Advanced High Temperature Solar Thermal

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Artic Solar, Inc. is the exclusive manufacturer of a revolutionary high-temperature solar thermal technology. The XCPC collector utilizes cutting-edge developments in non-imaging optics to provide industrial and facility heating and cooling at lower cost than any other renewable energy source. It is the only roof-mountable solar heating technology with the capability of cost-effectively reaching temperatures up to 200°C/392°F in direct or diffuse sunlight without costly and maintenance-heavy tracking systems.

The XCPC technology pairs a custom evacuated tube solar receiver with an external non-imaging reflector which allow it to operate at more than 50% efficiency (the amount of incident sunlight converted to usable energy) even at high temperatures. The efficiencies of all other market incumbents fall off rapidly at temperatures above 212°F.

The XCPC, U.S. Patent #9,383,120 B1, Solar Thermal Concentrator Apparatus, System and Method has been independently tested and is certified by the Solar Ratings and Certifications Corporation (SRCC) of the International Code Council (ICC). The technology has also been tested by the Gas Technology Institute and NASA Ames. The XCPC, developed by the University of California Solar Lab, will provide the high temperatures necessary for double-effect absorption chillers to efficiently provide refrigeration and air-conditioning, high temperature space heating, industrial process heat and, combined with a heat pump, the energy for multi-effect distillation (MED), reducing the energy cost of clean water by up to 49%. In addition, the XCPC combined with advances in Organic Rankin Cycle (ORC) heat engines will generate electricity and power.

For those of you who only know solar energy as photovoltaics (PV), there is another solar technology that has the potential to significantly reduce greenhouse gas emissions. Applications for solar thermal 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). The applications include dormitories, laundries, dining halls, and central heating/cooling plants and food processing.

The installed cost of the XCPC is competitive with the low cost of natural gas in the US and can be installed for less than $1.50/watt at scale and has the highest GHG reductions of all solar technologies.

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.[i]

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 Federal installations, commercial buildings, business owners and industrial processes money. (Hundreds of thousands of dollars.)

A recent study titled "**Initial Investigation into the Potential of CSP Industrial Process Heat for the Southwest United States"** [ii] by Parthiv Kurup and Craig Turchi of the National Renewable Energy Laboratory looked at the technical potential and 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 are 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 plants. 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.

The important fact is that solar thermal technologies capable of reaching 350ºF for industrial process heating plants are currently economical and available today in the marketplace.

In today's 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, 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.

THE DOD IS PURSUING ENERGY EFFICIENCY, RENEWABLES AND NET-ZERO ENERGY INITIATIVES

The Department of Defense has installed many solar thermal systems for recreational and training swimming pools, hot water for dining halls, dormitories and laundries and a smaller number of solar cooling systems. The opportunities for solar cooling are growing and complete turn-key commercial packaged solar air-conditioning systems are readily available. Clearly, solar thermal has earned a place in the national and global energy mix. In fact, solar water heating and solar industrial process heat have the potential to be the largest contributor in the next growth era of renewable energy and emission reductions. Energy security is a priority for DoD.

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 accounts for the majority of the US and all of the Caribbean and other Island nations or facilities. The XCPC Concentrating Parabolic Collector with the non-imaging optics of the reflector and the proprietary evacuated tube collectors can be mounted on either the roof or ground. The XCPC use both direct normal irradiance and global horizontal irradiance to generate high temperatures without tracking.

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. Solar thermal technology in the United States 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, but energy costs are forecasted to continue to rise. In its January 2017 Short-Term Energy Outlook (STEO), EIA expects the Henry Hub natural gas spot price to average $3.55 per million British thermal units (MMBtu) in 2017 and $3.73/MMBtu in 2018, 41% and 49% higher than the 2016 average of $2.51/MMBtu. These higher prices reflect increased natural gas consumption as well as exports exceeding supply and imports, leading to lower average inventory levels. Natural gas prices have been historically low but we knew they would rise again, they always do.

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 US 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 and many will apply to Federal or DoD facilities. In addition, Renewable Portfolio Standards (RPS) or other renewable requirements or goals have been passed in about 40 states, requiring utilities to derive specified percentages of their power from renewable sources. Of those, about 16 currently allow solar thermal to meet the goals.

Installing 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.

