SERINYX QUORUM SHOWCASE

The Best Temperature Is Taken

850 to 950

degrees Celsius, the first-of-a-kind window inside six live ranges

147.87

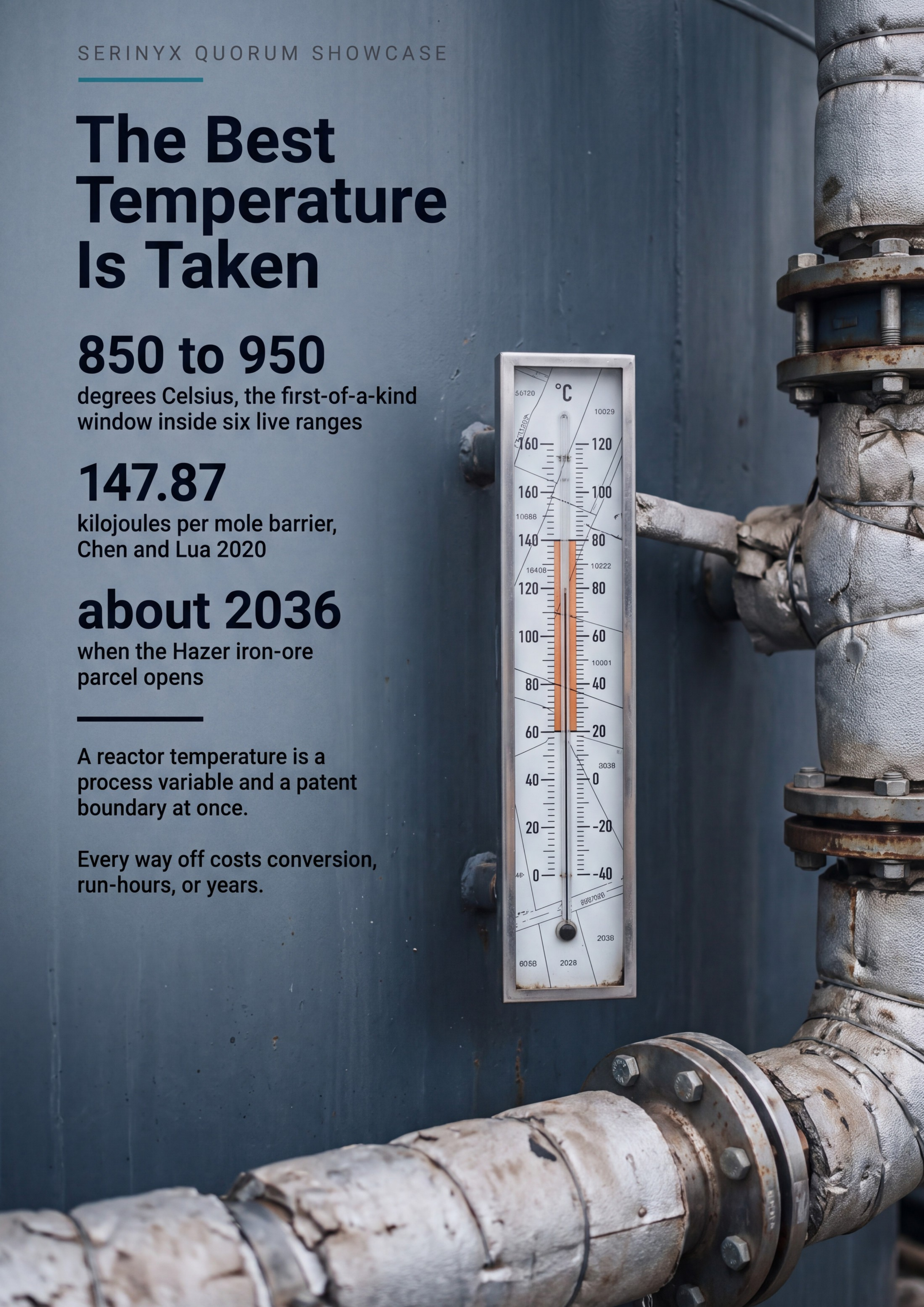
kilojoules per mole barrier, Chen and Lua 2020

about 2036

when the Hazer iron-ore parcel opens

A reactor temperature is a process variable and a patent boundary at once.

Every way off costs conversion, run-hours, or years.



SERINYX · QUORUM SHOWCASE SERIES Hydrogen and Energy

The Best Temperature Is Taken

A reactor temperature is a process variable and a patent boundary at once. The physics-optimal point on the axis is the most heavily claimed point on it, and every escape route costs conversion, run-hours, or years.

850-950 °C	147.87 kJ/mol	2036
the corpus FOAK window, inside six live claimed ranges	the catalyst-clock barrier; about two fifths of nickel life per 10 °C	about when the Hazer parcel over that window opens

CAPABILITY DEMONSTRATED
Process-physics modelling and patent claim-boundary landscaping

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A showcase of the Quorum evidence pipeline. This report summarises a small part of a much larger body of research; the scale of that work, and how to commission it, are set out on the closing page.

Prepared by Serinyx GmbH. Every factual statement carries a superscript reference to a verified source list. AI disclosure: researched, drafted and checked by Serinyx's Quorum evidence pipeline under named human sign-off; it should empower human judgement, not replace it.

