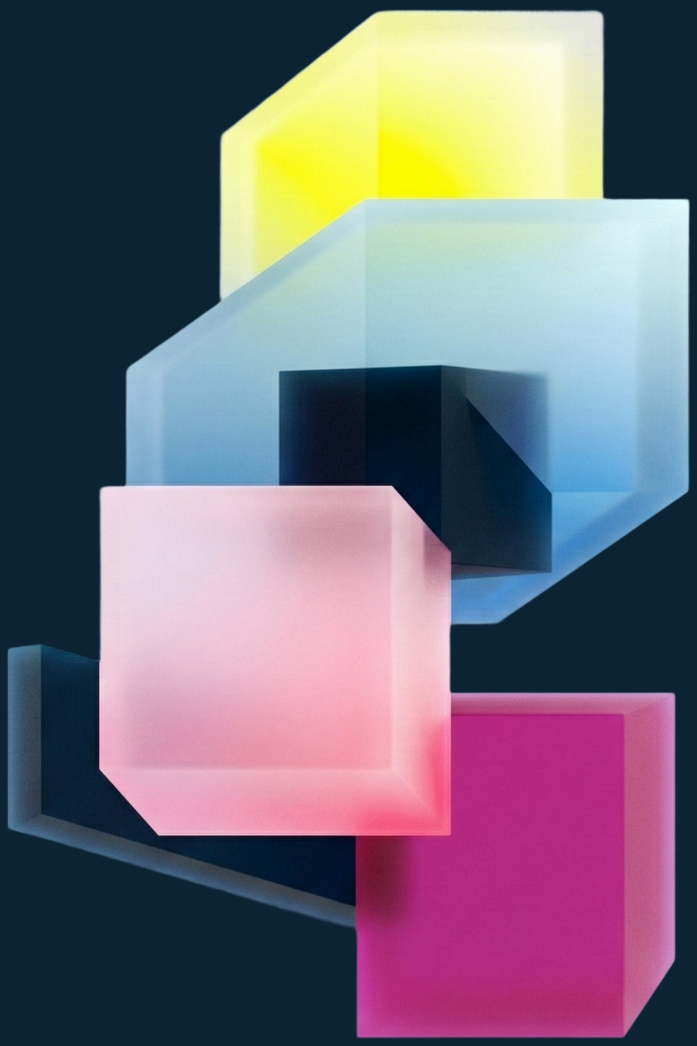
[PT1] | DWR eco

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# Fires to wires

Our investment thesis on industrial heat electrification

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Written by PT1 with DWR Eco. All analysis is in sterling; € and $ figures are quoted as reported by their sources. Lettered superscripts refer to the source key in Appendix B.

# Executive summary

Industrial heat — the high-temperature energy behind steel, cement, chemicals, aluminium, glass and paper — is the overlooked half of the energy transition. Depending on accounting boundaries, it is responsible for roughly one-fifth of global emissions, comparable to and in some estimates larger than the entire transport sector. More than 85% of it still comes from burning fossil fuels.

This paper is our investment thesis on how that changes. The temperature bands tell the story. Below 200°C, heat pumps are winning and the returns are being competed away. Above 1,000°C, parts of the technology stack exist, but the capital intensity and integration burden make the core assets a market for infrastructure capital, not venture. Between those poles, the 800–1,000°C band will hybridise before it fully electrifies. And at roughly 250–800°C sits the anomaly: around a third of global industrial heat demand, served by proven, commodity technology, with almost nobody building the businesses to deploy it.

The economics of that band hinge on one pairing: electric heating plus thermal storage plus intelligent dispatch. A resistance-and-brick system buying electricity on a flat tariff delivers heat at roughly twice the cost of gas; the same hardware, charging through cheap and curtailed hours, undercuts gas comfortably. The hardware does not decide whether the project wins. The dispatch does.

That logic shapes where value accrues along the chain. The first wave of capital went to the makers — hot bricks, carbon blocks, molten salts, high-temperature heat pumps — and that layer shows the early signs of eventual commoditisation. The next wave should go to the solvers: the companies that integrate, finance, dispatch, monitor and contract heat, turning commodity equipment into bankable delivered energy. The scalers — utilities, EPCs, OEMs and infrastructure funds — will be their customers and, ultimately, their acquirers. Our thesis in one line: don't back the brick; back whatever makes the brick bankable.

# Don’t back the brick.
# Back whatever makes the brick bankable.

Europe has particular reasons to move first: acute exposure to imported fossil fuels, an established carbon pricing framework, record renewable curtailment, and an industrial base co-located with growing clean power. Whether that potential converts depends on policy — above all the electricity-to-gas price ratio, grid access and flexible network charges, de-risking support and lead markets for clean materials — analysed in Chapter 6.

This is not SaaS. Timelines run five to ten years, capital intensity is real, and exits will look like strategic acquisitions rather than IPOs. But the compliance wall arrives in the early 2030s, incumbents will buy rather than build, and the companies proving the model now will be the obvious acquisitions when they do.

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## PT1 VENTURES

PT1 Ventures is a European venture capital platform investing in early-stage tech that's upgrading the physical world in three core clusters: electrification & energy transition; built world AI & automation; climate & infrastructure resilience.

With initial tickets ranging from €300k to €4M, PT1 backs the boldest founders across the UK and Europe who are redefining how we build, power and sustain our world. PT1 doesn't just fund startups — they actively support to add value where it matters most. Combining deep domain expertise with data-driven insights, PT1 leverages their AI-enabled deal flow engine to identify and accelerate future category winners.

Championed by their network of 100+ industry experts — from unicorn founders to corporates and industrial veterans — PT1 Ventures provides startups with collective wisdom, hands-on guidance, strategic acceleration sprints and the backing needed to scale.

DWR eco

dwr-eco.com

## DWR ECO

DWR eco is a strategy consultancy specializing in cleantech. Since 2012, DWR eco has worked exclusively with companies whose technologies are driving the transition to a climate-neutral and resilient economy. This level of specialization remains rare, and it is our advantage: we know the technologies, the markets and the key players.

DWR eco was founded at a time when Germany's energy transition had been agreed politically but had barely begun in practice. Since then, cleantech has evolved significantly, and DWR eco's focus has evolved with it, from renewable energy and the circular economy to mobility and green industry.

DWR eco works across the three areas that shape the success of cleantech: the regulatory environment, public and political perception, and viable business models. DWR eco combines strategic advice with deep industry expertise and a well-established network across business, politics, media and investment. When the path ahead is unclear, we provide direction rather than standard answers and create the connections that help companies move forward.

GET IN TOUCH

## **Building** what makes the brick bankable?

We back the solvers — the founders who integrate, finance and dispatch electrified heat. If that is you, we want to hear from you.

Talk to PT1: pt1.vc

Policy questions: dwr-eco.com

# Fire to furnace
## the story of heat

Humanity has been making heat for hundreds of thousands of years, almost entirely by controlling fire — some of the earliest evidence, found in the Levant, dates back roughly 800,000 years. We first used it for cooking and protection, then for ceramics, metallurgy, steam power, and eventually the fossil-fuelled industrial economy. Over that time we became remarkably good at making heat and moving it around. But the system we built was designed around combustion — and combustion turns carbon-rich fuels into $CO_2$.

There's one thing in common between the furnaces that make our steel, the kilns that cure our cement, and the vats that produce our chemicals: heat. It's everywhere. It is the silent force behind all our manufacturing, and yet it remains one of the most overlooked drivers of climate change. We're not talking about the heat that warms our homes or cooks our food, but the high-temperature heat needed in reactors, factories and processing plants — generally above 200°C, in some cases beyond 2,000°C. Depending on accounting boundaries, industrial heat is responsible for roughly one-fifth of global emissions — comparable to, and in some estimates larger than, the entire transport sector.[a] How has a number that large gone unnoticed?

The answer is simple: heat is invisible. As we race towards net zero, attention has gone to clean electricity and electric vehicles, and real progress has followed — in the EU, overall greenhouse gas emissions are now 40% below 1990 levels. But the easy fixes are running out, and decarbonising industrial heat is among the hardest problems left. Around 85% of it comes from burning coal, oil or gas.

Today, we make heat through chemistry. We burn hydrocarbons, and combustion works because those fuels react with oxygen to form lower-energy products — mainly $CO_2$ and water. Energy is absorbed breaking the chemical bonds in the fuel and the oxygen, but more energy is released when the new, more stable bonds form in the

products. The net release appears as heat — and the carbon appears as $CO_2$. Every tonne of fossil heat carries that arithmetic with it.

Physical processes are different. Here we harness the laws of physics — mainly electricity and magnetism — to make things hot directly. This can be cleaner, and in some cases requires no fuel at all. It also lets us rethink industrial supply chains. But it won't be easy. Heat is about half of all final energy demand in the EU, and we need to change how we produce essentially all of it. Electricity, by comparison, is only around 20% of global final energy — and decarbonising power generation has already taken three decades of sustained effort. The harder half of the transition is still ahead.

The prize justifies the difficulty. High-temperature heat is expensive; if this transition makes it cheaper, European industry becomes more competitive and resilient. It makes factories and chemical plants safer places to work. And it addresses the largest remaining piece of the climate puzzle. This will be a trillion-euro opportunity.

This paper is our investment thesis on industrial heat electrification, written with DWR Eco. It is the story of fires to wires: we start with the heat landscape today, cover the technologies and business models emerging to change it, and end on where we intend to invest. Let's get cooking.

# Some like it hot

## What is heat and why does it matter?

Heat is energy in transit — it flows from hotter bodies to colder ones because of a temperature difference. The best way to imagine it is as energy in motion, measured in joules.

Globally, we are a heat civilisation: half of all final energy demand is heat, accounting for nearly 40% of energy-related $CO_2$ emissions. In 2022, total final energy demand was ~440 exajoules (EJ), and heat alone made up ~220 EJ.[b] That's:

~220 EJ OF HEAT DEMAND IN 2022 IS

| $2.2 \times 10^{20}$ | ~7 TW | ~61,000 | ~7,000 | ~36bn |
|---|---|---|---|---|
| joules per year | of continuous thermal demand | TWh of heat annually | 1 GW power stations running flat out | barrels of oil equivalent per year |

Industry alone consumed 166 EJ of final energy in 2022 — about 37% of global demand. Roughly two-thirds of that is process heat, meaning ~110 EJ per year of industrial heat. The International Energy Agency's analysis shows that more than half of this is above 200°C, with a large share above 300°C.[c] That is the hard-to-abate frontier where fossil fuels dominate today.

### Europe's strategic angle

Industrial heat is no longer only a question of decarbonisation. It is increasingly a strategic issue of energy security, industrial resilience, and competitiveness. Today, more than 85% of industrial heat is still fossil-based, leaving European industry directly exposed to volatile global fuel markets. The recent disruption in the Strait of Hormuz illustrated how quickly this exposure translates into economic pressure: in the first 52 days of the crisis alone, the EU spent an additional €24 billion on fossil fuel imports without receiving additional energy in return.[w] These shocks are not exceptional events.

They reflect a structural dependence on imported fossil fuels that continues to shape European industrial competitiveness.

Industrial electrification offers a different model. Instead of relying on imported fuels, industrial heat can increasingly be powered by domestically produced electricity — reducing exposure to geopolitical disruption while improving long-term price stability. But the more interesting point runs the other way: the grid needs industry as much as industry needs the grid.

Every major European grid now faces the same paradox: record renewable capacity, and record renewable curtailment. Wind and solar increasingly generate more power than the system can absorb, and operators throw clean energy away. High-temperature heat could be the missing sink. Electrify a refinery's cracker or a cement kiln's preheater and you haven't just decarbonised a plant — you've created a demand-side asset that soaks up surplus renewable power at scale.

Pair that with thermal storage and the effect compounds. Thermal storage is cheap and long-duration in a way lithium-ion isn't. It lets industry take power when the wind blows and release it as steady process heat on the plant's own schedule. For the grid, that flattens peaks, reduces curtailment and stabilises wholesale prices. For industry, it's insulation from fuel volatility and carbon costs.

This is why industrial heat is a bigger story than cement, steel or chemicals. It's a lever that decarbonises supply and demand simultaneously.Hold that thought; we'll come back to it when we get to storage and dispatch.

## Defining the industrial temperature spectrum

Not all heat is created equal. The heat that pasteurises milk (72°C) has little in common with the heat that melts glass (1,600°C), even though both get lumped into the same "industrial heat" bucket. Temperature is the single most important variable in this story. It decides which technologies work, which economics pencil, and where the opportunity actually sits. So let's define our terms.

