Solar Thermal Energy: Why the wait?

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In 2012, Johnson Controls, Inc. published a white paper I wrote titled “Solar Thermal Energy: The Time Has Come.” In it, I stated “Solar heating, often overshadowed by photovoltaic systems, is the most cost-effective on-site renewable energy resource. It presents a vast opportunity for public and private organizations to save on fossil fuels, cut costs, and reduce carbon emissions”. What’s changed? These facts are truer today.

In the white paper I discussed the technical potential for solar water heating in the United States valued at about one quadrillion Btu of energy savings per year, worth billions of dollars in energy cost savings and 50 million to 75 million metric tons of carbon dioxide emissions. (The Technical Potential of Solar Water Heating to Reduce Fossil Fuel Use and Greenhouse Gas Emissions in the United States. National Renewable Energy Laboratory, Technical Report NREL/TP-640-41157, March 2007)

These figures may be merely theoretical, but they illustrate the vast possibilities for solar thermal technology to displace fossil fuels, counteract climate change, and save building and business owners and industrial processes money. (Hundreds of thousands of dollars)

For those of you who only know solar energy as Photovoltaics (PV) there is another solar technology that has the potential to significantly reduce Green-House-Gas emissions often referred to as the other solar “White Meat” basically ignored by most of the State and DOE, Federal Energy and R&D programs except Solar Thermal Electric Generation (CSP). Common uses of the other white meat or I should say the other solar technology include: swimming pool heating, boiler water preheating, domestic water and space heating, air conditioning, and high temperature heat for a wide range of commercial and industrial processes such as Industrial Process Heat (IPH).

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A recent study titled “Initial Investigation into the Potential of CSP Industrial Process Heat for the Southwest United States” (Initial Investigation into the Potential of CSP Industrial Process Heat for the Southwest United States Parthiv Kurup and Craig Turchi, National Renewable Energy Laboratory, Technical Report NREL/TP-6A20-64709, November 2015) by Parthiv Kurup and Craig Turchi of the National Renewable Energy Laboratory looked at the technical potential and the applications of the different CSP technologies based on solar delivery and facility temperature requirements.

The assessment for California indicates a technical thermal energy potential of almost 23,000 TWhth/yr. significantly more than the estimated demand of about 48 TWhth/yr for the industrial sectors in California that utilize mostly natural gas for IPH. The report validates the contributions and opportunities for commercial Solar Industrial Process Heat (SIPH) plants which is becoming a growth industry and opportunity to re-establish the contributions of solar thermal heating.

The report also states “After significant interest in the 1970s, but relatively few deployments, the use of solar technologies for thermal applications, including enhanced oil recovery (EOR), desalination, and industrial process heat (IPH), is again receiving global interest. In particular, the European Union (EU) has been a leader in the use, development, deployment, and tracking of Solar Industrial Process Heat (SIPH) plants.


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In the nonresidential sector, users of solar thermal technology include hotels, hospitals, prisons, restaurants and cafeterias, government buildings, universities and schools, athletic facilities, manufacturing plants, and laundries.”

These are all growth markets which are not limited to Europe and the Southwest US. These applications are in every community and city in the nation. Industry, Universities like the University of California

Merced Solar Lab and National laboratories continues development of high temperature concentrating technologies that are capable of temperatures from 230 F to 350 F or higher and the US DOE are investing in R&D for advanced Concentrating Solar Power (CSP) technologies up to 1200 F.

In today's renewable energy market Solar Thermal Collection Systems provide lower Levelized Cost of Energy (LCOE) than any other solar energy technology due to technological efficiencies and cost advantages, therefore making a better business case than any other technology for broader market acceptance. When the LCOE, the relatively low US market penetration, and manufacturing demand needs of the Solar Thermal market are collectively considered, a tremendous investment opportunity is revealed.

Most high temperature thermal technologies in the market, require large surface areas and tracking systems adding significant hardware and O&M costs.

These concentrating technologies also need direct beam radiation which limits their applications to the desert and dry environments and generally have significant production losses in diffused radiation which makes up the majority of the US and all of the Caribbean. Some of the Evacuated Tube collectors which can be mounted on either the roof or ground use both Direct Normal irradiance and Global Horizontal irradiance to generate the efficiencies for high temperatures without tracking. And they generating up to 400oF temperatures for use anywhere in the US or Caribbean.

