Set 8 — Practical Inventions

400 inventions · 100 screened · 20 developed · 3 engineered

2 November 2026

Set 8 — Practical Inventions

400 inventions, 100 screened, 20 developed, 3 engineered. Compiled 2 November 2026. Every entry is a proposal. **No prototype was built.**

What this set is

The previous sets hunted surprises. This one hunts **things that could be built and sold**, but that nobody has built because the enabling part only recently became cheap, or because the integration was never attempted, or because the field that would use it does not read the field that invented the mechanism.

The grid is 20 capability domains × 20 physical approach classes = 400. Every approach is applied once in every domain. The previous set asked "what is being missed?"; this one asks "what is buildable now that was not buildable five years ago?"

The novelty test

An invention is only included if its blocking reason is specific and has changed. Each entry names the blocker explicitly under *Why not yet*. The four acceptable blockers are:

1. **A component became cheap** (UV-C LEDs, Peltier modules, MEMS magnetometers, printed sensors).
2. **A material became available** (phase-change materials near room temperature, selective emitters, mycelium composites, printed piezoelectrics).
3. **A fabrication method reached a small lab** (silicone 3D printing, flexible circuits, microfluidics).
4. **The integration was simply never attempted** — the mechanism is standard in field A and unknown in field B.

"Nobody thought of it" is not accepted as a reason, because it is almost always false.

The four tiers

Tier	What	Where
400	One device per cell: what it does, the principle, why not yet, the first build, the kill.	Part I (`inv/`)
100	Five per domain, scored on blocker specificity and build cost.	Part II (`screen/`)
20	One per domain: critical component, cost, 90-day build, main risk, competition.	Part III (`dev/`)
3	Sizing calculations that decide whether to build.	Part IV (`eng/`)

What the three studies decided

- **Radiative dew harvesting works in humid air and not in dry air** — the opposite of intuition, because dry air gives a colder sky but a dew point too far below the achievable surface temperature. Yield 0.05–0.10 L/m²/night. Marginal.

- **The single-slot compliant drip emitter fails**: the best achievable flow variation over a 6:1 pressure range is 47% against a target of 10%. The next build must be a diaphragm, not a slot.
- **The passive vaccine cooler works**: 6.5 kg of phase-change material for 72 h, reduced to 3.0 kg with a radiative night panel.

Two of the three results are negative or marginal, which is the point of doing the arithmetic before the tooling.

Honest framing

- **No prototype was built.** Costs are estimates; the numbers are model outputs.
- **The 100 → 20 and 20 → 3 steps are editorial**, not mechanical. The 400 → 100 step is a stated rule.
- **No patent search was performed.** Several of these may be covered by existing filings. Treat the set as a source of buildable ideas, not as a freedom-to-operate analysis.
- **No prior Incoprea concept was reused**; the 400 were checked against 7,717 prior titles.

Where to start

1. **D04 / E3** — the vaccine cooler is the closest to a product and the arithmetic is done.
2. **D16** — electrostatic plastics separation is the largest commercial prize on the list (black plastics that NIR cannot sort).
3. **D08** — concrete strength from batching data needs no hardware and no new science, only data access.

Files

File	What
`Set8.pdf` / `Set8.docx`	The full document
`inv/01…04-*.md`	The 400
`screen/screened-100.md`	The 100
`dev/dev-20.md`	The 20
`eng/ENGINEERING.md`, `eng/E1_E2_E3.py`	The three studies and the code
`data/inventions400.csv`, `selected100.json`, `engineering.json`	Structured data
`METHODOLOGY.md`, `CORRECTIONS.md`	Method and corrections

Part I — The 400

What this is. 400 devices and processes, generated on a 20 × 20 grid: 20 capability domains × 20 physical approach classes. Each cell is a buildable thing. No entry claims a prototype has been built.

The novelty test used throughout. An invention only counts as "advanced but not tried" if the blocking reason is specific and has recently changed — a component got cheap, a material became available, a fabrication method reached a lab, or the integration simply was never attempted. "Nobody thought of it" is not a reason; it is usually false.

Entry format: **name** — what it does. *How:* the physical principle. *Why not yet:* the specific blocker. *First build:* the cheapest step that would show whether it works. *Kills it:* the failure mode that ends it.

Domain 1 — Water and sanitation

I001 · *Water* × *Passive thermal* — **Multi-effect wick still.** A solar still that reuses its latent heat across three wick layers instead of one. *How:* each condensing surface feeds the next evaporator, so the same joule of sunlight evaporates three times. *Why not yet:* multi-effect stacks work in industry but need pumps and pressure vessels; a gravity-fed wick stack at $20/m² was never engineered. *First build:* a three-layer stack on a roof in one location with a daily weigh-scale. *Kills it:* yield below 2× the single-effect baseline over a two-week trial.

I002 · *Water* × *Phase change* — **Waste-heat desiccant still.** A solar still whose condenser is regenerated by the same heat that drives evaporation, using a desiccant loop with no electricity. *How:* the desiccant absorbs vapour at night and releases it to a condenser when the collector heats. *Why not yet:* desiccant wheels are HVAC components priced for buildings, not for a $30 household unit. *First build:* a silica-gel cassette in a single-basin still with a manual damper. *Kills it:* no net gain over the baseline still across three humidity levels.

I003 · *Water* × *Capillary* — **Salt-gated wicking evaporator.** An evaporative cooler whose wick self-regulates by salting out when the air is too humid. *How:* the salt front moves with the evaporation rate, changing the wick's permeability. *Why not yet:* the effect is treated as fouling to be prevented rather than a control mechanism. *First build:* a wick column with a salt gradient instrumented with a camera and a mass balance. *Kills it:* no measurable flow regulation over a humidity sweep.

I004 · *Water* × *Triboelectric* — **Flow-powered UV tap.** A triboelectric generator inside a tap aerator that powers a UV-C LED sized to the flow. *How:* water-driven contact electrification charges a capacitor that pulses the LED. *Why not yet:* TENG power density is low and UV-C LEDs need watts; the integration only closes at low flow with a duty-cycled LED. *First build:* a bench loop with a TENG, a supercapacitor and one LED, measuring disinfection dose. *Kills it:* achievable dose below 5 mJ/cm² at 2 L/min.

I005 · *Water* × *Piezoelectric* — **Ultrasonic membrane antifoulant.** A piezoceramic ring bonded to a hollow-fibre membrane module that keeps the surface vibrating below the cavitation threshold. *How:* surface acoustic streaming disrupts the concentration polarisation layer. *Why not yet:* transducer bonding to polymer housings is a manufacturing problem, not a physics one. *First build:* one module with a bonded ring, flux measured over 72 h against a control. *Kills it:* flux decline unchanged versus control.

I006 · *Water* × *Optical* — **Turbidity-locked UV dose.** A UV reactor whose lamp current is set by a turbidity reading so the delivered dose stays constant as water quality changes. *How:* dose is the product of intensity and residence time; turbidity sets the attenuation, so the lamp follows. *Why not yet:* reactors are sized for the worst case because cheap turbidity sensors drifted. *First build:* a bench loop with a variable-turbidity feed and a biodosimetry check. *Kills it:* dose error exceeding 30% across the turbidity range.

I007 · *Water* × *Electrochemical* — **Self-desalting CDI cell.** A capacitive deionisation cell that reverses polarity on a conductivity trigger, dumping its salt to waste without a rinse pump. *How:* the electrode's stored charge is the salt's driving force, so a polarity flip releases it. *Why not yet:* the control electronics cost more than the cell in every commercial design. *First build:* a single cell with a comparator-based flip circuit and a conductivity probe. *Kills it:* energy per litre above 1 kWh/m³ in brackish feed.

I008 · *Water* × *Magnetic* — **Magnetic-seeded microplastic floc.** A cartridge that doses a magnetic seed into wash water and captures the floc on a magnet, releasing it on field removal. *How:* the seed binds to polymer surfaces and gives the floc a moment. *Why not yet:* the seed chemistry was developed for ore processing and never reformulated for ambient-temperature, near-neutral water. *First build:* a jar test with a bench magnet and turbidity before and after. *Kills it:* capture below 60% of the microplastic mass.

I009 · *Water* × *Acoustic* — **Acoustic rain-barrel clarifier.** A piezo disc that coagulates fine turbidity acoustically so a barrel settles in hours rather than days. *How:* acoustic radiation force drives particle clustering at pressure nodes. *Why not yet:* acoustic coagulation works at high intensity, and the low-power regime for a barrel was never characterised. *First build:* a barrel with two transducers and a settling column sampled over 6 h. *Kills it:* settling time unchanged versus a still control.

I010 · *Water* × *Compliant* — **Pressure-compensating drip emitter by geometry.** A one-piece silicone emitter whose flow is set by a slot that narrows as pressure rises, holding flow constant from 0.5 to 3 bar. *How:* the compliant wall deflects with pressure and the gap closes. *Why not yet:* compensated emitters exist but are multi-part and cost several times an uncompensated one; a single-moulded compliant design was never tooled. *First build:* a 3D-printed silicone emitter on a bench manifold with a flow meter. *Kills it:* flow variation above 15% across the pressure range.

I011 · *Water* × *Microfluidic* — **Paper arsenic strip with a timed read.** A lateral-flow strip whose colour front's position, not just its intensity, encodes concentration. *How:* the reaction consumes a reagent as the front advances, so distance maps to concentration without a reader. *Why not yet:* paper sensors are read by intensity because cameras were assumed; a distance readout needs no optics. *First build:* strips run against standard arsenic solutions, photographed and measured with a ruler. *Kills it:* distance-concentration correlation below $r^2 = 0.9$.

I012 · *Water* × *Bio-based* — **Mycelium heavy-metal filter.** A mycelium-bound agricultural waste cartridge that biosorbs lead and cadmium and can be ashed for recovery. *How:* fungal cell walls carry phosphate and carboxyl groups that chelate metals. *Why not yet:* mycelium composites were developed for packaging, where water resistance is the goal; the opposite property is wanted here. *First build:* a column with mycelium-bound straw and a breakthrough curve. *Kills it:* capacity below 10 mg/g at drinking-water concentrations.

I013 · *Water* × *Catalytic* — **Solar-arsenite oxidiser cartridge.** A titania-coated mesh that oxidises arsenite to arsenite(V) in sunlight so a downstream adsorbent can capture it. *How:* photocatalytic oxidation changes the speciation, and As(V) adsorbs far better. *Why not yet:* photocatalysis is researched for destruction of

organics, not for speciation changes ahead of adsorption. *First build:* a mesh in a flow cell under a solar simulator with speciation analysis. *Kills it:* no measurable conversion after 30 min of illumination.

I014 · *Water* × *Radiative* — **Radiative dew harvester.** A selective emitter that cools below the dew point and condenses water without power. *How:* a surface with high 8–13 μm emissivity and low solar absorptance radiates to the sky and reaches 5–10 K below ambient. *Why not yet:* the materials existed for a decade but no one optimised the *condensation* side — droplet shedding, fouling and the yield-per-night economics. *First build:* a 1 m² panel on a roof with a load cell and a weather station. *Kills it:* less than 0.1 L/m²/night in a 70% RH climate.

I015 · *Water* × *Thermoelectric* — **Peltier membrane still.** A thermoelectric stack that drives a membrane distillation cell, using the cold side to condense and the hot side to evaporate. *How:* the same Peltier junction provides both temperature differences. *Why not yet:* Peltier efficiency is poor, but the device only needs a temperature difference across a membrane, not a large one. *First build:* an off-the-shelf Peltier, a PTFE membrane and a flux measurement. *Kills it:* less than 1 L/m²/h per watt.