The convention is to split process heat into three bands: low (below 100°C), medium (100–500°C), and high (above 500°C).

| BAND | RANGE | WHAT HAPPENS HERE | EU DEMAND | WHO SUPPLIES IT TODAY |
|---|---|---|---|---|
| **Low** | <100°C | Washing, pasteurisation, drying (food, textiles), space heating | 228 TWh/yr | Gas boilers; heat pumps growing fast |
| **Medium** | 100–500°C | Steam raising, distillation, pulp & paper drying, food processing, chemicals pre-heat | 706 TWh/yr | Gas and oil boilers, CHP |
| **High** | >500°C | Steel reheat (1,100–1,300°C), cement clinker (1,450°C), glass melting (1,500–1,600°C), steam cracking (~850°C), ammonia reforming (~900°C) | 1,035 TWh/yr | Coal, coke and gas, with EAFs in scrap steel |

EU figures: Rehfeldt et al., 2020.[d]

For calibration: frying oil sits at around 180°C, a pizza oven at 450°C, lava at 700–1,200°C. A cement kiln runs at 1,450°C — roughly a quarter of the temperature of the sun's surface.

These bands aren't bureaucratic conventions. Each one maps to a different physics regime. Below ~200°C, thermodynamics is on your side: a heat pump turns one unit of electricity into three to six units of heat, and electrification is simply cheaper than combustion. Between 200°C and 500°C, that multiplier collapses. Above 500°C, essentially everything converts one electron into one unit of heat. At that point, the technology question becomes a power price question. We will come back to this repeatedly.

And the demand skews hot. The IEA's temperature-band analysis shows more than half of global industrial heat demand sits above 200°C, with a distinct chunk well above 400°C.[c] That is where the emissions are, and it is where the fossil incumbency is strongest.

The market opportunity follows the physics. The low band is commercially solved — heat pumps already undercut boilers on operating cost, and this is where the bulk of projected heat-decarbonisation investment is currently headed. Crowded, subsidy-shaped, and not where differentiated returns live. The medium band has a split personality: below 200°C it's heat pump territory; above 200°C it's contested ground with no default winner. The high band is the prize. The EU's >500°C demand alone represents a delivered-heat market worth £36–52 billion per year at current values of £35–50/MWh — and including the hotter half of the medium band (chemicals and refining, much of it above 300°C) pushes the high-temperature total higher still. Almost all of it is fossil-fired, and the innovation serving it is thinnest exactly where the emissions are thickest.

That mismatch — biggest market, least innovation — is the anomaly this paper is about.

| SECTOR | KEY HEAT PROCESSES | OPERATING TEMPS | DIRECT $CO_2$ (GLOBAL) | ENERGY USED IN >500°C PROCESSES |
|---|---|---|---|---|
| **Steel** | Blast furnaces, coke ovens, reheat lines | 900–1,600°C | ~2.6 Gt/yr | ~83% |
| **Cement & lime** | Clinker kilns, calcination | 850–1,450°C | ~2.4 Gt/yr | ~82% |
| **Chemicals & refining** | Steam cracking, reforming, distillation | 200–900°C | ~1.4 Gt/yr | Mixed — large >300°C share |
| **Aluminium** | Smelting, remelt, anode baking | 700–1,200°C | ~1.1 Gt/yr* | High |
| **Glass & ceramics** | Melting tanks, firing kilns | 1,000–1,600°C | ~0.4 Gt/yr | High |

$CO_2$ figures: IEA sectoral estimates, direct and process emissions; *aluminium includes indirect electricity emissions; >500°C shares: McKinsey.[e]. Benchmarks used in this paper: gas-fired process heat at £35–50/$MWh_{th}$ excluding carbon costs, and ~£59/$MWh_{th}$ where ETS exposure at current allowance prices is included; European industrial electricity at ~£100/$MWh_e$ on flat tariffs. All analysis is in sterling; € and $ figures are quoted as reported by their sources.

These five sectors account for roughly 7–8 Gt of $CO_2$ annually — around 20% of global emissions.[v] These are not marginal or niche applications.

## The PT1 heat taxonomy

This map is how we hunt. The vertical axis is temperature. The horizontal axis is the adoption barrier: at 0, a technology is retrofit-friendly — you can bolt it onto an existing plant within a normal capex cycle. At 10, it's deep-tech frontier — someone needs to invent new materials before it exists at all.

Our first instinct was to cut this market by temperature versus direct/indirect heating. But direct versus indirect is a property of the technology, not the market. What actually determines whether a technology gets adopted is what's blocking it. So that's the axis we chose.

Read the map and three regions jump out.

The bottom-left is solved. Industrial heat pumps, waste heat recovery, district heating tie-ins: commercially proven, increasingly crowded, and largely a deployment-and-subsidy game from here. Good for the climate. Not much venture alpha.

The middle of the map is stuck — but for boring reasons. Resistance heating paired with thermal storage, induction, modular heat batteries: the physics is proven, the components are commodity, and the temperatures they serve (roughly 300–900°C) cover the largest slice of industrial demand. What blocks them isn't invention. It's integration

— threading electrons into forty-year-old plants, financing the capex, dispatching around volatile power prices. Plumbing, contracts, and software.

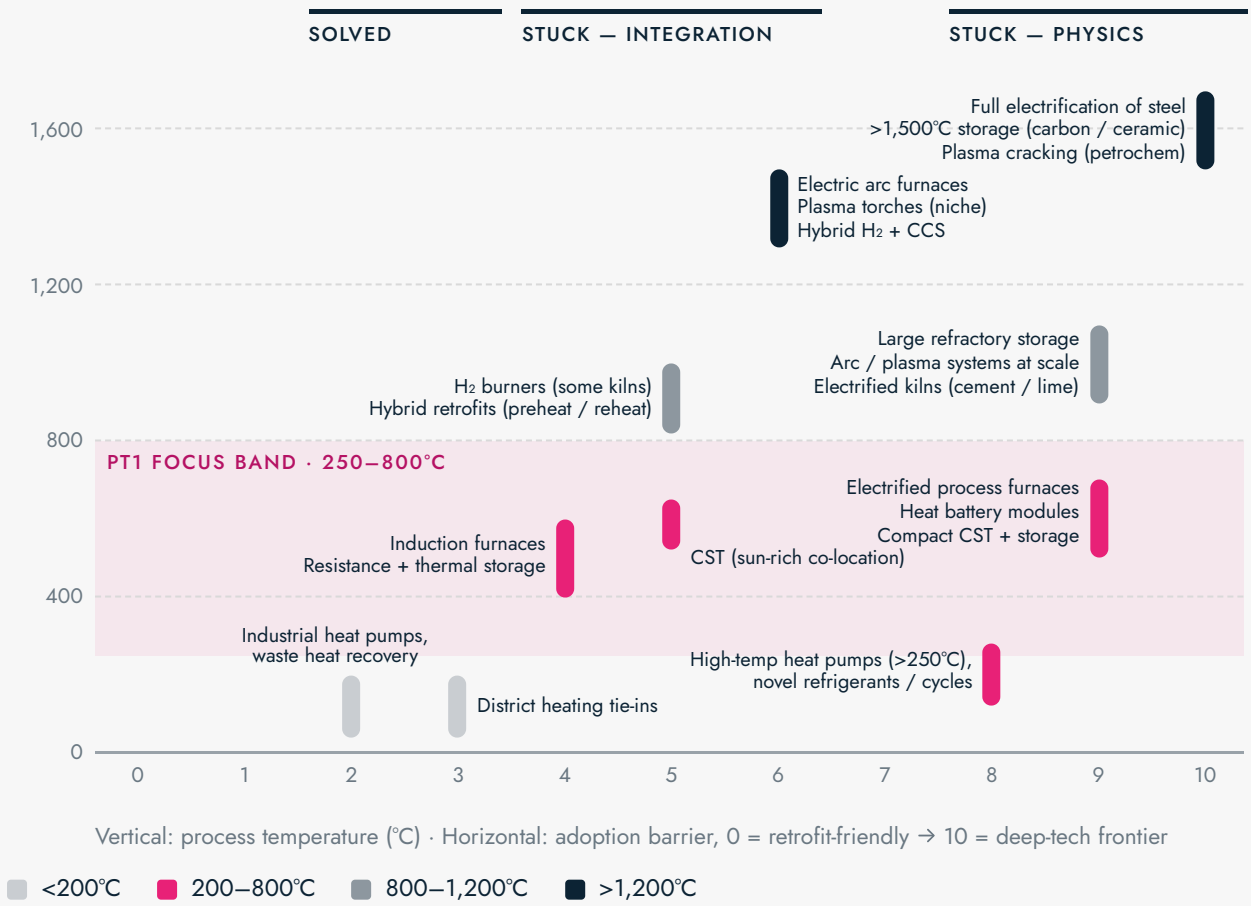
The right-hand edge is stuck for physics reasons. Heat pumps above 250°C need refrigerants, compressors and seals that don't yet exist at industrial duty cycles. Plasma cracking of petrochemicals and the full electrification of primary steel sit in the top-right corner: real, important, and a decade of materials science away from bankability.

Here's the distinction that matters: boring reasons are fixable with venture money on venture timelines. Physics isn't. So we hunt in the middle.

FIGURE 1

## The PT1 heat taxonomy: adoption barrier versus temperature

Each bar spans the operating temperature range of a technology cluster.




Source: PT1 analysis.

## What does decarbonisation look like here?

Physics, as is common in this field, is the ultimate master. Decarbonisation of industrial heat can only take a few routes: electrification — using electricity to produce heat directly (infrared, resistance, electric arc) or to move heat (heat pumps); sticking with combustion but switching to alternative fuels (biomass and hydrogen); or using renewable sources of heat directly (concentrated solar and geothermal). On top of these sit the optimisation layers — fuel circularity and capturing waste heat for reuse — all covered in due course. Of the core routes, we think electrification is the most likely. But there's no silver bullet, and different sectors need different approaches.

Hydrogen (and the broader e-fuel enthusiasm) has crowded the headlines and the policy decks, but the economics don't survive scrutiny outside a few specific use cases. We understand the appeal: swap the fuel, keep the infrastructure, change little else. Unfortunately, the energy accounting doesn't cooperate. Electrolysis converts electricity to hydrogen at roughly 65–75% efficiency, and a burner converts hydrogen to useful heat at perhaps 80–95%. Even on optimistic assumptions, green hydrogen burned for heat therefore consumes roughly 1.5–2 times as much clean electricity as direct resistance heating — and several times more than a heat pump, wherever heat pumps work.[f] Europe's power system is not large enough to carry that overhead across mid-temperature industry. Hydrogen has real roles — as a reductant in steel, as a chemical feedstock, and as a fuel for a handful of ultra-high-temperature processes — but the idea that it replaces combustion across the 250–800°C band does not hold. What is plausible is hybridisation: partial electrification alongside clean fuels such as hydrogen, biogas or syngas, letting operators de-risk adoption through incremental substitution rather than wholesale re-engineering.

The reality of high-grade heat today remains overwhelmingly fossil: natural gas and oil dominate process heat, with biomass filling roughly 10% where reliable local supply chains exist, such as parts of Northern Europe. Direct electrification appears only in specific niches — induction for metals, resistance furnaces for ceramics, electric arc furnaces in steel — each tightly bound to its process requirements. But these are also the sectors where electrification, once cracked, matters most.

### What area are we most interested in?

So, where do we want to play? Two questions define the answer: how high up the temperature ladder, and direct or indirect heating? Let's take both.

On temperature: high, but not the highest. The sub-200°C market is real but solved — heat pumps will win it, and the returns will be competed away. The >1,000°C market is

enormous but is an infrastructure game: multi-billion-pound plants, decade-long sales cycles, and capital requirements that suit infra funds better than a seed cheque. The band in between — roughly 250–800°C — is the anomaly. It holds around a third of global industrial heat demand, the technology to serve it already exists, and almost nobody is serving it. That's our band.

On direct versus indirect: we're agnostic on the physics and opinionated on the retrofit. It genuinely doesn't matter to us whether the heat comes from a resistance coil, an induction field, or a discharging brick. What matters is whether it can be threaded into an existing plant as a standardised 1–5 $MW_{th}$ block without stopping production. Indirect, storage-buffered systems usually win that test — not because the physics is prettier, but because storage decouples the heat source from the process timing. A plant doesn't care when you charged the bricks. It cares that the steam is there at 6am.

