U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
SOLAR ENERGY TECHNOLOGIES OFFICE

SETO CSP Program Summit 2019

Solar for Industrial Process Heat

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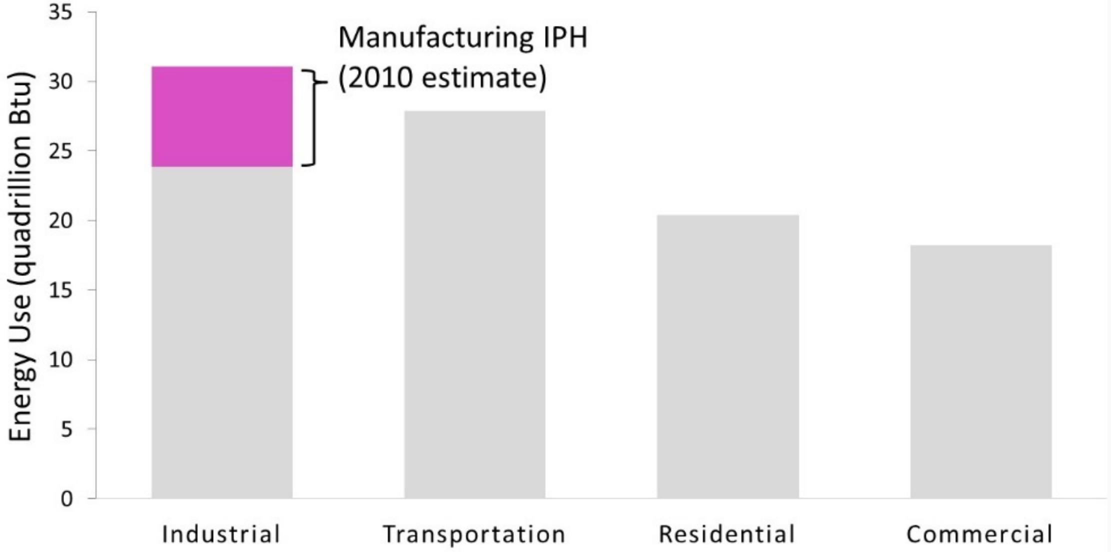
Overview

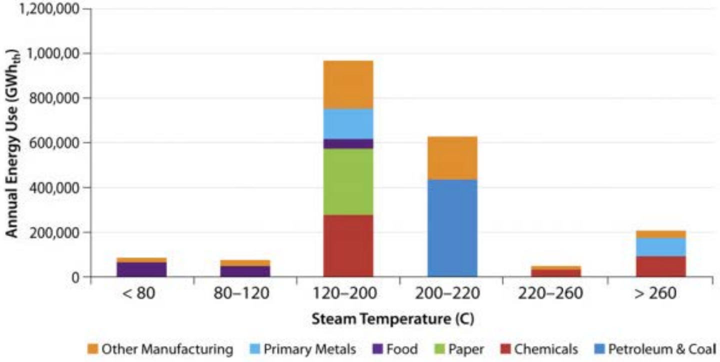
- The industrial sector accounts for roughly 1/3rd of all U.S. primary energy use (32 Quads).
  - Industrial Process Heat (IPH) accounts for roughly 7.5 Quads.
  - IPH for manufacturing is > 90% through fuels like NG
- What role can solar technologies (CSP and PV) play in meeting a wide range of IPH end uses in the U.S.?
  - Fuel saving
  - Broader transformation