I016 · *Water* × *Shape memory* — **Freeze-protection valve.** A nickel-titanium element that opens a drain when a pipe approaches freezing and closes on warming, with no power or sensor. *How:* the martensitic transformation's shape change is set by a composition-tuned transition temperature. *Why not yet:* SMA valves exist in aerospace at high cost; a plumbing-grade part was never cost-engineered. *First build:* a valve body in a freezer cycling between 2 °C and −5 °C, with a flow check. *Kills it:* actuation failing after 100 cycles.

I017 · *Water* × *Soft robotics* — **Soft pipe crawler.** A silicone peristaltic robot that inspects small-bore water mains, driven by the flow itself. *How:* alternating inflatable segments inch along the pipe, harvesting the pressure differential. *Why not yet:* pipe robots are rigid and need a tether; soft peristaltic designs were made only in millimetre-scale lab demonstrations. *First build:* a 20 mm crawler in a 25 mm transparent pipe loop. *Kills it:* propulsion slower than 0.1 m/s or unable to pass a bend.

I018 · *Water* × *Harvesting* — **Pipe-flow energy harvester.** A vibration harvester clamped to a service pipe that powers a leak sensor from the water's own turbulence. *How:* a bimorph cantilever tuned to the pipe's dominant vibration band. *Why not yet:* leak sensors are sold with batteries and radio budgets designed for five years, which made harvesting unnecessary rather than unavailable. *First build:* a clamp-on harvester and a load resistor measuring average power over a week. *Kills it:* less than 50 μW average.

I019 · *Water* × *Inference* — **Acoustic leak classifier on a phone.** A model that identifies the pipe material and leak size from a tap recording made by a utility worker's phone. *How:* the leak's spectral signature depends on the pipe's material and pressure, both recoverable from a short recording. *Why not yet:* acoustic leak detection is expert-heuristic; the training data exist only inside utilities. *First build:* a labelled set from one utility and a simple classifier with a held-out street. *Kills it:* material classification below 70% accuracy on the held-out street.

I020 · *Water* × *Structural* — **Greywater heat-recovery shower panel.** A drain-pipe heat exchanger moulded into a shower tray that preheats incoming cold water. *How:* counterflow between the drain film and the supply coil. *Why not yet:* the units are sold as plumbing accessories at a price that only pays back in cold climates; a moulded tray version was never mass-produced. *First build:* a tray insert with thermocouples and a measured recovery fraction. *Kills it:* recovery below 25% at 8 L/min.

Domain 2 — Food and agriculture

I021 · *Food* × *Passive thermal* — **Zeer-pot cold store.** A double-pot evaporative cooler sized for 50 kg of produce, with a sand layer that is re-wetted once a day. *How:* evaporative cooling in dry air holds 8–12 K below ambient. *Why not yet:* the design is ancient and dismissed as low-tech; the modern version needs a humidity-responsive wick and a produce-specific loading pattern. *First build:* two pots with a data logger and a weighed produce load over a week. *Kills it:* less than 6 K depression or produce loss above the ambient control.

I022 · *Food* × *Phase change* — **Eutectic cold-chain brick.** A salt-hydrate brick tuned to hold 2–8 °C for 96 h, replacing water ice in vaccine carriers. *How:* a eutectic at 5 °C stores latent heat in the right band and does not freeze the payload. *Why not yet:* phase-change materials are sold for buildings at €5/kg; the food-cold-chain price point is below €1/kg. *First build:* a brick in an insulated box with a thermocouple chain and an ambient profile. *Kills it:* hold time under 72 h or supercooling that misses the band.

I023 · *Food* × *Capillary* — **Capillary hydroponic mat.** A felt mat that delivers water to roots by wicking and stops when the mat is saturated, with no pump or timer. *How:* the matric potential of the mat sets the delivery rate. *Why not yet:* hydroponics is engineered around pumps and timers; passive systems exist only as houseplant products. *First build:* a tray of lettuce on a mat against a timer-irrigated control. *Kills it:* yield below 80% of the control over one cycle.

I024 · *Food* × *Triboelectric* — **Electrostatic pest screen.** A charged mesh around a crop row that captures small flying insects without insecticide. *How:* the insect's charge and the field produce a capture force on contact. *Why not yet:* electrostatic crop protection was tried in the 1970s with unreliable high-voltage supplies; modern DC-DC converters make it cheap. *First build:* a charged mesh on one row with sticky-trap counts on both. *Kills it:* capture rate no better than an uncharged mesh.

I025 · *Food* × *Piezoelectric* — **Ultrasonic sprout suppressor.** A low-power ultrasonic transducer in a potato store that inhibits sprouting without chlorpropham. *How:* mechanical stress at the bud disrupts cell division. *Why not yet:* the regulatory withdrawal of chemical suppressants is recent, and the ultrasonic dose-response in bulk storage was never established. *First build:* two boxes, one with transducers, weighed and scored at 8 and 16 weeks. *Kills it:* sprout mass unchanged versus control.

I026 · *Food* × *Optical* — **Handheld ripeness index.** A two-wavelength reflectance probe that reports a ripeness index for a specific fruit without a spectrometer. *How:* chlorophyll absorption against a reference band tracks the ripening front. *Why not yet:* NIR spectrometers are used in packing houses; the cheap two-band version needs a per-fruit calibration that was never published. *First build:* 200 fruit measured with the probe and with a destructive reference. *Kills it:* prediction error above the between-fruit spread.

I027 · *Food* × *Electrochemical* — **Battery-free spoilage tag.** A printed electrode that changes colour when amine vapour from spoiling fish accumulates. *How:* the amine shifts the potential of a pH-sensitive redox couple in a printed cell. *Why not yet:* time-temperature indicators exist, but chemical spoilage indicators need a food-specific threshold and were never calibrated per species. *First build:* tags on fish fillets at 4 °C with parallel microbial counts. *Kills it:* colour change not aligned with the microbial threshold.

I028 · *Food* × *Magnetic* — **Magnetic weed-seed separator.** A seed-cleaning drum that coats weed seeds with magnetic dust and lifts them out of a grain stream. *How:* the seeds differ in surface texture, so the dust adheres differently. *Why not yet:* seed cleaning is mechanical and cheap; magnetic separation was developed

for ore and never scaled down to a farm unit. *First build:* a bench drum with coated weed seed in a wheat sample. *Kills it:* removal below 70% with grain loss above 2%.

I029 · *Food* × *Acoustic* — **Acoustic ripeness sorter.** A tap-and-listen device that sorts fruit by firmness from the sound of a light impact. *How:* the resonant frequency of the fruit scales with its stiffness. *Why not yet:* acoustic firmness sensors are lab instruments; the signal processing needed for a cheap unit became available only with small microcontrollers. *First build:* 100 fruit tapped and measured with a penetrometer. *Kills it:* correlation below $r^2 = 0.7$.

I030 · *Food* × *Compliant* — **Compliant fruit gripper.** A single-moulded soft gripper with fingers that conform to any fruit without a sensor or controller. *How:* the finger's geometry sets the contact pressure below the bruising threshold regardless of size. *Why not yet:* soft grippers are demonstrated with pneumatic control; a passive, geometry-only design was never commercialised for harvest. *First build:* a gripper on a bench arm picking 100 fruit of three sizes, bruise-scored. *Kills it:* bruise rate above 5%.

I031 · *Food* × *Microfluidic* — **On-farm milk antibiotic strip.** A paper strip that detects beta-lactam residues in milk in five minutes at the tank. *How:* a printed enzyme-inhibition reaction with a distance readout. *Why not yet:* lab tests are used because the regulatory thresholds vary by jurisdiction and a single strip cannot serve all. *First build:* strips tested against spiked milk at the EU and US thresholds. *Kills it:* false-negative rate above 5% at the threshold.

I032 · *Food* × *Bio-based* — **Mycelium evaporative cooler pad.** A growable cooler pad that replaces cardboard honeycomb in evaporative coolers and is compostable. *How:* the mycelium's open cell structure gives a high wetted surface area. *Why not yet:* mycelium composites are made in flat sheets for packaging; a thick, wetted, airflow-oriented pad was not developed. *First build:* a pad in a bench evaporative rig with a pressure-drop and saturation-efficiency measurement. *Kills it:* saturation efficiency below 70% or structural collapse when wet.

I033 · *Food* × *Catalytic* — **Ethylene scrubber sachet.** A sachet that oxidises ethylene at room temperature inside a produce box, extending shelf life. *How:* a manganese-oxide catalyst oxidises ethylene to CO_2 and water at ambient temperature. *Why not yet:* the catalyst exists; the sachet's humidity tolerance and food-contact approval were not developed. *First build:* sachets in sealed boxes with ethylene dosing and a colourimetric measurement. *Kills it:* less than 50% ethylene removal over 24 h.

I034 · *Food* × *Radiative* — **Night-sky pre-cooler for harvest.** A radiative panel that pre-cools picked produce before cold-store entry, cutting the pull-down load. *How:* the panel radiates to the sky and cools a water loop that pre-chills the produce. *Why not yet:* radiative cooling is demonstrated on roofs, not integrated into harvest logistics. *First build:* a panel and a water loop with produce core temperature measured. *Kills it:* less than 3 K pre-cooling in a clear-sky climate.

I035 · *Food* × *Thermoelectric* — **Peltier grain drier.** A thermoelectric dehumidifier that dries a small grain batch using the cold side to condense and the hot side to warm the air. *How:* the same junction provides the sensible heat and the condensation. *Why not yet:* grain drying is done with large fossil-heat driers; a small electric unit suits off-grid farms that were never a market. *First build:* a 20 kg batch with moisture measured daily. *Kills it:* drying rate below 0.5%/day per kWh.

I036 · *Food* × *Shape memory* — **Self-venting grain silo cap.** A cap that opens at a set temperature and humidity using an SMA spring, preventing condensation drip. *How:* the spring's transition is tuned to the dew point margin. *Why not yet:* silo

vents are passive grilles sized for worst case; an actuated vent was never cost-engineered. *First build:* a cap on a sealed drum in a cycling chamber. *Kills it:* no reduction in condensate versus a fixed vent.

I037 · *Food* × *Soft robotics* — **Soft weeding end-effector.** A soft gripper that pulls weeds by the stem while leaving crop roots undisturbed. *How:* the fingers conform to the stem and pull along its axis. *Why not yet:* weeding robots use rigid tools and vision; the soft end-effector needs a different control philosophy. *First build:* a bench rig over a tray of crop and weed. *Kills it:* crop damage above 5%.

I038 · *Food* × *Harvesting* — **Vibration-powered soil moisture node.** A sensor node that harvests energy from tractor vibration and reports soil moisture once per pass. *How:* a cantilever harvester charges a capacitor that wakes a radio. *Why not yet:* soil nodes use batteries because the duty cycle is low; a vibration-only node was never fielded. *First build:* a node on a tractor-mounted probe logging transmissions per pass. *Kills it:* fewer than one successful transmission per pass.

I039 · *Food* × *Inference* — **Camera-based feed intake meter.** A cheap camera over a feed bunk that estimates intake per pen from the change in feed height. *How:* a depth map of the feed surface before and after. *Why not yet:* feed intake is measured with load cells on the bunk, which are expensive and fragile. *First build:* a depth camera and a load cell on one bunk for two weeks. *Kills it:* intake error above 10% per day.

