RENEWABLE
THERMAL
COLLABORATIVE

Electrification Action Plan

PREPARED BY THE RENEWABLE THERMAL COLLABORATIVE

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FOREWORD

The Renewable Thermal Collaborative (RTC) is the leading global coalition tackling the long-neglected challenge of reducing greenhouse gas emissions from energy used for heating and cooling to help reach critical climate goals. The coalition is comprised of companies, institutions, and governments committed to decarbonizing thermal energy by scaling up renewable heating and cooling technologies across their operations and facilities. The RTC collaborates with end users (“Members”) and solutions providers (“Sponsors”) to accelerate industrial decarbonization by identifying and addressing ways to overcome the technology, policy, and market challenges facing large thermal energy users. The RTC was founded in 2017 and is facilitated by the Center for Climate and Energy Solutions (C2ES), David Gardiner and Associates (DGA), and the World Wildlife Fund (WWF).

The RTC developed this Electrification Action Plan through close collaboration with our Members and Sponsors in the RTC Electrification Working Group. The Electrification Action Plan is a multi-year strategy to address barriers to electrification. It provides a vision for the priority market, policy, and community actions that will drive the RTC to achieve our goals of reducing U.S. industrial thermal emissions 30% by 2030 and full sector decarbonization by 2050.

To translate this strategic action plan into tangible emissions reductions, we will develop subsequent work plans and implement these actions in a prioritized, integrated manner as specific opportunities, market and policy conditions, and resources warrant. The RTC Electrification Working Group will continue to serve as the main forum for ongoing discussions on the evolving barriers to technology deployment, and for prioritizing and implementing actions to accelerate electrification.

While this report primarily focuses on accelerating the electrification of industrial thermal applications, many of the challenges and recommendations are cross-cutting and relevant to commercial and institutional applications. As we collaborate with the RTC community and external partners to prioritize and implement this action plan, we invite large thermal energy users from around the world to join us in this effort.

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Electrifying industry and buildings with renewable electricity is one of the key pathways to wide-scale decarbonization, with the potential to immediately deliver significant emissions reductions. Thermal energy used in industrial processes and to heat and cool buildings accounts for half of global energy demand and produces nearly 40% of energy-related carbon dioxide emissions.[1] In the United States, industrial thermal energy use accounts for 13% of total emissions, as industrial process heat is typically generated from fossil fuels.[2]

Electrification should be a major component of any plan to decarbonize industry, accelerating in parallel with the electric grid's clean energy transition. When cost-competitive heat pumps, electric boilers, and electrified thermal batteries are powered by low- or zero-carbon electricity, they can significantly and immediately reduce emissions. Deployment of improving electrification technologies like high temperature heat pumps can reduce emissions even more over the long term. As less than 5% of industrial process heat in the U.S. is currently electrified, the near-term opportunity for electrification to decarbonize industry is considerable.[3]

Electrification technologies can serve a range of industrial applications and temperature ranges. Electric heat pumps can cost-effectively replace fossil fuel-powered systems for applications under 130°C, representing 29% of U.S. industrial thermal demand. Electric resistance technologies can electrify low, medium, and high temperature thermal processes up to 1,800°C. Thermal energy storage (TES) systems, commonly known as thermal batteries, that can deliver heat and steam up to 750°C are commercially available today, and thermal batteries that can support temperatures up to 1,500-1,800°C will likely become commercially available in the next decade (see Figure ES1).[4]

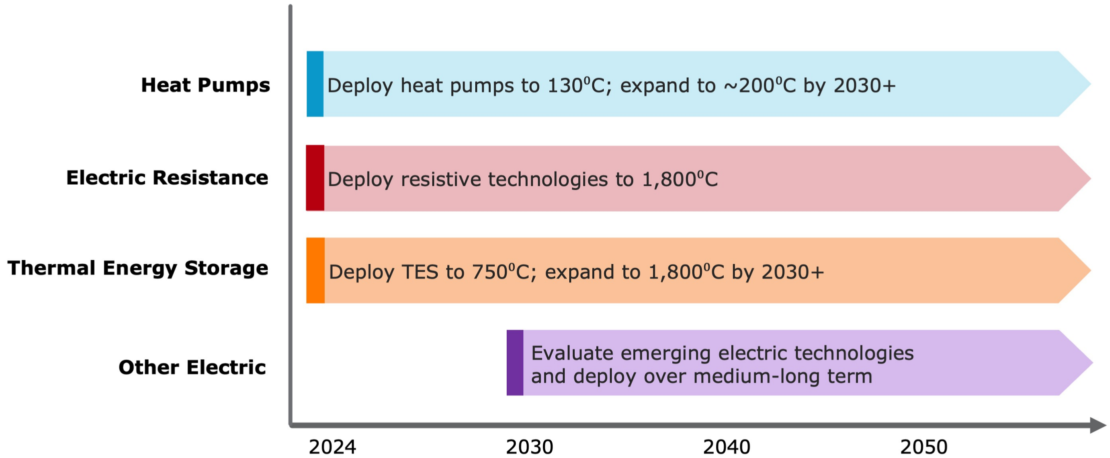

Figure ES1. Electrification Technology Deployment Timeline

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[1] International Renewable Energy Agency (IRENA), "Innovation Can Pave the Way to Decarbonise High-temperature Heat in Industries," 2023.
[2] Includes emissions from machine drive applications. World Wildlife Fund (WWF) and Renewable Thermal Collaborative (RTC), *The Renewable Thermal Vision*, 2022.
[3] American Council for an Energy-Efficient Economy (ACEEE), *Industrial Heat Pumps: Electrifying Industry's Process Heat Supply*, 2022.
[4] WWF and RTC, *The Renewable Thermal Vision*, 2022.

Although key electrification technologies are ready for deployment, they face significant barriers that impede both demand from large thermal end users and supply from manufacturers. These barriers include:

- **Project affordability.** The considerable upfront cost of new equipment, process integration, and electricity infrastructure upgrades—in combination with the high price of electricity relative to natural gas—lead to high electrification project costs that are unaffordable for many industrial end users.
- **Buyer confidence.** The limited operational track record of electrification technologies in the U.S. leads buyers and investors to question the operational performance, reliability, and financial viability of electrification technologies.
- **Limited supply.** The supply of electrification technologies in the U.S. is limited. The lack of supply prevents buyers from gaining confidence in electrification technologies and finding economically viable routes to deployment.
- **Workforce capacity.** The domestic workforce lacks the knowledge and skills needed to design, manufacture, install, maintain, and scale electrification technologies in industrial settings. Without greater workforce capacity, it will be challenging to electrify industry at the pace and scale needed to deliver significant emissions reductions.
- **Insufficient renewable electricity supply.** Electrified processes must be powered with cost-competitive renewable electricity to fully decarbonize industrial process heat, and the supply of electricity must be large—demand from widespread industrial electrification could more than double total U.S. electricity demand.[5] The slow pace of long-distance transmission construction and wholesale market rules that exclude thermal batteries exacerbate the challenge of meeting future renewable electricity demand.