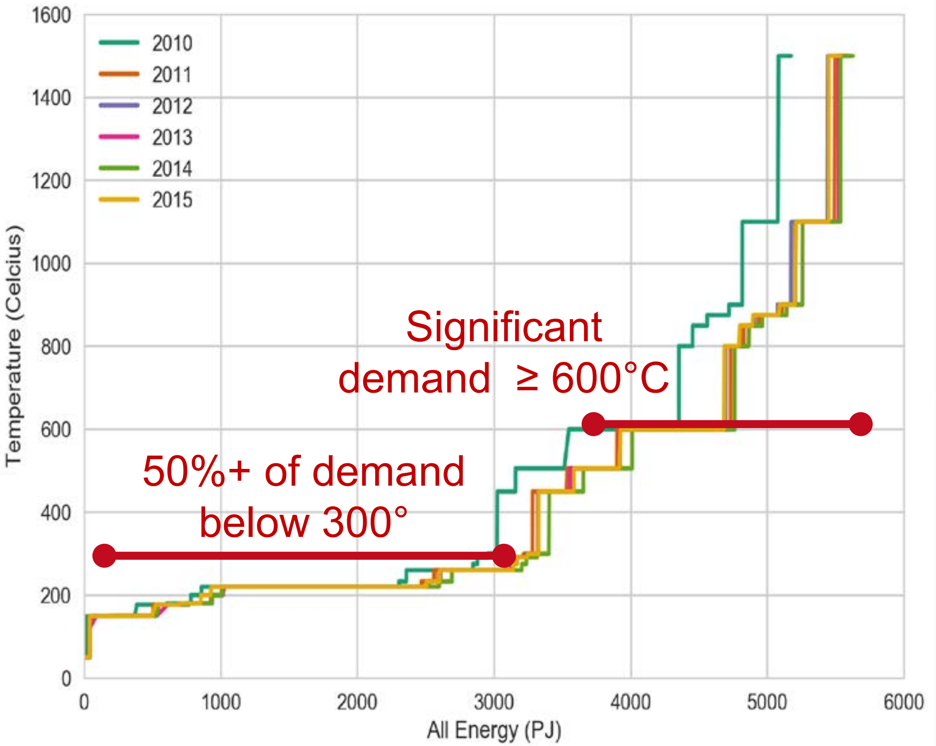
U.S. energy use by sector (2016) with manufacturing IPH estimate (2010)
(Data from EIA 2017; U.S. DOE 2014)

Industrial Processes Require a Wide-Range of Temps

- Industrial processes range from those requiring hot water at 70°C to those melting steel scrap at 1,800°C.
- Select industrial players could be prime targets for technology adoption and demonstration.



Kurup and Turchi, “Initial Investigation into the Potential of CSP Industrial Process Heat for the Southwest United States”, NREL, 2015



Energy demand by process temperature (Source: McMillan and Ruth 2019)

Potential Solar IPH Configurations

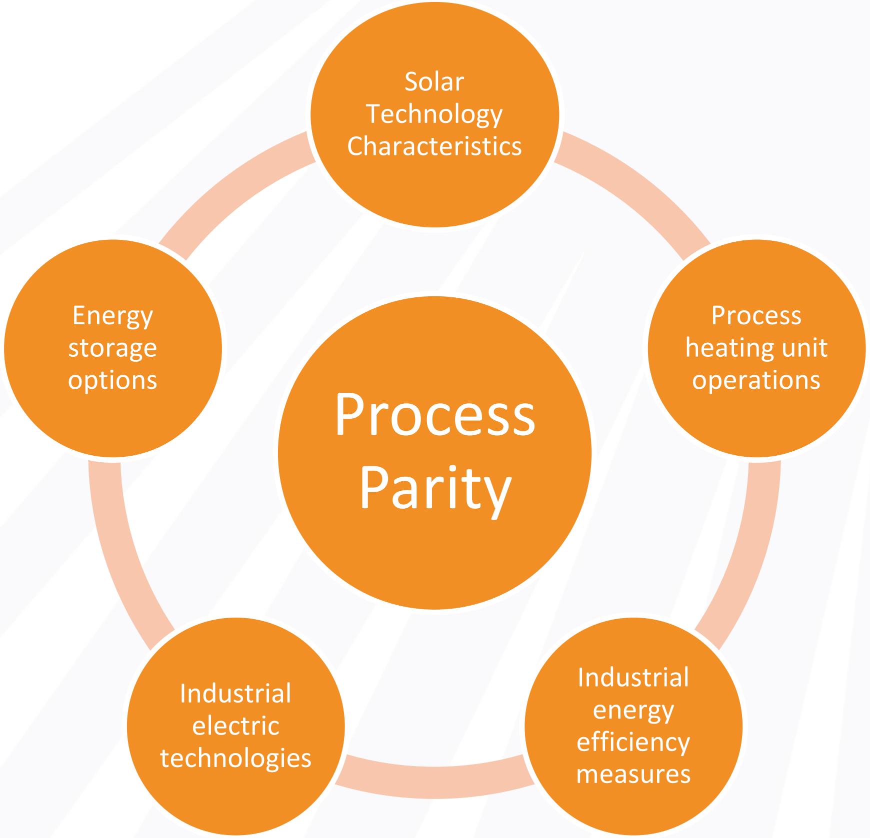
- New Solar IPH markets could open up as:
  - the cost of solar technologies (CSP and PV) declines
  - the cost of complementary technologies (storage, efficiency, electrification) declines
- Solar technologies could meet a broad range of industrial process temperature requirements.