The solar thermal collection technologies are field-proven. In the past 15-20 years, product research and development and improved manufacturing have created a new generation of simple, reliable, efficient solar water heating systems. Modeling tools are available to predict system performance, costs, energy savings and return on investment based on local sun and weather conditions.

At present, solar thermal technology faces some headwinds, but longer-term trends appear to work in its favor. For the time being, the price of natural gas—the main fuel solar heating displaces—are at low levels as hydraulic fracturing (fracking) operations dramatically increase domestic supplies.

At the same time, commodity prices for glass, copper and aluminum used in solar thermal collectors are rising as the economy improves. There is also a shortage of contractors trained in solar thermal installations, and the same financing obstacles exist as for solar thermal as for many types of renewable energy. Finally, prospective users of solar thermal energy may not fully understand it or appreciate its versatility and value.

All these conditions are likely to be temporary. Fuel and commodity prices are cyclical by nature. In 2008, prior to the great recession, natural gas prices stood near historic highs. Prices may rise again as the U.S. exports more gas, as utilities add gas-fired peaking power plants and replace older, polluting coal-fired power plants used for base load with smaller gas turbines. Also with potential to tip the scale are the increased production of liquefied natural gas (LNG) for export and wider acceptance of compressed natural gas (CNG) as a fuel for buses, taxis, cars, and a wide assortment of fleet vehicles.

Growing numbers of states and utilities offer incentives and rebates for renewable energy installations. In addition, renewable portfolio standards (RPS) or some kind of Renewable requirements have been passed in about 40 states, requiring utilities to derive specified percentages of their power from renewable sources of those about 16 allow solar thermal to meet the goals.

Electric utilities, municipalities and some state legislatures have developed incentives and marketing campaigns using photovoltaics to meet RPS requirements. As I just said, the 16 States that include Solar Water Heating, 13 states allow Solar Space Heating and 11 states include Solar Industrial Process Heat to qualify for the RPS. Much more could be done to develop Solar Thermal incentive programs for residential, commercial and industrial applications.

A simple and reliable metering technology would enable conversion of solar thermal energy to its kilowatt-hour equivalent, allowing solar water heating or cooling to count toward RPS compliance, as well. A growing number of states now allow solar thermal projects to qualify for utility incentives or may qualify for renewable energy credits (RECs) under their RPS programs.

The California Energy Commission, again leading the way to Energy Independence, Renewable Energy and Energy Efficiency to reduce carbon emissions has issued a RFP for Advanced Water Heating System Demonstrations, Advanced HVAC and Building Envelope Demonstrations, Integrated Natural Gas System Demonstrations, and Applied Research Strategies for Appliances, Zero Net Energy Buildings, and Codes and Standards.

UC Merced XCPC array

The State of California has set aggressive goals demonstrated by this RFP for increasing energy efficiency in buildings and reducing greenhouse gas emissions. In addition, they say recent events at Aliso Canyon in Southern California emphasize the urgency in identifying, demonstrating and deploying technology solutions and strategies that can reduce natural gas consumption in these building sectors while overcoming other barriers associated with using new and/or emerging natural gas reducing technologies.

This is a big step in accelerating the applications and demonstrations of advanced solar thermal heating technologies. And a big win for the “other white meat” let’s hope it’s a start to increased funding and market deployment for Solar Heating and SIPH.

More opportunity than meets the eye

The principle behind solar thermal energy is simple: A solar collector absorbs heat from the sun, and fluid warmed by passing through tubes in the collectors is distributed to the appropriate system. The basic technology has existed for more than 100 years, and systems have been proven to last more than 25 years—longer than a conventional water heating systems—at a fraction of the life-cycle cost. Solar collectors can be installed anywhere on a facility with adequate access to unobstructed sunlight. Estimates show that tapping the United States’ full potential for domestic and commercial solar water heating could:

• Save 578 billion cubic feet of natural gas per year—2.5% of the nation’s usage.
• Save 35 billion kWh of electricity per year, just under 1 percent of U.S. consumption.
• Prevent 52 million metric tons of carbon dioxide emissions annually, equivalent to the emissions from 13 coal-fired power plants or 9.9 million cars. (3 Smart, Clean and Ready to Go: How Solar Hot Water Can Reduce Pollution and Dependence on Fossil Fuels. Wisconsin Environment Research & Policy Center, March 2011.)