MORE OPPORTUNITY THAN MEETS THE EYE

Prospective users of solar thermal energy may not fully understand it or appreciate its versatility and value.

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 percent 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.[iii]

Water Heating

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 removed 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.

A small commercial solar water heating system with 500ft^2 of collectors 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 CO_2. A larger commercial or industrial process heating system or a 200-ton solar cooling project can generate the equivalent of 38,258 Therms and offset around 530,000 lbs. of CO_2. 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 Heat Engines for electric generation

Space Heating

Similar to solar water heating systems, these systems generally use more solar collectors, larger storage units, and more sophisticated designs. In the past, only concentrating or tracking solar thermal technologies operated at high enough temperatures to meet space heating loads. For the higher temperatures needed for hydronic forced air heating systems (180ºF), flat plate collectors and most evacuated tube systems cannot consistently operate at those temperatures. The XCPC is the only non-tracking technology that can provide space heating temperatures in all climates.

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 between 36ºF and 44ºF 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.

Several solar-assisted cooling projects have been demonstrated in the past 15 years. For example:

- A flat plate collector system in Madrid drove a single effect water/LiBr absorption chiller.
- An evacuated tube collector system in Wales powered a small LiBr/H_20 absorption chiller.
- A combined flat plate and evacuated tube system powered a single effect LiBr/H_20 absorption chiller in New Mexico.
- A 30-Ton Yazaki 1E chiller was installed at the Sandhill Power Plant in Austin, Texas to provide the primary water heating, space heating and air-conditioning system.
- The US Army installed a 40-Ton YORK single effect chiller with a micro-trough tracking solar array when I was leading the Johnson Controls Solar Heating & Cooling business at Ft. Bliss Texas.

Several high temperature solar cooling systems powering double-effect chillers have also been demonstrated.

- A linear Fresnel collector system in Seville drove a double-effect LiBr/H_20 absorption chiller, and a parabolic trough system in Pennsylvania drove a double-effect LiBr/H_20 absorption chiller.
- Also in 1998 a double-effect LiBr/H_20 absorption chiller was run by a field of non-tracking integrated compound parabolic concentrators in California. These were non-concentrating evacuated tubes that performed exceedingly well, but failed to be even remotely economical.
- Duke Solar Energy commissioned a double-effect 50-Ton Broad chiller for an NREL solar cooling demonstration program using the Solar Roof system by Solargenix in Raleigh, NC.
- Henkel Solar installed a 83/99-Ton multi-energy (solar & natural gas) 2E Broad chiller at the Steinway & Son's piano factory in Staten Island, New York.

Linear Fresnel and parabolic trough collector systems can achieve temperatures much higher than those needed by a double-effect absorption chiller, but they require single axis tracking mechanisms to concentrate solar radiance.

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 nation's ranking has dropped from 35th to 50th globally in solar water heating (excluding swimming pools)[iv] – although such installations increased by 10 percent in 2009,[v] and increased by another 5 percent in 2011 despite a slow economy with historically low natural gas prices.[vi] 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 systems 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.

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 100ºF) for purposes such as swimming pool heating and boiler water preheating.
- Medium-temperature (100 to 160ºF), largely for domestic/service hot water heating and space heating.
- High-temperature (180 to 350ºF+) for industrial processes, air conditioning and hybrid HP desalination systems.

Evacuated Tube

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 the systems are not buried in the snow, for a commercial process.[vii] 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

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

XCPC

The 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 non-tracking and capable of 350ºF+ temperatures for SIPH applications and more importantly for advanced HP integrated desalination systems for cleaning up subsurface agricultural waste water as demonstrated by WaterFX in California. [viii]

WHAT YOU NEED TO KNOW

Solar water heating systems can be highly cost-effective in facilities that have constant or even intermittent hot-water demands. 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 the Solar Rating and Certification Corporation (SRCC) to produce a specified energy output should be under stated 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 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.

[i] 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

[ii] 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

[iii] 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.

[iv] Werner Weiss and Franz Mauthner, International Energy Agency, Solar Heat Worldwide: Markets and Contributions to the Energy Supply 2008, 2010.

[v] Solar Energy Industries Association, *U.S. Solar Industry Year in Review 2009*, April15, 2010.

[vi] SEIA/GTM Research U.S. Solar Market Insight 2010 Year in Review.

[vii] 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.

[viii] 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