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Every section header states the number of separately sourced claims that section rests on. Superscript numerals throughout resolve to the reference list, and every value in every figure and table resolves to a source in the same way.

EXECUTIVE SUMMARY

A methane-pyrolysis reactor is set by one dial. Temperature fixes equilibrium conversion, recycle load and specific electricity, and it fixes catalyst run-hours through a measured deactivation barrier. The same dial is the horizontal axis on which patent claims are drawn, so a chosen operating point sits inside a named claimed range with a named holder and a named opening date[3].

The physics-optimal window, 850 to 950 degrees Celsius, sits inside six live claimed ranges at once, and live-family occupancy across the axis peaks above it. Every exit carries a process-term price. Colder ground is graded TRL 2 to 4 with no commercially viable path before 2031, hotter ground spends catalyst life against the deactivation clock, and waiting for term-end runs into the mid-2030s. A reader leaves able to choose which temperature, pressure and catalyst corner to design a first-of-a-kind reactor into, and whether to licence, design around or wait for the parcel to open.

01 Three numbers worth holding

RESTS ON 8 SEPARATELY SOURCED CLAIMS

1,034 °C. That is the temperature at which methane cracking reaches 90 per cent equilibrium conversion at atmospheric pressure. Below it, unreacted methane has to be recycled.

Six. The first-of-a-kind operating band this corpus recommends, 850 to 950 °C on an iron-ore catalyst, sits inside the claimed temperature ranges of six live patent families at once. Six is the temperature-overlay count, not a count of families that cover the recommended plant on every element.

147.87 kJ/mol. One measured activation barrier against catalyst death. An activation barrier is the energy hurdle the reacting molecules must climb, and it is measured in kilojoules per mole. This value comes from Chen and Lua 2020 as cited by the corpus in three files. It was fitted to a nickel catalyst on a silica support (Ni/SBA-15) between 525 and 600 °C, with a deactivation order of 0.5, the exponent in the decay law that describes how the catalyst loses activity over time[3]. Running hot moves that clock.

02 One number, two disciplines

RESTS ON 24 SEPARATELY SOURCED CLAIMS

Methane pyrolysis (also called turquoise hydrogen, or methane cracking) does one reaction. CH_4 goes to solid carbon and hydrogen, with no oxygen present. The whole trick is making the reaction go fast and clean. The single dial on the front of the plant is temperature. That same dial is also the horizontal axis on which patent claims are drawn. This report holds those two readings together.

A layman should understand what the reaction is. Natural gas is methane, one carbon atom stuck to four hydrogens. Splitting it yields hydrogen gas, the product, and a solid lump of carbon, the by-product. No combustion means no carbon dioxide in the reactor itself. The carbon comes out as a black solid that may be sold, buried, or wasted. The process name comes from that product: turquoise hydrogen sits between grey (steam reforming) and green (electrolysis) in the colour chart.

Why does it matter? Grey hydrogen, made by reforming natural gas with steam, is cheap and everywhere, but it emits carbon dioxide. Green hydrogen, made by splitting water with renewable electricity, is clean but expensive. Turquoise hydrogen sits between them. It uses natural gas as the feed, so it is cheap and already piped to where hydrogen is wanted. It captures the carbon as a solid instead of a gas, so it can in principle be decarbonised. That is why a decade of engineering effort has gone into one reactor and one temperature dial.

Temperature decides how much methane can possibly break apart in one pass. This ceiling is called equilibrium conversion. At 527 °C it is 22.7 per cent. At 627 °C it is 39.9 per cent. At 727 °C it is 58.3 per cent. At 827 °C it is 73.4 per cent. At 927 °C it is 83.5 per cent. It takes about 1,034 °C to reach 90 per cent at one bar. At 1,200 °C the model says 95 per cent.

There is a floor underneath this curve. At 527 °C the equilibrium model already gives only 22.7 per cent conversion. The curve then climbs steeply, and 90 per cent needs about 1,034 °C at one bar. The low end of the axis is not a recipe. It is a doorway the reaction barely steps through. Below the doorway, no amount of clever catalyst raises the equilibrium ceiling, though a catalyst can approach it faster. The door opens slowly at first, then rushes upward. The 90 per cent mark is a long climb from 527 °C to 1,034 °C.

A layman should hear one thing here. The reactor does not ask how hot it may go. It asks how much methane it may leave unreacted. The answer climbs almost monotonically with temperature. Each degree up buys more single-pass conversion, right up to about 1,034 °C for a 90 per cent target.

Single-pass conversion is the lever that decides the recycle loop. Anything that leaves the reactor unreacted must be collected, compressed, and sent back in. The register holds a critical about-80 per cent single-pass bar for an electrified demonstrator, below which recycle volumes grow large. Compressors and heat exchangers grow to chase the gas back. At 11 per cent single-pass, the lowest equilibrium reading near 700 °C, roughly 89 per cent of the feed returns through the recycle loop. This is the pessimistic bound. Under the higher 700 °C equilibrium readings the recycle penalty is far smaller. The plant stops being a compact reactor and becomes a recycling station.

