Decarbonizing Process Heat: VC Opportunity Landscape

Executive Summary

Despite being responsible for roughly 25% of global CO_2 emissions, industrial process heat remains among the most difficult sectors to decarbonize due to diverse temperature needs, geographic differences and cost challenges. However, our analysis suggests that selective venture opportunities are emerging—particularly in high-temperature heat pumps and enabling components such as turbocompressors and advanced refrigerants, which meet both economic and technological readiness criteria. Other areas, including thermal energy storage and electrochemical reduction, are showing rapid progress and capital formation, making them relevant for later-stage VC investors. Emerging solutions like plasma heating, inductive systems and next-gen materials also merit attention for their long-term potential to reshape the landscape.

Understanding Process Heat: Market Landscape, Challenges, and Segmentation

Industrial process heat refers to the thermal energy required to drive manufacturing and chemical transformation across a wide range of industries—such as steelmaking, cement production, petrochemicals, food processing and pulp and paper. It accounts for roughly 25% of global CO_2 emissions and 19% of total global energy consumption [1][2], making it one of the largest single contributors to climate change.

Unlike power or transportation, where decarbonization technologies are well-established, process heat is technically and commercially harder to address. It spans a vast range of temperatures, is often embedded in legacy systems and tends to be capital-intensive with long asset lives.

Why It's Hard to Decarbonize

- **Heterogeneous use cases**: Heat is used for drying, distilling, melting, reacting—each with unique technical and regulatory constraints.
- **Diverse temperature needs**: Processes span from under 100°C (e.g., cleaning, sterilization) to over 1600°C (e.g., steel furnaces) [1].
- **Integrated systems**: In many facilities, process heat is tightly coupled with other operations—such as co-generation of heat and power (CHP), or heat cascading through multiple production stages. This integration makes it difficult to isolate

and upgrade the heat supply without costly and disruptive redesign of the entire process.

- **Asset lock-in**: Long-lived infrastructure and conservative industrial procurement cycles slow down retrofit adoption.
- **High-temperature processes (>400°C)** often require direct radiant or flame-based heat, which current electrification technologies cannot easily replicate. These applications typically lack mature, plug-and-play electric alternatives and often require redesigning the entire process flow.
- **Unfavorable cost economics in some regions**: In markets like the U.S. where fossil fuels—especially natural gas—are relatively inexpensive, emissions-free alternatives often struggle to compete on cost without significant policy support [1].

Cost as a Unifying Constraint

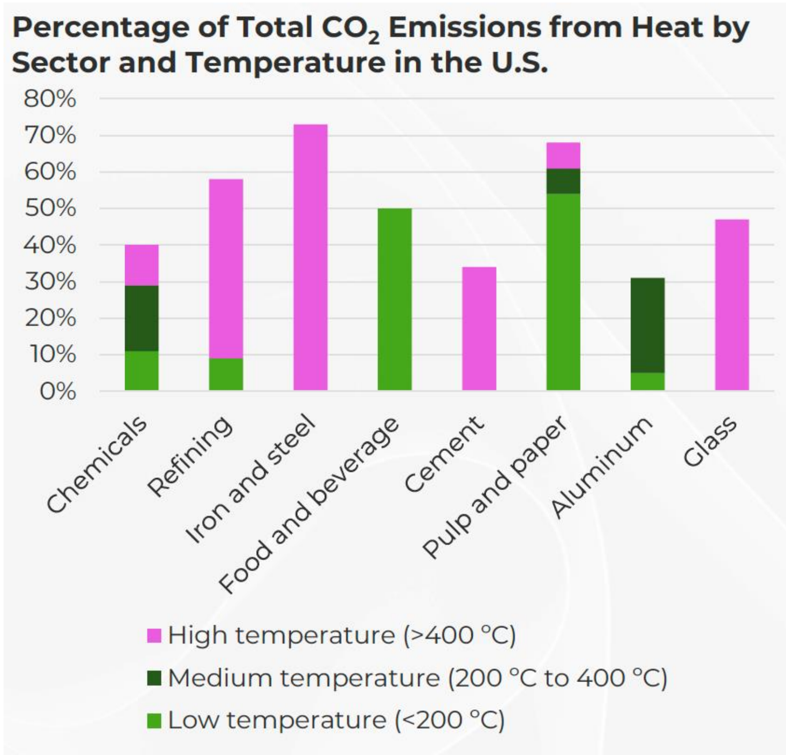
Across all geographies and temperature bands, the levelized cost of heat (LCOH) is a critical metric for comparing technologies. LCOH accounts for capital expenditure, energy cost, operating life and utilization—making it especially relevant for industrial users evaluating whether new heat systems can compete with fossil incumbents. In many cases, emissions-free options remain significantly more expensive than fossil alternatives like natural gas or coal, particularly in North America where fuel prices are low [1].