Which brings us to the real dividing line in this market, and the one our taxonomy is built on: technology-blocked versus retrofit-blocked. Where a solution is blocked by technology — heat pumps above 250°C, say — we wait. Betting on materials science breakthroughs is a fine strategy for someone, but the timelines and binary outcomes don't fit early-stage venture. Where a solution is blocked by retrofit and integration — resistance plus storage in the 250–800°C band — we invest. Those are problems of plumbing, financing and dispatch software. Problems, in other words, that startups are built to solve.

The rest of this paper builds out that case: why this band is hard (Chapter 2), why it's big (Chapter 3), which tools can crack it (Chapter 4), and — most importantly — which layer of the value chain the returns will accrue to (Chapter 5), and whether EU policy creates the conditions for deployment to scale (Chapter 6).

# The hard thing about hot things

The heat landscape is complex. When most people talk about decarbonising heat, they mean the easier part: low and medium grade heat — food pasteurisation, district heating, drying pulp in paper. We focus on the grade above that: temperatures beyond 200°C, where more than 50% of industrial demand sits and where supply has not caught up with demand. That gap is the opportunity — but it exists for a reason, and understanding why is the first piece of diligence.

Decarbonising this segment is hard because of six things:

- Technology: heat pumps — the best tool we have for electrifying heat — don't scale past ~200°C, and above that the right kit is either missing or unproven
- Retrofit: high-temperature plants are asset-locked, with 40–60 year investment cycles
- Economics: European electricity is expensive relative to gas, and relative to what our trading partners pay
- Infrastructure: renewables are being built faster than industry can connect to them — and grid tariffs punish the very flexibility that makes electrified heat work
- Demand: nobody yet knows who will pay the green premium
- Horizontal constraints: too few electrical engineers, and twenty-seven versions of the single market

The first two are physics and plant problems. The last four are market design problems. We take the physics first, then come back to the market.

In industrial heat, we either have technologies that can in principle deliver the required temperatures but cannot be retrofitted into existing plants, or we have no mature technologies at all. The result is a vacuum in the 200–1,000°C range — the very band where climate impact is greatest and innovation is thinnest.

Major OEMs offer few standardised solutions in this range, and project developers are reluctant to propose unfamiliar systems without proven references. With policy only beginning to catch up, little capital flows in, and the problem sits off managerial agendas until 2050 targets loom. The market has largely avoided the problem above 250°C — not because it is irrelevant or unsolvable, but because it is hard. At lower temperatures it is easier to show progress, scale commercially and decarbonise with existing technology.

The implication is clear. The industrial baseline remains combustion-centric and capex-heavy. Most plants are built around fossil systems, with long-lived assets deeply integrated into site-wide utilities. Any credible decarbonisation plan cannot assume a greenfield reset. It must contend with brownfield constraints — retrofitting into existing plants without major downtime, system redesign or stranded assets. This is the core challenge any electrification technology must overcome to scale.

## Why heat pumps don't scale

We already have functioning heat pumps, and they already make up more than a third of new heating installations in some European markets. Their operating costs (£20–35/MWh) clearly undercut fossil boilers (£35–50/MWh), and most innovation is now optimisation. This is where the bulk of the projected $12 billion of investment in heat decarbonisation is headed by 2030.[e] But they hit a hard ceiling: past ~200°C, conventional heat pumps become uneconomic — efficiency collapses, operating costs converge with gas, and the capital premium stops being justifiable.

The Gulpener Brewery in the Netherlands cut its total energy use by 75% by installing an industrial heat pump to reclaim waste heat from fermentation and reuse it for heating — and "they even noticed an improvement in beer quality."[g]

To stress-test the economics, we looked at a TRL 9 heat pump claiming operation up to 225–250°C with COP values of 4–6. Heat pump performance is defined by the coefficient of performance (COP): the ratio of heat output to electricity input. At low lifts, one unit of electricity yields 4–6 units of heat, but as the lift climbs past 200°C, COPs fall fast, towards 2–3, and operating costs rise accordingly. At today's European power prices (~£100/MWh), industrial heat pumps beat fossil boilers decisively below 150°C, delivering heat at £20–35/MWh against combustion's £35–50/MWh. But beyond 200°C, costs climb to £35–40/MWh, erasing the advantage. Factor in capex 2–3× higher than gas boilers, plus material stresses on compressors, seals and heat exchangers, and the business case collapses without subsidies or breakthrough design.

## The tech gap and the retrofit trap

Once conventional heat pumps fall away, we're left with direct electrification — resistance, induction, arc and plasma systems — which can deliver the temperatures but convert electricity to heat one-for-one, making them uneconomic without ultra-cheap power or storage integration. Solar thermal is technically capable but geography-locked. In other words, the technology exists but the economics don't yet pencil, and innovation in this band must clear three bars: materials and components that withstand extreme temperatures, corrosive conditions and high pressures; heat delivered evenly and precisely, not just at high intensity; and — because processes are tightly integrated — heat sources that can be swapped in without redesigning the plant around them.

## Heavy industries, heavier inertia

For the technologies that are ready to deploy, the opposite challenge waits. Heavy industries — cement, steel, chemicals, refining — together account for ~45% of industrial $CO_2$ emissions[v] and are asset-locked. Plants run for 40–60 years, with heat, pressure and product streams tightly coupled across units. Swapping in a new heat source is like rewiring a city while keeping the lights on. Solutions therefore need to be close to plug-and-play, with minimal change to surrounding equipment.

Layered on top is managerial inertia and policy lag. High-temperature processes are capital-intensive, long-lived, and designed around specific combustion systems; the people running them are used to a very particular way of working, and nobody wants to be first. Decarbonisation is treated as a 2040 problem, not a 2025 opportunity — so R&D budgets are minimal and pilots are rare. Without stronger carbon price signals or regulatory mandates, the ROI isn't there, which is why most companies will wait for their "oh-no moment" a decade before the 2050 deadline.

And then there's the shape of the clean-energy playbook so far: clear regulatory tailwinds → visible cost-curve compression → modular hardware → quick payback. Heavy industry offers none of that on its own. It is capex-heavy, process-integrated and asset-locked, with payback cycles measured in decades.

## It's not just the physics

Suppose the perfect 600°C heat block existed tomorrow — proven, modular, retrofittable over a long weekend. Four market problems would still be standing in its way.

Start with the power price. European industry pays two to three times what its American competitors pay for electricity, and four to five times for gas — the numbers the Draghi report made famous.[h] Worse, within Europe, electricity is taxed harder than the gas it's

supposed to replace. A heat pump's efficiency multiple can absorb that spread at low temperatures. At one-to-one conversion, nothing can. Every euro loaded onto electricity is, functionally, a subsidy for combustion. And the comparison with trading partners cuts deep: a European chemicals plant that electrifies at today's power prices isn't just decarbonising — it is accepting a cost disadvantage against a Gulf Coast rival burning $3 gas. Boards notice. The single most important number in this whitepaper may therefore not be a temperature at all, but the electricity-to-gas price ratio. Brussels is starting to think the same way: the new Electrification Action Plan sets an indicative objective of bringing that ratio to two or below for industry by 2030.

Then there's the grid, where Europe has built itself a paradox. On one side, record renewable capacity and record curtailment — clean power discarded because the system can't absorb it. On the other, industrial sites queuing years for a larger connection, because their plants were designed around fat gas pipes and thin cables. And when they do connect, network charges in most Member States still reward flat baseload consumption and penalise flexible load — punishing precisely the storage-buffered, price-following profile that makes electrified heat economic. The grid is discarding the exact cheap power industry wants to buy, while charging industry extra for offering to buy it flexibly. It would be difficult to design a worse set of incentives. No wonder a once-technical grid question has become a central industrial-policy debate: who gets connected, how fast, and on what terms.

Fourth: demand uncertainty. Electrifying a plant is a bet, held for decades, that someone will pay for the cleaner output. Green steel and low-carbon cement command a premium today, and early offtakes from automotive OEMs exist — but they are thin, and Europe's flagship green-materials projects have already shown how hard it is to finance against a premium that is assumed rather than contracted. Until lead markets — public procurement, product standards, labels — make clean-materials demand legible, every operator's CFO can reasonably ask: who, exactly, is buying this?

And finally, the mundane constraints: people and paperwork. Electrifying heavy industry needs high-voltage electricians, power-electronics engineers and controls specialists, all in short supply across Europe. And a startup scaling a heat platform from the Netherlands to Germany to Spain re-learns the permitting rules, subsidy schemes and grid codes each time. The hardware is standardisable. The bureaucracy isn't — yet.

None of these four are physics. All of them are fixable — by policy, by market design, or by startups that treat the friction itself as the business. That is both the frustration and the opportunity, and it is why this paper has a policy chapter at all.

# The growth market above 200°C

We've established that above 200°C is where climate impact is greatest and innovation thinnest. For this to be a venture case, though, it needs to be not just urgent but investable at scale — so let's size it carefully, because "industrial heat is enormous" is true and useless in equal measure. Different numbers answer different questions:

| MARKET | DEFINITION | SIZE |
|---|---|---|
| **Global industrial heat** | All temperature bands; final energy for process heat | ~110 EJ (~30,500 TWh)/yr[c] |
| **Global >300°C heat** | Conservatively 40% of the above | ~44 EJ (~12,200 TWh)/yr → £430–610bn/yr at £35–50/MWh |
| **EU >500°C heat** | High-temperature process heat | 1,035 TWh/yr → £36–52bn/yr[d] |
| **The venture-serviceable wedge** | EU 250–800°C demand, electrifiable and retrofit-accessible | ~732 TWh/yr → £30–45bn/yr (derived estimate[d]) |
| **Near-term beachhead** | Modular 1–5 $MW_{th}$ systems in early-adopter sectors | A subset measured in single-digit TWh this decade |

Price basis: the >500°C row is valued at current gas-heat prices of £35–50/MWh; the 250–800°C wedge is valued at £40–60/MWh — the delivered price band for electrified heat in this range, consistent with the case study in Chapter 4.

A note on what these figures are: they size delivered-heat demand — valued at the price bases stated above — not equipment revenue, not fuel spend, not Heat-as-a-Service revenue. The revenue pool available to any single layer of the value chain is smaller than the headline, which is exactly why Chapter 5 asks where along the chain the value concentrates. The headline's job is different: to show that even conservative slices of this market are an order of magnitude larger than most sectors venture capital calls large.

If the opportunity is clear, the path to unlocking it lies in technology wedges that extend electrification and clean heat across the full range above 250°C. This is where differentiation matters and where startups can win.

## Three wedges of opportunity

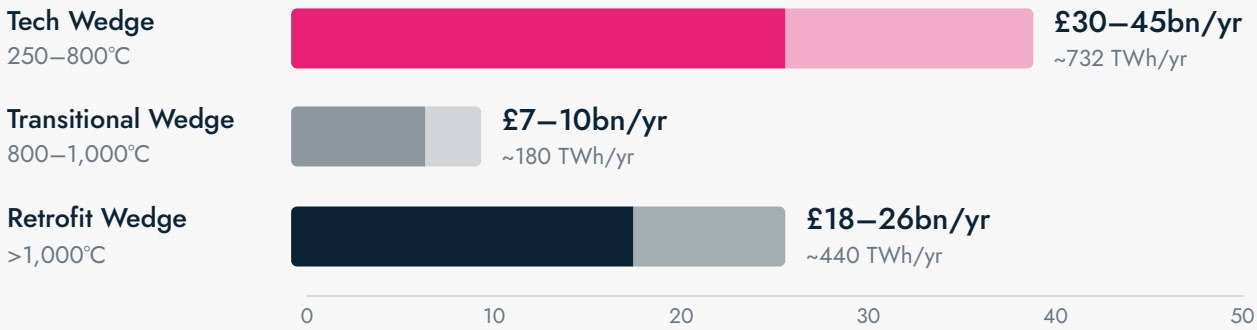
Before we get into the technologies, let's understand the shape of the market. Electrifying heat is not one market — it's a stack of wedges, each defined by temperature, technology maturity and retrofit complexity. Each wedge demands a different strategy, attracts a different kind of capital, and pays out on a different clock.

First, let's set aside everything under 250°C. With the number of pilots already running, from startups and incumbents alike, that band will decarbonise itself — most probably through heat pumps. The interesting question starts where the heat pumps stop.

FIGURE 2

### Three wedges of opportunity for industrial heat decarbonisation

EU delivered-heat demand by temperature wedge.




Delivered-heat market, £bn per year (EU). Solid = low estimate; shaded = range to high estimate.

