Solar Heat for Industrial Applications

Posted on October 22, 2013 Concentrated Solar Thermal

Intense reliance on heat presents massive opportunity for concentrating solar thermal technologies to reduce carbon emissions.

By ALISON MASON and KEVIN BOXER

Concentrated Solar Power (CSP) Photo: Skyfuel

Heat powers the world economy. According to the International Energy Agency, heat accounts for 47 percent of the world's energy consumption. (1)

Most of this heat is supplied by carbon-based fuels; 67 percent globally and 85 percent in OECD countries (2) presenting a massive opportunity for solar heat to reduce carbon emissions.

We will describe the market opportunity and benefits of promoting solar heat for industrial applications, a particularly promising market. We'll also put to rest discussion of "which renewable energy" will dominate the market. We're going to need them all.

Speculating about whether photovoltaics (PV) or concentrating solar power (CSP) will win out in the market is like wondering whether it is healthier to eat greens or exercise. They work toward the same goal — clean, carbon-free production of energy — in different and complementary ways. Photovoltaic solar collectors turn sunshine into direct current electricity in one step.

Concentrating solar thermal collectors (commonly but ambiguously referred to as CSP) turn sunshine into heat that then can be used to produce electricity in a turbine generator. Picture a coal power plant where the coalmine and coalladen rail cars are replaced with a field of gleaming solar collectors. Using solar heat to generate electricity has been proven through 30 years of operation of the Solar Energy Generating Stations, or SEGS, in California's Mojave Desert. Building on this legacy, the 64-megawatt-electrical(MWe) Nevada Solar One project came online in 2005, the 75-MWe Martin project came online in 2009, and four more utility-scale solar power plants are under construction in California and Arizona.

The most commercially advanced concentrating solar thermal technologies (we'll use this term, abbreviated as CST) are power tower, parabolic trough and linear Fresnel. Power towers use an array of sun tracking heliostats (reflectors) to focus sunlight onto a single-point receiver to heat a fluid atop a tower as tall as 540 feet (165 m). Most of the power tower systems in operation make electricity on a utility scale via a steam Rankine cycle turbine generator. Parabolic trough and linear Fresnel solar concentrators reflect sunlight onto a linear receiver tube, filled with a working fluid, which is situated above or attached to curved, sun-tracking reflectors. There are operating power tower and parabolic trough plants using molten salts for heat collection and thermal storage up to 565°C (1,049°F). Parabolic troughs and linear Fresnel systems are readily scalable, and have the greatest potential to be incorporated into industrial heating applications.

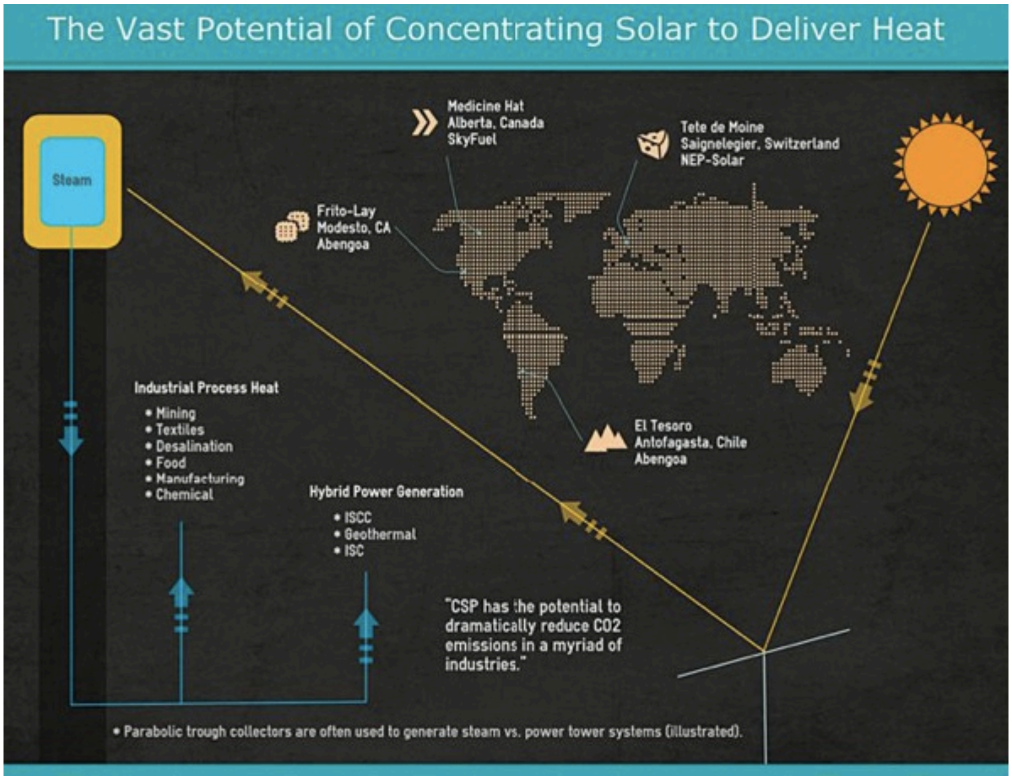
The surging market in solar electric power generation has pushed down the cost of CSP collectors over the past 10 years, from around $300 per square meter3 to below $200 per square meter. The scale-up in the solar electric power market has had other benefits, as well: growth of the supply chain, standardization of components, increased quality and reliability and increased performance of the collectors.