Specific energy input climbs on the same dial. The corpus's own first-of-a-kind window of 850 to 950 °C carries an electrical demand of roughly 6 to 10 kWh per kilogram of hydrogen for an electrified demonstrator. Higher temperature means more electricity through the same product. A non-catalytic bed pushed toward 1,100 to 1,200 °C burns more still, because there is no catalyst to do the chemical work at lower heat. The physics optimum is therefore not a single point. It is a compromise among conversion, recycle load, and energy, all set by one number.

Now the second discipline. That same number, the reactor temperature, is also the horizontal axis on which patent claims are drawn. A patent family does not claim a pyrolysis reactor in the abstract. It claims a process run at a stated temperature, at a stated pressure, over a stated catalyst. Put the reactor at 900 °C and the question is no longer just whether conversion is good enough. It becomes which claimed temperature range contains 900 °C, and who holds it.

The process design and the claim landscape use the same coordinate. They are not two documents glued together. They are two overlays on one thermometer. A design team that optimises the reactor without reading the overlay is optimising into a field the register shows occupied by live claims. The overlay does not replace process engineering. It sits on top of it.

A second axis sits behind temperature: pressure. The foundational Hazer claims run at 0 to 100 bar(g), that is, gauge pressure measured above atmospheric. The molten-alloy mist family claims 1 to 20 bar. The electrified demonstrator designs sit near atmospheric or a few atmospheres. Higher pressure shifts the equilibrium unfavourably for a reaction that makes two gas molecules from one, so pressure is a design choice with a physics penalty attached. It is also a second claim element. On this surveyed map, though, pressure almost never decides who owns the ground: 44 of the 48 patent families examined state no pressure range, and the foundational family claims the whole 0 to 100 bar(g) axis. An axis that almost nobody bounds is itself a cadastre observation. A temperature alone is one coordinate; a temperature at a pressure over a catalyst is the point that lands on a parcel.

A layman should separate two ideas that sound alike. Equilibrium is the ceiling: how much methane can split at this temperature, if the reactor waits forever. Rate is the speed: how fast it actually splits in the short residence time of a real reactor. A catalyst raises the rate, not the ceiling. That is why a reactor can sit at a temperature whose equilibrium says 80 per cent, and still only deliver 65 per cent in practice, because the gas does not stay long enough to reach the ceiling. Single-pass conversion in a real plant is always below equilibrium. The gap between the two is the reactor volume, the residence time, and the catalyst.

A note on the numbers at 700 °C, because they disagree. The corpus holds five readings of equilibrium conversion near 700 to 727 °C. One temperature model says about 11 per cent. An Aspen table, from a process-simulation tool, says 35 per cent. A Gibbs minimisation, a thermodynamic calculation that estimates the most stable product mix, says 58.3 per cent. A second Gibbs minimisation says 85.3 per cent. A literature-validated equilibrium says 82 to 86 per cent. These are not rounding differences. They reflect different thermodynamic bases and feed assumptions. The report carries all five rather than averaging them. The trend, though, is not in dispute. Conversion rises steeply through this band, and by the high 800s it sits comfortably above the about-80 per cent single-pass bar the register holds.

Measured catalytic results show the same scatter. A bimetallic Ni-Fe on lanthanum oxide reports 92 per cent at 700 °C. A commercial nickel catalyst at the same 700 °C reports 65 per cent against an 80 per cent equilibrium. A Fe-Mo catalyst reaches 98 per cent at 750 °C. Catalyst choice moves the measured number as much as temperature does. That is a reminder that a temperature alone never tells the whole process story.

The same disagreement appears higher up the axis. One Gibbs minimisation reports 97.2 per cent at 927 °C, while the equilibrium series at the same point reports 83.5 per cent. At 1,200 °C one model says 95 per cent, another says about 80 per cent, and a third places near-complete conversion only at 1,500 °C. The numbers diverge because they use different free-energy bases and different product-phase assumptions. The direction of travel stays firm. What a designer should take is not a single table, but a band: 850 to 950 °C reliably delivers high single-pass conversion, and the exact ceiling depends on the model chosen.

What is a catalyst, for the layman? A catalyst is a surface that lets the methane split at a lower temperature than the bare reaction requires. The non-catalytic route wants the gas almost red hot on its own. A good nickel or iron surface does the same work at 700 to 900 °C. The trade is that the surface slowly fouls with the very carbon the reaction produces. That is why temperature pulls in two directions at once. Hotter pushes conversion up. Hotter also pushes the fouling rate up, because the carbon chemistry speeds up with the same Arrhenius rule, the usual exponential rise of a reaction rate as temperature climbs[3].

The consequence is one sentence. Pick the temperature, pressure, and catalyst together, and both questions move at once: the process question and the claim-map question. Optimising the first without reading the overlay means not knowing which parcel the point lands in. Whether that parcel is a live claim a plant falls within is an all-elements question for element-by-element counsel, not one the temperature dial settles.

03 The physics optimum sits in a crowded live band

RESTS ON 31 SEPARATELY SOURCED CLAIMS

The corpus's own first-of-a-kind recommendation is specific. Run an electrified catalytic reactor between 850 and 950 °C, on an iron-based or Ni-Fe bimetallic catalyst. The design clears the 80 per cent single-pass bar at about 6 to 10 kWh per kilogram of hydrogen. A second design basis in the same corpus leans slightly cooler, to 800 to 850 °C on iron at 2 to 15 atmospheres. The two windows overlap heavily. They bracket the same ground.