The most widespread solar thermal application is water heating. A typical residential-sized solar water heating system produces 7 to 10 kWh per day, or 3,400 kWh per year, depending on local conditions and type of collector and the system design. On average, for each such system installed in place of an electric water heater, 0.5 kW of peak demand is deferred from the utility’s load. When a utility solar water heating program like Hawaii’s has thousands of solar water heaters installed displacing electricity, the demand reduction is measured in megawatts.

So, what’s the problem in Florida? I refer to it as the land of the electric water heater and little potential for natural gas expansion. It is also a state with a huge coastline, barrier islands and water shortages that are being ignored by the pro-business electric utility legislature. It’s been documented many times in the past, solar water heating in Florida is a net revenue loss to the electric utilities. Isn’t less electricity generation using fossil fuels one of the solutions to climate change and rising sea levels? Who has the most to lose; the electric utility industry, the coastal businesses and homeowners or possibly the whole Florida economy? What are the long term plans for rising waters and drinking water shortages? That is a stupid question. Why make plans when you deny there is a problem. Climate change plans would have a negative impact on future political contributions for those in office who support studying the problem.

A commercial solar water heating system with 500ft2 of collector will displace the hot water generated by a small natural-gas-fired boiler, generating 2,281 therms per year and offsetting more than 26,825 pounds of CO2. On a larger scale, solar thermal energy creates economic development and local jobs in manufacturing, installation, operations and maintenance.

Commercial SIPH plants will provide the necessary energy for:
• Industrial Process Heat
• Desalination,
• Food and Beverage processing,
• Solar Cooling & Refrigeration systems,

• Oil & Gas extraction,
• ORC or Stirling electric generation

Space heating
Similar to solar water heating systems, these systems generally use more solar collectors, larger storage units, and more sophisticated designs. Concentrating or tracking solar thermal technologies are required to meet space heating loads. For the higher temperatures needed for hydronic forced air heating systems (180oF) temperatures, Flat Plate collectors and most Evacuated Tube systems cannot consistently operate at those temperatures.

Cooling
Here, solar heating systems are coupled with absorption chillers and use a thermal-chemical sorption process or ammonia to produce air-conditioning without electricity. The process is like that of a refrigerator except that there is no compressor. The absorption cycle is driven by a thermal transfer fluid—heated water or glycol mixture—from the solar collector. Water cooled to about 44 degrees F runs through copper piping, and forced air passing over the piping produces air conditioning. Options include replacing electric chillers or injecting chilled water generated by a solar absorption chiller into a building with a large cooling load.

Despite the high potential, solar thermal capacity in the United States lags behind much of the world. For example, on a per-capita basis, the nations' ranking has dropped from 35th to 50th globally in solar water heating (excluding swimming pools)(Werner Weiss and Franz Mauthner, International Energy Agency, Solar Heat Worldwide: Markets and Contributions to the Energy Supply 2008, 2010.) – although such installations increased and grew by 10 percent in 2009,(Solar Energy Industries Association, U.S. Solar Industry Year in Review 2009, April15, 2010.) and increased by another 5 percent in 2011 despite a slow economy with historically low natural gas prices.(SEIA/GTM Research U.S. Solar Market Insight 2010 Year in Review.) Bad news is the solar heating industry is experiencing a steep downturn in the residential solar heating market not just in the US but the industry is down globally by an average of 15% since 2013 as reported by the SH&C Program of the International Energy Agency (IEA)

Most (94%) of the solar systems installed worldwide provide domestic hot water (small-scale and large-scale systems). However, megawatt-scale solar thermal applications for district heating and solar heating and cooling in the commercial and industrial sector is a growing market. The two largest solar thermal systems are in Denmark and supply heat to district heating networks. The two largest solar cooling systems are in Singapore and the United States. And, the world's largest solar process heat system is installed in Chile at a copper mine.

