UC Solar Thermal Symposium

Nov. 15, 2019

Identifying Solar Thermal Driven Solutions for Medium and High Temperature Industrial Applications

This symposium brought together representatives from R&D agencies, research institutions, and industry to identify promising solutions that could generate significant commercial impact. The central question discussed in the symposium pertained to the role of solar thermal technologies in delivering a cost-effective low-carbon supplemental source of energy for industrial processes in California and the world. The agenda for the meeting is provided, followed by a succinct summary.

Agenda:

Introductory session

Welcome/Setting the stage

California goals and challenges to meet them – **Virginia Lew** (CEC)

Industrial processes needing high temperatures: An Overview – **Vinod Narayanan** (UC Davis)

Types of solar collectors and temperatures they reach: An Overview – **Roland Winston** (UC Merced)

Opportunities for solar thermal to provide heat for industrial applications –**Avi Shultz** (DOE)

Opportunities for using Solar Thermal in Industrial Applications to Produce Medium and Higher Pressure Steam Generation

Requirements for replacing natural gas for food processing – **Thomas Maulhardt** (Campbell Soup)

Lessons learned from solar thermal in upstream oil-gas facility – **Stanleigh Cross** (Chevron)

An 850 MW solar thermal project: when solar thermal can replace natural gas – **John O'Donnell** (Glasspoint)

New Ideas for the Design and Construction of Collectors for Industrial Solar Boilers – **Nicolas Peralta** (Sunvapor)

Lunch and Poster Session

Opportunities for using Solar Thermal in Industrial Applications to Provide Heat for Driving Chemical Processes

Applications for solar thermal for industrial processes – **Parthiv Kurup** (NREL)

Pathways to hydrogen production using solar heat – **Anthony McDaniel** (SNL)

Lessons learned commercializing an emerging solar thermal technology - **John King** (Hyperlight Energy Solar)

Panel discussion: Bringing it all together

Moderator: **Mary Werner** (NREL) Panelists: **Brian Borak** (ARPA E), **Trevor Demayo** (Chevron), **Lun Jiang** (UC Merced)

- *What are the best strategies for meeting the needs of industrial processes? What would it take for solar thermal to satisfy these needs? What's needed to bring down cost?*
- *When will solar thermal have an advantage over other energy sources?*
- *Where are the technical opportunities?*

• What policies would be needed to help start this market? Why aren't people taking advantage of the current opportunities?

Summary of UC Solar Thermal Symposium

Background and Motivation

The UC Solar Thermal Symposium was organized by UC Merced and UC Davis to answer these questions and convened on Nov. 15, 2019 at UC Davis. California has targeted zero-carbon electricity by 2045 and 30% industrial energy needs relative to 2015; others around the world are setting similar targets. The photovoltaic (PV) solar industry in now approaching 1 TW of installed capacity. On the other hand, Solar thermal industrial applications are only on the order of 1 GW[1]. Solar thermal technology is an obvious tool that has been underutilized toward achieving low-carbon targets, specifically on the reduction of the use and dependence on fossil fuels.

The goal of the Symposium was to identify what can be done (through formation of partnerships, R&D execution, policy implementation or other actions) to enable solar thermal to become a widespread tool to reach California's and the world's clean-energy targets. The symposium allowed for important interactions and fostering key relationships for future collaborations.

Key takeaways

• Solar thermal is complementary to solar PV in that it can provide medium and high temperature heat while solar PV can provide low temperature heat efficiently. Solar thermal shares many of the advantages of solar PV and has additional advantages, but is further challenged by the needs to a) locate solar thermal systems near the heat load, and b) separately engineer each project, which adds costs and development time for each project. Additionally, solar thermal competes with relatively low fuel costs in CA while solar PV competes with more expensive electricity in California. The similarities and differences between the two solar technologies were discussed repeatedly during the Symposium.

• Solar thermal needs to greatly increase volume to reduce cost by either a) identifying applications that require very large systems in similar or the same industries, or b) install thousands of small, modular systems.

• Majority of industrial processes require < 300°C, suggesting that that should be focus in near term, while high temperature applications (>500°C) may be explored through early stage research.

• Major opportunities for policy incentive exist today for near-term technology solutions such as the Food Processing Investment Program (FPIP), CSI Thermal rebate, and Low Carbon Fuel Standard (LCFS) at \$200/CO_2ton.

• Solar thermal's "gap" to success is many things, not just one thing

Detailed takeaways:

• *Advantages of solar*:
  - Sunlight is free
  - No emissions
  - Cost will come down; solar provides less uncertainty than for natural gas
  - Customer perception can be favorable

• *Advantages of solar thermal over solar PV*:
  - Thermal energy can be stored at lower costs than electrical energy

[1] https://www.iea-shc.org/solar-heat-worldwide, section 4.3

- Direct heating of fluids, i.e. heat for heat applications
- Thermal energy may be stored (in some cases) more safely than electrical energy. The lifecycle of solar heat systems e.g. water or oil storage is significantly greater than battery based systems which are currently unproven for long time periods e.g. 20 yrs.
- Thus, as solar electricity saturates electrical demand during the day, solar thermal energy may compete with solar electricity plus batteries, or solar electricity plus a heat pump rather than directly with solar electricity
- Solar thermal brings added value to locations without easy access to natural gas (e.g. oil fields that have oil and no natural gas) or when the supply of natural gas is unreliable.