Source: PT1 analysis based on Rehfeldt et al. (2020).[d]

## The Tech Wedge (250–800°C) — the VC frontier

This is the largest and most immediate of the three. Roughly a third of global industrial heat demand falls in this band — refining, chemicals, ceramics, light metals, food processing, textiles — and in the EU alone it amounts to some 732 TWh a year, roughly the entire industrial energy demand of Germany.[d] Combustion still dominates every corner of it. Translate the demand into money and you're looking at a £30–45 billion annual market for delivered heat services in Europe.

The physics here is unforgiving but simple. Below roughly 250°C, high-temperature heat pumps can still hold a useful efficiency multiple; past that point, as Chapter 2 established, everything converts electricity to heat at close to one-for-one — resistance, induction, the lot. Bought at flat European power prices, these technologies lose to a £35–50/MWh gas boiler every time.

Which is exactly why storage changes everything. Pair a resistance heater with brick storage and you stop buying electricity at the average price and start buying it in the cheap hours — £30–40/MWh in windy and sunny windows — then discharging stable heat at £45–60/MWh whenever the plant needs it. Run the numbers on a concrete system: resistance plus brick storage at ~£500/kW capex and 88% end-to-end system efficiency delivers heat at ~£55/$MWh_{th}$ on £40 electricity, which beats gas. Induction tells a similar story at ~£700/kW — pricier, but in metals processing the precision, product quality and yield often justify the premium on their own. And in sun-rich regions, concentrated solar thermal delivers dispatchable heat in this exact range at £25–50/MWh, cheaper than gas today: geography-locked, but where it fits, unbeatable.

Better still, the demand is sticky. Steel, glass, ceramics and chemicals aren't going anywhere, and once a plant electrifies, it doesn't switch back — these assets live for forty to sixty years. Win the retrofit and you've won the site for a generation.

Where does the first demand come from? The first deployments will not respect our neat temperature boundary: many attractive beachheads straddle 150–300°C, where heat pumps, resistance, steam electrification and storage all compete. They matter because they are the operational on-ramp into the 250–800°C wedge — and the early customers are identifiable:

| SECTOR | PROCESSES | TEMPERATURE | WHY ATTRACTIVE EARLY |
|---|---|---|---|
| **Food & beverage** | Drying, roasting, frying, steam | 150–400°C | Fragmented, batch-tolerant, lower integration risk |
| **Pulp & paper** | Drying, steam | 150–300°C | Very large steady loads; waste-heat synergies |
| **Chemicals & refining** | Pre-heat, distillation, reactors | 200–600°C | The biggest loads; complex but high value |
| **Metals processing** | Pre-heating, heat treatment | 300–900°C | Induction and resistance already familiar |
| **Ceramics & glass processing** | Kilns, annealing, tempering | 600–1,200°C | High heat; batch processes suit storage |

The first buyers share a profile: sites with existing steam networks (so a heat block plugs in rather than re-plumbs), tolerance for scheduled downtime, exposure to volatile local power prices (so the arbitrage exists), rising ETS and CBAM exposure (so the counterfactual gets worse every year), and procurement functions capable of signing long-term heat contracts. Food, paper and metals sites tick more of those boxes today than cement or primary chemicals — which is why we expect the wedge to be won from the bottom of its temperature range upwards.

So where's the venture opportunity? Not in reinventing hardware that commoditised decades ago — nichrome wire, induction coils, arc electrodes. It's in the system around the hardware. The winning company in this wedge looks something like this: standardised 1–5 $MW_{th}$ modules that ride down a cost curve; utilisation held at 70–85% so the capex spreads thin across every megawatt-hour; Heat-as-a-Service contracts that move the capex off the customer's balance sheet and guarantee performance; dispatch software that buys into the £20–40/MWh windows and sells steady £40–60/MWh heat; and additional value streams — ETS savings, flexibility revenues, public support and green premiums — layered on top. In one sentence: the winners at 250–800°C will be the companies that turn volatile £100/MWh-average power markets into £40–60/MWh delivered heat. The economics are tight, but the wedge is wide open.

## The Transitional Wedge (800–1,000°C) — the innovation frontier

Here electrification becomes possible but not yet easy — the widest gap between what the technology can do and what the plants need. Roughly 150–200 TWh of EU industrial heat demand sits in this band, a £7–10 billion annual delivered-heat market if it decarbonises.

Three things get harder above 800°C. The physics turns hostile: every technology converts one-for-one, and the systems are larger than anything in the Tech Wedge, so cheap electricity stops being an advantage and becomes a precondition. The integration turns hostile too: these processes are continuous, high-throughput, and welded into legacy plant designs, so a retrofit isn't swapping in a heater — it's re-plumbing the site while it runs. And the storage has to scale with it: at these temperatures you need denser media — ceramics, carbon blocks — holding heat for 12 to 48 hours, not a few.

The plays that work here are correspondingly deeper. Larger refractory storage blocks — 10 to 100 $MWh_{th}$ — can smooth operations and arbitrage electricity volatility down to £30–40/MWh averages, putting plants within reach of fossil economics. Load-flexing helps too: a furnace that ramps down for a few hours when prices spike and reheats from storage is a furnace that pays for its own flexibility. And where full

electrification doesn't pencil, partial retrofits do — electrify the preheat, reheat and finishing stages, keep combustion for the hottest and least flexible steps, and you still cut $CO_2$ intensity by 30–50% with a project a bank will actually finance.

This isn't the biggest wedge or the easiest one. It's the long game. The companies that master 800–1,000°C build the credibility, the defensible IP and — most valuably — the relationships with steel, chemicals and glass majors, just in time for the first big wave of decarbonisation spending we expect around 2035. Whoever holds those relationships when the wave breaks gets first call on the wedge above.

## The Retrofit Wedge (>1,000°C) — the final frontier

Above 1,000°C sits over 600 TWh of annual EU demand — roughly £22 billion a year — dominated by steel and cement. Electrify even a slice of this wedge and you bend the EU's emissions curve. It is also, by some distance, the toughest.

The thermodynamic multiplier is gone for good: arc, plasma and resistive systems all convert electricity to heat one-for-one. The saving grace is that fossil systems lose efficiency at these temperatures too, so one-for-one conversion can still compete — but only on cheap power. Breaking even against £59/$MWh_{th}$ carbon-inclusive fossil heat needs electricity at ~£30/MWh or below, which in practice means captive renewables, sleeved PPAs, or soaking up curtailment. Site next to wind and solar overbuild and the co-location economics are exceptional; site anywhere else and you're negotiating long-duration PPAs before you've poured concrete. And the integration problem reaches its final form: these are multi-billion-pound assets, designed around combustion, running on margins too tight to afford downtime. Threading new electrical systems into that, mid-operation, is the whole job.

The technology exists. The challenge is everything around it — which is why this wedge belongs mostly to patient capital: infra-PE, EPC-led consortia, and the rare industrially-networked VC with genuine alpha. The differentiator isn't the electrode; it's how you package power electronics, thermal storage with 12–72 hours of buffering, and plant process controls into a retrofit that works with the pre-existing process rather than against it. Hybrid retrofits — electrify the reheat stages, leave the hottest burn zones on combustion — deliver major $CO_2$ cuts while protecting uptime. And carbon economics do the rest of the pushing: at ETS levels of roughly €90–200/$tCO_2$, electrification becomes viable even for some >1,000°C applications, while CBAM phasing in shields exposed producers from carbon leakage.

## One market, three clocks

What unites the three wedges is a business model shift: from selling equipment to selling delivered heat. Thermal storage, dispatch optimisation and Heat-as-a-Service contracts are what transform intermittent renewable electricity into stable, affordable, high-temperature heat — and they're where venture-backed companies build durable moats while incumbents and utilities bring the scale and the financing.

The wedges also hand investors their sequencing. Start in the Tech Wedge now, where the economics are provable today at project level and the wins come fastest. Use the Transitional Wedge to build integration muscle and the relationships that matter. Then push into the Retrofit Wedge over the next decade, when the heaviest emitters finally open their chequebooks. Same market, three clocks — and the first one is already ticking.

# **Tools** of the trade

Chapters 2 and 3 established the problem and the prize. This chapter is about the tools — and the stakes of choosing well are high. Data from McKinsey shows that in steel and cement, ~82–83% of energy is used in >500°C heat processes.[e] Since these sectors are among the largest emitters in industry (70% of direct emissions in the "basic materials" grouping per the IPCC[i]), failure to decarbonise the >250°C frontier risks leaving, on our derivation from those figures ~40–60% of industrial $CO_2$ unaddressed by low-temperature solutions alone.

## My Chemical Romance

Combustion won for good reasons: it is energy-dense, cheap, controllable, storable, and embedded in a century and a half of industrial design. That incumbency is why fossil fuels still dominate industrial heat, with ~10% from biomass and only a sliver of direct electrification in niche operations — induction for metals, resistance furnaces, EAFs.[j] Chapter 0 covered the chemistry of the swap; the strategic question is what actually changes when you trade molecules for electrons. Three things.

First, transport and flexibility: electricity moves long distances with low losses and converts cleanly into heat, motion or chemistry on site. Hot fluids don't. Where and how you generate heat suddenly becomes a choice rather than a constraint.

Second, thermodynamics: at small temperature lifts, a heat pump multiplies each kilowatt-hour of electricity into 3–5 kWh of useful heat. As lifts rise past ~200°C, that multiplier collapses and the cost edge over gas disappears — unless you pair with storage and smart dispatch. This is why commercial heat pumps taper off in industry: not because electrification can't work, but because the economics break first.[e]

Third, system fit: a net-zero energy system is, to a first approximation, an electrified system. The IEA's net-zero pathway leans on rapid power-sector decarbonisation and broad electrification.[k] High-temperature heat sits at the difficult end of that spectrum,

but the direction of travel is the same: electrons over molecules wherever possible, with green molecules reserved for what electricity can't yet serve.

Saying "chemical to physical" doesn't make the problem simpler, though. To make a real impact, we need the how.

## The toolkit

There is no winner-takes-all technology here. What's emerging is a portfolio, each tool carving out the range where it beats fossil fuels on cost, performance or retrofit practicality. Electrification is the anchor: no pipelines, no molecules to move, no combustion to control — clean, controllable heat wherever electrons are cheap. Everything else (green fuels, waste heat recovery, CCS) plays a supporting role in this thesis: essential in specific sectors and gaps, but not the engine of broad heat electrification.

In Chapter 3 we cut the market by demand. Here we flip the lens: what are the actual tools in the box, and how do they score?

| | EFFICIENCY | CAPEX | MATURITY | RETROFIT | HEAT COST |
|---|---|---|---|---|---|
| **Industrial heat pumps**<br><250°C | COP 2.5–6 | 2–3× gas boiler | Commercial | Medium | £20–40/$MWh_{th}$ |
| ■ Solved below 200°C; deep tech above it | | | | | |
| **Resistance + thermal storage**<br>250–800°C (electric boilers below ~400°C; brick-buffered blocks above) | ~88% system (incl. storage losses) | ~£500/$kW_{th}$ | Pilot → commercial | High (storage-buffered) | ~£55/$MWh_{th}$ with arbitrage |
| ■ Back the platform, not the heater | | | | | |
| **Induction**<br>300–900°C | ~95% conversion | ~£700/$kW_{th}$ | Commercial (metals) | Medium | £45–60/$MWh_{th}$ |
| ■ Back applications + software, not coils | | | | | |
| **Arc / plasma**<br>1,500–10,000°C | ~1:1 conversion, no multiplier | Bespoke, very high | Commercial (EAF) / pilot (plasma) | Low | Power-price dependent |
| ■ Infra-PE kit; VC plays the enabling layers | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Solar thermal (CST)**<br>250–1,000°C | EFFICIENCY<br>n/a (fuel-free) | CAPEX<br>High, land-hungry | MATURITY<br>Commercial in high-DNI | RETROFIT<br>Low (siting) | HEAT COST<br>£25–50/$MWh_{th}$ |
| | ■ Geography play; back the enabling layer | | | | |
| **Waste heat recovery**<br><300°C | EFFICIENCY<br>>1× (upgrading) | CAPEX<br>Site-specific | MATURITY<br>Commercial | RETROFIT<br>Medium | HEAT COST<br>Very low, where local |
| | ■ Platform and marketplace plays | | | | |
| **$H_2$ / green fuels**<br>Any (flame) | EFFICIENCY<br>~50–65% power-to-heat | CAPEX<br>Burner cheap, fuel dear | MATURITY<br>Pilot at scale | RETROFIT<br>High | HEAT COST<br>>£100/$MWh_{th}$ unsubsidised |
| | ■ The last 10–20%; back burners, crackers, $NO_x$ control | | | | |

## Reading the toolkit

Seven technologies, one pattern. Run down the verdict column and the same conclusion keeps appearing: the value is never in the kit itself.