Solar Technologies	Temp Range	Applications
Thermal flat plate, Non-tracking compound, Solar pond, PV + heat pump or microwave	<80°C	Hot water, Space heating, Drying, Curing
Parabolic trough, Linear Fresnel, PV + infrared	<550°C (depending on HTF)	Drying and curing Steam for IPH
Heliostat/central receiver	>550°C	Steam for IPH, Lime calcining
PV + Induction	<1,100°C	Heat treating
PV + Resistance	<1,700°C + (material dependent)	Steam for IPH Glass melting
PV + Electric arc	<4,000°C	Metal melting

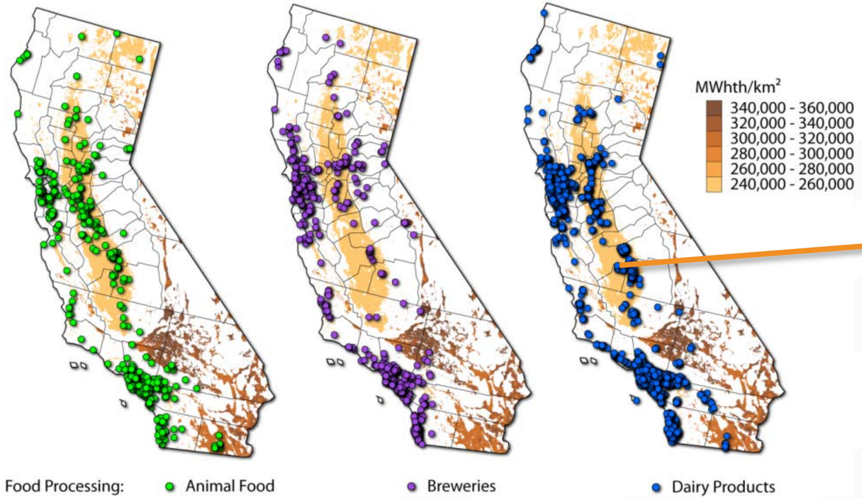
Based on data in: Chindris and Sumper (2012) and Cheremisinoff (1996).

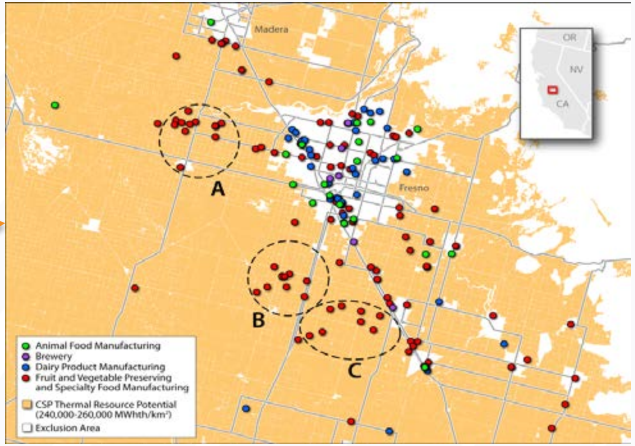
Defining Process Parity

- Process parity is the point at which the levelized cost of heat (LCOH) from solar is equivalent to the levelized cost of heat from other sources, e.g. fuel
- Estimating process parity requires expanding datasets and carrying out detailed process level modeling.