I040 · *Food* × *Structural* — **Pallet-integrated cooling duct.** A pallet whose deck channels cold air through the stack rather than around it, cutting cool-store energy. *How:* the deck's internal geometry distributes air to the box gaps. *Why not yet:* cold-store airflow is designed around the room, not the pallet; the pallet is treated as a commodity. *First build:* two stacks in a cold room with temperature mapping. *Kills it:* no reduction in pull-down time or temperature spread.

Domain 3 — Health diagnostics

I041 · *Health* × *Passive thermal* — **Fever-strip triage card.** A card that changes colour irreversibly above 38 °C and holds the record, for use where thermometers are shared. *How:* a melting-point ink in a capillary. *Why not yet:* single-use thermochromic labels exist for shipping, not for clinical triage with a validated threshold. *First build:* 200 cards against digital thermometers in one clinic. *Kills it:* sensitivity below 90% at the threshold.

I042 · *Health* × *Phase change* — **Cold-chain vial monitor.** A phase-change label that irreversibly marks a vial that has been frozen. *How:* a water-based indicator that expands on freezing. *Why not yet:* freeze indicators exist for shipping cartons, not bonded to individual vials at low cost. *First build:* labels on vials in a freeze-thaw cycle with a logged profile. *Kills it:* failure to trigger at -1 °C.

I043 · *Health* × *Capillary* — **Capillary blood-collection card.** A card that meters a fixed volume by capillary stop and dries it for shipping, removing the centrifuge. *How:* a defined channel with a geometric stop fills a known volume. *Why not yet:* dried blood spots are made by pipette; a metered capillary card was never validated for clinical chemistry. *First build:* cards against venepuncture on 50 paired samples. *Kills it:* analyte bias beyond clinical acceptability for more than one analyte.

I044 · *Health* × *Triboelectric* — **Self-powered respiration band.** A chest band that generates its own signal from breathing motion, with no battery. *How:* a TENG's output tracks the band's strain. *Why not yet:* respiration bands are resistive or accelerometric and need power; the TENG's signal is small but the respiration frequency is slow, which suits it. *First build:* a band on ten subjects against a spirometer. *Kills it:* rate error above 2 breaths/min.

I045 · *Health* × *Piezoelectric* — **Piezo cough monitor.** A piezo film on a bed frame that counts and characterises coughs overnight. *How:* the cough's mechanical signature is distinctive in the frame's vibration. *Why not yet:* cough monitors use microphones, which raise privacy objections. *First build:* a film on a bed with audio and video as reference. *Kills it:* cough count error above 20%.

I046 · *Health* × *Optical* — **Anemia nail-fold scanner.** A phone attachment that estimates haemoglobin from the nail bed's colour under controlled illumination. *How:* the absorption of the nail bed at two wavelengths tracks haemoglobin. *Why not yet:* pulse oximetry measures saturation, not concentration, and the calibration for concentration needs a per-population correction that was never assembled. *First build:* 300 paired readings against a blood count. *Kills it:* bias above 1.5 g/dL.

I047 · *Health* × *Electrochemical* — **Sweat chloride patch.** A patch that measures chloride in sweat for cystic fibrosis screening without a laboratory. *How:* an ion-selective electrode printed on a flexible substrate. *Why not yet:* the sweat test requires pilocarpine iontophoresis and a lab; a fully integrated patch was never validated. *First build:* patches against the standard test in one clinic. *Kills it:* disagreement beyond the diagnostic threshold.

I048 · *Health* × *Magnetic* — **Magnetic lateral-flow reader.** A reader that quantifies a lateral-flow strip by measuring the magnetic moment of a labelled line, rather than its optical density. *How:* the magnetic label's signal is independent of lighting and of the strip's pigment. *Why not yet:* magnetic labels exist in labs; the reader was never cost-engineered against a phone camera. *First build:* a reader on strips of known concentration against a benchtop reader. *Kills it:* limit of detection not improved by 10×.

I049 · *Health* × *Acoustic* — **Acoustic sputum quality check.** A device that accepts or rejects a sputum sample by the sound of the cough that produced it. *How:* the cough's spectrum differs with the sample's depth and quality. *Why not yet:* sample quality is judged by eye in the lab, after transport. *First build:* recorded coughs from patients with paired sample quality scored by a microbiologist. *Kills it:* classification below 70%.

I050 · *Health* × *Compliant* — **Self-limiting tourniquet.** A compliant band whose pressure saturates at a safe value regardless of how hard it is tightened. *How:* a buckling element limits the tension. *Why not yet:* tourniquets are either manual and over-tightenable or pneumatic and expensive. *First build:* a band on a pressure rig with a limb analogue. *Kills it:* occluding pressure not reached, or pressure exceeding 300 mmHg.

I051 · *Health* × *Microfluidic* — **Metered fingerstick panel.** A card that splits one drop into four channels for four analytes with no pipetting. *How:* capillary splitting with geometric metering. *Why not yet:* point-of-care panels use cartridges that need a reader; a passive splitter was never validated for whole blood. *First build:* cards on 50 paired venous samples. *Kills it:* channel-to-channel volume variation above 10%.

I052 · *Health* × *Bio-based* — **Bacterial cellulose wound contact layer.** A grown dressing that conforms and is translucent enough to inspect the wound without removal. *How:* the cellulose's nanofibre mesh is wet, conformable and transparent when thin. *Why not yet:* bacterial cellulose is made for food and audio diaphragms; a clinical-grade contact layer was never manufactured at scale. *First build:* dressed wounds on a porcine model against a standard dressing. *Kills it:* no improvement in healing time or in inspection frequency.

I053 · *Health* × *Catalytic* — **Room-temperature sterilant sachet.** A sachet that releases a sterilant vapour when wetted, for instruments in low-resource settings. *How:* an acid-catalysed release of peracetic acid vapour. *Why not yet:* sterilants are

liquids in bulk; a single-use sachet with a validated cycle was never developed. *First build:* sachets in a sealed box with biological indicators. *Kills it:* no log-6 reduction of the indicator.

I054 · *Health* × *Radiative* — **Passive vaccine cooler.** A radiative-cooling box that holds 2–8 °C without power, using a selective emitter and a phase-change buffer. *How:* the emitter dumps heat to the sky while the phase-change material buffers the day. *Why not yet:* the materials are demonstrated in papers; a box designed for the vaccine cold chain was never built or field-tested. *First build:* a box in a hot climate with a logged internal temperature over a week. *Kills it:* excursion above 8 °C within 24 h.

I055 · *Health* × *Thermoelectric* — **Peltier sample transporter.** A portable box that holds a sample at 4 °C on a Peltier stage powered by a vehicle socket. *How:* the junction's cold side cools the sample block while the hot side vents. *Why not yet:* sample transport uses ice packs, which fail on long routes; a Peltier box was never cost-engineered. *First build:* a box in a vehicle over an 8 h route with a logger. *Kills it:* temperature excursion above 8 °C for more than 1 h.

I056 · *Health* × *Shape memory* — **Auto-retracting safety needle.** A needle that retracts on removal using an SMA spring triggered by body heat. *How:* the martensitic transition at 37 °C releases a stored spring. *Why not yet:* safety needles use passive springs and a manual click; the SMA version removes the user step. *First build:* 100 actuations in a water bath at body temperature. *Kills it:* actuation failure above 1%.

I057 · *Health* × *Soft robotics* — **Soft rehabilitation glove.** A glove with soft actuators that assist hand opening using a single low-pressure source. *How:* the actuators' geometry sequences the fingers without individual control. *Why not yet:* rehabilitation gloves use multi-channel pneumatics with a compressor; a single-source sequenced design was never validated. *First build:* one glove with a pressure source and a grip-force and range measurement. *Kills it:* range of motion improvement below 10°.

I058 · *Health* × *Harvesting* — **Body-heat powered hearing aid.** A thermoelectric element behind the ear that runs a low-power aid from the skin-to-air gradient. *How:* a 2 K gradient across a thin TEG with a low-power amplifier. *Why not yet:* hearing aids use zinc-air batteries that last a week, which made harvesting unnecessary. *First build:* a TEG on a warm plate driving a representative load. *Kills it:* less than 50 μW average.

I059 · *Health* × *Inference* — **Cough-to-X-ray triage.** A model that decides whether a cough recording warrants a chest X-ray, for triage where imaging is scarce. *How:* the cough's acoustic features correlate with lower-respiratory involvement. *Why not yet:* triage is clinician-judgement and the datasets were never assembled with imaging outcomes. *First build:* a retrospective set with cough audio and radiograph reports. *Kills it:* sensitivity below 80% at a fixed specificity of 60%.

I060 · *Health* × *Structural* — **Cold-chain box with integral phase-change walls.** An insulated box whose walls are the phase-change material, eliminating the separate packs. *How:* the wall's latent heat buffers and its low conductivity insulates. *Why not yet:* boxes use separate ice packs because the walls are structural; a phase-change structural composite was never moulded. *First build:* a box with a logged payload over 72 h. *Kills it:* hold time below 48 h.

Domain 4 — Medical devices and care

I061 · *Medical* × *Passive thermal* — **Passive neonatal warmer.** A phase-change mattress that absorbs heat during the day and releases it at night for kangaroo-care support. *How:* a salt hydrate tuned to 37 °C. *Why not yet:* neonatal warmers

are electric and cost thousands; a passive mattress was never clinically trialled. *First build:* a mattress in a simulated neonatal setting with a thermal manikin. *Kills it:* core temperature falling below 36.5 °C.

I062 · *Medical* × *Phase change* — **Cold-therapy sleeve with a set point.** A sleeve whose phase-change material holds 10 °C for hours without ice. *How:* a eutectic tuned to the therapeutic band. *Why not yet:* cold therapy uses ice or electric wraps; a set-point material was never packaged for limbs. *First build:* a sleeve on a limb analogue with a thermal log. *Kills it:* hold time below 2 h.

I063 · *Medical* × *Capillary* — **Capillary drainage dressing.** A dressing whose channels move exudate away from the wound by capillary action alone. *How:* a graded channel array with a strong capillary stop at the absorbent. *Why not yet:* dressings rely on absorbents and pressure; a capillary-engineered layer was never manufactured. *First build:* a dressing on a wound simulator with a measured fluid-handling rate. *Kills it:* no improvement in fluid handling over a standard foam.

I064 · *Medical* × *Triboelectric* — **Self-powered pressure-injury sensor.** A TENG mat under a patient that logs repositioning from the pressure changes, with no battery. *How:* the mat's output changes when the body moves. *Why not yet:* pressure mapping is done with powered mats in research settings; a battery-free disposable mat was never made. *First build:* a mat under a volunteer with a camera reference. *Kills it:* repositioning detection below 80%.

I065 · *Medical* × *Piezoelectric* — **Piezo swallow monitor.** A throat patch that detects swallow frequency and duration for dysphagia screening. *How:* the swallow's vibration signature is distinctive in a piezo film. *Why not yet:* dysphagia is assessed by videofluoroscopy; a screening patch was never validated. *First build:* patch recordings with fluoroscopy as reference. *Kills it:* agreement below 80%.

I066 · *Medical* × *Optical* — **Jaundice eye scanner.** A phone attachment that grades scleral icterus against a colour reference, replacing a bilirubin meter in screening. *How:* the sclera's yellowness is compared with an in-frame reference patch under controlled light. *Why not yet:* transcutaneous bilirubin meters are the standard and cost thousands; the eye method is dismissed as subjective. *First build:* 200 neonates against serum bilirubin. *Kills it:* correlation below $r^2 = 0.7$.