Jobs
The number of jobs in the fields of production, installation and maintenance of solar thermal systems was estimated to 730,000 worldwide in 2014. The worldwide turnover of the solar thermal industry was US$ 24 billion.(Solar Heat Worldwide, IEA Solar Heating & Cooling Programme, May 2016: Franz Mauthner, Werner Weiss, Monika Spörk-Dür) The Solar foundation has recently documented the growth of the US solar Industry and a majority of those new jobs are in the PV industry but imagine the thousands of new jobs a robust National Solar Thermal Initiative would create.

Catching the sun
Many organizations fail to benefit from solar thermal energy largely because they do not know the many

possibilities it offers. There are three basic levels of solar thermal energy:

• Low-temperature (80 to 100 degrees F) for purposes such as swimming pool heating and boiler water preheating.

• Medium-temperature (100 to 160 degrees F), largely for domestic/service hot water heating and space heating.

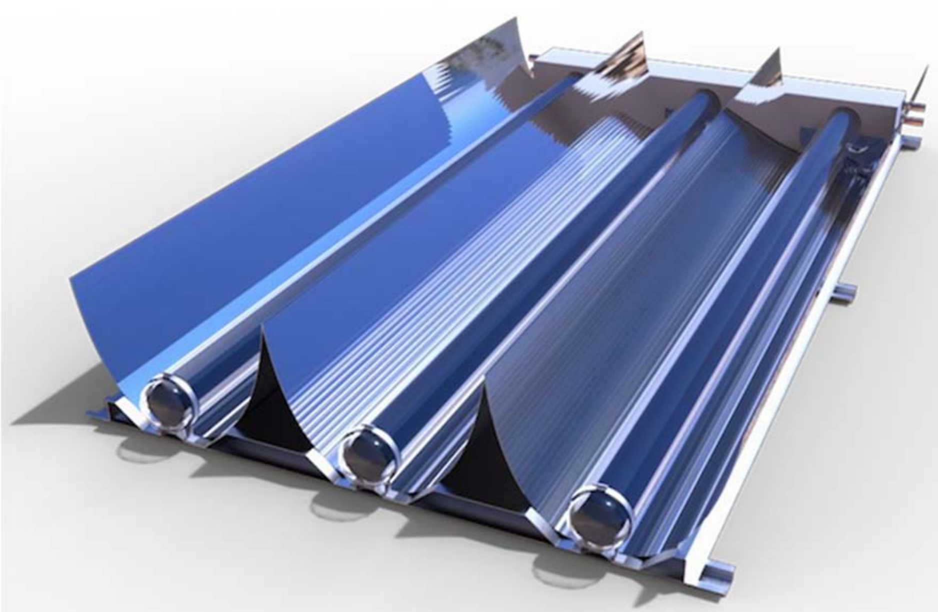
• High-temperature (180 to 350+ degrees F) for industrial processes and air conditioning and hybrid HP desalination.

Evacuated tube systems do the same basic work as flat-plate collectors but perform better in cold climates when not buried under snow because the vacuum inside the tubes reduces heat loss from conduction and convection. The basic structure includes a glass tube made of borosilicate glass that allows sunlight to pass through, and a black-coated copper or aluminum absorber inside the tube.

The performance advantage over flat-plate systems is not significant in warmer climates, except where users desire very hot water and are not buried in snow, for a commercial process.(It is proven that flat-plate collectors perform better than evacuated tubes in areas with snow in winter, as the insulated evacuated tube does not re-radiate heat to melt the snow off the collector.

The typical heat loss of a flat-plate collector will melt snow and start generating energy on clear days, Typically, a flat-plate collector is the first thing on a roof to become free of snow.) Installed costs are about the same as or higher than for flat-plate systems that have been around for more than 100 years.

Micro-trough systems, use parabolic reflectors to focus sunlight on a receiver, can achieve temperatures from 160 to 350+ degrees F. They are used mainly for space heating, industrial process, and solar air conditioning (when coupled to absorption chillers). Micro-troughs depend on direct-beam radiation as in the desert southwest and track the sun in a single axis (east to west) for maximum heat generation.