Assessing the Market for Industrial Process Heat

Solar energy for heating in industrial processes has enormous potential. Heat is used at many different temperatures and rates, so to determine how big the market is for concentrating solar thermal, we need to dig a little deeper.

In 2010 the United Nations Industrial Development Organization (UNIDO) assessed the potential market for renewable energy in industrial applications,4 using the International Energy Association Global Energy Assessment Scenario M as the baseline projection. UNIDO found that by 2050, of the 230 exajoules (EJ) per year projected to be used in industrial processes globally, 5.6 EJ can be supplied by solar thermal. Of these 5.6 EJ, 4.7 EJ are at temperatures low enough to be supplied by flat-plate or evacuated-tube solar collectors, leaving 1.3 EJ that requires or is most economically served by CST. Multiplying by 277,778 to get gigawatthours, and dividing by the average number of sun-hours in a year (2,920) to get gigawatts, we arrive at a total CST capacity of 124 gigawatts thermal (GWth) in 2050. The UNIDO report describes an additional 1.7 EJ of CST potential in the chemical industry — equal to another 161 GWth. For comparison, there are 23 GWth of CST for power generation in operation or under construction in the world today.(5)

Historically, the combustion of fossil fuels, including wood, coal, oil and natural gas, has been the only feasible way to produce the levels of heat required for numerous industrial processes. The food industry, for example, uses steam ranging from 60°C to 150°C (140°F to 302°F) for sterilization, sugar milling, pasteurization and canning. Similarly, the textile industry requires heat and steam for several processes, including dyeing, fixing, drying and degreasing. In the mining industry, the heap leaching process uses mild acid solutions that are heated and then drizzled over piles of crushed ore in order to extract metals from raw materials.



Over the past few decades, flat-plate and evacuated-tube collectors have been successful in generating the required heat for numerous small to mid-scale projects. However, due to the growth of CST in generating electricity at the utility scale, concentrating solar (with energy conversion efficiencies as high as 76 percent) has the potential to provide industrial process heat at increasingly lower costs. Particularly in regions of the world with high levels of solar radiation, the cost of providing heat from CST has already proven to be less than that of burning fossil fuels (e.g., transporting diesel fuel to a remote mine in order to run a generator). Furthermore, as industries continue to be pressured to reduce their carbon emissions, CSP will become a more attractive, if not necessary, option.

Assessing the Hybrid Power Generation Market

With the exception of PV power and hydropower, electricity starts out as heat. To generate the 15,623 terawatt-hours of electricity the world consumed in 2008,(6) 36,763 TWh of heat were produced from coal, oil and natural gas. Not all of that amount can be supplied economically today by CST. The Electric Power Research Institute and the National Renewable Energy Laboratory collaborated on the 2011 study, "Solar Augment Potential of U.S. Fossil-Fired Power Plants." The authors looked at existing coal and natural gas combined cycle power plants in 16 southern states and, accounting for solar resource, operating hours, topography and land available for solar collectors, found a potential for 21 GWe (roughly equivalent to 60 GWth) of CST.

