries, the global demand for air conditioning is also increasing. The potential for replacing conventional electrically-driven systems with thermally powered systems offers a number of benefits. This off-the-grid technology is highly attractive with its lower carbon footprint, especially as air conditioning is expanded in areas where the solar intensity is strong and higher ambient temperatures are present.

Figure 1 – Typical Solar Array

Solar-powered cooling systems are generally classified into two (2) categories: solar electric refrigeration and solar thermal refrigeration. On the following page are schematics of these basic solar powered cooling systems (Figures 2.1 and 2.2). Table 1 on page 3 shows various solar refrigeration systems, while Table 2 provides an economic comparison of different types of solar collectors.

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The Techno-Economics Comparison of Various Solar Cooling Methods *(Part-1continued)*

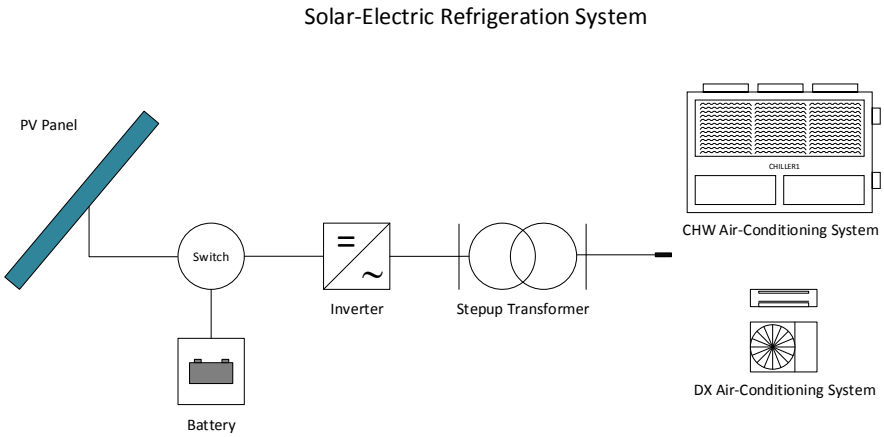

Figure 2.1 – Solar-Electric Refrigeration System
Air-Cooled System

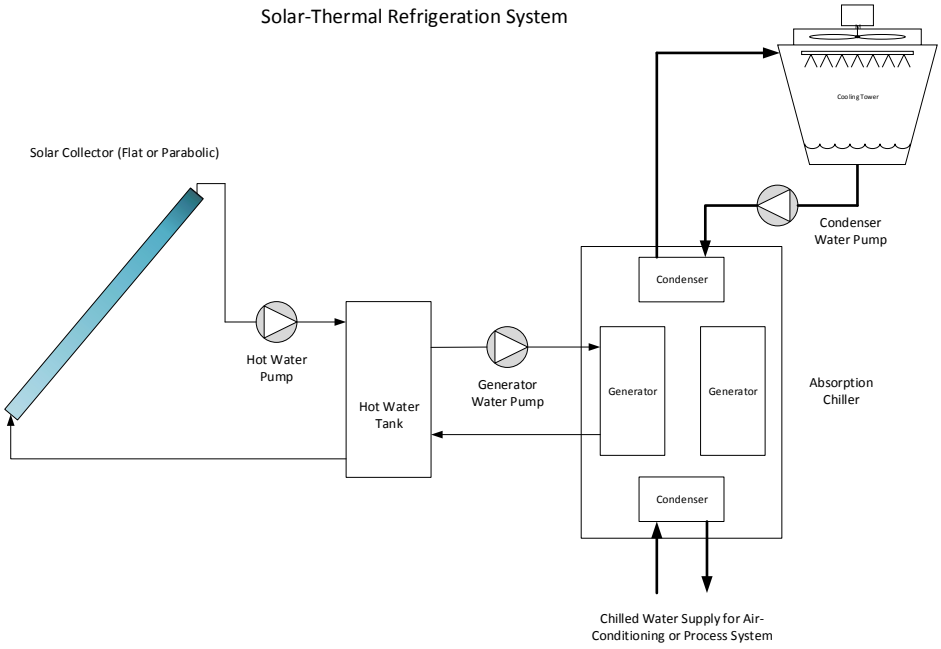

Figure 2.2 – Solar-Thermal Refrigeration System
Water-Cooled System

The Techno-Economics Comparison of Various Solar Cooling Methods *(Part-1 continued)*