Heat pumps below 200°C are the exception that proves it — the efficiency multiple does the work, and the market is already crowded. Above 250°C, they're where steam engines were in the late 1600s: Thomas Savery's "fire engine" of 1698 could pump water, but made no economic sense; the industrial breakthrough came a century later. Getting heat pumps past 250°C needs new working fluids, cascade cycles, and compressors that survive continuous duty at 40–60 bar — genuine deep tech, with binary outcomes and no guarantee any bet pays off. We watch with interest. We are not writing that cheque yet.

Resistance, ohmic and induction heating are the workhorses of the 250–1,000°C band: instant, precise, 85–95% efficient at converting electricity into heat, and built from components that have been commodities for decades. Their constraint is that one-for-one conversion. At £100/MWh European power, that's £100/MWh of heat against a £35–50 gas boiler — unpaired, they lose everywhere except niches where precision and cleanliness command a premium (semiconductors, high-purity materials). Paired with thermal storage and dispatch software, they win. That pairing is the entire argument of the next section.

Arc and plasma own everything above 1,500°C — arc furnaces have been the backbone of scrap steel recycling for decades, and plasma torches reach 10,000°C. But the kit is bespoke, capital-hungry and welded to its site: infra-PE territory. The venture

entry point is making these systems easier to finance, operate and integrate, not building them.

Concentrated solar thermal is the geography play. Commercial plants already deliver 250–600°C at £25–50/MWh in high-sun regions — cheaper than gas, with storage baked in. Where the sun cooperates (southern Europe, MENA, Chile, Australia), it is unbeatable; where it doesn't, it is unavailable. Mirror fields are utility capital; the wedge is modular co-location units, high-temperature storage, and the integration layer that makes solar heat plug-and-play.

Waste heat recovery is the insult added to injury: Europe vents an estimated 300–500 TWh of technically recoverable waste heat into the sky every year — roughly France's entire industrial demand.[u] Heat doesn't travel, so the opportunity is hyper-local: platforms that map, match and monetise heat sources within a few kilometres of their offtakers, bundled into turnkey heat-as-a-service.

Green molecules — hydrogen, ammonia, biomass, e-fuels — are the patch kit for the final 10–20% of heat: processes where a flame or combustion atmosphere is genuinely non-negotiable (cement clinker, some glass furnaces), sites without the grid connection for multi-MW electrification, and the insurance value of a fuel you can store and trade. Because they consume roughly 1.5–2 times the clean electricity of direct electrification for the same heat,[f] they will never be the core engine, and their economics remain challenging: for hydrogen-based routes, even carbon prices around €200/t$CO_2$ may not be enough without targeted support ([ac]). The venture opportunities are the enablers: $H_2$/$NH_3$-compatible burners, modular ammonia crackers, $NO_x$ control, and the P2X software that decides when to make, crack or burn the molecule.

## The pattern, in one table

| TECHNOLOGY | THE COMMODITY — DON'T BACK | THE VENTURE PLAY — BACK THIS |
|---|---|---|
| **High-temp heat pumps** | — | **Nothing yet; watch the materials science** |
| **Resistance / ohmic** | Coils and electrodes | **Storage-coupled platforms, HaaS, dispatch software** |
| **Induction** | The coils (incumbents own them) | **Power electronics, modular SME units, AI process monitoring** |
| **Arc / plasma** | The furnace | **Financing, operations and integration layers** |
| **Solar thermal (CST)** | Mirror fields | **Modular co-location units, high-temp storage, retrofit integration** |

| | | |
|---|---|---|
| **Waste heat recovery** | Pipes and compressors | **Mapping and matching platforms, turnkey HaaS** |
| **Green fuels** | The molecules | **Burners, crackers, $NO_x$ control, P2X dispatch software** |

One column is where incumbents and infrastructure capital live. The other is where we do.

## Storage as the force multiplier

If electrification is the engine, storage is the gearbox. It turns volatile renewable power prices into stable, dispatchable heat that beats combustion on cost. Lithium-ion — the default for grids and mobility — isn't built for industry, so this is thermal storage's market: refractory bricks (600–1,200°C), molten salts (250–600°C, already commercial in CST), and lower-cost ceramic and hot-air systems in development.

Without storage, you're exposed to the hourly wholesale price — and an electric heater bought at average prices cannot compete with £35–50/$MWh_{th}$ combustion. With storage, you charge in the windy, sunny and curtailed hours at £20–40/MWh and discharge steady heat when the plant needs it. Storage also protects utilisation: expensive kit that idles through high-price hours destroys its own payback. And it stacks additional revenue on top — grid balancing payments, avoided curtailment, and negative-price arbitrage.

One discipline matters above all here: dispatch economics are local. A project should not be underwritten on average wholesale prices, but on site-specific hourly price distributions, tariff exposure, grid constraints, storage duration, charge-to-discharge ratios, and the offtaker's heat profile. Serious diligence also asks how many cheap hours actually exist in the local market, whether they persist as more flexible load arrives to chase them, and whether network charges erode the spread. These questions are answerable — but only at project level, which is precisely why the dispatch and integration layer, rather than the hardware, carries the value.

## Case study: resistance + brick storage (400–800°C)

Let's make the storage argument concrete. Take the workhorse system of the Tech Wedge — a resistance heater charging a stack of refractory bricks — and ask the only question an operator cares about: what does a megawatt-hour of heat from this system actually cost?

The answer has two parts: paying for the machine, and paying for the electricity that runs it. Our assumptions are deliberately conservative: £500/$kW_{th}$ of capex, 2% of that per year in maintenance, a 15-year life, an 8% cost of capital, an end-to-end system efficiency of 88% once storage and auxiliary losses are counted, and the unit running 80% of the hours in a year.

Part one: the machine. Borrow £500 per kilowatt at 8% and repay it over 15 years, and the annual bill is about £58 per kilowatt — the standard annuity calculation.[I] Add £10 of maintenance and the machine costs £68.45 per kilowatt per year, regardless of how it is used. Now spread that over its output: at an 80% capacity factor, each kilowatt delivers about 7 MWh of heat a year (8,760 hours × 0.80). Divide one by the other and the machine itself adds just £9.77 per $MWh_{th}$ — call it £10. Hold onto that number, because it carries the argument. Ten pounds of fixed cost against a £59 gas benchmark. The hardware is not where the economics are won or lost. Everything now depends on the electricity.

Part two: the electricity. An 88% system efficiency means every megawatt-hour of heat consumes 1.14 megawatt-hours of power — so the electricity component is simply the power price divided by 0.88. Which gives us the entire economics of the system in one line:

THE SYSTEM ECONOMICS IN ONE LINE

**Delivered heat cost ≈ (power price ÷ 0.88) + £10**

Now run that formula through four ways of buying electricity:

**Flat European average**
£100/$MWh_e$ power

Power £113.6
Fixed £9.8

£123

per $MWh_{th}$ delivered

LOSES BADLY

**Flat industrial tariff**
£80/$MWh_e$ power

Power £90.9
Fixed £9.8

£101

per $MWh_{th}$ delivered

LOSES

**Storage + arbitrage**
£40/$MWh_e$ power

Power £45.5
Fixed £9.8

£55

per $MWh_{th}$ delivered

■ WINS

**Curtailment windows**
£30/$MWh_e$ power

Power £34.1
Fixed £9.8

£44

per $MWh_{th}$ delivered

■ WINS COMFORTABLY

Gas benchmark: ~£59/$MWh_{th}$ including ETS exposure. Delivered heat ≈ (power price ÷ 0.88) + £10 fixed cost.

Read the table top to bottom and notice what doesn't change: the machine. Same bricks, same heater, same £10. The only thing that moves is when you buy power — and it swings the delivered cost from £123 to £44, from uninvestable to comfortably beating gas. Buy electricity on a flat tariff and the project is dead on arrival. Buy it like a trader — charging the bricks through the windy, sunny and curtailed hours, coasting through the expensive ones — and the same hardware undercuts combustion with room to spare.

That is the entire thesis of this paper compressed into one column of a table. The brick doesn't decide whether you win. The dispatch does — which is why we keep insisting the software layer, not the heater, is where the value lives.

Negative-price hours — which now cover meaningful chunks of the year in Germany, the Netherlands and California — push the logic further still: the system is paid to charge. That said, negative prices should be treated as upside in an underwriting model, not base case.

A necessary caveat. This is a deliberately simplified levelised cost of heat (LCOH). It excludes site integration, grid connection charges, electrical upgrades and network tariffs, and it treats capex as a single £/$kW_{th}$ figure when a real system is sized on three linked variables: charging power, discharge power, and storage duration. A system that buys only the cheapest hours must charge faster than it discharges and hold enough thermal inventory to bridge the gaps between them — which raises capex, and makes the 80% capacity factor and £30–40/MWh average purchase price design targets to be earned, not assumptions to be granted. In practice, the key design variable is the ratio between charging power, discharge power and storage duration, and it is project-specific. The direction of the conclusion survives all of this; the precise numbers are illustrative.

## No silver bullets

Look across the toolkit and the pattern is unambiguous: electrification is the anchor, storage is the enabler, and the moat is in integration. Green fuels and waste heat recovery matter, but they're the last 10–20% of heat, not the engine.

The wedges told us where the market sits; the toolkit tells us which technologies fill them. And in every single row of the table, the verdict points the same way: nobody makes billions selling electrodes or molten salt tanks. The value sits in the layer between the commodity kit and the industrial end-user.

Which raises the obvious next question: if these are the tools, and these are the wedges, where along the value chain should capital flow to capture the upside?

# **Makers,** solvers, scalers

The opportunity above 250°C has multiple points of entry for startups and investors, each with its own risk/return profile. We break the chain into three layers: the makers, the solvers, and the scalers.

## Makers

WHO THEY ARE
The hardware: storage media, heating elements, high-temp heat pumps, power electronics

EXAMPLES
Rondo (US, firebricks), Antora (US, carbon blocks to 1,800°C), Kraftblock (DE), Kyoto Group (NO, molten salt), Caldera (UK), Heaten (NO, high-temp heat pumps), Coolbrook (FI, electric cracking)

HOW THEY MAKE MONEY
Sell or lease equipment

THE CATCH
Commoditisation — margins compress as the tech proves out

## Solvers

WHERE WE FOCUS

WHO THEY ARE
The integration layer: system integrators, dispatch and optimisation software, MRV, Heat-as-a-Service structurers

EXAMPLES
The thinnest layer in Europe today — and that's the point

HOW THEY MAKE MONEY
Recurring: £/$MWh_{th}$ delivered, software, a share of carbon value

THE CATCH
Commercial execution across operators, financiers and grid

## Scalers

WHO THEY ARE
The balance sheets: EPCs, OEMs, utilities, infra funds

EXAMPLES
Siemens Energy, MAN Energy Solutions, ENGIE, E.ON, infrastructure PE

HOW THEY MAKE MONEY
Own assets, sell heat under long-term contracts

THE CATCH
Capital intensity — and they'd rather buy capability than build it

The makers are where the money has gone so far. Thermal storage startups raised roughly $300 million in 2024 (including Antora's $150m Series B) and another $200 million in 2025.[m] The result is a well-stocked shelf: firebricks, carbon blocks, recycled

steel slag, molten salt — pick your medium. Kraftblock's is our favourite detail in this market: their storage material is made from steel slag, a blast-furnace waste product.[n] The decarbonisation technology is literally built from the waste of the industry it decarbonises.

But the makers layer is starting to rhyme with solar panels circa 2010: necessary, investable early, commoditised late. As soon as three companies can sell you a hot brick, the brick stops being the moat. And the early deployments show where the commercial pragmatism lives: Rondo's first commercial 100 MWh heat battery went live in October 2025 — in the Kern County oil fields, making steam for enhanced oil recovery.[o] The first paying customer for clean heat was an oilfield. Purists will wince. We see commercial discipline: revenue first, decarbonisation follows the cost curve down.

The solvers are where the money should go next. This is the layer that turns a commodity brick into bankable heat: origination, plant integration, dispatch software that buys the £30/MWh hours, MRV that turns abatement into auditable carbon value, and the contract structures that move the capex off an operator's balance sheet. In the taxonomy we use across our portfolio, this is the picks-and-shovels and the books-and-ledgers of industrial heat — and in Europe it is almost entirely unclaimed. Nobody has yet built the platform that does for a 5 $MW_{th}$ heat block what the residential players did for rooftop solar: show up, finance it, install it, run it.