I067 · *Medical* × *Electrochemical* — **Wound Infection early warning.** A dressing with an electrode that flags a pH rise before clinical signs. *How:* infected wounds alkalinise, and an iridium-oxide electrode tracks pH. *Why not yet:* wound infection is diagnosed clinically; the sensor was never integrated into a dressing. *First build:* dressings on a wound model with bacterial challenge. *Kills it:* no pH difference before visible infection.

I068 · *Medical* × *Magnetic* — **Magnetic capsule retention test.** A swallowed magnetic bead whose transit is tracked by a handheld sensor, replacing a radiological study. *How:* the bead's position is inferred from the field at the sensor. *Why not yet:* capsule endoscopy uses cameras; a passive magnetic marker was never developed for transit testing. *First build:* a bead in a phantom and then in volunteers with X-ray reference. *Kills it:* position error above 5 cm.

I069 · *Medical* × *Acoustic* — **Acoustic fracture-healing monitor.** A device that taps a limb and listens for the change in resonance as a fracture heals. *How:* callus stiffening raises the limb's resonant frequencies. *Why not yet:* healing is assessed radiographically; the acoustic method was studied in the 1990s and abandoned for lack of a cheap analyser. *First build:* patients with paired radiographs over 12 weeks. *Kills it:* no correlation with the radiographic score.

I070 · *Medical* × *Compliant* — **Compliant airway stent.** A stent whose geometry self-adjusts to the airway's pressure so it does not erode. *How:* a compliant lattice that buckles locally at a set pressure. *Why not yet:* stents are rigid metal or

silicone; a tuned compliant lattice needs additive manufacturing at clinical scale. *First build:* a stent in an airway phantom with a pressure–diameter curve. *Kills it:* migration or collapse in the phantom.

I071 · *Medical* × *Microfluidic* — **Organ-on-chip with gravity-driven flow.** A chip that perfuses a cell culture by gravity siphon, with no pump. *How:* a height difference drives a controlled flow for 24 h. *Why not yet:* organ chips use syringe pumps, which dominate the cost and the footprint. *First build:* a chip with a gravity column and a viability and flow-rate check. *Kills it:* flow rate varying by more than 30% over 24 h.

I072 · *Medical* × *Bio-based* — **Alginate embolic bead with a trigger.** A bead that dissolves on a pH change, so an embolisation can be reversed. *How:* the alginate's crosslinks are pH-labile. *Why not yet:* embolic beads are permanent; a reversible one needs a trigger that is safe in vivo. *First build:* beads in a flow phantom with a pH switch. *Kills it:* dissolution not achieved within 30 min of the trigger.

I073 · *Medical* × *Catalytic* — **Catalytic NO donor patch.** A patch that releases nitric oxide at a controlled rate from a sweat-activated catalyst, for wound healing. *How:* a nitrite salt on a catalytic surface releases NO on contact with moisture. *Why not yet:* NO donors are unstable in storage; a dry patch was never stabilised. *First build:* a patch on a moist surface with a chemiluminescence NO analyser. *Kills it:* release rate outside the therapeutic window.

I074 · *Medical* × *Radiative* — **Radiative cooling cast.** A cast liner that radiates heat away so a limb under plaster does not overheat. *How:* a selective emitter in the liner moves heat through the plaster's infrared window. *Why not yet:* casts are chosen for mechanical properties; thermal comfort was never a design goal. *First build:* a cast on a limb analogue with an internal thermocouple. *Kills it:* no temperature reduction.

I075 · *Medical* × *Thermoelectric* — **Peltier transport incubator.** A small incubator for a newborn that runs on a vehicle battery with a Peltier stage. *How:* the stage heats and cools with polarity reversal, and a phase-change mass buffers. *Why not yet:* transport incubators are expensive and use compressors; a Peltier version was never cost-engineered. *First build:* a box in a vehicle with a thermal manikin. *Kills it:* temperature outside 36–37 °C for more than 30 min.

I076 · *Medical* × *Shape memory* — **SMA bone staple.** A staple that closes as it warms to body temperature, compressing a fracture. *How:* the martensitic transition provides a controlled recovery force. *Why not yet:* SMA staples exist in foot surgery; the general fracture application was never trialled. *First build:* a staple in a bone analogue with a force measurement. *Kills it:* compression outside the therapeutic range.

I077 · *Medical* × *Soft robotics* — **Soft robotic retractor.** A retractor that holds tissue with distributed pressure rather than point loads. *How:* an inflatable bladder with a segmented surface. *Why not yet:* retractors are rigid and hand-held; a soft one needs a pressure source and a sterilisable bladder. *First build:* a retractor in a cadaver model with a pressure map. *Kills it:* tissue pressure above the ischaemic threshold.

I078 · *Medical* × *Harvesting* — **Motion-powered infusion pump.** A pump that runs on the patient's own movement, for ambulatory infusion where power is unreliable. *How:* an eccentric-mass harvester charges a capacitor that drives a stepper. *Why not yet:* pumps use batteries and are designed for hospital power. *First build:* a harvester on a walking volunteer driving a representative load. *Kills it:* less than 1 mW average.

I079 · *Medical* × *Inference* — **Wound-photo healing trajectory.** A model that predicts healing at week 4 from a photo at week 1, to flag wounds that need escalation. *How:* the change in wound area and colour in the first week predicts

the trajectory. *Why not yet:* healing is judged at each visit, not predicted; the longitudinal image datasets were never assembled. *First build:* a retrospective set of weekly images with outcomes. *Kills it:* prediction no better than the clinician's.

I080 · *Medical* × *Structural* — **Crash-tested ambulance stretcher with integrated weighing.** A stretcher whose load cells are in the frame and survive impact. *How:* strain gauges in the frame's main beams, calibrated for the patient's position. *Why not yet:* weighing is done by a separate scale; integrating it into a crash-rated frame was never engineered. *First build:* a frame with gauges and a crash-sled test. *Kills it:* weight error above 2 kg after impact.

Domain 5 — Energy storage

I081 · *Storage* × *Passive thermal* — **Thermal battery from waste heat.** A graphite block store that captures industrial waste heat at 400 °C and returns it as process heat. *How:* sensible heat in a low-cost refractory. *Why not yet:* thermal stores are built for power plants; a modular block for a factory's intermittent waste heat was never productised. *First build:* a 100 kWh block on a foundry's flue with a charge-discharge cycle. *Kills it:* round-trip recovery below 60%.

I082 · *Storage* × *Phase change* — **Salt-hydrate cold store.** A store that freezes at −5 °C and shifts refrigeration load to off-peak hours. *How:* the hydrate's latent heat at a temperature useful for commercial cooling. *Why not yet:* phase-change materials for cold storage are sold in small sachets; a bulk store needs a corrosion-compatible container. *First build:* a 50 kWh store on a cold room with a load-shift measurement. *Kills it:* phase separation after 100 cycles.

I083 · *Storage* × *Capillary* — **Capillary-fed zinc electrode.** A zinc-air battery whose anode is fed by capillary wicking, avoiding dendrites and leaking electrolyte. *How:* the wick delivers a controlled ion flux to the electrode face. *Why not yet:* zinc-air cells flood or dry out; a capillary feed is used in fuel cells but never in a primary zinc-air product. *First build:* a single cell with a wick and a discharge curve against a gelled control. *Kills it:* capacity below the gelled control.

I084 · *Storage* × *Triboelectric* — **Static pre-charge for supercapacitors.** A triboelectric layer that pre-charges a supercapacitor stack so the converter sees a higher voltage. *How:* the TENG's high voltage and low current suit the capacitor's charging profile. *Why not yet:* TENGs are demonstrated for sensors, not as pre-charge for storage; the impedance match was never designed. *First build:* a TENG and a supercapacitor with a charge-efficiency measurement. *Kills it:* less than 20% of the TENG's energy reaching the capacitor.

I085 · *Storage* × *Piezoelectric* — **Piezo preload sensor for cell stacks.** A piezo washer in a battery stack that measures compression and flags loss of preload. *How:* the washer's charge is proportional to the stack's clamping force. *Why not yet:* stack pressure is set at assembly and never monitored; a piezo washer is a standard part looking for this application. *First build:* a washer in a 10-cell stack with a force reference. *Kills it:* charge drift making the measurement unusable after a week.

I086 · *Storage* × *Optical* — **Fibre-optic state-of-charge probe.** A fibre in a cell that reads the electrolyte's refractive index and so its concentration. *How:* the index shifts with salt concentration, read as a wavelength shift. *Why not yet:* cell diagnostics are electrical; an optical probe needs a feedthrough that survives the chemistry. *First build:* a probe in a transparent test cell against a titrated reference. *Kills it:* no correlation with the measured concentration.

I087 · *Storage* × *Electrochemical* — **Desalination battery with a salinity-driven recharge.** A cell that charges while desalinating and recovers part of the energy on discharge. *How:* the electrode's redox potential depends on the salinity it has

absorbed. *Why not yet:* desalination batteries are lab cells; the energy-recovery mode was never engineered into a stack. *First build:* a 10-cell stack on brackish water with an energy balance. *Kills it:* net energy above 1 kWh/m³.

I088 · *Storage* × *Magnetic* — **Magnetic flywheel bearing.** A passive magnetic bearing for a small flywheel that removes the vacuum pump and the active control. *How:* a Halbach array gives stable levitation with eddy-current damping. *Why not yet:* flywheels use active magnetic bearings with control electronics; a passive design was never taken past prototypes. *First build:* a 1 kWh rotor on passive bearings with a spin-down test. *Kills it:* spin-down time below 24 h.

I089 · *Storage* × *Acoustic* — **Acoustic agitation for flow batteries.** A transducer that disrupts the boundary layer at a flow-battery electrode, raising the limiting current. *How:* acoustic streaming thins the diffusion layer. *Why not yet:* flow batteries are designed around flow rate; acoustic enhancement was never applied to them. *First build:* a cell with and without a transducer at fixed flow. *Kills it:* less than 20% improvement in limiting current.

I090 · *Storage* × *Compliant* — **Compliant cell compression frame.** A frame that maintains constant stack pressure as the cells swell over life. *How:* a buckling beam with a low stiffness in the swelling direction. *Why not yet:* stacks use rigid end plates and springs; a compliant frame with the right stiffness curve was never designed. *First build:* a frame with a load cell over 200 cycles. *Kills it:* pressure variation above 30%.

I091 · *Storage* × *Microfluidic* — **Microfluidic redox-flow cell for screening.** A chip that screens redox couples for flow batteries using microlitre volumes. *How:* a microfluidic channel with electrodes and a reference. *Why not yet:* flow-battery screening is done in beakers at millilitre scale; a chip would cut the cost of exploring couples. *First build:* a chip tested against a known couple. *Kills it:* results not reproducing the beaker values.

I092 · *Storage* × *Bio-based* — **Lignin-derived hard carbon anode.** An anode made from agricultural lignin for sodium-ion cells, with a processing route suited to a paper mill. *How:* the lignin's disordered carbon hosts sodium. *Why not yet:* hard carbon is made from biomass but the lignin route's economics were never tested inside an existing pulp mill. *First build:* a batch of lignin carbon in a coin cell. *Kills it:* capacity below 250 mAh/g.

I093 · *Storage* × *Catalytic* — **Catalytic hydrogen getter for cells.** A getter that recombines leaked hydrogen inside a cell, preventing pressure build-up. *How:* a low-temperature catalyst recombines H_2 with O_2 on the cell's headspace. *Why not yet:* getters are used in vacuum devices, not in cells; the safety case was never made. *First build:* a getter in a sealed cell with a pressure sensor over a month. *Kills it:* no measurable pressure reduction.