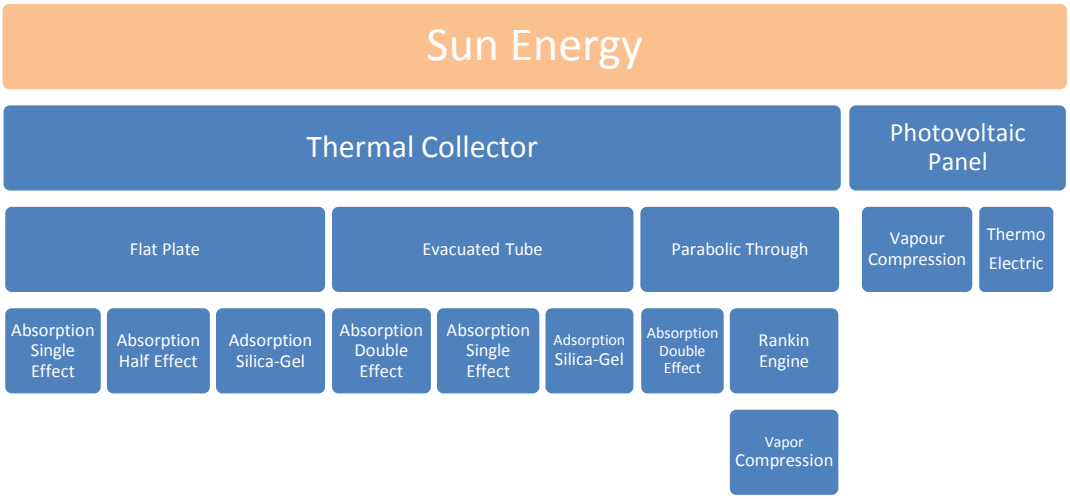

Table 1 – Various Solar Refrigeration Systems

Techno-Economics Comparison of Solar Collectors					
Solar Collector	Solar Cooling System	Average Solar Collector Cost		Solar Collector Efficiency (Thermal at EN12975 condition and PV at peak condition)	
		$\$/W$	$\$/m^2$	η_0	η_{PV}
Photovoltaic (PV)	Vapour Compression System	2.97			15.4 %
Flat Plate (FPC)	Absorption or Adsorption Refrigeration		434	0.748	
Evacuated Tube (ETC)			807	0.718	
Parabolic Through (PTC)			559	0.6	

Table 2 – Economic Comparison of Solar Collectors

In the next part of this article we will take this information and review the various routes (options) for thermally powered space cooling and refrigeration systems and their performance.

Sustainability Through Power Management – A Case Study

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Prior to any sustainable project a college or university must first assess their priorities. Are they interested in saving money, being “green”, or both? Yes, it’s true some green / sustainable endeavors do not end up saving money in the long term. With this in mind Volunteer State Community College (VSCC) elected to find the middle ground through automated controls and active management.

In 2013, Vol State was working hard to reduce campus utilities costs. The campus consisted of nineteen (19) buildings totaling 468,814 square feet. The control systems were all pneumatic and prone to inefficiencies. The thermostats were analog and unreliable. The annual utility cost per square foot was $1.66.

Sustainability Through Power Management – A Case Study

(continued)

Working under funding from the American Recovery & Reinvestment Act, VSCC began implementing electronic automated controls throughout the entire campus. The project took two (2) years to complete and cost $1.3 million. This was the initial building block to a long term plan of sustainability and cost savings.

Figure 1 – VSCC Campus

After realizing a quick return on the initial investment, VSCC elected to implement variable frequency drives (VFD's) and lighting controls across campus. These changes paired with daily active management from the Plant Operations Staff have made a dramatic impact. Now, almost four (4) years later, and with an additional four (4) buildings which increased square footage by 24%, VSCC is maintaining electrical operating costs at $1.50 per square foot.

Lighting – Is it Getting too Complex? *(Part 2)*

By: Thomas D. Mull, PE, PEM, CEM

In the previous Newsletter the question was asked: "What do you want from your lighting system and controls?" The simple answer is we want the desired level of illumination, when we want it, and as efficiently as possible. This simple answer may not be quite as simple as it first appears.

- We perceive illumination levels differently based upon color schemes in a space, the types of fixtures / lamps employed, color temperature of the lamps, amount of natural lighting, and even the age of the occupants. But, whatever that desired level is we know it when we see it.

- When we want it – This is the controls aspect. Controls are generally considered to be manual or automated. While manual controls can be effective, we have all been pressed for time, or simply forgotten and left lights operating, sometimes for extended periods. Therefore, manual control is not as reliable as we might like. It does, however, provide the least exposure to outside influence.

  Automating controls can provide a greater degree of assurance that fixtures are on when needed and off when not required. The level of automation employed is where we begin to risk exposure. Basic time clocks, photocells, timed switches and occupancy / vacancy sensors can enhance our control capabilities with essentially no outside exposure. When automation involves internet / cloud-based technology, such as computer scheduling or an app on a phone to control systems, we dramatically increase our exposure.