That ground is already claimed.

The foundational family on that ground is Hazer. Its claims run 600 to 1,000 °C at 0 to 100 bar(g), over non-synthetic iron oxide ore such as hematite or goethite, with temperature and pressure used to steer graphite morphology. That is the same catalyst the FOAK recommendation names. The FOAK window of 850 to 950 °C sits entirely inside 600 to 1,000 °C. The Hazer family is expected to open around 2036.

Hazer's own demonstration backs the physics. Its iron ore catalyst ran about 850 to 900 °C at above 80 per cent conversion for more than 450 continuous hours in 2024[9]. The longest solid-catalyst run in the corpus is about 450 hours continuous, with 1,250 hours cumulative, roughly one-ninth of a 4,000-hour lender threshold. The physics and the patent point at the same temperature band.

It is not alone. Count the live families whose claimed temperature ranges overlap the 850 to 950 °C band:

TABLE 1

Family	Holder (per register)	Claimed range	Pressure or medium
C-105	Hazer Group	600 to 1,000 °C	0 to 100 bar(g)
C-110	Shell	800 to 1,000 °C	molten salt
C-114	see conflict row	650 to 1,400 °C	1 to 20 bar
C-116	BASF with ThyssenKrupp and Linde	900 to 1,200 °C	moving carbon bed
C-117	see conflict row	500 to 1,200 °C	fluidised bed
C-125	Levidian Nanosystems	800 to 1,200 °C	atmospheric

That is six live families over the recommended band, not the whole field. Two of those six rows carry an unresolved holder conflict in the register, so the six is a temperature-overlay count rather than six clean counterparties. The element-matched subset is smaller and is the subject of the counsel-level work in the next beat.

The wider axis shows why temperature is the right coordinate. At the hot end, a molten tin family claims up to 1,200 °C. An electric-bed family claims 1,000 °C or more with coke particles as the heat carrier. A molten Ni-Bi family demonstrated 95 per cent conversion at 1,065 °C[7]. A Monolith hot-plasma family runs far hotter again, at about 1,500 to 2,000 °C in operation, though it states no broad thermal claim in the corpus. At the cool end, a low-temperature family claims 500 to 650 °C with in-situ hydrogen regeneration. The map runs from a 500 °C catalytic corner to a 2,000 °C plasma corner, and the recommended 850 to 950 °C sits at the cool end of the busiest stretch.

The axis is not new. Expired prior art anchors it. A 1966 catalytic decomposition patent is public domain and is cited against newer claims. A 1931 molten iron bath is expired. A 1998 molten tin bath is foundational, with its current legal status not established in the corpus. A 1996 plasma torch family is also expired. These are expired; none of them occupies the band. They set the baseline: the idea of splitting methane with heat or a catalyst is old. The live claims are about how to run it cheaply and durably today.

Away from the band, the count plateaus. The 900 to 1,100 °C range carries eight overlapping live families. Below 800 °C the count drops to at most four overlapping live families. The count peaks just above the recommended band, so the recommended window sits at its cool edge. Occupancy is a lower bound, not a census. Sixteen live families in the corpus state no broad temperature range at all, so they cannot be plotted on this axis, and whether their other elements read on a chosen point is an all-elements question the register does not resolve.

Those sixteen deserve a word. They include families that claim a reactor shape, a carbon product, a pressure range, or a regeneration step without naming a temperature. A pulsed-combustion reactor family, for example, makes no thermal range claim in the corpus. A plasma family claims its carbon black product rather than a window. A ductless inductively heated reactor claims a 760 °C demonstration point but not a range. Such a family cannot be shaded on the temperature map at all; whether its other elements read on a point is an all-elements question the register does not resolve. That is why the count of six is a lower bound on the real crowding, not an undercount to be ignored.

The Hazer claim is worth a closer read because it is the foundational parcel. It does not merely claim a temperature. It claims control over the shape of the carbon that comes out, by choosing temperature and pressure together. That matters commercially. The solid carbon is not always a waste product. It can be sold if it has a useful structure. A claim that reaches the product morphology reaches beyond the reactor vessel into what the plant earns from its by-product. The 600 to 1,000 °C band is wide because it is a control range: at one setting the graphite looks one way, at another it looks another.

The published operating points straddle every boundary on the axis. At 500 °C a tuned Ni-Mo catalyst reaches 26 per cent in a twelve-hour test[5]. At 550 °C a nickel-on-silica catalyst runs beyond 2,500 hours with cyclic hydrogen regeneration[4]. At 650 °C a Ni-Fe spinel reaches 91 per cent over twenty cycles[6]. At 700 °C an iron mineral-grade catalyst holds above 80 per cent for 160 hours. At 850 to 950 °C a moving carbon bed runs at about 80 per cent conversion for over 1,000 hours at pilot scale. Above 1,000 °C the process goes non-catalytic.