I094 · *Storage* × *Radiative* — **Radiative cooler for battery packs.** A pack surface that radiates heat to the sky, reducing the chiller load in hot climates. *How:* a selective emitter on the pack's top face. *Why not yet:* packs are cooled by coolant loops; a passive radiative path was never added to a real pack. *First build:* two packs, one coated, in a hot car park with cell temperatures logged. *Kills it:* no reduction in peak cell temperature.

I095 · *Storage* × *Thermoelectric* — **Peltier cell balancer.** A thermoelectric element that moves heat from hot cells to cold ones inside a pack, equalising temperature. *How:* the Seebeck-driven current runs a small Peltier that shifts heat down the gradient. *Why not yet:* balancing is electrical, not thermal; thermal balancing was never implemented. *First build:* a pack with a thermoelectric element between two cells and a temperature map. *Kills it:* no reduction in cell-to-cell spread.

I096 · *Storage* × *Shape memory* — **SMA disconnect for thermal runaway.** A shape-memory element that breaks the circuit when a cell exceeds a threshold temperature. *How:* the SMA's transition at 90 °C releases a contact. *Why not yet:* protection is electronic, using a thermistor and a FET, which needs power and can fail. *First build:* an element in a heated fixture with a current-interruption test. *Kills it:* failure to interrupt at the set temperature.

I097 · *Storage* × *Soft robotics* — **Soft pouch cell constraint.** An inflatable bladder that applies uniform pressure to a pouch cell without a rigid frame. *How:* the bladder's hydrostatic pressure is uniform by construction. *Why not yet:* pouch cells are clamped with plates and foam; a hydrostatic constraint was never tried. *First build:* a bladder on a pouch cell with pressure and thickness over cycles. *Kills it:* thickness growth not suppressed.

I098 · *Storage* × *Harvesting* — **Regenerative suspension harvester.** A shock absorber that recovers energy from suspension motion and feeds the vehicle's auxiliary bus. *How:* a linear generator in the damper. *Why not yet:* regenerative dampers are demonstrated in research vehicles and dropped for cost; the case for a retrofit unit was never made. *First build:* a damper on a test rig with a power measurement. *Kills it:* less than 50 W average on a standard drive cycle.

I099 · *Storage* × *Inference* — **Impedance-based state-of-health from a phone.** A method that estimates a cell's capacity from a 10-second impedance chirp played by a phone's audio output. *How:* the cell's impedance spectrum is measured through the charging port with a simple circuit. *Why not yet:* impedance is measured by laboratory analysers; a phone-based method was never validated. *First build:* 30 cells measured by both routes. *Kills it:* capacity error above 10%.

I100 · *Storage* × *Structural* — **Load-bearing supercapacitor panel.** A structural panel that also stores charge, for building or vehicle integration. *How:* carbon-fibre electrodes in a structural laminate with a solid electrolyte. *Why not yet:* structural batteries are researched for vehicles; a building panel was never designed for the load case. *First build:* a panel with a flexural test and a capacitance measurement. *Kills it:* structural stiffness below the design value or capacitance below 1 F/cm².

Set 8 — Practical inventions, domains 6–10

Domain 6 — Energy generation

I101 · *Generation* × *Passive thermal* — **Solar chimney for ventilation and power.** A small chimney on a low-rise building that drives both ventilation and a turbine. *How:* buoyancy from a glazed absorber. *Why not yet:* solar chimneys were built at megawatt scale and failed on cost; the building-scale version is a different product. *First build:* a 3 m chimney on a test roof with an airflow and power measurement. *Kills it:* less than 20 W useful output.

I102 · *Generation* × *Phase change* — **Thermosiphon with a phase-change working fluid.** A solar collector that circulates by boiling and condensing a refrigerant at low temperature, with no pump. *How:* the density difference between liquid and vapour drives the loop. *Why not yet:* thermosiphons are used in solar water heaters with water; a low-temperature refrigerant loop needs a different plumbing standard. *First build:* a loop on a roof with a flow and temperature measurement. *Kills it:* no circulation on a cloudy day.

I103 · *Generation* × *Capillary* — **Capillary-fed microbial fuel cell.** A soil microbial fuel cell that wicks water to the anode and runs for years without maintenance. *How:* the wick maintains the anode's water content while oxygen reaches the cathode. *Why not yet:* MFCs are lab devices with pumps; a capillary-fed field unit was never deployed at scale. *First build:* a cell in soil with a load resistor and a months-long log. *Kills it:* power below 10 μW after one month.

I104 · *Generation* × *Triboelectric* — **Wave-driven TENG.** A triboelectric generator in a floating buoy that converts wave motion to charge. *How:* the buoy's relative motion drives dielectric layers into contact. *Why not yet:* wave energy converters are large and expensive; a small TENG buoy for sensor power was never built. *First build:* a buoy in a wave tank with a power measurement. *Kills it:* less than 1 W average in realistic seas.

I105 · *Generation* × *Piezoelectric* — **Piezo road-energy tile with a realistic claim.** A tile that harvests vehicle weight, specified honestly at watts not kilowatts. *How:* a piezo stack loaded by a cam. *Why not yet:* the field is full of overclaims; an honest engineering unit with a measured lifetime was never sold. *First build:* a tile in a car park with a counter and a load. *Kills it:* energy per axle below 0.1 J.

I106 · *Generation* × *Optical* — **Spectrum-splitting PV window.** A window coating that sends visible light through and infrared to a edge-mounted cell. *How:* a dichroic layer with a luminescent concentrator at the pane's edge. *Why not yet:* luminescent concentrators failed on self-absorption; the dichroic plus edge-cell combination was never productised for glazing. *First build:* a 30 cm pane with an edge cell and an efficiency measurement. *Kills it:* less than 1% overall conversion at usable transparency.

I107 · *Generation* × *Electrochemical* — **Reverse electrodialysis at a river mouth.** A stack that generates power from the freshwater–seawater salinity gradient with a low-cost membrane. *How:* the chemical potential difference drives ions through selective membranes. *Why not yet:* membranes dominate the cost; a design using low-cost, lower-selectivity membranes with a compensating stack geometry was never built. *First build:* a 10-cell stack on an estuary water sample. *Kills it:* less than 0.1 W/m² of membrane.

I108 · *Generation* × *Magnetic* — **Vibration harvester for power lines.** A magnetic harvester that draws power from the line's own aeolian vibration to run a sensor. *How:* a magnet moving through a coil, tuned to the line's vortex-shedding frequency. *Why not yet:* line sensors use current transformers, which require a minimum load; a vibration harvester works at any load. *First build:* a harvester on a spanned conductor with a load measurement. *Kills it:* less than 100 μW in light wind.

I109 · *Generation* × *Acoustic* — **Thermoacoustic generator for waste heat.** A resonator that converts a 200 °C waste-heat stream into sound and then into electricity with a linear alternator. *How:* the thermoacoustic effect in a stack between a hot and cold exchanger. *Why not yet:* thermoacoustics is a laboratory curiosity with low efficiency; a product for small industrial waste heat was never attempted. *First build:* a resonator on a hot-air source with an acoustic power measurement. *Kills it:* less than 1% of the heat converted.

I110 · *Generation* × *Compliant* — **Compliant wave surge converter.** A flexible membrane on the seabed that pumps water as waves pass, with no rigid moving parts. *How:* the membrane's deformation drives a one-way valve. *Why not yet:* wave energy uses rigid point absorbers; a compliant membrane pump was never field-tested. *First build:* a membrane in a wave flume with a pressure measurement. *Kills it:* no net pumping.

I111 · *Generation* × *Microfluidic* — **Microfluidic osmotic power chip.** A chip that generates power from a salinity gradient across a single nanopore array, as a screening tool for membranes. *How:* ionic current through the charged pores. *Why not yet:* osmotic power is studied at membrane scale; a chip for rapid screening was never commercialised. *First build:* a chip with a known pore array and a current measurement. *Kills it:* power density below the membrane benchmark.

I112 · *Generation* × *Bio-based* — **Algal biofilm power panel.** A panel that grows algae on an electrode and harvests their electrons. *How:* photosynthetic electron transfer to an anode. *Why not yet:* biophotovoltaics are lab-scale; a panel designed for a roof was never built. *First build:* a panel with an algal biofilm and a load. *Kills it:* power below 10 mW/m^2.

I113 · *Generation* × *Catalytic* — **Ambient formic-acid fuel cell.** A cell that runs on formic acid at room temperature with a non-precious catalyst. *How:* the catalyst oxidises formic acid at low overpotential. *Why not yet:* catalysts were precious-metal; the non-precious versions emerged recently and were never put in a cell. *First build:* a single cell with a polarisation curve. *Kills it:* power density below 10 mW/cm^2.

I114 · *Generation* × *Radiative* — **Night-sky thermoelectric generator.** A radiative cooler on one side of a TEG and ambient air on the other, generating power at night. *How:* the sky-facing surface runs below ambient. *Why not yet:* the temperature difference is small (2–5 K) and the TEG output is milliwatts; the application to sensor power was never engineered. *First build:* a TEG between a radiative panel and a heatsink with a load. *Kills it:* less than 10 mW/m^2.

I115 · *Generation* × *Thermoelectric* — **Wearable thermoelectric with a heat-spreader.** A TEG on the skin whose cold side is a thin anisotropic spreader that dumps heat to air. *How:* the spreader lowers the cold-side thermal resistance, which is the limiting term. *Why not yet:* wearable TEGs are limited by the air side; the spreader design was never optimised as a unit. *First build:* a TEG on a warm plate with and without the spreader. *Kills it:* less than 30 μW/cm^2 at 10 K ambient difference.

I116 · *Generation* × *Shape memory* — **SMA heat-engine for low-grade heat.** A Nitinol belt that turns a wheel as it cycles between hot and cold streams. *How:* the martensitic transition does work against a bias. *Why not yet:* SMA engines were

built in the 1970s and dropped for materials fatigue; better alloys are now available. *First build:* a belt loop between two water baths with a torque measurement. *Kills it:* belt failure within 10^4 cycles.

I117 · *Generation* × *Soft robotics* — **Dielectric elastomer wave generator.** A soft elastomer that charges as it stretches with each wave. *How:* capacitance change at constant charge raises voltage. *Why not yet:* dielectric elastomer generators are lab demonstrations; a marine version was never durability-tested. *First build:* an elastomer in a wave tank with an energy measurement. *Kills it:* electrical breakdown within 10^4 cycles.

I118 · *Generation* × *Harvesting* — **Rain-impact harvester.** A roof panel that converts raindrop impact into charge for a weather station. *How:* piezo film under a roofing membrane. *Why not yet:* rain is intermittent and low-energy; a device designed for a specific sensor budget was never built. *First build:* a panel on a roof with a rain gauge and a power log. *Kills it:* less than 1 mJ per mm of rain.

I119 · *Generation* × *Inference* — **Shadow-based solar forecasting.** A camera looking at the ground that predicts a rooftop array's output from cloud shadows minutes ahead. *How:* the shadow's motion across a calibrated ground plane gives the cloud's speed and opacity. *Why not yet:* forecasting uses sky cameras pointed up; a downward camera on the array's own roof was never used. *First build:* a camera and an array's inverter data for a month. *Kills it:* forecast skill no better than persistence.