• *Challenges unique to solar thermal*: When comparing solar thermal with photovoltaic solar technology, we find that solar thermal technology faces different challenges including:

- *Portability*: Thermal energy can be conveniently transported only meters rather than kilometers, reducing flexibility in locating projects
- *Land availability*: Large solar thermal systems may not fit near the process plant that would like to use the heat.
- *Each project requires new engineering*: While DC-DC converters or inverters can be used to easily deliver electricity for any electrical load, optimal design of thermal energy systems may be unique for each customer depending on the desired temperature, steam pressure, capacity and temporal load profile (which seldom matches the solar irradiance profile)
- *Long-term return on investment*: Solar electric projects have been able to sign twenty-plus-year power-purchase agreements, but such long-term agreements are more difficult for solar thermal since if the thermal load disappears, it may be difficult to find a replacement local application.
- *Time to completion (permitting)*: Solar thermal projects are taking many years due to permitting challenges and lack of familiarity on all sides
- *Cost of permitting*: Not only does the permitting delay the projects, but the costs associated with the many reviews increase return on investment by years.
- *Lack of site readiness*: Existing process hardware doesn't have the controls to easily integrate with a solar thermal system and provide desired control
- *Price competition*: In California, electricity prices are much higher than natural gas prices, making it easier for solar PV to gain market share
- *Demonstration system size*: Solar PV pilot systems could be very small compared with the large systems needed to demonstrate solar thermal economically today
- *Safety*: When very high temperatures are used, there can be risk of injury or damage
- *Track record*: Solar thermal for process heat is not yet viewed as a "proven" technology. Insufficient sites have been developed in the U.S. Traditional energy efficiency engineers are risk averse. This makes new tech adoption harder, with the fast payback constraint.
- *Operational costs*: Solar thermal plants have more moving parts than solar PV plants and may require substantially higher operational costs

• Challenges shared with solar PV:

- Permitting
- Variability of solar resource
- Soil variability, complicating site preparation
- Need consistent (multi-year) incentive programs

• Solutions shared with solar PV:

- Incentive programs that enable people to invest and save or make money
- Achieving close to "plug & play" and streamlined methods for designing each system, through modular approaches
- "Solar ready" for new buildings and industrial power systems. Standardization is needed for quick interfacing at lower cost for the whole system.
- May be able to delay investing in storage systems (enhanced oil recovery is example of application that doesn't need storage).

• Key strategies

- Reaching high volume to reduce cost is key (select high-volume applications, or define modular approach without need to engineer every system, like domestic hot water)
- Focus on lower temperature for market development; High Temperature is still at R&D stage and is not a priority because it is the smaller fraction of energy.

• Actions - policies:

- Government to take some risk for initial projects to "prove" technology and help to bring cost down. Establish programs that can have a long runway for the application to scale up.
- Feed In Tariff (FIT)-like incentives: Solar PV enjoyed large amount of FIT but solar thermal has none for all these years.
- Streamline permitting
- Provide low-cost (and long-term) financing
- Government guaranteed loan.
- Somehow guarantee a minimum trading price for the LCFS

• Actions – other

- Universities should create a joint effort that would:
    a) bring together key stakeholders
    b) assess the industrial applications which may benefit from solar thermal
    c) work on lower TRL technologies for energy storage or higher temperature solutions
- Innovation in financing, such as ESCO (Energy Service Companies) and power purchase agreements (PPA).
- Word of mouth, one successful project can help a whole industry to change.
- A reliable control and good integration with existing thermal loop is critical for success.
- Pilot at food industry and large scale at oil and gas industry.

References:

Manufacturing Energy Consumption Survey (MECS): https://www.eia.gov/consumption/manufacturing/data/2014/: *Provides data describing the energy used for manufacturing in the U.S.*

California Energy Commission, 2019, "Research Roadmap for Advancing technologies in California's Industrial, Agriculture and Water Sectors," Energy Research and Development division Final Project Report CEC-500-2019-016. *Energy consumption data for Western census region and for California by type of industry.*

McMilan et al., 2016, Generation and use of thermal energy in the US Industrial Sector and Opportunities to Reduce its Carbon Emissions, NREL/TP-6A50-66763, INL/EXT-16-39680. *Use of energy for a variety of industrial processes* .

C. Garitsky, E. Worrell, 2004, Profile of the Chemicals Industry in California- California Industries of the Future Program, LBNL 55668. *Use of energy in chemical manufacturing*.

https://arena.gov.au/knowledge-bank/renewable-energy-options-for-industrial-process-heat/
Austalian summary of process heat

http://www.solarpaces.org/wp-content/uploads/IRENA_2017_Power_Costs_2018.pdf. *Figure ES.2 shares a learning curve to show how costs have decreased for Concentrating Solar Power.*

Further readings:

- "CSP Systems Analysis Final Report" – Report which includes a CSP for IPH review - https://www.nrel.gov/docs/fy19osti/72856.pdf
- "Initial Thermal Energy Yield Potential for the Use of Concentrating Solar Power (CSP) for Coal Hybridization in India" – Initial thermal yield simulations and calculations on the thermal yield proximal to coal plants in India - https://www.nrel.gov/docs/fy19osti/74024.pdf
- A colleague's report and tool will help develop the energy use perspective. See here for the "Industrial Energy Tool" - https://www.nrel.gov/docs/fy19osti/71990.pdf .
- "Parabolic Trough Collector Cost Update for the System Advisor Model (SAM)" – Detailed cost update for the parabolic trough - https://www.nrel.gov/docs/fy16osti/65228.pdf
- "Revisiting Parabolic Trough Costs"– Costs for parabolic troughs - http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=2579476
- "System Advisor Model (SAM) Validation of the liquid-HTF and DSG models" – SAM model validations for the process heat models - https://www.researchgate.net/publication/320907845_SAM_Process_Heat_Model_Development_and_Validation_Liquid-HTF_Trough_and_Direct_Steam_Generation_Linear_Focus_Systems
    - SAM now has solar IPH modules: Parabolic trough with liquid-HTF and linear collectors (trough and Fresnel) with DSG