One apparent hole turns out not to be a hole. A 1998 European filing over nickel catalysts at about 400 to 900 °C looks, on paper, like it should occupy the low-temperature band. The register does not support that. The European application was deemed withdrawn on 3 April 2002 and never granted, and the Canadian member is recorded as abandoned[1,2]. It does not occupy the 400 to 900 °C band in the jurisdictions verified. It is not called an expired patent here, because it never became one. It is simply absent, and the band it would have covered is shown unoccupied by any verified live family; the register does not establish who, if anyone, occupies it.

The consequence is blunt. The temperature the reactor design wants is the temperature where six live families state a claimed range that contains the point. Eight families do so over the hotter 900 to 1,100 °C stretch, and at most four do so below 800 °C; whether any of those families also covers the plant on its other elements is an all-elements question the register does not resolve. The optimum is not a quiet corner. It is a crowded junction on the map.

04 Every exit has a price, and it is not money first

RESTS ON 47 SEPARATELY SOURCED CLAIMS

A junction occupied by six live families has three exits: run colder, run hotter, or wait for the calendar. Each has a price. The price is not a licence fee here. It is conversion, run-hours, or years.

Exit one: colder. Running below the recommended band means accepting lower single-pass conversion. At 500 °C the best published result is 26 per cent over twelve hours[5]. At 550 °C a commercial nickel catalyst reaches 30 per cent against a 40 per cent equilibrium. At 650 °C the same nickel catalyst reaches 55 per cent against a 70 per cent equilibrium. The recycle loop then does the work the reactor is not doing.

The sub-700 °C field is graded TRL 2 to 4, and the corpus states no commercially viable pathway before 2031. Its own staged plan runs lab to TRL 4 from 2026 to 2031, TRL 4 to pilot from 2031 to 2034, and pilot to commercial demonstration from 2034 to 2038. A colder design moves the point below the recommended band, where the register shows at most four overlapping live families, at the cost of a decade of development and a recycle penalty now.

The endurance record for the colder route is real but narrow. One nickel-on-silica catalyst ran beyond 2,500 hours at 550 °C, but it used cyclic hydrogen regeneration that consumes roughly 6 per cent of the hydrogen it makes[4]. Full activity recovery was achieved over 22 hydrogen-regeneration cycles on a bulk nickel catalyst at 550 °C. Long life there is not free life. It buys itself with a steady bleed of product.

The sub-700 °C frontier is moving, but on a research clock. A 550 °C run that lasted 2,500 hours emerged from a European programme that reached TRL 4 and secured follow-on funding in April 2025, targeting an industrial demonstrator by 2028, that is, a demonstration unit rather than a commercial plant[4]. A Ni-Mo catalyst reached 26 per cent at 500 °C with an unusually low reaction barrier of 43.27 kJ/mol over a twelve-hour test[5]. A Ni-Fe spinel hit 91 per cent at 650 °C over twenty cycles[6]. These are bright spots on a field the corpus still grades TRL 2 to 4. A brighter catalyst does not yet make a bankable colder plant.

Exit two: hotter. Running above the band trades catalyst life for conversion. The deactivation clock is the price. The one rigorous deactivation barrier in the corpus is 147.87 kJ/mol. It comes from Chen and Lua 2020, as cited by the corpus in three files, fitted to Ni/SBA-15 between 525 and 600 °C with a deactivation order of 0.5[3]. That value is a literature-cited secondary compilation, not a primary measurement in the collection, and it is stated at exactly that basis every time it appears. As a rough estimate derived from the same Arrhenius relation, each 10 °C rise would shorten the useful life of a nickel catalyst by about two fifths at this barrier (about a fifth per 5 °C). The exact multiplier at a chosen temperature is not held as a register row, and this report does not assert one.

The regeneration numbers show how hard the clock bites. Nickel-based solid catalysts are estimated for replacement every 10 to 100 hours of continuous operation. Iron-based catalysts stretch that to 50 to 300 hours. Thermal cycling accelerates the damage. Ni/Al_2O_3 under cycling degrades three to five times faster than continuous use, and more than ten cycles a day cuts lifetime by 70 to 85 per cent. A design that heats and cools frequently is paying for it in catalyst.

Regeneration is the other side of the clock. Cleaning the carbon off the surface has three chemical routes. Burning it off with air recovers 85 to 90 per cent of activity but loses 2 to 5 per cent permanently per cycle. Gasifying it with carbon dioxide at 800 °C recovers 75 to 85 per cent and causes less structural damage. Steam at 750 °C recovers 80 to 90 per cent but risks sintering the catalyst in hot water vapour. The longest hydrogen-regeneration run, 22 cycles at 550 °C, recovered full activity each time. None of these routes is free. Each one consumes gas, heat, and part of the product, or costs a little catalyst every cycle.

The deactivation science is not a single number. The 147.87 kJ/mol figure is one fitted nickel surface[3]. Activated carbon shows a deactivation barrier near 194 kJ/mol, and general coking models span 150 to 200 kJ/mol. Nickel encapsulation is estimated at 118 to 149 kJ/mol, and a separate literature line puts encapsulating-carbon formation at 147 to 149 kJ/mol. The band sits around 150 kJ/mol. That is why the figure is stated with its catalyst and temperature basis every time: it is not a universal constant. Sintering, the other death of a catalyst, behaves differently below and above about 570 °C. Below that line the particle-migration barrier is near 150 kJ/mol. Above it, the barrier is 200 to 250 kJ/mol for Ostwald ripening, the process in which small particles merge into larger ones.