I120 · *Generation* × *Structural* — **Solar-thermal façade panel with integral storage.** A façade panel that collects heat and stores it in its own phase-change core. *How:* a PCM core behind an absorber, with the façade's mass providing the structure. *Why not yet:* façades are structural and solar panels are add-ons; an integrated unit was never certified. *First build:* a panel on a test façade with a heat-recovery measurement. *Kills it:* less than 1 kWh/m² recovered per sunny day.

Domain 7 — Buildings and HVAC

I121 · *Buildings* × *Passive thermal* — **Thermal-mass ceiling with a night purge.** A ceiling that stores cool night air and releases it during the day, with a damper that needs no power. *How:* the mass's diurnal cycle plus a bimetal damper. *Why not yet:* night purging needs controls; a passive damper removes them but was never designed for the application. *First build:* a test room with a ceiling slab and a temperature log over a week. *Kills it:* less than 2 K peak reduction.

I122 · *Buildings* × *Phase change* — **PCM wallboard with a melting range matched to the climate.** A gypsum board with a PCM tuned to the local summer range rather than a generic 23 °C. *How:* the board buffers the daily swing. *Why not yet:* PCM boards are sold with one melting point because manufacturing is centralised; a climate-tuned product was never offered. *First build:* two test rooms, one with tuned board, one with standard. *Kills it:* no reduction in overheating hours.

I123 · *Buildings* × *Capillary* — **Capillary evaporative roof.** A roof layer that wicks water and evaporates it, cooling the building with no fan. *How:* the wick keeps the surface wet and the evaporation removes heat. *Why not yet:* evaporative roofs were researched in the 1990s and dropped for water use; a wick that runs on greywater was never tried. *First build:* a roof section fed by greywater with a heat-flux measurement. *Kills it:* less than 20 W/m² of cooling.

I124 · *Buildings* × *Triboelectric* — **Occupancy sensor with no power.** A floor tile that generates a pulse when stepped on, waking a radio. *How:* the tile's TENG output on loading. *Why not yet:* occupancy sensors use PIR and batteries; a self-

powered tile was never productised. *First build:* a tile in a corridor with a counter and a radio log. *Kills it:* missed detections above 5%.

I125 · *Buildings* × *Piezoelectric* — **Piezo dust-fan bearing monitor.** A piezo element in a fan mount that detects bearing wear from the vibration signature. *How:* the wear changes the high-frequency spectrum. *Why not yet:* fans are replaced on schedule, not on condition; a cheap sensor was never justified. *First build:* a fan with an accelerometer reference and a piezo patch. *Kills it:* detection no better than a schedule.

I126 · *Buildings* × *Optical* — **Daylight-redirecting blind.** A blind whose slats have a prismatic profile that sends daylight deep into a room without glare. *How:* total internal reflection in the slat's profile. *Why not yet:* prismatic panels exist as fixed glazing; an adjustable blind with the same optics was never manufactured. *First build:* a window mock-up with illuminance measurements at depth. *Kills it:* no increase in daylight at 4 m depth.

I127 · *Buildings* × *Electrochemical* — **Electrochemical dehumidifier.** A cell that removes humidity by pumping water across a membrane electrochemically, with no compressor. *How:* an electrochemical cell transports water as ions through a membrane. *Why not yet:* dehumidification uses refrigeration or desiccants; the electrochemical route was demonstrated only in small cells. *First build:* a cell in a humidity chamber with a moisture-removal rate. *Kills it:* less than 0.5 kg/day per m^2.

I128 · *Buildings* × *Magnetic* — **Magnetic bearing for a ceiling fan.** A passive magnetic bearing that removes the fan's mechanical wear and noise. *How:* a Halbach array levitates the rotor. *Why not yet:* ceiling fans use ball bearings that cost pennies; a magnetic bearing is over-engineered for the application but could suit very large fans. *First build:* a large fan on a magnetic bearing with a noise measurement. *Kills it:* no reduction in noise or no cost path.

I129 · *Buildings* × *Acoustic* — **Acoustic leak detector for pressurised ducts.** A handheld that locates duct leaks by the acoustic signature of the jet. *How:* the jet noise's spectrum scales with the pressure and the hole size. *Why not yet:* duct leakage is measured by pressurisation tests, not located. *First build:* a duct rig with known leaks and a detection test. *Kills it:* localisation no better than the survey.

I130 · *Buildings* × *Compliant* — **Compliant window seal.** A seal whose geometry accommodates frame movement over decades without a gasket. *How:* a buckling beam that maintains contact across a range of gaps. *Why not yet:* seals are elastomer gaskets that age; a compliant metallic seal was never cost-engineered for windows. *First build:* a seal in a cycling rig with an airtightness measurement. *Kills it:* leakage above the standard after 10^4 cycles.

I131 · *Buildings* × *Microfluidic* — **Microfluidic radon detector.** A chip that concentrates radon from air into a small volume for counting. *How:* a microfluidic trap with a scintillator. *Why not yet:* radon is measured with charcoal canisters or electrets over days; a chip would give a fast reading. *First build:* a chip in a radon chamber against a reference. *Kills it:* sensitivity below the action level.

I132 · *Buildings* × *Bio-based* — **Hemp-lime wall with a tuned hygrothermal profile.** A wall mix designed to buffer humidity and moderate temperature, with the mix specified for a climate. *How:* the bio-aggregate's moisture buffering value. *Why not yet:* hemp-lime is used for its carbon story, not its hygrothermal performance; a climate-tuned mix was never specified. *First build:* a wall panel in a twin-climate chamber. *Kills it:* no reduction in humidity swings.

I133 · *Buildings* × *Catalytic* — **Indoor formaldehyde scrubber.** A passive coating that oxidises formaldehyde at room temperature on a wall surface. *How:* a manganese catalyst oxidises formaldehyde to CO_2 at ambient temperature and

humidity. *Why not yet:* air cleaners are filters or plasma; a passive wall coating was never validated for indoor concentrations. *First build:* a chamber test with a formaldehyde source and a reference. *Kills it:* less than 30% reduction in 24 h.

I134 · *Buildings* × *Radiative* — **Radiative cooling roof with a humidity guard.** A roof coating that cools radiatively but switches to a lower emissivity when condensation would form. *How:* a humidity-responsive polymer layer changes the infrared emissivity. *Why not yet:* radiative roofs are static; a switchable layer that prevents dew and fouling was never made. *First build:* a roof panel with a dew sensor and a net cooling measurement. *Kills it:* no net cooling benefit over a static coating.

I135 · *Buildings* × *Thermoelectric* — **Thermoelectric condensate-free window.** A window frame with a Peltier element that keeps the inner pane above the dew point, preventing condensation. *How:* the warm side of the junction heats the frame's inner edge. *Why not yet:* condensation is managed by ventilation or by triple glazing; a targeted frame heater was never optimised. *First build:* a frame on a cold chamber with a condensation observation. *Kills it:* no reduction in condensation at the same energy cost.

I136 · *Buildings* × *Shape memory* — **SMA fire damper.** A damper that closes on a temperature rise with no actuator, spring or power. *How:* the SMA element's transition drives the closure. *Why not yet:* fire dampers use fusible links or motors; an SMA element gives a resettable, testable action. *First build:* a damper in a heated duct with a closure test. *Kills it:* failure to close at the rated temperature.

I137 · *Buildings* × *Soft robotics* — **Soft robotic shading.** A pneumatic cushion array that opens and closes shading without mechanical linkages. *How:* inflating the cushions changes their opacity and geometry. *Why not yet:* shading is mechanical; a pneumatic shading system needs a low-pressure source but no moving parts. *First build:* a cushion panel with a solar transmission measurement. *Kills it:* less than 50% modulation in transmission.

I138 · *Buildings* × *Harvesting* — **Door-swing harvester for access control.** A harvester in a door closer that powers a lock's radio. *How:* the closer's arm drives a small generator. *Why not yet:* access control uses batteries; the closer already does work every cycle. *First build:* a closer with a generator and a lock's power budget. *Kills it:* less than 5 mJ per swing.

I139 · *Buildings* × *Inference* — **Thermal-comfort estimate from a smart meter.** A method that infers room temperature and occupancy from a household's electricity pattern, with no sensors. *How:* the heating and cooling load's signature encodes the setpoint and the occupancy. *Why not yet:* comfort is measured with sensors; the meter data are already there and unused. *First build:* a house with meters and reference sensors for a month. *Kills it:* temperature error above 2 K.

I140 · *Buildings* × *Structural* — **Floor slab with integrated chilled beams.** A slab whose voids carry cooling water, using the structure as the terminal unit. *How:* the slab's mass and the water's flow give a radiant terminal with no ceiling unit. *Why not yet:* chilled beams are separate products; an integrated slab was never standardised. *First build:* a slab section in a test room with a cooling-output measurement. *Kills it:* less than 40 W/m² of cooling.

Domain 8 — Construction and materials

I141 · *Construction* × *Passive thermal* — **Phase-change concrete for bridge decks.** A deck mix that buffers freeze-thaw cycles, reducing salt damage. *How:* microencapsulated PCM releases latent heat at the freezing point. *Why not yet:*

PCM concrete is researched for buildings, not for freeze-thaw protection of infrastructure. *First build:* two deck slabs, one with PCM, cycled in a freeze-thaw chamber. *Kills it:* no reduction in scaling.

I142 · *Construction* × *Phase change* — **Self-healing capsule concrete.** Concrete with capsules that release a sealant when a crack reaches them. *How:* the capsule's shell fails at a set crack width. *Why not yet:* self-healing concrete is demonstrated in labs; the capsule's survival through mixing was the blocker, and better shell chemistries now exist. *First build:* a beam with capsules, cracked and re-tested. *Kills it:* no strength recovery after healing.

I143 · *Construction* × *Capillary* — **Capillary-active waterproofing.** A render whose pore structure is graded so water cannot enter but vapour can leave. *How:* a hydrophobic gradient with a hydrophilic interior. *Why not yet:* renders are single-function; a graded pore structure needs a manufacturing method that was never scaled. *First build:* a panel in a driving-rain rig with a vapour-permeance measurement. *Kills it:* water ingress above the standard.

I144 · *Construction* × *Triboelectric* — **Static-dissipative flooring for cleanrooms.** A floor whose surface charge is drained by a percolating carbon network at a controlled rate. *How:* the network's conductivity is tuned to dissipate without sparking. *Why not yet:* dissipative floors exist; the tuning of the percolation to a target relaxation time was never specified. *First build:* a tile with a charge-decay measurement. *Kills it:* decay time outside the standard band.

I145 · *Construction* × *Piezoelectric* — **Piezo weigh-in-motion pad.** A thin pad under a road that weighs axles from the piezo signal. *How:* the charge is proportional to the axle load. *Why not yet:* weigh-in-motion uses bending plates and load cells; a piezo pad is cheaper but its temperature drift was never solved. *First build:* a pad on a test track against a static weighbridge. *Kills it:* axle-load error above 10%.

I146 · *Construction* × *Optical* — **Fibre-optic crack sensor in a road.** A fibre embedded in the pavement that reports the strain of a crack opening. *How:* the fibre's Brillouin shift gives distributed strain. *Why not yet:* distributed sensing is used in bridges; a road pavement's installation method was never developed. *First build:* a fibre in a pavement section with a load test. *Kills it:* no detectable strain before visible cracking.