Lighting – Is it Getting too Complex? *(Part 2)*

(continued)

- As efficiently as possible – This is essentially a focus on operating cost. We all want to be as efficient as possible to minimize our operating expenditures and reduce associated emissions from power generation, as long as it is cost-effective. As noted previously, the percentage of utility expenditure associated with illumination has come down dramatically with the adoption of more efficient sources, such as LEDs, and the adoption of automated controls. Therefore, the economic driver to employ even more efficient sources is becoming less of an issue. Case in point, the BR30 reflector lamp used in recessed fixtures. A LED lamp equivalent to a 65 watt incandescent lamp (800 lumens) requires only 9 watts. With the price of LED lamps continually dropping, a more efficient lamp source will likely not to be cost-effective.

Assuming we do a *reasonable* job of controlling fixtures now, with questionable cost-effectiveness of more efficient sources, the quest for additional control automation becomes one of enhanced convenience rather than monetary savings.

Exposure with the Downside –

Let's examine the potential downside of internet / cloud-based lighting controls. While the downside of increasing exposure to outside influences can be categorized several ways, let's look at it in the following terms: Irritating, Impacting operating costs, Political and Terrorism.

- Irritating – This encompasses everything from simple malfunctions (the app does not respond on the phone and you have to reboot), to purposeful tampering with on/off operation to create inconvenience and chaos. This could be anyone from a co-worker, neighbor, to someone in the Ukraine testing a new algorithm.

- Impacting operating costs – This is a higher level of interference whose purpose is to increase utility costs by scheduling unneeded operation at night and during unoccupied periods. It could involve keeping lighting in a shop area, gymnasium, garage, remote building or warehouse operating when not required. A disgruntled student, ex-employee or competitor might see this as a way of expressing their discontent.

- Political – This may seem a bit extreme. But, there are accounts of organizations censoring personal postings on social media of individuals that did not agree with their political leaning. Is it then too much of a stretch to consider that a large organization might target an adversary with a different political viewpoint, to aggravate and create discourse?

- Terrorism – Why would a terrorist be concerned about turning off lights? While admittedly not at the top of their "To Do List", consider the following: How much confusion and chaos would be created in a large venue, such as World Cup finals, if at a critical point all of the lights went out? And stayed out. What would be the issues if a large international airport suddenly went completely dark during peak nighttime operations, including back-up generation? While these events may be unlikely, I do remember a Super Bowl where the lights went out. In circumstances such as these, people have been injured and killed. But, the real objective would be to demonstrate the vulnerability of an event, organization, or country.

Reliance on Technology –

Technology has undoubtedly made life better. It has reduced laborious tasks to simple keystrokes at a computer terminal or pushing an app on a tablet or mobile phone. It is difficult to find anyone today who has not utilized technology to simplify their life. With respect to lighting systems, what do we actually need? The answer to that question depends on the overall cost-effectiveness of the controls and the risk of exposure we are willing to assume.

Lighting – Is it Getting too Complex?

(continued)

For most individuals the application of currently available sources and a combination of manual switching and sensors is a reasonable cost-effective approach. This provides the least amount of exposure to potential outside interference. Smart-Homes enhance control flexibility, but at increased exposure.

The commercial sector has varying needs, depending upon the size of the facility. Smaller to moderate size entities may meet their needs with a combination of sensors and intranet-based controls. Larger facilities, including office buildings, college campuses, etc., rely on more sophisticate controls, often cloud-based. These can encompass whole building lighting and energy management functions. This results in enhanced savings potential, but provides the greatest level of exposure.

Hubbell – NightHAWK2
Dual Technology Sensor

Quantum®
Lutron Whole Building
Lighting Control

Lutron – Ceiling Mounted Sensor

Hubbell - PowerHUBB™

WattStopper –
Timed Switch

Gamma
Siemens Whole Building
Lighting Controls

Many industrial facilities already employ cutting edge technology and controls in their processes and administrative areas. For these applications lighting controls can run the entire spectrum. Three-shift operations can have simplistic controls, while the controls for one and two-shift operations can be significantly more sophisticated, based upon requirements. As the level of sophistication increases, so does potential exposure.

Summary –
With any technological advancement there can be unforeseen consequences. With enhanced internet / cloud-based lighting controls we receive increased control flexibility that can help optimize operations and minimize costs. However, with this enhanced flexibility comes increased vulnerability.

While the likelihood of experiencing some of the potential negative aspects previously noted is minimal, it is worth mentioning that sophisticated lighting controls can provide a “backdoor” to hackers to access other data files / systems. Therefore, before implementing enhanced lighting controls proprietary information, customer/ personnel files, and other data files should be protected with additional safeguards.

This article started with the question *Lighting – Is it Getting Too Complicated?* From an economic perspective, without a quantum leap in lighting technology that provides greater efficacy at equivalent cost, the focus of technology is on convenience. The answer then becomes an individual answer. For most of us, utilizing available high efficiency sources and the application of off-the-shelf programmable switching, sensors and breakers is cost effective and sufficient for our needs. For everyone else, it becomes a question of the level of risk they are willing to assume for the potential savings and greater convenience.