How to Segment the Market: By Temperature

A foundational way to understand the process heat market is by segmenting it according to temperature range. Different industrial processes require different levels of heat intensity, and these bands often align with sector-specific applications:

- **Low temperature (<200°C)**: Common in food and beverage, textile and building operations. Applications include cleaning, pasteurization, drying and space heating. Steam is often used as a flexible heat transfer medium.
- **Medium temperature (200–400°C)**: Frequently used in the chemical, pharmaceutical and pulp & paper industries. Typical applications involve steam generation, distillation and certain forms of heat treatment.
- **High temperature (>400°C)**: Dominant in heavy industries such as cement, steel, glass and ceramics. Processes in this range often require direct flame, radiant heat or very high thermal loads for melting and transformation.

These temperature bands help define the industrial roles of process heat and the physical form in which heat is delivered (e.g., steam, hot air, direct flame) [1][2].



Share of U.S. industrial heat demand by temperature band. Source: NREL via Lux Research (2025).

How to Segment the Market: By Geography

Local energy prices, carbon policies and industrial structure significantly shape decarbonization feasibility, as well as local infrastructure and grid readiness:

- **Europe**: High natural gas prices, carbon pricing (EU ETS) and public funding drive strong interest in electrification.
- **United States**: Lower gas prices and uncertain carbon signals make economics more mixed, though IRA incentives are starting to change the landscape.
- **Rest of World**: Markets like China and India depend on domestic fuel mixes, industrial policy and access to capital. In many regions, coal remains dominant.

The same technology can have vastly different ROI and adoption potential depending on where it's deployed [1][2]. For early-stage innovation, regional targeting is often as important as technical performance.

Decarbonization Pathways by Temperature Band

Before identifying investable opportunities, it is important to understand how different temperature ranges are being targeted by decarbonization strategies. Each band is characterized not only by distinct industrial applications, but also by the types of solutions currently being developed or deployed to reduce emissions.

- **Low temperature (<200°C)**: Common decarbonization pathways include electric boilers, industrial heat pumps, resistive heating and waste heat recovery. These solutions are already being applied in food and beverage, textiles and low-intensity chemical processes, particularly in geographies with high electricity-carbon intensity differentials (e.g., Europe).
- **Medium temperature (200–400°C)**: This range supports a mix of electric resistance, advanced high-temperature heat pumps (in development) and thermal energy storage (TES). Applications are often found in pulp and paper, pharmaceutical and mid-range chemical manufacturing. Technologies are in varying stages of maturity, with TES gaining traction for load shifting and peak shaving. TES does not directly reduce emissions but is a critical enabler for electrified systems—helping to manage the intermittency of renewable generation and take advantage of dynamic electricity pricing.
- **High temperature (>400°C)**: Harder-to-abate sectors such as steel, cement and glass dominate this range. Decarbonization strategies include hydrogen combustion, plasma heating, electrified kilns and high-temperature TES. Electrochemical reduction processes are also being explored for steel and aluminum but remain at low TRL. These solutions typically require reengineering core process equipment.

This landscape is important not just for understanding technical fit, but also for clarifying where venture-scale opportunities may—or may not—exist.

Our Approach to Identifying VC Opportunities

Given the scale and diversity of the industrial heat landscape described above, we sought to understand whether there are venture capital opportunities to support its decarbonization. To answer this question, we defined three broad VC categories:

1. **Early-Stage VC Opportunities**: Companies that meet three core criteria:
    a. No science risk (i.e., technology demonstrated at lab or pilot scale, roughly equivalent to TRL 5–6)
    b. A credible path to LCOH competitiveness within 5–7 years
    c. Valuations below ~$50 million, typically up to Series B
2. **Later-Stage VC Opportunities**: Companies or segments that may meet the technical and economic criteria but are likely beyond the reach of early-stage VC due to maturity, capital intensity or valuation.
3. **Emerging Opportunities**: Pre-seed technologies that do not yet meet the two core criteria (i.e. science risk and LCOH), but that could potentially disrupt specific applications within the process heat industry

Early-Stage VC Opportunities

1. High-Temperature Heat Pumps

High-temperature heat pumps aim to electrify steam and process heat applications traditionally served by fossil-fueled boilers in the 200–400°C range. They are relevant to pulp & paper, chemicals and other mid-temp industrial sectors and represent a key decarbonization lever as electrification pushes beyond low-grade heat.

Drivers of Adoption

- Large industrial demand at this temp band, historically served by gas-fired steam systems.
- Electrification of medium-temperature heat (200–400°C) remains limited today but is gaining momentum in regions with high fossil fuel prices, where electric systems are becoming cost-competitive.
- Recent technological advancements now enable heat pumps to operate efficiently at higher temperature ranges (200–400°C), whereas earlier generations were limited to 100–150°C.
- Early success with pilot systems in EU and U.S. points to technical viability.

Technology Maturity & Deployment
Most players are at pilot scale or early commercial deployment. Systems use novel refrigerants, turbo compression, or advanced thermal cycles such as Stirling engines.

Representative Startups

- **Futraheat** (https://futraheat.com/) – Turbo-based systems for industrial efficiency
- **Enerin** (https://www.enerin.no/) – Modular high-temp heat pumps now in pilot deployment

2. Components and Materials Enabling Electrification

These are the subsystems and materials that enable electrification technologies—like heat pumps and electric boilers—to operate effectively in industrial environments. They include high-performance refrigerants, turbocompressors, corrosion-resistant seals and thermal coatings.