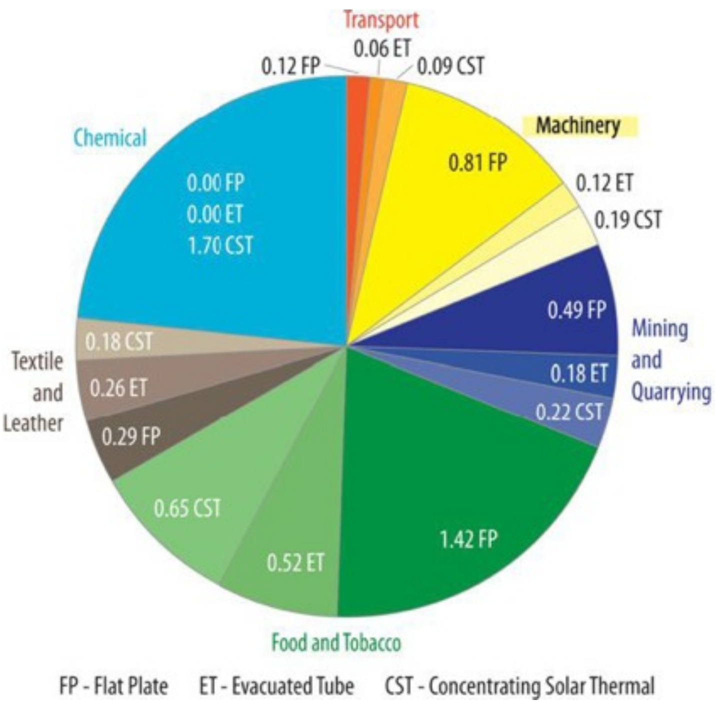
The beauty of adding solar collectors to fossil-fired power plants is that the marginal cost of the solar electricity is very low because the steam turbine, generator and transmission lines are already in place.

For a 100- MWe plant in the United States taking advantage of the 30 percent solar investment tax credit, McMahan et al. estimate a PPA price of 15 cents per kilowatt-hour for a standalone parabolic trough plant, and 10 cents per kilowatt-hour for an integrated solar plant.7 When a field of solar collectors is added to an existing power plant, many of the permitting and infrastructure costs and project risks are eliminated. In addition, this approach can help utilities comply with renewables requirements laws without developing new projects. CST can also be hybridized with a geothermal plant by increasing its operating temperature and/or mass flow rate to boost both the efficiency and output power.

Realizing the Benefits

Tapping into the vast potential of CST releases benefits for individuals, businesses, society and the natural world.

Because the sun provides energy predictably and for free, no energy source offers a more stable price. Stable energy costs contribute to stable government, stable businesses and stable societies. The displacement of combustion fuels reduces emissions of particulates and pollutants into the air, contributing to cleaner air and healthier lungs. Energy produced locally from the sun avoids the importation of fuels from abroad, keeping wealth local, reducing competition and conflict over scarce resources and contributing to peace. Every gallon of diesel displaced by solar keeps 22 pounds of CO_2 from joining the atmosphere (EPA Emission Facts, 2005) and slows the rate of global warming. By installing 3 EJ of CST for process heat by 2050, we will avoid 230,000 megatons of CO_2 (compared to using diesel). Supply of fresh water, the scarcity of which is poised to reach crisis proportions in the next decade, presents another immense opportunity for desalination with solar heat, and will be explored in a future article.



UNIDO found that by 2050, of the heat to be used annually in industrial processes globally, 5.6 exajoules (EJ) can be supplied by solar thermal. UNIDO describes an additional 1.7 EJ of CST potential in the chemical industry. Source: UNIDO, "Renewable Energy in Industrial Applications: An Assessment of the 2050 Potential," 2010.

Doesn't CST use a lot of water? Not really. The only water consumed by the CST system is for washing the reflectors, since water for cooling is needed only as part of the power conversion cycle.

All other thermal energy sources have associated water use either for cleaning or extraction, and the water requirements for washing are becoming less and less as better techniques and anti-soiling coatings are developed.

Another challenge for CST is the amount of land required; each thermal megawatt produced requires roughly an acre of land. But in prime solar regions with available land, existing metal fabricators will expand, hiring more workers and building the local economy. New industries will arrive, bringing factories to the solar projects to cut down on shipping costs and import duties and, in some cases, taking advantage of cheap local labor.