Go hotter still, above 1,000 °C, and the catalyst itself drops out. Non-catalytic thermal cracking needs about 1,100 °C in one corpus readingand more than 1,200 °C in another, with an apparent activation energy of 370 to 452 kJ/mol. The two readings disagree on the threshold. Both agree on the consequence. No catalyst means no deactivation, but a much larger electrical bill through the same kilogram of hydrogen. That is the energy penalty the colder design escapes by staying catalytic.

The run-hour records make the trade visible. A sacrificial iron ore bed holds the longest solid-catalyst run at about 450 continuous hours, against a minimum lender threshold near 4,000 hours. A molten Ni-Bi alloy runs 95 per cent conversion at 1,065 °C with no measurable activity loss over 170 hours[7]. A molten NiMo-Bi alloy is stable for 120 hours at 800 °C[8]. A NiMn-Bi alloy holds 80 hours at 850 °C. None of these approaches the run length a financed plant will demand.

The non-catalytic high-temperature exit trades that run-hour problem for an energy problem. A bare molten-salt bed at 850 °C holds only 55 per cent conversion over 30 hours. A carbon-encapsulated iron nanoparticle start at 95.7 per cent at 800 °C, then falls to 36.8 per cent over three hours as the surface fouls. Molten alloys avoid fouling because the carbon floats out of the liquid metal, but at 800 to 850 °C they still give only low conversion in short columns[8]. The hottest clean route, the plasma, lives at about 1,500 to 2,000 °C and uses an arc to split the gas, with its own patent families around the product carbon. Running hotter never makes the problem disappear. It moves the price from catalyst life to the electricity bill.

Exit three: the calendar. The map changes shape as patents expire. This is the exit that costs years rather than conversion.

TABLE 2

Date	Family	What opens
Already expired	Muradov carbon-catalyst family (US7157167; US8002854)	foundational carbon activation approach
2025	RTI ZnO-aluminate sorbents	adjacent sorbent field
2030	Johnson Matthey multi-stage guard beds	adjacent desulphurisation field
May 2033 vs about 2033	Hydrogenics/Cummins grid-services family	adjacent hydrogen-systems dispatch
about 2036	Hazer iron-ore family	the 600 to 1,000 °C core band

The Muradov row is marked expired on the register. The corpus's own phrase about opening this approach to all comers is the corpus's wording, not a freedom-to-operate conclusion adopted here. The Hydrogenics dates carry a granularity disagreement. One source says May 2033. Another says approximately 2033 at year level. Both rows are kept.

The verdict is not a number. It is a location and a date. Where on the thermometer does the point sit, which claimed range contains the point and who holds it, and when does that family's term end? The next beat pushes back on how hard that verdict should be trusted.

05 The map may not bind at all

RESTS ON 16 SEPARATELY SOURCED CLAIMS

This is the strongest case against the reading just given. A fair report states it before the reader has to.

A temperature range inside a claim is one element among several. A granted claim covers a whole apparatus: a catalyst composition, a pressure, a gas flow, a product morphology, a regeneration step. A reactor running at 900 °C is inside the number in family X. That is not the same as reading on family X. All-elements analysis, done by counsel against the granted claim as amended and interpreted, may clear what a range map darkens. A range map is a triage tool, not an opinion.

For the layman, all-elements means this. A claim is a list of ingredients. To read on the claim, a plant must match every ingredient at once. If the claim lists iron ore, 600 to 1,000 °C, 0 to 100 bar, and a graphite morphology controlled by those settings, then a plant can miss an ingredient in either of two ways. At 900 °C on nickel, it misses the catalyst. At 900 °C on iron ore but at 200 bar, it misses the pressure. It is not inside the claim even though its temperature is inside the range. The temperature map is necessary but not sufficient. It tells the lawyer where to look. The lawyer then checks the rest of the list.

TRL, the maturity grade used above, is a technology-readiness ladder from one (an idea in a lab) to nine (a plant in commercial operation). Sub-700 °C pyrolysis sits at TRL 2 to 4. That means bench work and small pilots, not a plant an investor can finance. The phases in the corpus run to 2038 for a first commercial unit. A colder design is therefore not just a lower conversion today. It is a bet on a field that has not yet finished its own development plan.

The corpus itself records conflicts that a careful reader must weight. US9359200B2 is listed as held by BASF in one file and by CB&I in another, with a third file naming both. The ExxonMobil electric-bed family is recorded as ceased in one reading and active in another, though a granted Japanese member keeps it live. Two more rows carry the same kind of split. The waste-catalyst family reads as FORTH/ICE-HT in one place and UCF/Florida in another. The low-temperature 500 to 650 °C family reads as a Portuguese company in one place and a research consortium in another. The molten-alloy mist family reads as PARC/Xerox and as an unassigned assignee. These are not averaged. They are named disagreements.