Accelerating electrification will require new federal and state policies as well as tactical tools, trainings, and convenings to support market development. To advance these efforts and achieve our goal of reducing U.S. industrial thermal emissions 30% by 2030, the Renewable Thermal Collaborative (RTC) facilitates collaboration between energy buyers, technology providers, investors, utilities, regulators, policymakers, and non-governmental organizations. By working closely with RTC Members and Sponsors, we developed an ambitious, multi-year strategic action plan to accelerate industrial electrification. We plan to implement the following market, policy, and community actions through ongoing collaboration with the RTC community and external partners:

Market Actions

- **Convene buyers and suppliers** through working groups and events to increase market transparency and build relationships to explore project opportunities.
- **Launch an electrification information and engagement campaign** to improve market awareness of the technical, operational, and financial characteristics of electrified technologies.

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[5] Gimon, E. "Full industrial electrification could more than double US power demand. Here's how renewables can meet it." 2023; and U.S. Department of Energy (DOE), *Pathways to Commercial Liftoff: Industrial Decarbonization*, 2023.

- **Strengthen demand signals and deployment opportunities** through curated networking, a demand platform, and increased engagement with utilities.
- **Scope workforce development strategies** through research and interviews to investigate industrial electrification workforce needs and the policies best suited to address them.

Policy Actions

- **Advocate for federal tax incentives** to lower costs for industrial end users to electrify and strengthen the economic case for manufacturers to increase supply.
- **Expand and support access to federal and state funding for RDD&D** to commercialize nascent technologies and strengthen the operational records of electrification technologies.
- **Engage on transmission and wholesale market barriers** to accelerate the pace of long-distance transmission construction and ensure access to low-cost, renewable electricity.
- **Engage on utility regulatory policy in key states** to encourage resource planning and rate structures that improve access to and reduce the relative price of electricity.

Community Actions

- **Build the RTC community** to include more companies committed to sharing challenges and best practices to accelerate electrification and dramatically cut carbon emissions.
- **Engage workforce and community stakeholders** to identify needs and issues of concern related to electrification and opportunities to ensure social, economic, and environmental benefits are shared equitably.

INTRODUCTION

Electrification refers to replacing technologies that rely on the combustion of fossil fuels with those that run on electricity and ensuring that the source of electricity generates emissions savings relative to the fossil alternative.[6] As renewables are rapidly deployed to decarbonize the electric grid, electrification technologies including heat pumps, electric boilers, and thermal batteries offer an opportunity to improve efficiency and dramatically cut emissions from industrial thermal processes and building heating and cooling. Accordingly, the Renewable Thermal Collaborative (RTC) and the U.S. Department of Energy (DOE), among others, view electrification as one of the key pathways to achieving wide-scale industrial decarbonization.[7]

In the United States, the industrial sector accounts for 30% of energy-related carbon dioxide emissions,[8] and industrial heating accounts for 13% of total emissions.[9] More than 75% of the emissions from industrial heating come from low and medium temperature (<500°C) industrial applications, which are predominately served by natural gas.[10] These applications include washing, drying, sterilizing, distilling, and more, and are common in the food, paper, and chemicals sectors. Industrial heat pumps, electric boilers, and thermal battery systems can replace fossil fuel-powered technologies in these industrial processes to significantly reduce emissions by 2030.

Given the RTC's position as the leading global coalition of organizations committed to scaling renewable heating and cooling solutions to dramatically cut carbon emissions, this report sets out a plan of action to accelerate the deployment of electrification technologies to meet industrial thermal demand. Specifically, this report aims to answer the following questions:

- What is the potential of electrification to deliver cost-effective, sustainable, low-carbon thermal energy in the short, medium, and long term?
- What are the major technical, market, and policy obstacles to scaling development and deployment of electrification technologies?
- What priority actions should the RTC and our partners implement to accelerate and scale electrification?

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[6] Electrification is sometimes referred to as beneficial electrification to highlight the need for the electricity source to have a lower emissions rate than the incumbent fossil fuel to achieve emissions reductions.
[7] DOE, *Industrial Decarbonization Roadmap*, 2022; and DOE, *Pathways to Commercial Liftoff: Industrial Decarbonization*, 2023.
[8] DOE, Industrial Heat Shot.
[9] Includes emissions from machine drive applications. WWF and RTC, *The Renewable Thermal Vision*, 2022.
[10] *Ibid.*

ELECTRIFICATION TECHNOLOGIES, TEMPERATURE RANGES, & TIMESCALES

Electrification technologies and their industrial process heating applications are gaining attention among researchers and practitioners interested in near-term industrial decarbonization. A growing body of literature emphasizes the potential for electrification technologies to immediately reduce emissions across industrial sectors ranging from food and beverage to iron and steel.

The RTC has contributed to this literature by publishing techno-economic assessments that describe technology, market, and policy hurdles and offer recommendations to accelerate market transformation. These include a national report on industrial electrification in key sectors, an analysis of electrification opportunities in 20 states, a report on thermal batteries, and an assessment of electrification's role in the full stack of renewable thermal industrial decarbonization pathways.

The RTC has also developed tools and case studies to support large thermal energy buyers in navigating the practical and tactical elements of deploying electrification technologies. These include a package of heat pump decision support tools, an electrification roadmap, a playbook for electrification in the food and beverage industry, a case study of Diageo's electric boiler deployment in Kentucky, and a case study of the University of California's 'Big Shift' electrification project.

These reports, tools, and case studies highlight a common theme: electrification is a primary decarbonization pathway in the short, medium, and long term. Building on this theme, this section describes the techno-economic characteristics of key electrification technologies and their time horizons for deployment, summarized in Figure 1 below.

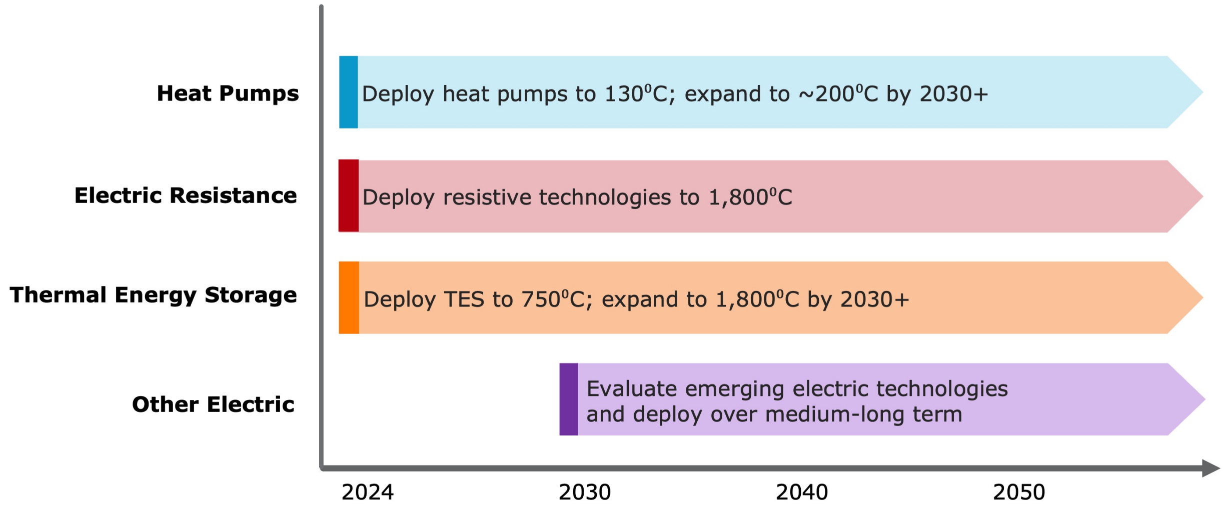

Figure 1. Electrification Technology Deployment Timeline[11]

[11] Adapted from WWF and RTC, *The Renewable Thermal Vision*, 2022.