Drivers of Adoption

- Industrial settings require longer lifetimes, chemical resistance and efficiency under pressure.
- As OEM systems mature, performance-limiting components present bottlenecks and differentiation opportunities.

Technology Maturity & Deployment
Some solutions (e.g., novel refrigerants or corrosion-resistant seals) are at Seed or Series A stage, often developed by domain-specific hardware or materials teams.

Representative Startups

- **Evari** (https://evarithermal.com/) – High-efficiency turbocompressors that support next-gen heat pump systems

Later-Stage VC Opportunities

1. Electrification of Low-Temperature Heat (<200°C)

Common in food & beverage, light chemicals and textile processing. Typical use cases include sterilization, cleaning, drying and pasteurization—processes that often rely on steam or hot water.

Drivers of Adoption

- Commercially mature technologies (e.g., heat pumps, electric boilers) already in market.
- Carbon pricing in Europe and retrofit incentives are making electrification cost-effective.
- Low engineering complexity for retrofits compared to higher-temp systems.

Technology Maturity & Deployment
Electric boilers and low-temp industrial heat pumps are commercially available with multiple deployments. Adoption is highest in Europe, with initial momentum emerging in North America.

Representative Startups

- **AtmosZero** (https://atmoszero.energy/) – Drop-in modular electric boilers
- **NextThermal (**https://nexthermal.com/**)** – Electrified heat pump systems targeting sub-200°C

Note: Hydrogen-ready boilers and burners are sometimes proposed as a transitional decarbonization solution, particularly in high-temperature industrial settings. However, current LCOH calculations show they are not cost-competitive without significantly lower prices for green or blue hydrogen. As such, we do not include them as a viable VC opportunity at this stage. Furthermore, supportive policies aim to make green hydrogen more accessible, but higher-priority applications challenge its use for industrial heating

2. Thermal Energy Storage (TES)

TES technologies are increasingly critical to enabling electrified heat systems by mitigating price volatility and intermittency of renewable energy sources. They offer high potential for integration with renewable power, especially where direct electrification is difficult or costly.

Drivers of Adoption

- Key enabler for flexible electrification strategies in both medium and high temperature ranges.
- Provides temporal decoupling between renewable energy supply and heat demand.
- Regulatory and grid signals (e.g., demand charges, peak shaving) improve economics.

Technology Maturity & Deployment

TES players vary by temperature and material (e.g., ceramic, molten salt, metal). Leading companies are piloting or deploying multi-MW systems.
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Representative Startups

- **Antora Energy** (https://www.antora.com/) – Solid-state thermal batteries for industrial use
- **Rondo Energy (https://www.rondo.com/)** – Brick-based thermal storage with large industrial pilots
- **Lava (https://lavapower.com/)** – Thermal battery system with integrated heat engine for electricity and industrial heat delivery
- **RedoxBlox (https://redoxblox.com/)** – Thermochemical TES platform focused on dispatchable high-temperature heat

3. Electrochemical Reduction for Iron and Cement

Electrochemical methods for producing iron and cement are being explored as radical alternatives to fossil-fuel-based thermal processes. These include direct electrochemical reduction of iron ore and electrochemical conversion of limestone or other mineral feedstocks.

Drivers of Adoption

- Potential to bypass combustion entirely and eliminate CO_2 from key process steps.

- May integrate more directly with renewable electricity supply.
- High strategic interest from corporates and investors focused on hard-to-abate sectors.

Technology Maturity & Deployment

Still in early pilot stages and not yet LCOH-competitive. However, some companies have already raised sizable rounds that place them beyond the early-stage VC category.

Representative Startups

- **Electra (https://www.electra.earth/)** – Electrochemical processing of nonferrous metals
- **Helios (https://heliosmatters.com/)** – Electrochemical process for iron reduction
- **Sublime Systems (https://sublime-systems.com/)** – Electrochemical process for cement production at ambient temperature

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Emerging Opportunities

Technologies that do not yet meet our investability criteria—due to unresolved science risk or lack of cost visibility—but may become relevant in the future.

Categories to Watch

- **Inductive Heating**: Uses electromagnetic fields to heat conductive materials directly. Potentially efficient for high-temperature applications such as glass or steel processing, but challenges remain in retrofitting and scaling for large industrial systems.
- **Shock Wave Heating (SWH)**: High-efficiency electric heating method that achieves extreme temperatures rapidly. Still early-stage, but could become relevant in high-temp chemical and materials processing.
- **Plasma and RF Heating**: Non-combustion high-temp methods with potential for integration in metals and materials processing.
- **Next-Gen TES Materials**: Advanced chemistries (e.g., thermochemical, phase change) that could push cost or temperature boundaries.
- **High-Performance Materials**: Coatings, ceramics, and composites for extreme environments not yet integrated into mainstream equipment.

References

[1] Lux Research (2025). *Beyond the Flames: The Economics of Heat Generation*.

[2] IEA (2023). *Energy Technology Perspectives* and *World Energy Outlook*.

[3] IPCC (2022). *Sixth Assessment Report – Mitigation of Climate Change*.