XCPC or External Concentrating Parabolic Collector is the new technology in the market, manufactured by Artic Solar in Jacksonville, Florida. The patented XCPC Non-Imaging Concentrating Collector is a nontracking high temperature collector capable of +350oF temperatures for SIPH applications and more importantly for Advanced HP integrated Desalination systems as demonstrated by WaterFX for cleaning up subsurface agricultural waste water in California. (Pilot demonstration of concentrated solar-powered desalination of subsurface agricultural drainage water and other brackish groundwater sources, Matthew D. Stuber, Christopher Sullivan, Spencer A. Kirk, Jennifer A. Farrand, Philip V. Schillaci, Brian D. Fojtasek, Aaron H. Mandell October 2014) Imagine if clean water was made available to the 1 in 10 people in the world without access to clean water. Solar thermal is making progress and is here to stay. The XCPC is proving to be a game changer.

Flat-plate or evacuated tube systems actually perform better in areas with hazy sunlight or diffused radiation such as the Gulf Coast. Knowing the technologies and their limitations is important in selecting the right technology for the job.

When is solar thermal attractive?
Solar water heating systems can be highly cost-effective in facilities that have constant or even intermittent hot-water demands. Other forms of solar heating can be economical in a wide range of settings, depending on heat requirements, local climate and sun conditions, and other factors.

Nonresidential solar heating systems generally require professional design and sizing. A key step is to determine the heat or cooling load to be met. In particular, sites like manufacturing plants, food processing, commercial laundries, hotel kitchens and restaurants require higher temperatures and appropriate sizing. Determining the feasibility of solar thermal for a given application is largely a straightforward site audit process.

Once the audit is complete, commercially available modeling tools can accurately predict the cost of the system, the thermal output, and the economic benefit, measured in time to achieve positive cash flow. Most off-the-shelf solar collectors have been tested by an independent laboratory and certified by the International Association of Plumbing and Mechanical Officials (IAPMO) or Solar Rating and Certification Corporation (SRCC) to specify what their energy output should be under specific local sun conditions. If a solar collector doesn’t have IAPMO or SRCC Certification, don’t buy it.

Advances in thermal or seasonal storage will have significant impacts on Net-Zero Energy buildings. There are low cost methods to integrate seasonal storage into buildings which will improve the economics and significantly reduce the energy required to heat buildings and homes in the winter. Years ago heating buildings with large solar thermal systems in the winter caused problems in the summer. Too much heat, stagnation and over-heating were common problems. Drainback system designs solved the over-heating issues but the economics were upside down using the system only in the winter. Today, new technologies allow us to heat the building in the winter and drive absorption chillers for cooling or ORC electric generators in the summer. These systems can easily couple to thermal storage if necessary so the economics for year-round solar thermal systems are significantly improved but unfortunately under-utilized.

Making the move
Opportunities for solar thermal energy are available to almost any organization. A company with expertise in solar energy can help evaluate the possibilities, select the most appropriate technology for the site, model the costs, savings and cash flow.

It is prudent to select a project partner that understands not only solar energy but also how to integrate a thermal system with the existing building heating system, cooling system, or process, and with the building or process controls. A well-qualified supplier will also have access to innovative financing programs and will be able to help secure rebates and other incentives from utilities and federal and state governments.

Solar thermal is a highly cost-effective way to deploy renewable energy, reduce long-term operating costs, and make progress toward sustainability, reducing GHG or green building goals.

William T. Guiney is President of Artic Solar, Inc., a certified Veteran Owned Small Business in Jacksonville, Florida. He has close to 34 years' experience in the solar industry as a contractor, educator, distributor and manufacturer, has provided renewable energy and energy efficiency training programs, and is an instructor for solar thermal energy systems at the North Carolina Clean Energy Technologies Center and the Florida Solar Energy Centers. He has served on the solar thermal technical committee of the North American Board of Certified Energy Professionals (NABCEP) and was chair of its Thermal Entry Level Committee. Guiney is currently a serving on the advisory council for the Solar Heating & Cooling Alliance (SH&C) of the Solar Energy Industries Association (SEIA).