HEAT PUMPS

Electric heat pumps are a mature technology, commonly used in buildings for space and water heating. Heat pumps have also been deployed to meet demand for low temperature heat across a range of industrial processes, particularly in Europe and Asia, with fewer examples in the U.S. Some commercially available industrial heat pumps (IHPs) can deliver heat up to 160°C, although efficiency degrades at temperatures above 100°C.[12] With this temperature range, IHPs are well-suited to applications in the chemicals, food and beverage, and pulp and paper sectors, wherein a large share of emissions come from low temperature process heat.

The RTC's Renewable Thermal Vision Report (hereinafter "Vision Report") finds that IHPs can cost-effectively decarbonize applications with temperature requirements under 130°C, representing 29% of industrial thermal demand in the U.S., and recommends that IHPs be deployed immediately to electrify low temperature applications such as washing, drying, and preheating. With further research and development, IHPs capable of delivering heat at temperatures above 200°C are expected to become commercially available by 2030, which would expand the range of IHP applications and the potential for emissions reductions.[13]

IHPs use electricity to transfer heat from their surroundings or waste heat (the "heat source") to a process at a higher temperature (the "heat sink"). While there are several types of IHPs, they can be separated into two main categories: closed cycle and open cycle. Closed-cycle mechanical vapor compression heat pumps mechanically compress a refrigerant in a closed loop to increase the temperature and use heat exchangers on both the heat sink and heat source sides.[14] By contrast, open-cycle mechanical vapor compression heat pumps mechanically compress water vapor, usually from low pressure waste steam, to increase its temperature.[15]

IHPs are typically highly efficient because the amount of heat delivered exceeds the amount of energy used to increase the temperature of the heat. This ratio is known as the Coefficient of Performance (COP). The high efficiency of heat pumps bolsters the case for their immediate deployment—because IHPs can achieve efficiencies of 300% or more, they can reduce emissions relative to natural gas even in areas where the electric grid is "dirty." Specifically, the Vision Report finds that IHPs could reduce emissions using grid electricity in 35 states in 2022, and in all 50 U.S. states by 2035 or sooner (see Figure 2).

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[12] WWF and RTC, *The Renewable Thermal Vision*, 2022.
[13] *Ibid.*
[14] ACEEE, *Industrial Heat Pumps: Electrifying Industry's Process Heat Supply*, 2022.
[15] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.

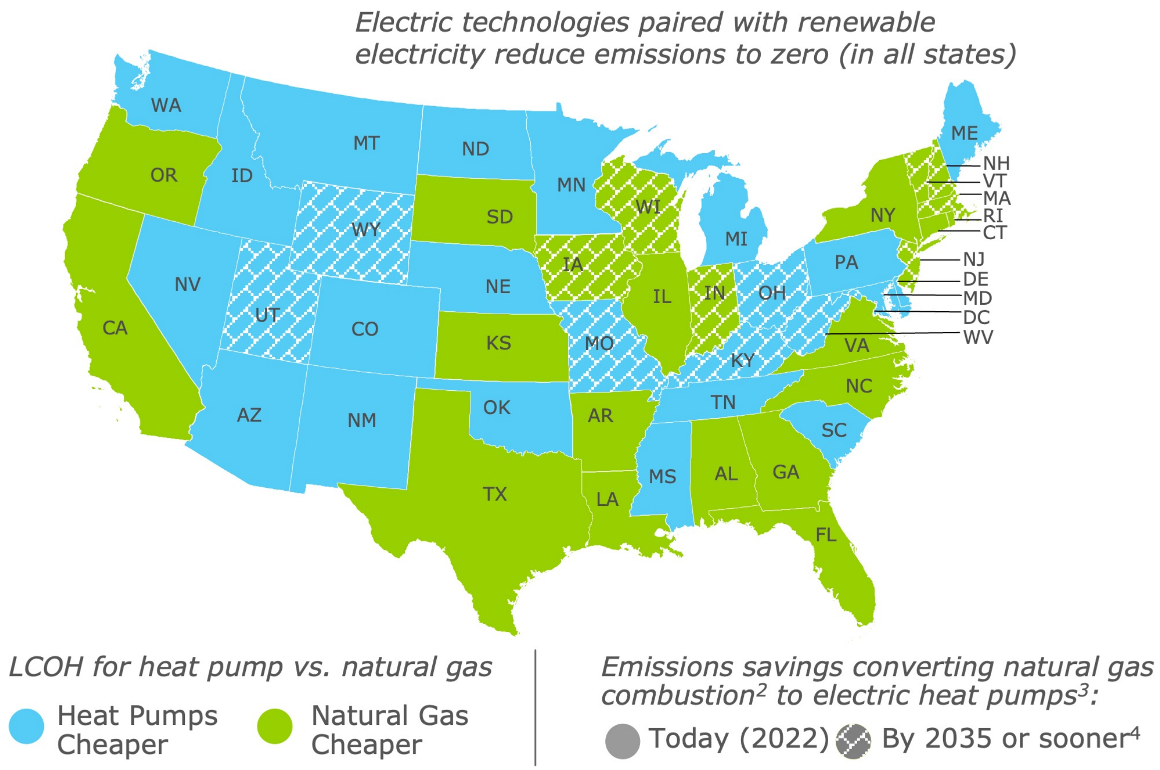

Figure 2. Heat pumps can cost-competitively reduce emissions across all U.S. states by 2035 or sooner[16]

Despite the significant potential for IHPs to deliver immediate energy savings and emissions reductions, the U.S. market for IHPs is nascent. The high upfront cost of IHP equipment, as well as other barriers including the lack of domestic supply, workforce capacity, cost-competitive renewable electricity, and buyer knowledge, must be addressed to deploy IHPs at an accelerated pace.

ELECTRIC RESISTANCE

Electric resistance technologies use an electric current to produce heat from a material's electrical resistivity. Electric resistance heating can achieve temperatures up to 1,800°C,[17] which applies to all industrial process heat applications except for those with the highest temperature requirements (e.g., cement kiln, steelmaking, metal fabrication).[18] However, the applicability of electric resistance technologies to industrial processes depends on the type and commercial availability of the technology. Common

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[16] Reproduced from WWF and RTC, *The Renewable Thermal Vision*, 2022. Figure 2 footnotes: "2. Calculated using 85% efficiency for natural gas boiler. 3. Calculated using a conservative COP of 3; COP can increase if a waste heat source is available. 4. IN, WV electric grid offer abatement by 2035, UT by 2030, WY, MO, KY, OH by 2026. Source: US EIA; State Renewable Portfolio Standards; IEA ETSAP Industrial Combustion Boilers Fact Sheet; BCG analysis."

