

The Clean Heat Climate Opportunity

A Roadmap for Electrifying Low- and Medium-Temperature Industrial Heat

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Report Highlights

Long considered “hard-to-abate,” the industrial sector has often been overlooked by decarbonization efforts. Growing interest in near-term action is refocusing attention on what can be done today to cut pollution. Electrification of U.S. manufacturing offers a practical path forward.

In this roadmap, we outline a new approach to understanding electrification of low- and medium-temperature process heat in manufacturing. Drawing on a growing body of industrial decarbonization research, we develop tools for policymakers, facility managers, and other stakeholders to plan and implement a cost-effective, clean transition with commercial-ready technologies. We identify states, processes, and policy solutions that can accelerate deployment, based on our rigorous engineering analysis of the U.S. chemicals, pulp & paper, and food & beverage manufacturing sectors.



We use process system archetypes—which model energy and mass flows to characterize how a typical plant operates in a given subsector—to determine where it is technically and economically feasible to deploy electrode boilers, air-source high-temperature heat pumps, electric ovens, and electric dryers. We then estimate the impact of eight different policy scenarios on electric technology adoption.

Electrification can significantly cut climate pollution in the industrial sector. With technology ready to deploy today, we can make significant progress in cleaning up and modernizing industry. With 95% grid decarbonization by 2050, strategic electrification of low- and medium-temperature process heat can reduce cumulative climate pollution at major facilities by 19% to 26% (~930-1320 MMT CO₂e) over the same timeframe. With additional improvements in the technology and economics of electrification, further reductions of pollution from sources such as combined heat and power, biogenic and other byproduct fuels, and higher temperature processes can be achieved.

Industrial electrification cuts the most pollution in states with lower carbon grids. Industrial electrification allows manufacturers to reduce their onsite pollution. But, this could theoretically shift pollution from the industrial site to off-site power generation. On average, we find that electrification can already reduce pollution today in most states, with the largest savings in states with low-carbon grids like Washington, California, and Vermont. Even in places with dirtier grids, electrification today will cut pollution between now and 2050.

Electrification combined with a clean grid creates major public health benefits. Not only will combining industrial electrification with a cleaner grid reduce climate pollution, it will also reduce criteria pollutants such as nitrogen oxides (NO_x), sulfur dioxide (SO₂) and particulate matter (PM_{2.5}). These pollutants are detrimental to human health, causing respiratory diseases and increasing cancer risk. We estimate that electrification of low to medium temperature process heat could reduce health burdens, resulting in roughly \$288 to \$475 billion in cumulative economic benefits through 2050.

The costs to electrify can vary widely between different industries and different states, but we estimate that electrification may be cost-competitive in some places. High electricity prices make electrification more expensive. But in New York, Pennsylvania, and Washington, we estimate that electric heat technologies in some subsectors could cost the same or even less than traditional fossil fuel combustion technologies over their lifetimes. Additionally, some sectors, like plastics & resins, pulp & paper, and ethanol manufacturing, present particularly cost-effective opportunities for deploying air-source high temperature heat pumps and maximizing energy efficiency.

Policy support can drive faster and more affordable electrification. Policies can reduce upfront capital costs for equipment, including state grants or federal investment tax credits. Other policies can reduce operating costs, including PUCs and utilities setting beneficial electricity rates for electrified facilities and a federally-funded production tax credit. These interventions can be layered, and policy costs can be spread between different actors (such as a utility and a state government, for example).

Policies can target industries where process heating costs are a relatively small share of total expenses to encourage first-movers to electrify. Electrification may be easier in industries where fuel costs are a smaller share of total expenses, since firms can more easily absorb higher energy costs. For example, increased energy costs in food & beverage production may only increase total production costs by a fraction of a percent. If electrification doubled fuel-related operating costs in milk production, the average retail price of milk would increase by just one cent, from \$4.47 to an estimated \$4.48 per gallon.

Energy efficiency is a “win-win” for business, the environment, and the public. Technologies such as waste heat recovery heat pumps, improved process controls, and steam system optimization can reduce the amount of energy required to make the same amount of product. This lowers the cost of electrification for businesses—via reduced electricity costs and equipment sizing—while also reducing load growth and lowering grid emissions.

Increasing grid capacity and resilience is essential to meet increasing electricity demand. Today’s industrial sector consumes an estimated 1,000 TWh of electricity from the grid annually. Electrifying the low- and medium-temperature process heat considered in the study could add an estimated 158 to 301 TWh to existing grid demand, equivalent to 16 to 30% of current industrial electricity grid consumption. Accommodating this new load will require proactive grid planning, expanded transmission and clean generation capacity, and policies that encourage load shifting to off-peak hours and the deployment of energy storage and/or off-grid clean heat technologies.

Understanding the technical details of how manufacturing works in different sectors is key to driving positive change. Industrial plants are made up of complex and interdependent systems. Every sector is different and a solution for one might not be suitable for another. This analysis provides a novel approach to evaluate electrification options at the plant level by offering detailed process models for 32 subsectors. This allows us to assess which electrification options are most effective and where they can be implemented.

Clean heat technologies are already being deployed at facilities across the country. Industries around the U.S. have already started to implement clean heat technologies. New Belgium Brewing Company installed an industrial heat pump at their Colorado brewery. Other clean heat technologies are used in milk production, ethanol production, and biofuels. These cases show the possibilities of using industrial heat pumps, solar thermal, energy efficiency upgrades, thermal batteries, and other decarbonization technologies. In previous work, we have also looked at the potential for geothermal for industrial heat.

The 2035 Initiative at UC Santa Barbara is a cutting-edge “think-and-do” tank that brings together world-leading environmental policy research labs to develop politically viable roadmaps for a low-carbon, equitable, and climate-resilient energy system. Learn more about [who we are](#) and [what we do](#).