The category is emerging rather than hypothetical. The first solver-shaped companies are appearing as heat developers spun out of energy-trading and battery-optimisation businesses, and as service arms attached to the makers themselves — the leading storage companies increasingly sell delivered heat rather than hardware, which is a solver business wearing a maker's badge.

Concretely, we expect three archetypes to define the layer: the heat developer, which originates, finances, builds and operates HaaS assets on industrial sites; the dispatch layer, software that optimises charging, trading and delivery across a fleet of heat assets it doesn't own; and the structurer, which packages operating data, performance guarantees and carbon value into financeable — eventually securitisable — contracts. The winning companies will likely combine two of the three.

We've also watched this movie before, twice, in our own portfolio. In grid-scale batteries, the value didn't accrue to whoever made the cells — it accrued to whoever ran the trading and dispatch stack on top of them, which is why our investment in Terra One was never really a bet on hardware. And in residential energy, Fornax finances heat pumps and batteries by underwriting the operating data and securitising the leases.

Industrial Heat-as-a-Service needs exactly that machinery, one order of magnitude up in ticket size. Same playbook. Hotter set.

The scalers are not a venture play — they're the exit. EPCs, OEMs and utilities will own and operate the assets at scale, and history says they'd rather acquire the capability than spend five years building it. Siemens Energy is already partnered with EnergyNest on thermal storage; the acquirers are circling before the market has even formed. This is what underwrites the eight-year exit path we come back to below: every solver we back should be legible, from day one, as an acquisition to someone on that list.

So: selective on makers, concentrated on solvers, and treat the scalers as the customers and acquirers they are. Don't back the brick. Back whatever makes the brick bankable.

## Anatomy of Heat-as-a-Service

Because the solver thesis leans so heavily on Heat-as-a-Service, it's worth being precise about what the model actually contains.

A full HaaS contract bundles the entire journey from site audit to delivered megawatt-hour: system design and storage sizing against the plant's heat profile; grid connection strategy; financing; installation; power procurement (PPAs, market access, hedging); dispatch optimisation; operations and maintenance; MRV and carbon accounting; and — the piece that makes it a service rather than a project — a guaranteed delivered heat price over the contract term.

The customer's logic is straightforward. HaaS removes the capex from their balance sheet, transfers the technology and power-price risk to a counterparty built to hold it, guarantees uptime and performance, and converts a daunting decarbonisation programme into a service contract their procurement team already knows how to sign. The operator keeps doing what they're good at — making steel, paper, or food — while someone else worries about the electrons.

The financing evolves with scale. Early deployments sit on the startup's balance sheet; the next tranche moves into SPVs and project finance as reference data accumulates; utility and infrastructure partners take the growth capital; and eventually — once operating histories exist across a portfolio of contracts — the assets can be securitised, exactly as residential solar leases were before them. That last step is what turns a heat company into a platform: the operating data underwrites the paper, and the paper recycles the capital. It is also why the dispatch and MRV software matters twice over — once for the margin, and once because it generates the very data the financing depends on. None of this is easy, and we should say so: the solver owns the risk stack — uptime, power procurement, performance guarantees, counterparty quality and financing cost.

That is why the category is difficult, why the layer is still thin, and why, executed well, it is valuable.

## The window is open

One more reason this chapter matters now rather than in 2030. Incumbent strategies today are efficiency tweaks and pilot-scale hydrogen, while the full pressure from carbon pricing, CBAM and (albeit potentially slower) declining free allocation builds progressively through the 2030s. Most boards will treat it as tomorrow's problem right up until their "oh-no moment". When the pressure arrives, they won't spend five years building in-house. They'll buy. Which means the solvers that exist by then — validated technology, contract pipelines, regional references — get acquired at strategic prices.

The reality check still applies: this isn't SaaS. Timelines run 5–10 years, capital intensity is real, and exits look like strategic acquisitions, not IPOs. The arithmetic behind the eight-year path is simple: enter in 2026–27, and the compliance wall lands roughly eight years into the hold — inside a venture fund's life, at precisely the moment strategic buyers are most motivated. But that's a feature if you enter early: prove the model while the incumbents wait, and be the obvious call when they move. A textbook timing play.

RISK REGISTER

### What kills this thesis

A thesis paper should name its own failure modes, so here are ours.

**01 Gas price collapse**

If European gas returns to pre-crisis levels and stays there, the arbitrage spread narrows and every project in this paper gets harder to finance — carbon pricing is the hedge, which is why the ETS trajectory and the last July proposed revision matters more to us than any single technology.

**02 Hardware from China**

If Chinese thermal storage undercuts European makers on cost, the makers layer commoditises faster than expected — painful for hardware investors, but note that it strengthens the solver thesis, since integration, financing and dispatch are local-service businesses that imported bricks cannot displace.

**03 The grid**

If connection queues and tariff reform stall, the deployment curve flattens regardless of project economics — the single biggest exogenous risk, and the reason Chapter 6's grid files deserve close watching.

**04 Cheap-hour erosion**

Dispatch arbitrage is a spread, and spreads attract competition; as batteries, electrolysers and heat loads all chase the same cheap hours, the spread compresses. We think heat's advantage — cheap, long-duration thermal storage — lets it outlast lithium-ion in that competition, but any project underwritten today should be stress-tested against a materially thinner spread in 2035.

None of these kill the direction of travel. Any of them can kill an individual deal — which is, once again, why the diligence is local.

# **Brussels** holds the thermostat

By this point, the report's taxonomy is clear. There is no single route to decarbonising industrial heat, but across much of the 250–800°C wedge at the centre of our thesis, electrification is the most likely pathway and the opportunity is no longer purely technology-blocked. The remaining barriers are economics, infrastructure, demand and horizontal constraints. This chapter looks at the main policy responses currently taking shape, from carbon and power prices to grid access, investment support and demand for cleaner products, and what investors should watch.

Industrial heat decarbonisation has moved rapidly up the EU agenda as competitiveness, energy security and fossil-fuel dependence have become as important as climate ambition, with electrification becoming a prominent part of the policy response. The recent EU Electrification Action Plan (EAP) is a clear signal of this shift: it sets an indicative objective to increase electricity's share of final energy consumption from around 23% today to 46% by 2040 across industry, buildings and transport[ad].

For industrial heat, the important development is not one individual target or subsidy. A broader policy mix is emerging, and necessary.

## Carbon pricing is the central tool — but no longer expected to do all the work

The EU Emissions Trading System remains the core decarbonisation policy instrument for energy-intensive industry. Its logic is straightforward: putting a price on fossil emissions makes carbon-intensive production more expensive relative to cleaner alternatives. ETS II, expected to start in 2028, extends that logic to fuels used by smaller industrial installations outside ETS I.

Recent analysis by EPICO and FfE shows both how far carbon pricing can go and where its limits begin. In their economy-wide 2050 model, a carbon price of around €200/t$CO_2$ would make measures covering roughly three quarters of the assessed emissions-reduction potential economically viable. The final quarter is much harder:

some measures would only become economical at carbon prices above €1,000/$tCO_2$[ac]. Carbon pricing can therefore drive a large share of the transition, but relying on ever-higher prices alone quickly runs into economic and political limits.

This is why the 2026 ETS review is such a consequential policy development for industrial decarbonisation. The Commission is proposing a more gradual tightening of the system than under current legislation, alongside extended free allocation and additional flexibility through international credits and permanent removals. This would reduce some of the carbon-cost pressure industry would otherwise face during the 2030s[ag][aj].

But this is only half of the story. The same proposal would make free allocation increasingly conditional on decarbonisation investment and expand dedicated industrial funding, including through a new Industrial Decarbonisation Bank[ag]. Both are designed to accelerate low-carbon investment in energy-intensive industry and are discussed further below.

This marks an important shift in the role of the ETS. Rather than relying on an increasingly stringent carbon price, the Commission is trying to turn the system more directly into an industrial investment tool. The logic is pragmatic: a very high future carbon-price pathway is a weak investment signal if companies expect governments to intervene before it is reached. The proposed compromise therefore trades some future carbon-cost pressure for stronger investment conditions and support. For investors, the key question is whether this produces a more credible pipeline of industrial decarbonisation projects, rather than simply reducing pressure on incumbents.

## Electricity prices: shifting the economics

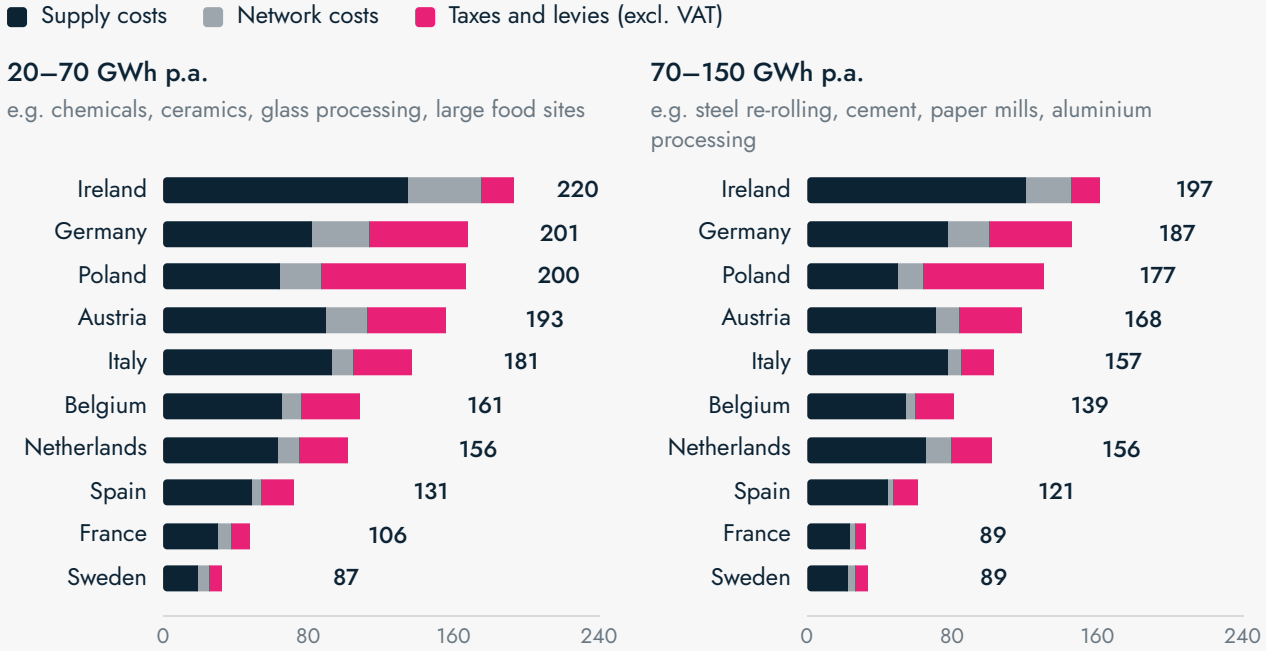
Carbon pricing makes fossil heat more expensive. For electrified heat technologies, the other half of the business case is the price of power: if electricity remains too expensive relative to gas, many projects will struggle to compete[x]. The EAP therefore encourages Member States to bring the industrial electricity-to-gas price ratio down to two or below by 2030[ad]. This is not a universal break-even point, but it signals the direction in which EU policy is trying to move the economics.

One of the most recent proposals to narrow this gap concerns taxation. Taxes have often disadvantaged electricity compared with gas. The EAP and accompanying proposal on future-proofing electricity bills would require electricity excise duties to be no higher than those on natural gas and make it easier for qualifying energy-intensive businesses to benefit from reduced or potentially zero electricity taxation. After years of limited political progress, this could remove part of electricity's structural cost disadvantage.[ae]

FIGURE 3

## Industrial electricity costs vary sharply across EU markets, with taxes, levies and network charges materially shaping the final bill

2025 electricity-price composition for non-household consumers in the 20–70 GWh and 70–150 GWh annual consumption bands, selected EU countries (€/MWh).




€/MWh, 2025. Countries ordered by total price in the 20–70 GWh band.

Source: Representation based on Eurostat (2025), electricity price components for non-household consumers, annual data [nrg_pc_205_c].

Taxation is only one part of the electricity-price challenge. Industrial power costs also reflect wholesale market prices and the generation mix, network charges and the contracts through which companies buy electricity. For storage-buffered heat, it is not only the average price that matters, but the spread between lower- and higher-price hours. Power-market design and procurement are therefore central to the policy response. The EAP, for example, again puts PPAs and industrial demand pooling at the centre of efforts to reduce exposure to short-term price volatility and make future power costs more predictable[aaad].