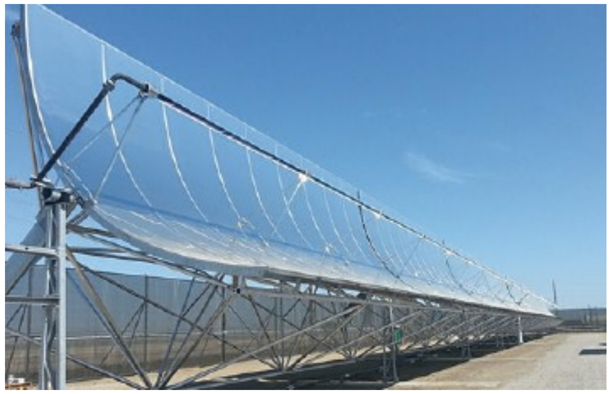
While quite a few initiatives exist to catalyze the CST electric power market, far less attention has been paid to using CST for heat. As with any emerging technology with high capital costs, the only way to get started is with the pooled resources and investment of governments and organizations until the market grows enough to reduce costs and achieve economic profitability. The Carbon Trust, which studied the potential for the United Kingdom to accelerate the deployment of small-scale CST systems in developing countries through the International Climate Fund,8 reports of three such programs in India—one of which has grant-funded 30 demonstration projects. Other organizations studying the heat applications for CST include the IEA Solar Heating and Cooling programme, the European Solar Thermal Industry Federation and Solar PACES Tasks IV (solar heating for industrial processes) and VI (solar desalination).

Municipal Power » Medicine Hat, Canada

THE CITY OF MEDICINE HAT in Alberta, Canada, will offset fuel consumption at the city's combined cycle gas power plant with a SkyFuel parabolic trough solar field, slated for commissioning in November.

Each of the eight SkyTrough solar collectors produces 480 kilowatts of heat at reference conditions of 1,000 watts per square meter of insolation.

The 1.1-megawatt-electric (3.8-megawatt-thermal) rated project will offset natural gas consumption by 12,420 gigajoules and avoid 600 metric tons equivalent of CO_2 emissions per year. This installation demonstrates the feasibility of concentrating solar thermal technology at small scale, integrated with an existing gas generation plant and in a colder climate. The $9 million project on 5.56 square acres is being funded through a partnership of the city of Medicine Hat, the province of Alberta and the Climate Change and Emissions Management Corp. WorleyParsons engineered the project using SkyFuel solar technology.



The city of Medicine Hat in Alberta, Canada, is integrating a 1.1-MWe-rated concentrating solar thermal plant to offset natural gas combustion at its combined cycle gas power plant. Photo: SkyFuel

Mining Industry » Minera El Tesoro, Chile

Commissioned in November for about $14 million, the Minera El Tesoro project will save more than 50 percent of its diesel fuel use, and reduce annual CO2 emissions by 79 metric tons. Photo: Industrial Solar Technologies

MANY MINING OPERATIONS are located in remote areas, sometimes hundreds of miles from a consistent energy source.

A large percentage of these operations require diesel fuel, which needs to be transported to the site in order to generate electricity and provide heat for the mining operation.

Abengoa Solar, a subsidiary of Abengoa, built South America's first CSP plant for Minera El Tesoro, a copper mining operation in the Atacama Desert in Chile.

Utilizing 1,280 parabolic trough collector modules, the plant produces the equivalent of 24 gigawatt-hours of electricity, or 7 megawatts of thermal power, and covers an area of 7 hectares. Commissioned in November for about $14 million, Minera El Tesoro is projected to save more than 50 percent of its diesel fuel use and reduce annual CO_2 emissions by close to 79 metric tons.

Dairy Industry »Tête de Moine Dairy, Switzerland

BY INTEGRATING concentrating solar into several of its production facilities, the forward-thinking Swiss milk industry provides a shining example of how CST technology can help a wide range of companies improve their economic and environmental sustainability.

NEP Solar AG, which won a prestigious Swiss Solar Award in 2012, manufactured and installed 17 of its PolyTrough 1800 solar collectors on the roof of the famous Tête de Moine cheese factory in Saignelégier, Switzerland.

NEP Solar installed 17 of its PolyTrough 1800 solar collectors on

The 600,000 euro ($793,000 U.S.) project, commissioned by the Emmi Group, produces sufficient heat to replace an estimated 30,000 liters of fossil fuel and eliminate 79 tons of CO_2 emissions annually.

the roof of the famous Tête de Moine cheese factory. Photo: NEP Solar AG

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Kevin Boxer (kboxer@gmail.com) is a recent graduate of Colorado School of Mines (CSM), where he majored in metallurgy and materials engineering with a minor in renewable energy. Boxer has worked as an intern at the National Renewable Energy Laboratory in Golden, Colo., and was selected to participate in the NSF-sponsored Renewable Energy Materials Research Science and Engineering Center's Research Experience for Undergraduates program at CSM. Boxer is a fourth-generation native of Denver, and is currently looking for an opportunity to start his career in the renewable energy field.

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