Where Potential Meets Demand



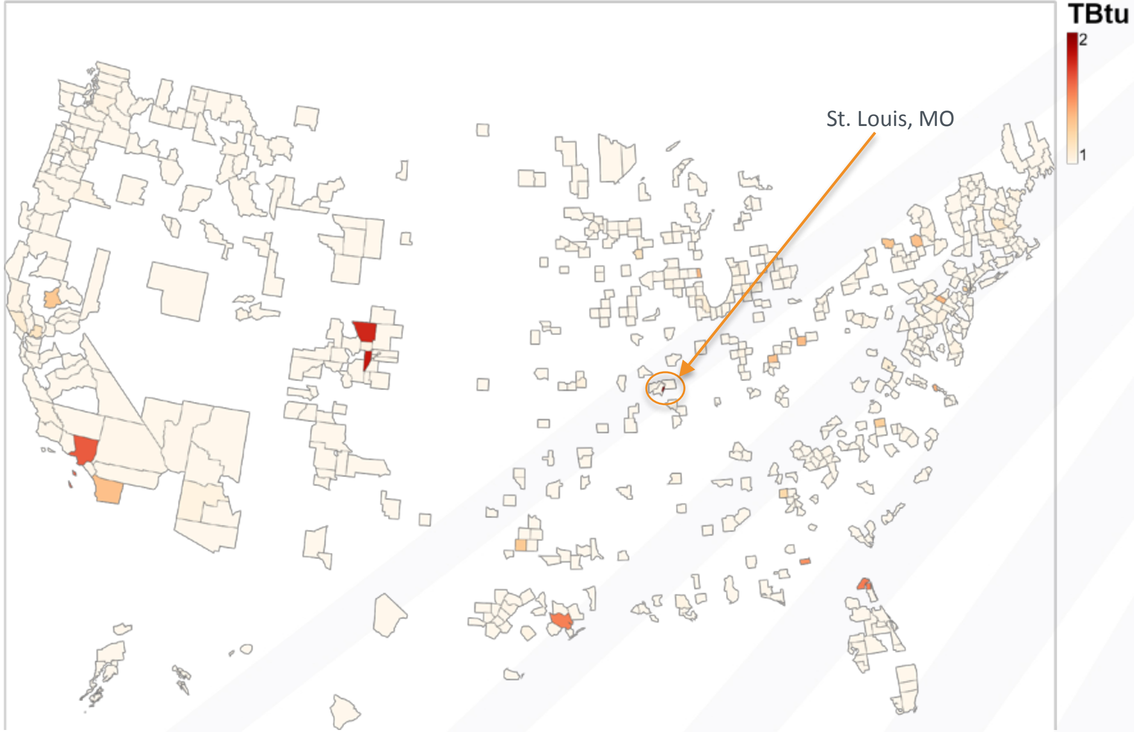


- Locations of food processing across California with solar-thermal energy potential
- Use the NREL System Advisor Model (SAM) and other analysis tools, to model systems (e.g. solar IPH) and determine locations with good potential

- Central Valley provides good resource and industry proximity
- Industries such as Fruit and Veg clustered together in good thermal potential areas and with nearby available land

Source: Kurup and Turchi, "Initial Investigation into the Potential of CSP Industrial Process Heat for the Southwest United States", NREL, 2015

Example: Energy Profile of Brewing in the U.S.



- Beverage sector
  - ~43 TBtu for boiler and process heat
  - ~84% natural gas
- Thermal demands by temperature
  - Washing (70°C)
  - Cooking (100°C)
  - Mashing (70°C)
  - Brewing (100°C)
  - Drying (100°C)
  - Pasteurizing (65°C)

Source: U.S. EIA. 2018. *2014 Manufacturing Energy Consumption Survey; and,* Brown, et al. Energy Analysis of 108 Industrial Processes. Prentice Hall, 1997.