"Achieving cost parity with fossil fuels in a specific application requires choosing the right combination of technologies, sizing them correctly against a site's heat load and demand profile, and structuring energy procurement to capture low-price hours. A heat pump paired with thermal storage, correctly configured, can beat gas on cost in many European markets today. But that outcome is not automatic. It requires people who understand both the thermodynamics and the economics, and who can navigate the national rules around grid tariffs, subsidies, and flexibility revenues that vary significantly across Europe."

CALDERA

## Grid access and flexibility: a make-or-break factor

An attractive electricity price means little without a usable connection. Industrial projects can face connection waits of two to ten years, including smaller projects. The challenge is highly location-specific: many established industrial regions face rising electricity demand without being located where large volumes of renewable power and spare grid capacity are available. Onsite generation, storage and flexible consumption can help, but the options differ substantially by site. Grid access, connection costs and network charges are therefore becoming decisive factors in where electrified industrial heat can scale.[afz]

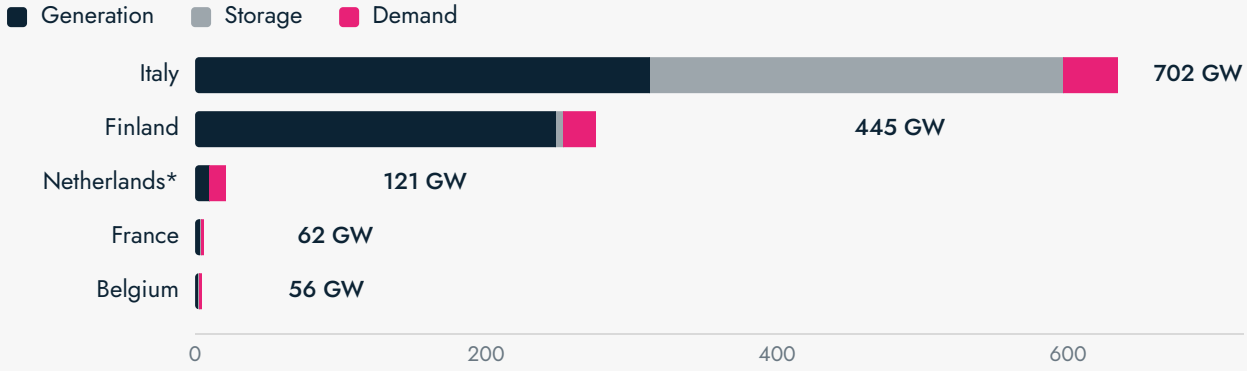
EU policy is starting to address these constraints more directly. The European Grids Package and the electricity-bills proposal promote better queue management, project-readiness checks and flexible connection agreements (FCAs), which can allow earlier access where companies accept limits on consumption at constrained times. They also seek to make network charges more responsive to flexibility, which matters especially for storage-buffered systems, whose economics depend on shifting electricity consumption into cheaper and less constrained hours.[afae]

The opportunity is real, but implementation largely sits with national regulators and network operators. Several Member States are now reforming network-charge design. For investors, this makes local grid conditions increasingly part of site selection and project screening: the same technology can face very different economics depending on connection availability, local tariff design and the value placed on flexibility.

FIGURE 4

### Grid connection queues have reached tens to hundreds of GW across several European markets

Projects in transmission-grid connection queues by type, selected European countries (GW).




Transmission-grid queues only, as of 2025 — from connection inquiry to physical delivery, including projects that may never be realised. *Dutch data include ~70 GW of battery storage within generation and demand.

Source: Boston Consulting Group, Tom Brijs et al. (September 2025), *Mind the Queue: Connection Reform for the Electricity Grid*, p. 5.

> "Grid access and grid fees are the two issues that will make or break industrial electrification. Power-to-heat with thermal storage offers exactly the combination of flexibility and off-peak consumption the grid needs."
>
> ALEX ROBERTSON, CEO ENERGYNEST

## Industrial heat is receiving more dedicated support

Lower operating costs and better grid access do not remove the investment hurdle. Industrial retrofits still require upfront capital, integration work, and can disrupt production. They also happen against long industrial investment cycles: miss the replacement window and another fossil asset can remain in place for years or decades. Public support can help bridge that gap, especially for first deployments and smaller companies, but its timing matters as much as the size of the funding pot and the design of the scheme[x].

Electrified heat may sit at the centre of this report's thesis, but it has not historically sat at the centre of EU industrial-decarbonisation funding. Direct electrification has been underrepresented compared with hydrogen and carbon-management pathways[y]. The

recent Innovation Fund Heat Auction marks a clear change in direction. It awards a fixed premium for verified decarbonised heat production for up to five years. In its first round, 65 projects were selected for around €400 million, covering electric heat as well as direct renewable heat such as solar thermal. A second Heat Auction, with a €1 billion budget, is due to open in December 2026[ah].

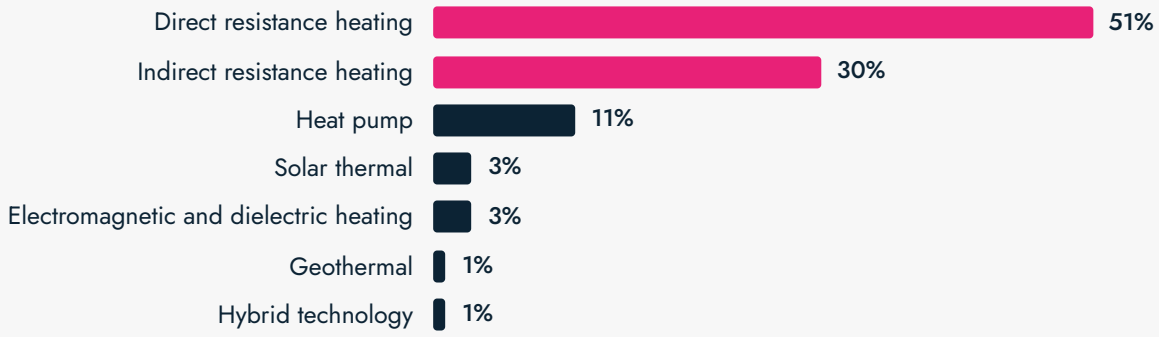
The importance of the auction goes beyond its first funding round. It provides a practical test of a more deployment-oriented model for industrial heat, and its strong uptake gives the EU a basis for refining and scaling support. The proposed ETS revision points to a potentially larger next step through the Industrial Decarbonisation Bank, which is intended to help mobilise €100 billion for industrial decarbonisation[ag].

For investors, the direction is encouraging. The key question is whether this support can scale beyond individual auctions while remaining flexible enough to reflect the very different economics of industrial sectors, technologies and sites.

FIGURE 5

### Resistance heating dominates applications to the EU's first industrial heat auction

Technology distribution of applications to the IF25 Heat Auction (% of applications).




Resistance heating, direct and indirect, accounts for 81% of applications.

Source: European Commission (20 March 2026), *Innovation Fund 2025 auctions attract almost €10 billion of bids from European industry for decarbonisation support.*

## Public purchasing is becoming an industrial-policy instrument

Public procurement is becoming one of the EU's new favoured industrial-policy tools. Rather than supporting cleaner production mostly through subsidies, policymakers are increasingly trying to use public demand to create markets for low-carbon and European-made products. With public procurement representing around 15% of EU GDP, public buyers can provide important anchor demand, particularly in the early stages of emerging markets.

The proposed Industrial Accelerator Act (IAA) is the clearest example: for the first time, it would introduce EU-wide low-carbon and local-content requirements across selected procurement and public-support schemes. Its current focus is on sectors such as steel, cement and aluminium, rather than the full range of industrial heat applications covered in this report. But the direction is important: policy is beginning to address not only the cost of cleaner production, but also demand for what that production delivers.[ai] [ab]

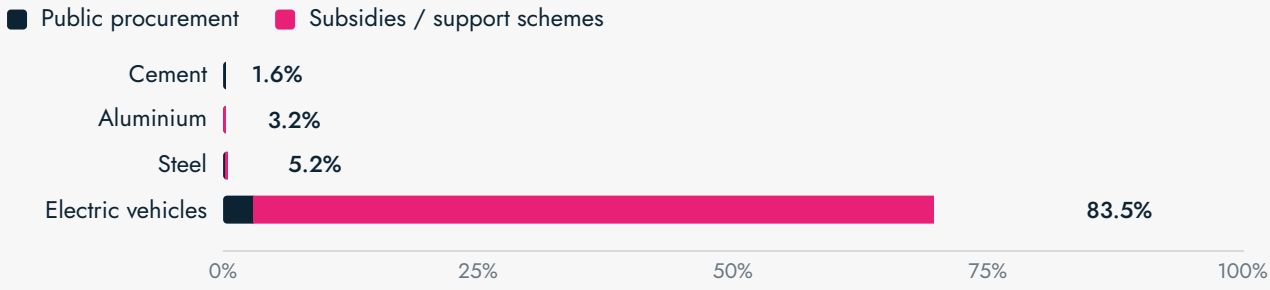
And public purchasing alone will not be enough. Product standards and better information can help extend the signal into private markets. The Ecodesign for Sustainable Products Regulation (ESPR), for example, provides a framework for sustainability and information requirements for products sold in the EU. Iron, steel and aluminium are among the first priority product groups, putting new sustainability rules for these materials into the policy pipeline[al].

How significant this becomes will depend on scope and implementation. In its current proposed form, the IAA would affect only a limited share of demand in several sectors[ab]. But the broader policy direction is likely to grow in importance: using procurement and other demand-side tools to create markets for cleaner European production. For investors, that matters because stronger demand signals can improve the business case for the technologies and projects that sit behind those products.

FIGURE 6

### The proposed IAA reaches only a small share of demand in basic materials

Estimated share of annual EU market or deployment covered by public-procurement and subsidy/support-scheme provisions, by sector (%).




Example: current provisions would touch about 5.2% of the EU steel market — 3.4% via public procurement and 1.8% via support schemes. Auction and manufacturing-project channels are not included.

Source: Jacques Delors Centre / Hertie School, Philipp Jäger and Nils Redeker (June 2026), assumptions and methodology underpinning Figure 5 of *Paradigm Shift in Principle, Paper Tiger in Practice? How to Make the Industrial Accelerator Act Count.*

# Execution roadmap

Each stakeholder has a part to play, and the parts are different. Here's what each of you should be doing — and watching for.

FIGURE 7 · EXECUTION ROADMAP, 2025–2035

| | 2025–2027 | 2028–2031 | 2032–2035 |
|---|---|---|---|
| **Operators** | Pilots (brownfield retrofits) | Phased rollouts (replication) | Deep retrofits / fleet-scale adoption |
| **Startups** | Prove drop-in capability | Modularise (1–5 MW+ blocks) | Build the software spine (dispatch + MRV) |
| **Investors** | Back pilots / early integration | Scale storage-paired systems | Strategic exits / infra partnerships |
| **Policymakers** | **Fix economics**<br>• ETS reform<br>• Electrification Action Plan<br>• Heat Auctions<br>• Power-market reforms | **Scale deployment**<br>• CBAM phase-in<br>• Industrial Decarbonisation Bank<br>• Lead markets<br>• ETS free-allocation phase-out | **Market-driven adoption** |

## For operators: brownfield first

Nobody expects you to bet the fleet. Industrial managers won't sign off multi-gigawatt greenfield plants, and they shouldn't — but a 5–20 $MW_{th}$ electrified block tied into an existing steam network is a pilot a plant manager can defend. Start there. Each successful pilot sharpens the economics of the next one, and repetition is the whole game: pilot, prove, replicate, until the retrofit has quietly spread across the fleet. The one mental shift that matters from day one: treat electrification as a full-system retrofit, not a furnace swap. The heat source touches everything downstream of it, and the operators who plan for that will be the ones whose pilots actually replicate.

## For startups: prove, then scale

Your first job is unglamorous and non-negotiable: show you can plug into a live plant with minimal to no disruption. Nothing else matters until an operator believes that. Your second job is to standardise — 1–5 $MW_{th}$ blocks, so every deployment gets cheaper

and faster than the last and the capex spreads thinner with each unit. And your third job is where the moat gets built: dispatch optimisation and MRV. Dispatch turns volatile power prices into predictable heat economics; measurement, reporting and verification turns the abatement into tradable carbon value that improves every customer's return. The hardware gets you in the door. The software keeps you in the building.