[17] Columbia University Center on Global Energy Policy, *Low-Carbon Heat Solutions for Heavy Industry: Sources, Options, and Costs Today*, 2019.

[18] WWF and RTC, *The Renewable Thermal Vision*, 2022.

electric resistance technologies include electric air heaters, boilers, furnaces, and ovens.[19] Broadly speaking, these technologies are highly mature and commercially available. For example, electric boilers that can generate heat or steam at temperatures up to 350°C are widely available,[20] and electric furnaces that can achieve temperatures above 1,000°C are commercially available for certain applications.[21] Accordingly, the Vision Report finds that electric resistance technologies are highly applicable to low and medium temperature industrial applications, and moderately applicable to high temperature processes.[22]

A key benefit of electric resistance technologies is that they can directly replace most natural gas-fired equipment without major system modifications.[23] Some energy buyers within the RTC report that the potential to use electric resistance technologies like electric boilers as a drop-in replacement for fossil fuel-powered equipment is a key benefit of these technologies, as they can avoid long periods of system downtime and expensive retrofits (e.g., de-steaming) that might otherwise threaten company profit margins. Moreover, the capital cost of an electric boiler is approximately 40% less than that of a natural gas-fired boiler on average.[24]

While electric resistance technologies are close to 100% efficient, their immediate decarbonization potential is constrained by the emissions intensity of U.S. electric grids. The Vision Report finds that electric resistance heating could reduce emissions relative to natural gas combustion in about half of U.S. states using grid electricity by 2026, which represents a considerable short-term decarbonization opportunity. However, because electric resistance technologies have high electrical demand and electricity is currently more expensive than natural gas in most of the U.S., electric resistance heating is typically not cost-competitive with natural gas combustion.[25] Industrial end users also report that the increased electricity load required for electric resistance heating usually exceeds their local distribution grid's capacity and may require costly

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[19] Electric arc furnaces, which generate heat through a combination of direct resistance and radiant heating, are commercially available and distinct from electric resistance furnaces. In the iron and steel sector, transitioning away from blast furnaces and basic oxygen furnaces that use coal to electric arc furnaces is a primary decarbonization pathway. Today, more than two-thirds of steel facilities in the U.S. use electric arc furnaces, while those facilities that still have blast furnaces generate more than 75% of the sector's total thermal emissions. Although electric arc furnaces with temperature outputs up to 1,800°C are readily available, the remaining blast furnaces are not expected to convert to electric arc furnaces in the near term because of sector-specific factors, such as insufficient direct reduced iron to produce high-quality steel. Global Efficiency Intelligence (GEI) and David Gardiner & Associates (DGA), prepared for RTC, *Industrial Electrification in U.S. States: An industrial subsector and state-level techno-economic analysis*, 2023; and WWF and RTC, *The Renewable Thermal Vision*, 2022.

[20] Electric resistance boilers are distinct from electrode boilers (jet type), which are used for specialized industrial applications that require quick recovery and high thermal outputs. Electrode boilers typically have higher thermal capacities than electric resistance boilers and create steam by passing an electric current through streams of water. Both types of boilers can generate superheated steam at temperatures up to 350°C. GEI and DGA, prepared for RTC, *Electrifying U.S. Industry: A Technology- and Process-Based Approach to Decarbonization*, 2021; and Lawrence Berkeley National Laboratory, *Electrification of Boilers in U.S. Manufacturing*, 2021.

[21] McKinsey & Company, "Plugging in: What electrification can do for industry," 2020.

[22] WWF and RTC, *The Renewable Thermal Vision*, 2022.

[23] *Ibid.*

[24] National Renewable Energy Laboratory, *Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050*, 2017.

[25] WWF and RTC, *The Renewable Thermal Vision*, 2022.

infrastructure upgrades.[26] Unless electric resistance heating is significantly incentivized or natural gas prices substantially increase (e.g., through a carbon price), electric resistance technology deployment may be limited to specific applications in the food, paper, pharmaceuticals, and chemicals sectors, or to regions where electricity prices are low relative to natural gas prices (e.g., the Pacific Northwest and portions of the southern Midwest).[27]

Hybrid electric boilers, which produce hot water or steam from electricity and another fuel source (e.g., natural gas), allow industrial end users to use electricity during periods when it is low-cost and opt for other fuels when electricity demand charges are high.[28] Because these hybrid systems reduce emissions and take advantage of cost-competitive electricity, some technology providers view hybrid applications as a significant near-term growth area.

THERMAL ENERGY STORAGE

Thermal energy storage (TES) systems store heat that can be used immediately or saved for future use. TES has historically been used in buildings for space heating and in combination with solar thermal systems. Now, an emerging class of commercially available TES systems, commonly referred to as thermal batteries, is gaining attention as an electrification technology with a variety of industrial process heat applications and grid balancing benefits.[29]

Electrified thermal batteries convert electricity into heat with electric resistance heaters, store the heat for hours or days, and release heat or steam for use in industrial processes. The heat is stored in a storage medium, such as carbon blocks, crushed rocks, refractory bricks, or silicon dioxide sand, and insulated to prevent heat losses.[30] Commercially available thermal batteries can produce heat up to 750°C, and companies are actively developing thermal battery systems that can deliver heat at 1,500 to 1,800°C—these higher temperature thermal battery systems are expected to become commercially available by 2030.[31]

As with other electrification technologies, thermal batteries must source electricity from renewable resources to deliver carbon-free heat. However, unlike other electrification technologies, thermal batteries can be scheduled to charge at specific times, meaning they can access renewable electricity during the lowest-price hours of the day (e.g.,

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[26] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.
[27] WWF and RTC, *The Renewable Thermal Vision*, 2022.
[28] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.
[29] The DOE considers TES in a portfolio of long duration energy storage technologies and evaluates strategies to catalyze action across the full technology value chain in its Pathways to Commercial Liftoff: Long Duration Energy Storage report. DOE, *Pathways to Commercial Liftoff: Long Duration Energy Storage*, 2023.
[30] Energy Innovation: Policy and Technology LLC, *Industrial Thermal Batteries: Decarbonizing U.S. Industry While Supporting a High-Renewables Grid*, 2023.
[31] The Brattle Group, prepared for the Center for Climate and Energy Solutions (C2ES) and RTC, *Thermal Batteries: Opportunities to Accelerate Decarbonization of Industrial Heat*, 2023.

whenever renewable power would otherwise be curtailed). The business case for thermal batteries is further underpinned by the technology's ability to smooth over mismatches in supply and demand for heating and supply a stable stream of heat at a given temperature, which is critical for 24/7 industrial operations. In areas with large quantities of low-cost renewable electricity, thermal batteries are already cost-competitive with natural gas. However, industrial end users are generally unfamiliar with the technology, and barriers related to traditional retail electricity rate structures and wholesale market access may slow down wide-scale thermal battery deployment.[32]