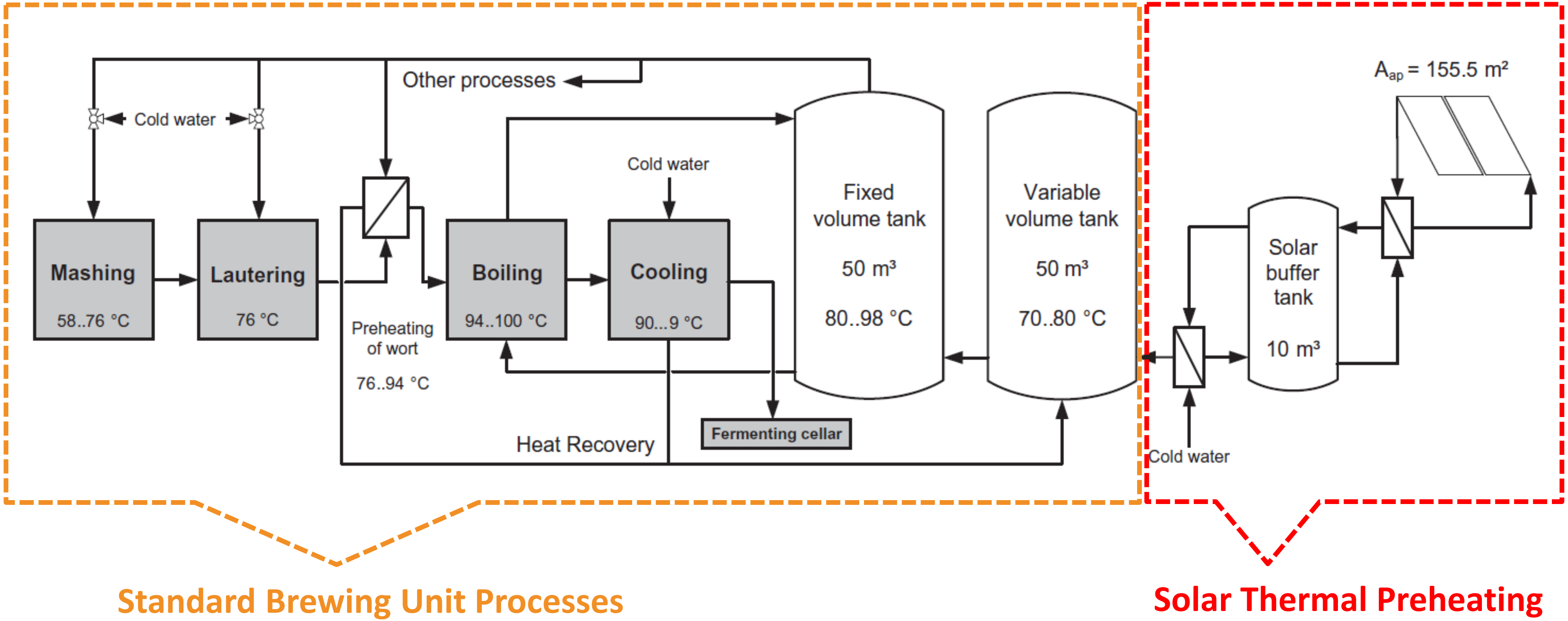
Energy data from: McMillan and Narwade (2018): United States County-Level Industrial Energy Use. National Renewable Energy Laboratory. https://dx.doi.org/10.7799/1481899 :

Characteristics of Brewery Process Heat Demand

- Brewery temperature requirements are well-matched to solar technologies
  - Solar thermal is already being used in the U.S., Germany and other countries
- Breweries have standard production processes (e.g. mash boiling), but are operated differently and at range of scales
- Opportunities also exist for waste heat recovery (e.g., from boiler flue gases and steam re-condensation), but timing of hot and cold streams needs matching
- Thermal energy storage (TES) is critical for reducing heat demand

Eiholzer, et al. "Integration of a Solar Thermal System in a Medium-Sized Brewery Using Pinch Analysis: Methodology and Case Study." *Applied Thermal Engineering* 113 (February 25, 2017): 1558–68. https://doi.org/10.1016/j.applthermaleng.2016.09.124.

Brewing with Solar Thermal Preheating



Source: Lauterbach et al. 2014. System analysis of a low-temperature solar process heat system. *Solar Energy.* 10.1016/j.solener.2013.12.014

Conclusions

- With the emergence of lower-cost solar technologies, it is important to develop data and analysis that enable decision makers and analysts to explore how IPH might shift toward renewable sources over the coming decades.
  - Industrial process heat represents a significant potential market for solar, roughly 7.5 Quads in the U.S.
  - A mix of solar technologies (CSP and PV) could be used to meet a broad range of industrial process temperature requirements.
- Two potential Solar IPH strategies:
  1. As an add-on to existing processes to provide fuel savings
  2. As part of a broader process modification strategy to drastically reduce fuel use (linked with storage, efficiency, electrification, etc.)