Zeroing in on the potential of solar energy to meet industrial process heat demand

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Today, natural gas and coal combustion supply most demand for industrial process heat (IPH), or the transfer of heat to a material within a production process. With the emergence of low-cost solar photovoltaic (PV) technologies, interest has grown in solar as an IPH option and decarbonization pathway for the industrial sector.

However, industry's thin margins and tight production schedules have raised questions about the reliability of on-site solar energy to meet required temperatures in industrial processes. This, along with other factors, has prevented adoption of solar energy for on-site use, which totaled just 0.8% of U.S. industrial total energy consumption in 2019.

To better understand the potential of solar for industrial process heat across all industries, NREL analysts developed higher-resolution data to study three main solar-for-IPH technologies—non-concentrating collectors, concentrating collectors, and PV-connected electrotechnologies—and their ability to provide on-site industrial process heat at low to medium temperature ranges across all industries in all U.S. counties, considering relevant end uses and technology limitations.

The findings, which are published in an NREL technical report and summarized in an interactive viewer, help establish the foundation for continued analysis to eventually match solar energy technologies with specific IPH demands.

Developing Higher-Resolution Data

Existing research on industrial process heat has tended to focus on high-temperature, energy-intensive processes. In addition, U.S. solar analysis thus far has lacked higher-resolution data, including hourly heat demand data.

Building upon a previous report that developed energy estimates for county-level industries, NREL researchers disaggregated existing energy data into process temperatures and end-use categories like conventional boilers or combined heat and power. The resulting data set represents the highest-resolution estimates of combustion fuel use for industrial process heat demands in the United States.

The analysts also developed a set of representative heat load shapes using a variety of data sources to capture differences in hourly process heat demand for different operating schedules based on industry, facility size, and seasonality. Additional process-level detail, including average equipment efficiencies, was also included in the analysis.

Finally, to consider solar resource availability and land use constraints that may prohibit system development, the analysts used NREL's System Advisor Model (SAM) and Renewable Energy Potential (reV) Model to calculate solar plant energy production for all counties in the contiguous United States.

A Step Closer to Matching Source and Demand

Based on solar energy's generation potential, topographic characteristics, land-use constraints, and system performance, the analysts determined that there are many opportunities for solar industrial process heat to reduce combustion fuel use and emissions across many industries and in all counties in the contiguous United States.

However, these opportunities are limited by solar energy generation's ability to meet IPH demands that occur when sunlight is not available, particularly for industries that operate around the clock. The analysts note that matching solar energy technologies with hourly IPH demand is a current barrier—more so than matching technologies with IPH temperatures, which has existing data.

Future research could develop higher-resolution IPH demand data, expanding industry-average data to information for individual facilities, such as operating schedule, process temperature requirements, and heating loads at the equipment level over time.

Along with facility-level data, future research could explore thermal

energy storage options and sizes to minimize thermal losses. The analysts highlight storage as a potential option for helping to balance demand by storing energy when it is not needed and dispatching it when sunlight is not available.

Finally, future research should consider how best to integrate solar industrial process heat technologies into industrial operations, possibly including the development of a decision-making tool for facilities to compare solutions against conventional technologies, track installations and their performance, and engage with other manufacturing subsectors.

"Now that the technical aspects of the opportunities for solar for industrial process heat in the United States are becoming clearer, we're starting to examine the economic aspects of these technologies relative to their conventional combustion counterparts," said Colin McMillan, NREL analyst and lead of solar-for-IPH research. "We're now focusing on the conditions needed for the economic and technical performance of these systems to match up with existing combustion technologies."

More information: Opportunities for Solar Industrial Process Heat in the United States. www.nrel.gov/docs/fy21osti/77760.pdf

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