OTHER ELECTRIFICATION TECHNOLOGIES

There is a variety of other electrification technologies that have been commercially deployed for specific industrial process heating applications, including electric arc furnaces, electromagnetic induction, plasma melting, infrared heating, dielectric heating, and electron beam heating. Many of these technologies can achieve temperatures higher than fossil fuel or hydrogen combustion.[33] For example, plasma melting, which has applications for metals, plastics, and ceramics, can generate heat at temperatures as high as 5,000°C.[34]

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[32] For more information, see The Brattle Group, prepared for C2ES and RTC, *Thermal Batteries: Opportunities to Accelerate Decarbonization of Industrial Heat*, 2023.
[33] Energy Innovation: Policy and Technology LLC, *Industrial Thermal Batteries: Decarbonizing U.S. Industry While Supporting a High-Renewables Grid*, 2023.
[34] For more information, see National Renewable Energy Laboratory, *Opportunities for Solar Industrial Process Heat in the United States*, 2021; Columbia University Center on Global Energy Policy, *Low-Carbon Heat Solutions for Heavy Industry: Sources, Options, and Costs Today*, 2019; Innovation for Cool Earth Forum, *ICEF Industrial Heat Decarbonization Roadmap*, 2019; and GEI and DGA, prepared for RTC, *Electrifying U.S. Industry: A Technology- and Process-Based Approach to Decarbonization*, 2021.

BARRIERS TO ELECTRIFICATION

Although many electrification technologies are ready for deployment, they face significant market and policy barriers, including challenges related to (1) project affordability, (2) buyer confidence, (3) limited supply, (4) workforce capacity, and (5) insufficient renewable electricity supply. These barriers impede both demand from large thermal end users and supply from U.S. manufacturers and must be addressed to accelerate the pace of industrial electrification.

PROJECT AFFORDABILITY

For many industrial end users, the cost of an electrification project is the most important factor in determining whether a project will go forward. Industrial energy buyers seeking to deploy electrification technologies must pay for a variety of expenses throughout project development and operation, including new equipment, process integration, electricity infrastructure upgrades, and electricity. Despite findings that electrification technologies like IHPs and thermal batteries can be cost-competitive with natural gas and that the former may have simple economic paybacks under two years, the cost of electrification remains a significant barrier to adoption.[35]

The capital expenditure (CapEx) for new equipment, process integration, and electricity infrastructure upgrades can be prohibitive:

- **New equipment** includes electrification technologies and any new manufacturing equipment required to accommodate the electrified process. Electrification technologies often represent a considerable upfront cost for buyers. The limited domestic supply of IHPs and thermal batteries results in less price competition among U.S. vendors. Buyers may also need to source units and specialists from international sellers due to insufficient local workforce capacity.[36]
- **Process integration** refers to facility upgrades and potential disruption to manufacturing lines as they are rebuilt to accommodate electrified processes. Many buyers report that process integration is the most challenging and expensive part of any retrofit electrification project, particularly when it involves replacing steam distribution systems with systems that can accommodate heated air or water ("de-steaming").[37] In some cases, integrating electrification technologies into an existing manufacturing facility may also require system downtime, which may not be economically feasible for some manufacturers, especially those in commodity markets with tight margins.
- **Electricity infrastructure upgrades** are often required at the facility and local distribution grid to meet increased electricity demand from electrification.

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[35] ACEEE, *Industrial Heat Pumps: Electrifying Industry's Process Heat Supply*, 2022.
[36] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.
[37] Some electrification technologies deliver steam, including electric boilers, thermal batteries, and specific configurations of IHPs. These technologies can plug into existing steam systems and simplify process integration. However, IHPs that deliver heated air or hot water are more common than IHPs that deliver steam, hence buyers' emphasis on challenges related to de-steaming.

Utilities often require industrial energy buyers to pay for upgrades on their side of the meter, and long queues for upgrades can create time delays that introduce additional costs.[38]

Although federal grants and incentives like the DOE Office of Clean Energy Demonstration's Industrial Demonstrations Program and the Section 48C Qualifying Advanced Energy Project Credit can reduce capital costs for successful applicants,[39] there is a significant need for additional federal and state funding to continue to drive down electrification project costs. Federal and state funding will also help de-risk electrification technology development and manufacturing to support U.S. market transformation.

Once an electrification project is complete, industrial energy buyers must pay for a variety of operating expenses (OpEx), including electricity and operations and maintenance costs (O&M). While O&M costs are often lower for electrified systems, the price of electricity is currently higher than natural gas in almost all parts of the U.S.[40] This is partially attributable to utility rate structures, which increase the gap between electricity and natural gas prices in many regions, particularly during hours of peak demand.[41] These rate structures conflict with decarbonization goals and require policy intervention to reduce the cost of electrification and enable rapid deployment. Thermal batteries, which can source electricity when it is cheapest, may circumvent the price gap barrier and deliver heat at or below the cost of heat from natural gas combustion. In practice, this may depend on whether utility rate structures reflect the ability of thermal batteries to avoid electricity consumption at times that would impose costs on utilities and the grid.[42]

Industrial energy buyers also face internal competition for capital, meaning that even when electrification projects are financially viable, they may not win out against competing uses within the company. In these cases, third-party finance or Energy-as-a-Service (EaaS) project financing can be critical enablers for electrification. EaaS financing, often referred to as Heat-as-a-Service (HaaS) for thermal projects, allows manufacturers to install decarbonization projects with no capital expense.

BUYER CONFIDENCE

Thermal energy buyers in the U.S. are largely unfamiliar with electrification technologies. While many electrification technologies are commercially proven and have been around for decades (e.g., IHPs and electric boilers), they have a limited operational record in U.S. contexts. A lack of case studies featuring domestic industrial

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[38] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.
[39] DOE Office of Clean Energy Demonstrations, Industrial Demonstrations Program; and DOE, Qualifying Advanced Energy Project Credit (48C) Program.
[40] GEI and DGA, prepared for RTC, *Industrial Electrification in U.S. States: An industrial subsector and state-level techno-economic analysis*, 2023.
[41] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.
[42] The Brattle Group, prepared for C2ES and RTC, *Thermal Batteries: Opportunities to Accelerate Decarbonization of Industrial Heat*, 2023.

applications leads buyers to question the operational performance, reliability, and financial viability of electrification technologies.[43]

This knowledge gap often makes buyers reluctant to electrify thermal processes and reduces their confidence that electrification projects will be successful. The lack of awareness of and confidence in electrification technologies can also slow organizational decision-making processes, as plant managers and decision-makers have little incentive to take on the risk of adopting a new technology unless they can find well-documented examples in similar contexts.[44]

Financial professionals and investors are also generally unfamiliar with electrification technologies because of their limited operational track record. Accordingly, they view electrification projects as higher risk than more familiar energy technologies and require buyers and/or project developers to borrow project funds at a higher cost of capital.[45] Buyers and investors must see more demonstrations and case studies featuring electrification projects across U.S. industrial applications to become confident in their operational and financial viability, thereby driving demand for these critical technologies.

LIMITED SUPPLY

Due in large part to the long-standing lack of buyer confidence and limited demand for electrification technologies, the supply of electrification technologies in the U.S. is limited. This is a circular challenge, as the limited domestic supply also contributes to the lack of market awareness of these technologies and leads to increased project costs for potentially interested buyers.