The corridors barely overlap in practice. On an all-elements reading, a designer may select a catalyst and pressure that no single granted claim covers on every element; whether any particular plant is clear is a question for counsel. The range count of six is therefore a warning to look, not a conclusion about any particular design.

Licensing cuts both ways. The corpus does not record an open third-party licence for the occupied iron-ore band. That means no signed or recorded licence appears on the register. It also means no one is asking for terms. The picture is not uniformly closed. The foundational holder itself pivoted to a capital-light licensing model with a global engineering firm in May 2025[9], so the front door exists as a conversation rather than as a recorded term sheet.

The patent-filing window adds a clock that is already spent. One corpus file flags a 12 to 18 month window on key white spaces, but that file is anchored at an Analysis Date of February 2025. By the 2026 report date that window is elapsed. It is a dated observation, not a live urgency. Waiting is itself a move with a cost, because the sector faces a decisive 2026 to 2028 commercialisation window of its own.

The qualifying sentence must not dissolve the verdict. The world still answers which claimed range a point falls inside, who holds it, and when it opens. It never says anyone infringes. Those two sentences stay apart on purpose. A temperature inside a range is one element among several. The report's job is to mark the parcel and the date, not to read a trespass.

A claim chart, the working document a lawyer builds, lists every element of a claim against every element of a plant. It can show where a plant reads on a claim. It cannot, on its own, show that the claim is valid, or that the plant is clear. That distinction matters here. A range map tells a design team where to look. It does not replace the claim chart, and it does not substitute for a formal opinion. Six overlapping families over a band is a reason to commission that work, not a verdict delivered by it.

The commercial backdrop makes the calendar real, not abstract. A European customer sample facility began operating early in 2025 at TRL 7 to 8. A major chemical producer signed a joint development agreement with an oil major in November 2025 to build a demonstration plant. Border carbon charges began covering hydrogen from January 2026[10]. These are not patent facts. They are the reason the 2026 to 2028 window is decisive rather than theoretical. A team that waits for 2036 is waiting past a window the industry is walking through now.

06 The reader can decide

RESTS ON 16 SEPARATELY SOURCED CLAIMS

The decision, reduced, has three moves.

A worked example makes the readout concrete. Take a candidate point: an iron-ore catalytic reactor at 900 °C, atmospheric pressure, in the recommended band. The cadastre answers three questions. A cadastre is a parcel-by-parcel register of who holds which claimed range, and when it opens. Which claimed ranges contain 900 °C? Six families do. Who holds the foundational iron-ore parcel? Hazer Group. When does that parcel open? Around 2036. That is the whole output: a parcel reference and a date. It says nothing about whether the plant reads on all the other elements of those claims.

Move one is to licence. Where all-elements analysis confirms the point reads on a family whose term is running, one option is to take a licence. The readout here is only the family name and the remaining term; it is not a coverage finding. For the 850 to 950 °C iron-ore point, that is the Hazer family, holding until about 2036.

Move two is to detour. Move the point off the occupied optimum and pay in process terms. Colder means lower single-pass conversion, a bigger recycle loop, and the sub-700 °C field stays at TRL 2 to 4 until 2031 at the earliest. Hotter means the deactivation clock and a larger energy bill, with non-catalytic operation needing about 1,100 to 1,200 °C. A third detour is non-temperature: change the catalyst family or the pressure so the point misses the other elements, at an unpriced process cost. Whether that clears any particular plant is again a question for counsel. Either detour is a design choice, not a free one.

Move three is to wait. Hold the cooler or hotter corridor and let the calendar do the work. The Muradov foundational family is already expired. Adjacent families open in 2025, in 2030, and in May 2033. The core Hazer band opens around 2036. Waiting has its own cost, because the decisive commercial window for turquoise hydrogen runs 2026 to 2028.

The three moves are not equally attractive. Licence keeps the process optimum and pays in access terms, but only if a licensor will talk. Detour moves the point into a band the register shows less crowded, but pays in conversion, recycle, run-hours, or electricity. Waiting pays in years, and the years may expire before the window does. A design team can combine them: run a detour now while filing, and step into the optimum when the parcel opens. The cadastre supports that, because it dates each parcel independently rather than forcing a single all-or-nothing choice.

The readout is a position in a named family plus an opening date, computed as a first-class output. Give a candidate temperature, pressure, and catalyst. The cadastre returns which claimed range contains the point, who holds it, and when it opens. It does not return a verdict on infringement. It returns a parcel and a date.

A reader should not leave with a legal conclusion. This report is not a freedom-to-operate opinion, and it does not say that any design is free or that any family blocks it. It says something narrower and more useful. The temperature a process engineer would naturally choose is the temperature where six live families already state a claimed range that contains the point, with a denser eight-family stretch just hotter. The way off that junction is known, and every way off has a price in conversion, run-hours, or years. The map opens on its own schedule. The decision is a position and a date, not a gamble and a prayer.

07 How this report knows

RESTS ON 9 SEPARATELY SOURCED CLAIMS

This report showcases process-physics modelling together with patent claim-boundary landscaping. Every equilibrium point, deactivation barrier, operating record, and calendar date below traces to a mapped row in a claim register built for this report.