I147 · *Construction* × *Electrochemical* — **Cathodic protection by a printed anode.** A printable anode coating that protects a steel repair patch without a power supply. *How:* a sacrificial or impressed-current layer in the repair mortar. *Why not yet:* cathodic protection is a system with wiring; a printed anode is a material that was never certified. *First build:* a repaired slab with a corrosion-potential survey over a year. *Kills it:* no change in corrosion potential.

I148 · *Construction* × *Magnetic* — **Magnetic rebar locator with a phone.** A phone magnetometer that locates rebar from its field, with a calibration for cover depth. *How:* the rebar's remanent and induced field. *Why not yet:* cover meters are dedicated instruments; the phone's magnetometer was never calibrated for this. *First build:* a slab with known rebar and a phone scan. *Kills it:* depth error above 10 mm.

I149 · *Construction* × *Acoustic* — **Acoustic pile-integrity check.** A method that detects a pile defect from the sound of a hammer strike, using a library of signatures. *How:* the pile's resonant response changes with a defect. *Why not yet:* integrity testing uses sonic echo with expert interpretation; a library-based classifier was never built. *First build:* piles with known defects in a test site. *Kills it:* detection below 70%.

I150 · *Construction* × *Compliant* — **Compliant seismic isolator from steel.** A single-material isolator that buckles in a controlled way to absorb seismic energy. *How:* a lattice column with a tailored buckling curve. *Why not yet:* isolators are laminated rubber or friction pendulums, both multi-material; a steel-only compliant design was never tested. *First build:* a column on a shake table with a base-isolated mass. *Kills it:* less than 50% reduction in acceleration.

I151 · *Construction* × *Microfluidic* — **Microfluidic chloride ingress sensor.** A sensor embedded in concrete that measures chloride concentration in the pore water. *How:* a microfluidic sampler with an ion-selective electrode. *Why not yet:* chloride is measured by coring and titration; an embedded sensor was never made durable enough. *First build:* a sensor in a chloride-exposed slab over six months. *Kills it:* no correlation with the core samples.

I152 · *Construction* × *Bio-based* — **Bacterial self-healing mortar.** Mortar with bacterial spores that precipitate calcite in cracks. *How:* the spores germinate on water ingress and precipitate calcium carbonate. *Why not yet:* the technology is demonstrated but the spores' shelf life in dry mortar was the blocker; encapsulated spores now last. *First build:* a mortar prism cracked and healed under a wet-dry cycle. *Kills it:* no permeability recovery.

I153 · *Construction* × *Catalytic* — **Photocatalytic NOx pavement.** A pavement coating that oxidises nitrogen oxides at the surface in sunlight. *How:* titania photocatalysis with a nitrate wash-off path. *Why not yet:* trial sections exist and were judged on cost; the wash-off of nitrate was never resolved. *First build:* a trial slab with an inlet and outlet NOx measurement. *Kills it:* less than 20% reduction.

I154 · *Construction* × *Radiative* — **Radiative-cooling pavement.** A pavement that radiates heat at night and reduces the urban heat island. *How:* a high-emissivity aggregate with a low solar absorptance. *Why not yet:* cool pavements are specified by solar reflectance; the infrared emissivity was never the design variable. *First build:* two pavement sections with surface-temperature logging. *Kills it:* no reduction in peak surface temperature.

I155 · *Construction* × *Thermoelectric* — **Thermoelectric de-icing strip.** A strip in a pavement that uses the ground's warmth to keep the surface above freezing. *How:* a heat pump that moves ground heat to the surface. *Why not yet:* de-icing uses salt or embedded electric heaters; a heat-pump strip draws far less power. *First build:* a slab with a strip and a freezing-chamber test. *Kills it:* surface temperature not held above 0 °C.

I156 · *Construction* × *Shape memory* — **SMA post-tensioning.** A tendon that maintains tension as concrete shrinks, using the SMA's recovery. *How:* the transformation supplies a near-constant force. *Why not yet:* post-tensioning uses steel tendons and grout; an SMA tendon was never used in a real structure. *First build:* a beam with an SMA tendon and a load measurement. *Kills it:* force loss above 10% over a year.

I157 · *Construction* × *Soft robotics* — **Soft robotic formwork.** An inflatable formwork that shapes concrete and is removed by deflation. *How:* the inflated membrane's geometry sets the concrete's surface. *Why not yet:* formwork is timber or steel; a reusable inflatable was never engineered for the pressures involved. *First build:* a column cast in an inflatable form with a dimensional check. *Kills it:* dimensional tolerance worse than ±10 mm.

I158 · *Construction* × *Harvesting* — **Pavement thermoelectric harvester.** A TEG between the pavement's hot surface and its cooler base that powers a road stud. *How:* the vertical temperature gradient in summer. *Why not yet:* road studs use solar cells; the pavement's own gradient was never exploited. *First build:* a stud with a TEG and a power log. *Kills it:* less than 1 mW average.

I159 · *Construction* × *Inference* — **Concrete strength from mixing-water data.** A model that predicts 28-day strength from the batching records, so fewer cubes are crushed. *How:* the water-cement ratio and the aggregate's moisture dominate the strength. *Why not yet:* strength is verified by crushing cubes; the batch data are recorded and discarded. *First build:* a plant's records against its cube results. *Kills it:* prediction error above 4 MPa.

I160 · *Construction* × *Structural* — **Timber-concrete composite with a demountable shear connection.** A connection that can be undone, so the components are reusable. *How:* a friction connection with a controlled preload. *Why not yet:* composite floors use glued or welded shear studs; a demountable connection was never standardised. *First build:* a composite beam tested, demounted and re-tested. *Kills it:* more than 20% stiffness loss after demounting.

Domain 9 — Manufacturing and metrology

I161 · *Manufacturing* × *Passive thermal* — **Thermal-error compensation by design.** A machine frame whose geometry compensates its own thermal growth, with no sensor or control. *How:* two materials with different expansion are arranged so the tool point stays fixed. *Why not yet:* compensation is done in software; a passive geometric solution was never designed into a low-cost machine. *First build:* a frame on a test stand with a displacement measurement over a warm-up. *Kills it:* drift above 20 μm.

I162 · *Manufacturing* × *Phase change* — **PCM-cooled welding fixture.** A fixture that absorbs weld heat so a thin part does not distort. *How:* a phase-change mass clamps the part and holds its temperature. *Why not yet:* fixtures are steel and rely on chill blocks; a PCM fixture was never used in production. *First build:* a fixture welding a thin panel with a distortion measurement. *Kills it:* no reduction in distortion.

I163 · *Manufacturing* × *Capillary* — **Capillary lubrication for a linear guide.** A guide that draws oil by capillary action from a reservoir, with no pump. *How:* a wick feeds the rail at a rate set by the motion. *Why not yet:* guides are greased for life or fed by a pump; a capillary feed was never productised. *First build:* a guide on a test rig with a friction measurement over 10^6 cycles. *Kills it:* friction rise above 20%.

I164 · *Manufacturing* × *Triboelectric* — **Powder-flow electrification sensor.** A sensor that measures the charge on a powder stream to infer the flow rate and the humidity. *How:* the streaming current scales with mass flow and with moisture. *Why not yet:* powder flow is measured by weighing; the charge is treated as a nuisance. *First build:* a rig with a load cell and a charge measurement. *Kills it:* no correlation with mass flow.

I165 · *Manufacturing* × *Piezoelectric* — **Piezo tool-wear sensor.** A piezo element in a tool holder that detects wear from the cutting-force spectrum. *How:* the wear changes the high-frequency force signature. *Why not yet:* tool wear is managed by schedule or by spindle load; a piezo insert was never standardised. *First build:* a holder on a lathe with a tool-life test. *Kills it:* detection no better than the schedule.

I166 · *Manufacturing* × *Optical* — **In-process surface-finish from speckle.** A laser speckle sensor that reads surface roughness during machining. *How:* the speckle's contrast and correlation time depend on the roughness and the feed. *Why not yet:* roughness is measured after the part is off the machine. *First build:* a sensor on a lathe with a stylus reference. *Kills it:* correlation below $r^2 = 0.8$.

I167 · *Manufacturing* × *Electrochemical* — **Electrochemical deburring of printed parts.** A post-process that removes burrs from additively manufactured channels electrochemically. *How:* the burr's high current density dissolves preferentially. *Why not yet:* AM post-processing is mechanical or thermal; electrochemical finishing was never adapted to lattice channels. *First build:* a printed channel before and after with a flow measurement. *Kills it:* no improvement in flow or in surface finish.

I168 · *Manufacturing* × *Magnetic* — **Magnetic clamping for thin sheets.** A clamp that holds thin sheet by distributed magnetic force, avoiding the distortion of mechanical clamps. *How:* an array of small magnets with a compliant backing. *Why not yet:* magnetic chucks are for ferrous thick stock; a compliant array for thin aluminium needs a different principle. *First build:* a clamp with a sheet and a flatness measurement. *Kills it:* no improvement in flatness.

I169 · *Manufacturing* × *Acoustic* — **Acoustic emission for additive manufacturing.** A sensor that detects porosity during a metal print from the acoustic emission of the melt pool. *How:* a pore collapse emits a characteristic transient. *First build:* a build with deliberately varied porosity and a trained classifier. *Kills it:* detection below 70% at fixed false-positive rate. *Why not yet:* AM monitoring uses cameras and thermography, which see only the surface.

I170 · *Manufacturing* × *Compliant* — **Compliant alignment fixture.** A fixture that self-centres a part by elastic averaging, without adjustment screws. *How:* a lattice of compliant elements averages the part's positional error. *Why not yet:* fixtures are rigid and adjusted; elastic averaging is known in precision engineering but never productised for general fixturing. *First build:* a fixture with a part and a repeatability measurement. *Kills it:* repeatability worse than a manual fixture.

I171 · *Manufacturing* × *Microfluidic* — **Microfluidic coolant for diamond turning.** A microfluidic nozzle that delivers coolant exactly to the cutting zone. *How:* the nozzle's geometry and the capillary feed place the fluid at the tool edge. *Why not yet:* coolant is flooded; a microfluidic delivery was never integrated into a tool holder. *First build:* a holder with a nozzle and a tool-life comparison. *Kills it:* no improvement in tool life or surface finish.

I172 · *Manufacturing* × *Bio-based* — **Mycelium tooling for composites.** Tooling grown from mycelium that is used once and composted, for large composite layups. *How:* the mycelium's growth forms a stiff, lightweight mould. *Why not yet:* composite tooling is metal or epoxy, kept for thousands of parts; a single-use grown tool suits one-off large parts that were never a market. *First build:* a mould grown and a panel laid up on it. *Kills it:* dimensional accuracy outside ± 2 mm.

I173 · *Manufacturing* × *Catalytic* — **Catalytic exhaust for 3D printers.** A small catalytic element that destroys the VOCs from a printer's enclosure. *How:* a low-temperature oxidation catalyst on a heated substrate. *Why not yet:* printers use carbon filters that saturate; a catalytic element was never fitted because the enclosure's airflow was too low. *First build:* a printer enclosure with a VOC sensor and a catalyst. *Kills it:* less than 50% VOC reduction.

I174 · *Manufacturing* × *Radiative* — **Radiative-cooled machine enclosure.** An enclosure that radiates heat so the machine needs no chiller. *How:* a selective emitter on the enclosure's top surface. *Why not yet:* enclosures are ventilated or chilled; a passive radiative path was never designed in. *First build:* an enclosure with and without the coating and an internal temperature log. *Kills it:* no reduction in internal temperature.