IHPs provide a clear example of this "chicken and egg" problem. Despite high technical maturity and deployment in European and Asian markets, low temperature IHPs are not abundant in the U.S., largely because of the lack of demand from industrial energy buyers and the dominance of natural gas-fired thermal systems. The lack of demand prevents supply from increasing, while the lack of supply prevents buyers from gaining confidence in the technology, finding economically viable routes to deployment, and adopting IHPs in their manufacturing processes. Clear demand signals would provide suppliers with the confidence needed to ramp up supply and seize the market potential.

For some electrification technologies such as thermal batteries, supply is limited because the technology is in earlier phases of commercialization and the market is nascent. As these technologies become commercially available with increasing temperature outputs, supply is likely to advance quickly to meet demand for higher temperature electrification technologies.

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[43] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.
[44] ACEEE, *A Market Transformation Strategy for Industrial Heat Pumps: An Opportunity to Reduce Industrial Greenhouse Gas Emissions by 20%*, 2023.
[45] GEI and DGA, prepared for RTC, *Electrifying U.S. Industry: A Technology- and Process-Based Approach to Decarbonization*, 2021.

WORKFORCE CAPACITY

The U.S. has an insufficient number of workers with the expertise and skill sets needed to design, manufacture, install, and maintain some electrification technologies in industrial settings. Many engineers and technicians are unfamiliar with the capabilities of electrification technologies and do not have the qualifications or training required to install or maintain them, largely because of the historically limited supply and low number of deployments in the U.S.[46] The current workforce also lacks capacity to complete the grid infrastructure upgrades that will be required for widespread industrial electrification.

As with the supply of electrification technologies, without greater workforce capacity, it will be challenging to electrify industry at the pace and scale needed to deliver significant emissions reductions. The electrification workforce shortage is compounded by a broader manufacturing skills gap in the U.S., which could result in more than two million unfilled jobs by 2030.[47]

The insufficient number of workers and skill limitations also increase project costs, as buyers may have to bring in specialized or international experts to support electrification at their facilities, which is more expensive than hiring local workers.[48] To proactively address this barrier, some electrification technology providers are establishing manufacturing processes and standardized systems designed to leverage existing local workforce knowledge, simplify maintenance, and reduce the need for custom engineering. In addition, some providers are using the EaaS model to coalesce specialized operational knowledge of specific technologies within a service company and enable technology integration at scale, rather than one-off installations at individual facilities.

Accelerating industrial electrification will require significant growth in workforce knowledge and skills, technical expertise, and equipment standardization. This growth can be achieved with policy and market support for expanded access to training and certification programs as well as by using financing models such as EaaS to consolidate operational knowledge.

INSUFFICIENT RENEWABLE ELECTRICITY SUPPLY

For electrification to decarbonize industrial process heat, electrified processes must be powered with renewable electricity that is reliable and cost-competitive. While the efficiency of certain electrification technologies can enable emissions reductions even when powered by "dirty" grid electricity, cleaning up existing generation sources is critical to achieving full industrial decarbonization. DOE reports that approximately 15%

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[46] ACEEE, *A Market Transformation Strategy for Industrial Heat Pumps: An Opportunity to Reduce Industrial Greenhouse Gas Emissions by 20%*, 2023.
[47] Deloitte, "Creating pathways for tomorrow's workforce today," 2021.
[48] Guidehouse Inc., prepared for WWF and RTC, *Playbook for Decarbonizing Process Heat in the Food & Beverage Sector*, 2023.

of total industrial emissions abatement potential by 2030 depends on the decarbonization of the electric grid.[49] In addition to decarbonizing the electric grid, renewable electricity supply must scale to meet demand from increased end-use electrification. DOE and other experts estimate that full industrial electrification could double, or more than double, total U.S. electricity demand.[50]

Existing grid infrastructure has limited capacity for new generation and long-distance transmission. These capacity constraints can introduce long interconnection queues, significant costs, and electricity supply risks for industrial buyers and others interested in electrification. The slow pace of long-distance transmission construction and the long wait time for grid interconnections both present significant barriers to meeting increased electricity demand from electrification. Long-distance transmission and a better-connected, cleaner grid would ensure that industrial facilities can access affordable, abundant renewable electricity to meet their needs and protect against outages.

While the insufficient supply of renewable electricity hinders deployment of all electrification technologies, thermal batteries also face unique challenges in procuring low-cost, renewable electricity. These challenges require attention from utilities, Public Utility Commissions (PUCs), and the Federal Energy Regulatory Commission (FERC). Traditional rate structures do not compensate thermal batteries for the grid balancing services they provide, and thermal batteries are often excluded from participation in wholesale power markets, unlike electric batteries and other forms of demand response. These rate structures and wholesale power market rules must be changed to ensure that thermal batteries can access electricity rates that reflect the technology's ability to avoid consumption at times when it would be costly to utilities and participate in wholesale markets with competitive price structures.[51]

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[49] DOE, *Pathways to Commercial Liftoff: Industrial Decarbonization*, 2023.
[50] Gimon, E. "Full industrial electrification could more than double US power demand. Here's how renewables can meet it." 2023; and DOE, *Pathways to Commercial Liftoff: Industrial Decarbonization*, 2023.
[51] The Brattle Group, prepared for C2ES and RTC, *Thermal Batteries: Opportunities to Accelerate Decarbonization of Industrial Heat*, 2023.

ELECTRIFICATION ACTION PLAN

Accelerating industrial electrification will require new federal and state policies as well as tactical tools, trainings, and convenings to support market development. To advance these efforts and achieve our goal of reducing U.S. industrial thermal emissions 30% by 2030, the RTC will implement a multi-year action plan to facilitate collaboration between energy buyers, technology providers, investors, utilities, regulators, policymakers, communities, and non-governmental organizations.[52]

We identified the barriers described in the previous section and actions outlined in this section by working closely with RTC Members and Sponsors, primarily through the RTC Electrification Working Group. To translate this high-level strategic action plan into tangible emissions reductions, we will develop subsequent work plans and implement these actions in a prioritized, integrated manner as specific opportunities, market and policy conditions, and resources warrant. The RTC Electrification Working Group will continue to serve as the main forum for ongoing discussions on the evolving barriers to technology deployment and for prioritizing and implementing actions to accelerate electrification.

MARKET ACTIONS

Convene buyers and suppliers

Connecting buyers, suppliers, service providers, and other market actors at events, working group meetings, and roundtables is an effective way to increase market transparency. Providing these opportunities also supports stakeholders in building relationships to explore demonstration project opportunities that are urgently needed to increase buyer confidence in electrification and motivate technology providers to ramp up supply. The RTC regularly convenes buyers and solutions providers at Electrification Working Group meetings, monthly Community Calls, and our annual Summit.

These meetings and events center on discussions of common barriers to technology deployment and actions to accelerate electrification, thereby fostering a community of buyers and suppliers who are committed to transforming the market through collaboration. The RTC will continue to convene the Electrification Working Group to serve as the forum for action to accelerate electrification.