The collection sits inside a hydrogen deep-tech research corpus. This pass walked the collection and counted 816 readable text files (.md, .txt, .csv), excluding the internal patent-filings subtree, a count computed for this report rather than taken from a register row. It read the reactor-and-catalyst files and the patent-landscape files specifically. It produced four evidence tables: equilibrium and measured operating pointsto, claim families with holders, ranges, pressures and statusesto, deactivation parameters and run-hour records[3]to, and dated calendar eventsto. Conflicting holder and status entries were kept as named disagreements, never averaged. A register check on one 1998 European family confirmed its withdrawn status directly[1,2].

The mechanics were deliberately conservative. Where two corpus files disagreed on a number, both rows were kept and the disagreement flagged. Where a value rested on a secondary citation, the original paper was named and the basis carried. Where no figure existed, the gap was marked rather than guessed. The numbers in this report are therefore a floor, not a polished mean. A later audit may tighten them. It will not need to invent them.

The evidence cut-off is 12 September 2026. Renewal and fee status after that date is not established, and live status for every family in every jurisdiction is not confirmed.

What this report could not establish. The all-elements claim construction is a task for element-by-element counsel, not this register. The exact per-10 °C lifetime multiplier behind the deactivation barrier is not held as a register row. Current third-party licence availability for the occupied band is not recorded. The status of the Chinese and Australian members of the 1998 family is beyond the European and Canadian members checked[1,2]. The external citation for the 550 °C beyond-2,500-hours point could not be verified under the printed article number (R04, none); the underlying register row remains a corpus observation, and the operating point is retained. The molten Ni-Bi demonstration at 1,065 °C traces to the corrected 2017 Science DOI 10.1126/science.aao5023 (R07); the intake article number was corrected after verification. These are carried as limits, not smoothed over.

WHAT WOULD CHANGE THE READING

Three watchable observations would move the reading.

1. A granted claim narrowing or widening the iron-ore band. If a new granted member of the ExxonMobil electric-bed family confirms it live, or if Hazer maintenance lapses before 2036, the parcel map shifts on its own.
2. A sub-700 °C catalyst crossing the run-hour bar. A demonstrated 4,000-hour run at commercial single-pass conversion below 700 °C would pull the colder exit out of TRL 2 to 4 and move the 2031 sentence.
3. A register resolution of the holder conflicts. A confirmed assignment flipping US9359200B2 from BASF to CB&I or back, or resolving the ExxonMobil ceased-versus-active split, would change the counterparty a licensor actually approaches.

08 This is a showcase

This draft is a small part of a much larger piece of work. The body of this report runs to about 6,700 words. The corpus behind it, across the collection read this pass, holds about 2.05 million words in 816 text documents. The ratio is about one word in three hundred and ten of the research behind it. Before a word was written, the study mapped equilibrium, deactivation, operating points, and patent families row by row, and kept every disagreement.

A commissioned engagement is not a longer version of this document. It is the study underneath it, run on the client's own question, with its own registers, its own jurisdiction set, and its own all-elements work. It answers a defined plant boundary, a defined schedule and a defined decision point.

SMALL PRINT

This report is an independent analytical showcase. It was prepared with automated assistance under human editorial direction. It does not constitute legal advice, freedom-to-operate opinion, or an infringement, validity, or clearance conclusion. Patent scope is an all-elements question for qualified counsel in each jurisdiction.

Corrections: if a factual error is found, it will be corrected in a numbered revision with the correction noted in the change log.

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ABOUT THE RESEARCH CORPUS

This report is a summary of a much larger evidence base. The figures below state the size of the research corpus synthesised here, measured on the working corpus at build time.

Full study corpus	816 readable text files across 16 research domains of working research text, about 2.05 million words
Spines of this report	reactor and catalyst technology, and the IP and patent landscape, plus the patent-exploration deliverable
Distilled into this report	158 individually sourced claims
Independently referenced	references with live verified public links, counted at citation verification
Review before release	independent editorial, factual, adversarial and layman review, plus a claim-language read with standing to block

Corpus word counts cover machine-readable text files; total sizes include datasets and rendered assets. Sources marked adjudicated were independently verified in the source study before this report used them.

THIS IS A SHOWCASE

You have read about one word in three hundred and ten.

about 6,700
words in this report

2.05 million
words across 816 text documents in the study corpus

A commissioned engagement is not a longer version of this document.
It is the study underneath it, run on your question.

THIS IS A SHOWCASE

About one word in three hundred and ten of the research behind it.

This report runs to about 6,700 words. It is a summary of one part of a study whose working corpus, across the collection read for this pass, holds about 2.05 million words in 816 text documents. The evidence behind those words runs row by row through equilibrium and measured operating points, claim families with holders and statuses, deactivation parameters and dated calendar events, 158 individually sourced records in all, every one checked before a sentence was drafted.

What you have read here is a showcase. It demonstrates a handful of capabilities on a topic chosen to be legible in twenty minutes. A commissioned engagement is not a longer version of this document; it is the study underneath it, run on your question, with sign-off on the brief and a full audit trail.

For a full piece of research or advisory work, contact Lorenz at lorenz@serinyx.com.

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Every link below was fetched and verified on 2 September 2026. Sources that cannot be publicly linked are listed without a URL and say so. No placeholder or reconstructed links are used.

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