## For investors: back what's bankable

The first thing to internalise is that the economics are local. A global TAM slide tells you almost nothing; local power prices, achievable capacity factor and integration cost decide whether a given deployment wins or loses. The second is that storage is a prerequisite, not a feature — without it, electrified heat is hostage to grid volatility, and not worth the bet. So the diligence checklist writes itself: pilots running, contracts in hand, and dispatch economics proven with real market data rather than assumed. And for anything pitching itself as a platform, ask the geography question early: how does this scale across markets whose power prices, tariffs and grid rules all differ — and does the team demonstrably know that they do?

## For policymakers: fix, scale, then step back

First, fix the economics (now–2027). Narrow the structural gap between electricity and fossil fuels while making early projects easier to finance. That means power-price measures, credible carbon pricing, deployment support and the first lead-market instruments.

Then, scale deployment (2028–2031). The proposed Industrial Decarbonisation Bank moving from design to implementation, lead markets creating stronger demand, and CBAM and the evolving ETS framework progressively reshaping industrial economics — giving early movers a clearer route from supported projects to commercial scale.

Then, step back (2032 onwards). If power economics improve, grid bottlenecks ease and demand for cleaner products becomes more visible, public support can become more targeted and commercial deployment should carry more of the load.

The sequencing matters more than any single instrument. Public funding cannot compensate indefinitely for structurally poor power economics, while lower electricity prices alone do not solve upfront capex, grid access or first-mover risk. The investable case strengthens when operating economics, infrastructure, deployment support and demand signals improve together.

# Where industry will land

### By temperature band (what actually wins)

Below 200°C, heat pumps win everywhere. The efficiency multiple still beats combustion, and by 2040 this band is simply finished business — crowded, subsidy-shaped, and commodified. Good for the climate; long since priced for investors.

The 250–800°C band — our Tech Wedge — is where the map redraws. Resistance and ohmic heating paired with thermal storage becomes the default across European and American grids, wherever price volatility lets dispatch buy cheap power and deliver £40–60/$MWh_{th}$ heat. Concentrated solar thermal runs a second lane through the high-DNI regions — southern Europe, MENA, Chile, Australia — with storage baked in and delivered costs of £25–50/MWh where the siting works. Hybrid electrification with green fuels covers the local gaps: constrained grid connections, awkward process chemistry.

Between 800 and 1,200°C sits the hard middle, and it resolves piecemeal rather than wholesale. Arc and plasma furnaces scale for recycling and specialty processes. Electrified kilns with integrated $CO_2$ capture start appearing in cement and lime. Hydrogen and ammonia burners take the slots where a flame or a combustion atmosphere is genuinely non-negotiable — enabled by the crackers and $NO_x$ control systems we flagged in the toolkit. And throughout, the storage blocks get bigger and the dispatch software stops being a differentiator and becomes table stakes.

Above 1,200°C stays niche and infra-heavy. Plasma torches and hydrogen combustion are feasible, but everything hinges on ultra-cheap power and deep integration — so infra-PE does the heavy lifting on the core kit, while venture plays the enabling layers: sensors, controls, safety systems, MRV, optimisation. Exactly the division of labour our value chain chapter predicts.

## Regional breakdown

EUROPEAN UNION

### The first mover, if it wants to be

Europe starts this game holding three cards no other region has together.

The first is urgency. No industrial bloc is more exposed to imported fossil fuels and volatile gas prices — the Strait of Hormuz disruption cost the EU €24 billion in fifty-two days, and every repeat is a reminder that combustion is a geopolitical liability, not just a climate one.[w] For European industry, electrification isn't only decarbonisation. It's insurance.

The second is the policy push — the strongest anywhere, but conditional. If power prices are dealt with seriously, if the ETS review maintains a credible carbon signal while strengthening investment incentives, if support measures such as the Heat Auctions and proposed Industrial Decarbonisation Bank are organised effectively, and if lead-market creation actually lands, Europe could create a powerful pull towards electrified heat. If those files stall, the tailwind becomes a breeze.

The third is the raw ingredients. Europe has a large industrial base sitting next to rapidly growing renewable capacity — precisely the combination the storage-plus-dispatch model feeds on: big continuous loads, volatile power prices, and curtailed clean energy going begging. The problem and the solution are already co-located.

Our call: EU sites electrify first, led by 250–800°C resistance-plus-storage deployments, with early cement and steel pilots in the 800–1,200°C band as carbon costs bite. Europe won't have the cheapest power or the biggest single market. But it has the strongest reasons to move and — conditionally — the strongest push. First-mover advantage in industrial heat will be won or lost here.

UNITED STATES

### The storage-and-dispatch market

The US combines a large renewables build-out with persistent transmission constraints, producing exactly the price shape our model feeds on: CAISO curtailed 3.4 TWh in 2024, and Southern California wholesale prices were negative in roughly 23% of hours in the first half of that year.[p] Resistance heating with brick or ceramic storage, wrapped in Heat-as-a-Service and dispatch software, fits that market naturally — the economics are made in the software: buy low, run high, sell steady. Federal support through the DOE's Industrial Demonstrations Program directed multi-billion-dollar funding into first-of-a-kind decarbonisation projects, though a number of awards were

cancelled in 2025 — the surviving pilot base still accelerates the market, but US federal support should be underwritten as volatile.[q] For investors, the US is where dispatch models can be proven fastest — and where a European solver's playbook can be tested against a deeper, more volatile power market.

CHINA AND INDIA

## Scale first, policy later

Both will prioritise cost and scale while policy tightens gradually. Expect electrification to begin in coastal and industrial clusters, with a second wave as compliance regimes and local supply chains mature. China's expansion of its national ETS to steel, cement and aluminium is the unlock to watch: once compliance bites, retrofits will accelerate quickly, and at a scale that resets global cost curves.[r] India's industrial demand keeps growing and policy is improving, but coal remains entrenched — expect selective electrification, and strong waste-heat and CST adoption where the economics already clear.[s] Neither is an early market for European solvers; both set the eventual scale of the prize.

MENA AND THE SUNBELTS

## CST territory

High direct normal irradiance and available land make concentrated solar thermal with molten-salt storage a natural fit for process heat close to load. By 2040 we expect on-site or nearby CST to supply a meaningful share of mid-temperature industrial demand in these regions, often at or below fossil parity.[t] The investment implication mirrors the toolkit: the mirror fields belong to utilities and sovereign capital; the enabling layer travels.

# The billion-dollar playbook

There is no credible net zero without high-temperature heat. More than half of industrial demand sits above 200°C, yet over 85% of it is still fossil-fired — and cement, steel, chemicals and glass are the building blocks of civilisation.

Industrial heat is the overlooked half of the energy transition. Low-temperature heat is being solved by heat pumps. Ultra-high-temperature heat will be solved slowly, by infrastructure capital. But the 250–800°C band is open now: the hardware exists, the demand is sticky, and the missing layer is integration — storage, dispatch, financing, MRV, and performance contracting.

Our view is simple: don't back commodity heat equipment. Back the companies that make electrified heat bankable for brownfield industry. The winners will standardise modular systems, buy electricity intelligently, guarantee delivered heat, and package decarbonisation as a service their customers already know how to buy. Don't back the brick. Back whatever makes the brick bankable.

Timing is the final piece. Policy pressure will build progressively through the 2030s, while renewable overbuild and curtailment are widening the price spreads that dispatch models monetise. By the early-to-mid 2030s, those pressures converge into a corporate compliance wall, when incumbents who treated decarbonisation as tomorrow's problem will need to buy proven capability rather than build it. The next five to ten years are the decisive window: the companies proving modular retrofits, Heat-as-a-Service pipelines and dispatch economics today will be the natural acquisitions when that moment arrives.

This isn't SaaS, but it is venture-scale: global >300°C delivered-heat demand is worth roughly £430–610 billion annually, and the EU's 250–800°C investable wedge alone is worth tens of billions a year. With storage as the gearbox, electrification as the engine, and integration as the moat, fires-to-wires is not a single technology bet. It is a new industrial energy stack — and the firms that assemble it will own the decisive decade ahead.

# Glossary

| | |
|---|---|
| **Brownfield / greenfield** | retrofit of an existing plant versus construction on a new site. This paper's thesis is brownfield-first: industrial assets live 40–60 years, so decarbonisation must thread into plants that already exist. |
| **CAISO** | the California Independent System Operator, manager of most of California's grid; cited here as the leading indicator of what renewable overbuild does to power prices. |
| **CBAM** | Carbon Border Adjustment Mechanism. The EU's carbon levy for imports of selected carbon-intensive goods, initially covering cement, iron and steel, aluminium, fertilisers, electricity and hydrogen. Its definitive regime applies from January 2026 and is designed to align the carbon cost of imports with those faced by EU producers under the ETS. Under current legislation, CBAM is phased in as free allocation for covered EU producers phases out; the Commission's 2026 ETS revision proposal would slow that phase-out, with free allocation ending fully by 2038 rather than 2034. |
| **CCfD** | Carbon Contract for Difference. A state contract that pays out the gap between an agreed carbon strike price and the actual ETS price, de-risking low-carbon industrial investment (Germany's Klimaschutzverträge are the reference example). |
| **CHP** | combined heat and power: plants that generate electricity and useful heat from the same fuel. |
| **COP** | coefficient of performance: the units of useful heat a heat pump delivers per unit of electricity consumed. Used in this paper only for heat pumps; direct electric heating is described by system efficiency instead, since it has no thermodynamic multiplier. Not to be confused with the UN climate conferences. |
| **CST** | concentrated solar thermal: mirrors or lenses focusing sunlight directly into heat, typically stored in molten salts or solid media. |
| **Curtailment** | the deliberate reduction of renewable generation when the grid cannot absorb it: clean power discarded, and the cheap-hour feedstock this paper's dispatch thesis feeds on. |
| **DNI** | direct normal irradiance: the direct-beam solar energy a site receives, in kWh/m$^2$/yr. CST needs roughly >1,800 to pencil. |
| **EAF** | electric arc furnace: the electrode-driven furnaces that have anchored scrap steel recycling for decades. |

| | |
|---|---|
| **EPC** | engineering, procurement and construction contractor: the firms that actually build and integrate industrial energy assets. |
| **ESPR** | Ecodesign for Sustainable Products Regulation: the EU framework for setting sustainability and transparency requirements on products sold in the single market. |
| **ETS I / ETS II** | the EU Emissions Trading System, the bloc's cap-and-trade carbon market covering power and heavy industry (ETS I); ETS II extends carbon pricing to buildings, road transport and smaller emitters from 2028. |
| **Fit-for-90** | shorthand used in this paper for the anticipated legislative package implementing the EU's proposed 2040 target of a 90% net emissions reduction. Unlike "Fit for 55," not yet an official package name; see Chapter 6. |
| **Free allocation** | ETS allowances granted to industry at no cost to limit carbon leakage; scheduled to phase out through 2034 as CBAM phases in. |
| **HaaS** | Heat-as-a-Service: delivered heat sold under a long-term contract at a guaranteed price, with the provider owning the asset, the power procurement and the performance risk. Anatomy in Chapter 5. |
| **IAA** | Industrial Accelerator Act: proposed EU legislation to create demand for low-carbon, European-made materials through procurement and support schemes. Under negotiation at time of writing. |
| **LCOH** | levelised cost of heat: the all-in cost per $MWh_{th}$ of delivered heat over an asset's life, including capital, maintenance and energy. (Elsewhere the acronym sometimes means levelised cost of hydrogen; in this paper it always means heat.) |
| **MRV** | measurement, reporting and verification: the instrumented accounting that turns claimed emissions abatement into auditable — and monetisable — carbon value. |
| **$MW_{th}$ / $MWh_{th}$** | thermal megawatts (heat output capacity) and thermal megawatt-hours (heat energy delivered); the subscript distinguishes thermal from electrical ($_e$) quantities. |
| **OEM** | original equipment manufacturer: the incumbent industrial equipment makers. |
| **P2X** | power-to-X: converting electricity into molecules (hydrogen, ammonia, synthetic fuels) or other carriers. |
| **PPA / sleeved PPA** | power purchase agreement: a long-term contract for electricity at agreed terms. "Sleeved" means routed through a utility that handles delivery and balancing between generator and buyer. |
| **SPV** | special purpose vehicle: a ring-fenced entity holding an asset and its contracts so it can be financed on its own cash flows. |

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| **TAM** | total addressable market. Used carefully in this paper; see the sizing hierarchy in Chapter 3. |
| **TRL** | technology readiness level: the 1–9 maturity scale, where 9 means proven in commercial operation. |

# Sources

## Technology and market chapters


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## Policy chapter


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# Don’t back the brick.

Back whatever makes the brick bankable.

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