In addition, we collaborated with the American Council for an Energy-Efficient Economy (ACEEE) and the National Electrical Manufacturers Association (NEMA) to form the Industrial Heat Pump Alliance (IHPA). The IHPA aims to accelerate the production and deployment of IHPs to significantly reduce industrial thermal emissions in the United States. The IHPA's Working Groups include ACEEE, NEMA members, and RTC Members and Sponsors, and are focused on raising awareness about the opportunity for IHPs to

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[52] Certain activities may require additional funding and we are actively pursuing opportunities to fill any resourcing gaps. The actions described in this section will be implemented and refined over time based on evolving market trends and priorities.

decarbonize industry and driving rapid deployment through market initiatives and policy action.

Launch an electrification information and engagement campaign

The lack of market awareness of electrification technologies and their potential to decarbonize industry is one of the most significant barriers to widespread electrification. Industrial end users, technology and service providers, investors, utilities, and others need more information on the technical, operational, and financial characteristics of electrification technologies. The RTC continues to raise awareness of electrification technologies and their potential through tools, case studies, reports, and events. With our IHPA partners and others, we are reinvigorating this effort to launch an information and engagement campaign, with activities including:

- Publishing a series of case studies.
- Hosting an annual electrification webinar.
- Updating and training buyers to use RTC's Heat Pump Decision Support Tools.
- Creating sector-specific playbooks and one-pagers.
- Sharing information on project finance and deployment models.

Strengthen demand signals and deployment opportunities

Going forward, and pending additional resources, the RTC will undertake several actions to strengthen demand signals and electrification deployment opportunities. First, we will institutionalize a curated one-to-one networking event, first launched in May 2023 around the Section 48C Qualifying Advanced Energy Project Credit, to allow buyers and suppliers to have pre-commercial conversations about pilot project partnerships in a series of brief, private meetings.

Second, we will encourage industrial end users to indicate strong interest in buying electrification technologies to provide technology providers with a signal to ramp up supply. This may include developing an Industrial Electrification Platform where buyers can indicate interest, needs, and technical specifications for suppliers of electrification technologies and electricity (e.g., utilities) to view and respond to. This Platform would be modeled after applicable elements of the RTC's Heat Pump Decision Support Tools and other demand platforms.

Third, we will increase the RTC's engagement with electric utilities to identify opportunities for pilot projects, develop supportive utility programs, and accelerate renewable electricity supply to meet increasing industrial electricity demand. This engagement will include facilitating small group meetings or information sessions with RTC Members and Sponsors in a given utility's service territory, encouraging utilities to participate in the RTC's Electrification Working Group, and conducting educational workshops with utilities and associations. We will do this work in parallel with the utility regulatory policy campaign described below and with the support of our IHPA partners.

Scope workforce development strategies

Increasing domestic workforce capacity with policy and market-driven actions is necessary to decrease electrification project costs and electrify industry at the pace and scale required to achieve significant emissions reductions. The RTC intends to conduct an assessment to investigate industrial electrification workforce needs and the policies best suited to address them, through actions such as:

- Conducting desk research to identify successful examples of workforce development policies. For example, the Illinois Climate and Equitable Jobs Act established a clean energy workforce network to support skills training and certification preparation,[53] and could be a model for other states.
- Interviewing Members of the RTC community, including our Community Benefits Advisory Board; workforce experts and labor unions; colleges and universities; and apprenticeship and training organizations.
- Developing strategic recommendations for how the RTC could most effectively support electrification workforce development.

POLICY ACTIONS

Advocate for federal tax incentives

Federal tax incentives for industrial electrification can unlock project opportunities that would otherwise not be economically viable for industrial end users and technology providers. Through the Bipartisan Infrastructure Law (BIL) and Inflation Reduction Act (IRA), the federal government allocated significant funding toward decarbonization efforts in the form of tax incentives, grants, and rebates. The RTC is seizing the opportunity to ensure that funding from BIL and IRA support industrial electrification by providing ongoing education to energy buyers, technology providers, and others about how to access these incentives. We are also pressing the Executive Branch, including DOE and Treasury, to implement the tax incentives in a manner that will properly support the deployment of key electrification technologies.

Despite BIL and IRA's significant investment in decarbonization efforts, including long-term extensions of the clean electricity investment and production tax credits that will accelerate renewable electricity deployment to decarbonize the grid, these policies do little to incentivize industrial end-use electrification. To fill this gap, the RTC is educating Members of Congress on the potential for electrification to decarbonize industry. We are also advocating for new investment tax credits to lower costs for industrial end users to electrify and expanded production tax credits that strengthen the economic case for manufacturers to increase supply. Because this will require new legislation, we are laying the groundwork now for action in 2025.

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[53] Illinois Department of Commerce & Economic Opportunity, CEJA Workforce Training.

Expand and support access to federal and state funding for RDD&D

Federal funding for research, development, demonstration, and deployment (RDD&D) is needed to advance electrification technologies that span a range of technology readiness levels. Federal investment in research and development (R&D) on high temperature electric heat pumps and thermal battery systems will quicken the pace at which these technologies become commercially available. For mature technologies like low temperature heat pumps and electric boilers, funding in the form of grants and loan guarantees for pilots and deployments can help strengthen their operational track records and ultimately improve buyer confidence.

DOE can leverage federal funding to research and develop nascent electrification technologies and conduct pilot projects through its National Laboratories and Clean Energy Manufacturing Innovation Institutes. For example, National Labs are leading and partnering with other organizations on more than a quarter of the 40 industrial decarbonization projects receiving awards from the DOE Industrial Efficiency and Decarbonization Office's $135 million funding announcement, including projects on high temperature heat pumps.[54] DOE also recently selected Arizona State University to lead the Electrified Processes for Industry without Carbon (EPIXC) Institute, which will leverage up to $70 million in federal funding over the next five years on R&D projects to electrify process heating in partnership with National Labs, private companies, and community partners, among others.[55]

The RTC continues to encourage these efforts with letters of support and direct engagement with DOE. In addition, we are participating as a Teaming Partner in the National Consortium for the Advancement of Long Duration Energy Storage (LDES) Technologies led by six National Labs, which will convene stakeholders to establish a comprehensive plan for LDES commercialization, including thermal battery systems.[56] As this work continues, we will seek opportunities to partner with National Labs and the EPIXC Institute on related initiatives.

Regarding demonstration and deployment efforts, the federal government is allocating funding to industrial decarbonization projects through several programs, including the Industrial Demonstrations Program,[57] the Advanced Industrial Facilities Deployment Program,[58] and heat pump manufacturing development under the Defense Production Act.[59] The RTC is conducting ongoing research on these programs and sharing information on how to access these funding opportunities with Members and Sponsors through workshops and events. By submitting annual appropriations requests, we are also urging Congress to expand DOE funding for electrification RDD&D, including pilots

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[54] DOE Industrial Efficiency and Decarbonization Office, Funding Selections: Industrial Efficiency and Decarbonization FOA; RTC, "RTC Members and Sponsors Receive DOE Funding to Develop Heat Pump, Heat Recovery, and Low-Carbon Fuel Technology," 2023.
[55] DOE Office of Energy Efficiency & Renewable Energy, "DOE Selects Arizona State University to Lead New Institute to Drive Industrial Decarbonization through Electrification of Process Heat," 2023.
[56] DOE Office of Technology Transitions, "DOE Announces Over $15 Million Towards Two Projects to Support Industry Engagement and Alignment for Clean Energy Solutions," 2023.
[57] DOE Office of Clean Energy Demonstrations, Industrial Demonstrations Program.
[58] DOE Office of Clean Energy Demonstrations, Advanced Industrial Facilities Deployment Program.
[59] DOE Office of Manufacturing and Energy Supply Chains, Defense Production Act Heat Pump Program Selections.

and industrial demonstration programs. Increasing federal funding for these activities will support further private sector investment to commercialize, adopt, and scale electrification technologies.

State-level funding programs will also help unlock electrification projects at the demonstration and deployment stage. Several states, including California, Colorado, and New York are offering funding to enhance or support federal funding for industrial decarbonization. More specifically, the California Energy Commission Cost Share program,[60] Colorado Clean Air Program,[61] and NYSERDA Commercial and Industrial (C&I) Carbon Challenge provide cost share funding that can be stacked with federal funding.[62] Elsewhere, state energy offices are seeking support to create energy funding programs that draw federal funding to their states. The RTC is supporting its Members and Sponsors in accessing existing state funding opportunities through information sessions and workshops, and may seek opportunities to engage with state energy offices to inform program development pending additional resourcing.

Engage on transmission and wholesale market barriers

New transmission infrastructure is needed to ensure the delivery of reliable, zero-emissions power to end users with electrified thermal systems. To develop the long-distance transmission infrastructure necessary for widespread industrial electrification, federal and regional actors, including FERC, Regional Transmission Organizations (RTOs), and Independent System Operators (ISOs), must develop detailed plans and implement siting and permitting reforms. The RTC plans to engage on these issues pending additional resourcing, with initial efforts focused on persuading FERC to finalize its proposed transmission planning rule in 2024.[63] We will also identify partners to build a coalition that represents buyers and other voices to influence FERC to streamline the transmission interconnection process and expand long-distance transmission. Over time, this work may expand to include a focus on regional transmission planning and Congressional action.

The RTC plans to partner with expert groups and advocacy organizations to engage FERC on the wholesale market rules that prevent thermal batteries from accessing bulk electricity rates. Specifically, we seek to persuade FERC to enable thermal batteries to participate in wholesale markets in a similar manner to how FERC Order 841 removed barriers to wholesale market participation for distributed and behind-the-meter energy storage.[64] This would include clarifying or establishing new market rules that ensure thermal batteries can participate in wholesale electricity markets, set wholesale market-clearing prices, and access intraday rates at granular intervals, likely as a distinct class of dispatchable load. In parallel, this effort may focus on RTOs/ISOs and PUCs at the state level.

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[60] See, for example, California Energy Commission, "GFO-21-901 – Cost Share for Federal Clean Energy Funding Opportunities," 2022.
[61] Colorado Energy Office, Clean Air Program (CAP) Grants.
[62] NYSERDA, Commercial & Industrial (C&I) Carbon Challenge.
[63] FERC, 179 FERC ¶ 61,028, RM21-17-000, 2022.
[64] FERC, 162 FERC ¶ 61,127, Order No. 841, 2018.

Engage on utility regulatory policy in key states

To accelerate industrial electrification, utilities and the PUCs that regulate them must address gaps in utility planning to ensure there is sufficient renewable electricity supply and change rate structures to reduce the price gap between electricity and natural gas. Building on the RTC's direct engagement with utilities, we are preparing to engage on utility regulatory policy in key states to press PUCs to:

- Encourage utilities to solicit input from industrial end users, technology suppliers, and service providers within their service areas for electricity demand projections and to incorporate these demand increases into their Integrated Resource Plans.
- Develop policies to ensure rapid construction of local distribution lines and substations to meet demand from industrial electrification, and adopt policies to ensure the fair allocation and payment of the associated costs.
- Establish more nuanced utility pricing structures through performance-based regulations that help reduce the gap between electricity and natural gas prices.

The RTC may also engage state legislators to the extent these actions require new legislation. To identify key states for PUC engagement, we will consider multiple criteria including the size of the emissions reduction opportunity and the speed at which it can be achieved, the willingness and interest of state policymakers to engage, and the interest of the RTC community and partners. We will then build RTC capacity to begin PUC engagement in the selected states and share lessons learned throughout the process.

COMMUNITY ACTIONS

Build the RTC community

As the RTC advances these efforts and launches new initiatives to address barriers to electrification, we will continue to grow our community of Members and Sponsors to ensure our actions make a material impact. Expanding our membership to include more companies committed to scaling electrification and other solutions to dramatically cut carbon emissions is critical to decarbonizing industry in the U.S. and abroad. By sharing best practices, lessons learned, and solutions to common challenges, RTC Members are well-positioned to lead the electrification transition.

Engage workforce and community stakeholders

Engaging workforce and community stakeholders, with an emphasis on disadvantaged and fence-line communities, is essential to industrial electrification. The RTC supports our Members and Sponsors in ensuring that the renewable thermal transition is just, equitable, inclusive, and accessible. As a community, we must advance a thermal energy transition that is guided by these values by learning from and partnering with a diverse group of stakeholders—including communities of color, environmental justice advocates, and the disability rights community.

Industrial electrification offers an opportunity to lessen negative impacts and maximize benefits as we shift to modernized, electrified systems. The RTC will work through our Community Benefits Advisory Board to engage workforce and community leaders, focusing on issues of concern related to industrial electrification and opportunities to ensure that social, economic, and environmental benefits are shared equitably. To inform this work, we plan to develop and share information and analysis on topics including the air quality benefits of electrification and opportunities for RTC Members to electrify facilities in disadvantaged communities.[65]

[65] For example, see RTC, *Justice40 Opportunity Assessment*, 2023.

CONCLUSION

Electrification should be a major component of any plan to decarbonize industry, accelerating in parallel with the electric grid's clean energy transition. When powered by low- or zero-carbon electricity, cost-competitive heat pumps, electric boilers, and thermal batteries can achieve very large emissions reductions immediately, while other electrification technologies like high temperature heat pumps can achieve even more over the long term. As less than 5% of industrial process heat in the U.S. is currently electrified, the near-term opportunity for electrification to decarbonize industry is significant.

While the opportunity is considerable and many electrification technologies are ready for deployment, they face significant market and policy barriers, including challenges related to project affordability, buyer confidence, limited supply, workforce capacity, and insufficient renewable electricity supply. These barriers impede both demand from large thermal end users and supply from U.S. manufacturers and must be addressed to accelerate the pace of industrial electrification.

The RTC is addressing these barriers through market, policy, and community actions. Key actions include convening stakeholders, strengthening demand signals, advocating for federal policy support, and engaging on utility regulatory policy, among others. Our multi-year action plan is designed to facilitate collaboration between energy buyers, technology providers, investors, utilities, regulators, policymakers, communities, and non-governmental organizations. As we continue to collaborate with the RTC community and external partners to prioritize and implement this action plan, we invite large thermal energy users—industrials, institutions, and localities—from around the world to join us in this effort.