I175 · *Manufacturing* × *Thermoelectric* — **Thermoelectric spot cooler for a weld.** A Peltier block that cools a weld's heat-affected zone to control cooling rate and microstructure. *How:* the junction removes heat at a set rate. *Why not yet:*

cooling rate is controlled by preheat and by the process; a local Peltier was never used. *First build:* a weld with a thermoelectric block and a hardness survey. *Kills it:* no change in the heat-affected zone.

I176 · *Manufacturing* × *Shape memory* — **SMA collet for repeatable clamping.** A collet that clamps with a constant, calibrated force set by its transformation. *How:* the SMA's plateau stress gives a fixed clamping force. *Why not yet:* collets are mechanical and torque-dependent; an SMA collet removes the operator variance. *First build:* a collet with a force sensor over 1000 cycles. *Kills it:* force variation above 5%.

I177 · *Manufacturing* × *Soft robotics* — **Soft robotic bin picker for fragile parts.** A gripper whose fingers conform to any part in a bin without a vision system. *How:* the fingers' compliance and the bin's geometry guide the grasp. *Why not yet:* bin picking uses vision and rigid grippers; a vision-free soft gripper was never deployed at production speed. *First build:* a picker on a bin of mixed parts with a success rate. *Kills it:* pick success below 90%.

I178 · *Manufacturing* × *Harvesting* — **Vibration-powered machine tag.** A tag on a rotating machine that harvests its own vibration to report temperature. *How:* a tuned cantilever with a piezo element. *Why not yet:* condition monitoring uses wired sensors or batteries; a harvester is unnecessary on mains-powered machines but essential on remote ones. *First build:* a tag on a pump with a data log. *Kills it:* less than 100 μW.

I179 · *Manufacturing* × *Inference* — **Machine-tool wear from spindle current.** A model that estimates tool wear from the spindle's current signature, with no additional sensor. *How:* the current's harmonic content changes with the cutting force. *Why not yet:* the drive already measures current, but the data are used only for protection. *First build:* a machine with a dynamometer reference over a tool's life. *Kills it:* wear prediction error above 20%.

I180 · *Manufacturing* × *Structural* — **Modular reconfigurable fixture plate.** A plate whose hole pattern and clamps are reconfigured by hand in minutes for a new part. *How:* a kinematic coupling with a standard grid. *Why not yet:* fixtures are bespoke; a reconfigurable plate exists in research but was never standardised across machine tools. *First build:* a plate set up for two parts with a changeover time measurement. *Kills it:* changeover slower than 30 min.

Domain 10 — Robotics and automation

I181 · *Robotics* × *Passive thermal* — **Thermally actuated gripper.** A gripper that closes on a temperature difference, for hot or cold environments where motors fail. *How:* a bimetallic or SMA element. *Why not yet:* grippers are electric or pneumatic; a thermally driven one suits extreme environments that are niche. *First build:* a gripper in an oven and in a freezer with a grip test. *Kills it:* no grip force at the extremes.

I182 · *Robotics* × *Phase change* — **PCM-actuated soft robot.** A soft actuator driven by the expansion of a phase-change material, with no compressor. *How:* a wax or hydrate expanding in a compliant chamber. *Why not yet:* soft robots use pneumatics with a compressor; a PCM actuator is slow but needs no infrastructure. *First build:* an actuator with a displacement and force measurement. *Kills it:* less than 10 mm stroke or cycle time above 1 min.

I183 · *Robotics* × *Capillary* — **Capillary self-refilling gripper.** A gripper that refills its own hydraulic fluid from a reservoir by capillary action. *How:* a wick maintains the working fluid. *Why not yet:* hydraulic grippers need maintenance; a self-refilling design suits robots in inaccessible places. *First build:* a gripper with a reservoir and a long-duration cycle test. *Kills it:* pressure loss within 10^4 cycles.

I184 · *Robotics* × *Triboelectric* — **Touch sensor with no wiring.** A robot skin that reports contact by a TENG pulse, with no power or data wire to each cell. *How:* each cell's pulse is coded by its capacitance. *Why not yet:* robot skins are wired matrices; a self-powered cell removes the wiring harness. *First build:* a 4×4 skin with a contact localisation test. *Kills it:* localisation error above one cell.

I185 · *Robotics* × *Piezoelectric* — **Piezo slip detection.** A gripper that detects slip from the vibration of the object in the fingers. *How:* the onset of slip has a characteristic high-frequency signature. *Why not yet:* slip is detected by force derivatives; a piezo film is cheaper and faster. *First build:* a gripper lifting objects with a slipping test. *Kills it:* detection slower than the slip event.

I186 · *Robotics* × *Optical* — **Single-photodiode gripper.** A gripper that estimates object size and reflectivity from one LED-photodiode pair. *How:* the reflected intensity and the occlusion time give the size. *Why not yet:* grippers use cameras or arrays; a single pair is enough for a binary grasp decision. *First build:* a gripper on a set of objects with a classification test. *Kills it:* size error above 30%.

I187 · *Robotics* × *Electrochemical* — **Electro-adhesive gripper for rough surfaces.** A gripper that uses electro-adhesion to hold rough or dirty surfaces that suction cannot. *How:* an interdigitated electrode induces charges across the surface. *Why not yet:* electro-adhesion is used for smooth panels; a version for rough surfaces needs a compliant electrode. *First build:* a gripper on concrete and on fabric with a pull-off test. *Kills it:* holding force below the object's weight.

I188 · *Robotics* × *Magnetic* — **Magnetic wheel for ferrous surfaces.** A wheel that climbs steel structures with a controlled magnetic normal force. *How:* a Halbach array that can be switched off for detachment. *Why not yet:* climbing robots use permanent magnets that are hard to detach or electromagnets that are heavy. *First build:* a wheel on a steel wall with a payload test. *Kills it:* detachment requiring more force than the robot's actuator.

I189 · *Robotics* × *Acoustic* — **Ultrasonic proximity for dusty environments.** A sonar that works where cameras fail because of dust. *How:* coded ultrasound with matched filtering. *Why not yet:* sonar is used in water; an air sonar for industrial dust was never productised. *First build:* a sensor in a dust chamber with a ranging test. *Kills it:* range error above 10% at 2 m.

I190 · *Robotics* × *Compliant* — **Compliant arm with gravity compensation by geometry.** A robot arm whose links are shaped so gravity is balanced without motors. *How:* the linkage's geometry makes the gravitational torque independent of configuration. *Why not yet:* arms compensate in software; a geometry-only solution suits very low-power robots. *First build:* an arm with a torque measurement across its workspace. *Kills it:* holding torque above 10% of the payload's.

I191 · *Robotics* × *Microfluidic* — **Microfluidic joint with hydraulic actuation.** A joint actuated by a microfluidic pump with no compressible air. *How:* a closed hydraulic circuit with a small pump. *Why not yet:* robots use pneumatics or electric motors; hydraulics is heavy but incompressible, which suits precise force control. *First build:* a joint with a position and stiffness measurement. *Kills it:* leakage within 10^5 cycles.

I192 · *Robotics* × *Bio-based* — **Biodegradable robot chassis.** A chassis grown or moulded from agricultural waste, for single-use field robots. *How:* a mycelium or fibre composite with adequate stiffness. *Why not yet:* robots are built to last; agricultural robots that are left in the field need to disappear. *First build:* a chassis with a stiffness test and a burial degradation test. *Kills it:* stiffness below the payload requirement.

I193 · *Robotics* × *Catalytic* — **Self-cleaning robot lens.** A lens coating that decomposes organic fouling in sunlight so a field robot's camera stays clear. *How:* a photocatalytic coating activated by ambient light. *Why not yet:* robots use wipers or air jets; a passive coating was never tested in field conditions. *First build:* a lens on an outdoor robot over a month with image contrast. *Kills it:* no improvement in contrast.

I194 · *Robotics* × *Radiative* — **Radiative-cooled robot enclosure.** An enclosure that stays near ambient in direct sun without a fan. *How:* a selective emitter plus a low-solar-absorptance coating. *Why not yet:* outdoor robots use fans and vents that admit dust. *First build:* an enclosure in the sun with an internal temperature log. *Kills it:* internal temperature above ambient by more than 10 K.

I195 · *Robotics* × *Thermoelectric* — **Thermoelectric spot cooler for robot electronics.** A Peltier that cools a processor hotspot in a sealed enclosure. *How:* the junction moves heat to the enclosure wall. *Why not yet:* robots use heatsinks and fans; a sealed robot cannot vent. *First build:* an enclosure with a hot processor and a temperature measurement. *Kills it:* no reduction in processor temperature.

I196 · *Robotics* × *Shape memory* — **SMA latch for a robot joint.** A latch that locks a joint with no power, released by a current pulse. *How:* the SMA's transition releases a spring. *Why not yet:* brakes are electromagnetic and hold with power; an SMA latch holds with none. *First build:* a latch with a holding-force and release-time test. *Kills it:* release time above 1 s.

I197 · *Robotics* × *Soft robotics* — **Soft robot that grows.** A robot that extends a soft body by everting a tube, reaching into spaces a rigid arm cannot. *How:* pressure everts the tube from the tip. *Why not yet:* growing robots are research prototypes; a version for inspection of collapsed structures was never fielded. *First build:* a grower in a rubble analogue with a reach test. *Kills it:* buckling before 3 m of reach.

I198 · *Robotics* × *Harvesting* — **Harvesting robot joint with energy recovery.** A joint that recovers energy on lowering, extending a battery-powered robot's shift. *How:* a regenerative drive returns energy on negative work. *Why not yet:* robot joints are not regenerative because the duty cycle was assumed dominated by positive work. *First build:* an arm with a regenerative drive and an energy measurement over a pick-and-place cycle. *Kills it:* less than 10% energy recovery.

I199 · *Robotics* × *Inference* — **Grasp success prediction from a single image.** A model that predicts whether a grasp will succeed before it is attempted, with no depth sensor. *How:* the object's silhouette and the gripper's approach geometry. *Why not yet:* grasp planning uses depth and simulation; a single-image predictor suits low-cost robots. *First build:* a dataset of attempts with outcomes and a held-out object set. *Kills it:* prediction below 80% on unseen objects.

I200 · *Robotics* × *Structural* — **Robot with a structural battery.** A chassis that is also the battery, extending runtime by removing the separate pack. *How:* a carbon-fibre composite supercapacitor or structural cell. *Why not yet:* structural batteries are demonstrated in labs; a robot chassis is a natural first product because mass matters and the load is modest. *First build:* a chassis with a capacity and stiffness measurement. *Kills it:* stiffness below the structural requirement.

Set 8 — Practical inventions, domains 11–15

Domain 11 — Transport and logistics

I201 · *Transport* × *Passive thermal* — **Passive refrigerated trailer panel.** A trailer roof that radiates heat at night so the unit's compressor runs less. *How:* a selective emitter on the roof's outer skin. *Why not yet:* trailers are insulated boxes; a radiative top layer was never added because the roof is a structural skin. *First build:* two trailers, one coated, with cargo-temperature logs. *Kills it:* no reduction in compressor duty.

I202 · *Transport* × *Phase change* — **Eutectic holdover for last-mile vans.** A phase-change slab that keeps a van's cargo cold across a delivery round with the engine off. *How:* a eutectic at −18 °C recharged overnight. *Why not yet:* vans use engine-driven refrigeration; holdover plates exist for older trucks but were never redesigned for electric vans. *First build:* a van with plates and a cargo log over a round. *Kills it:* cargo above −15 °C before the round ends.

I203 · *Transport* × *Capillary* — **Capillary fuel filter with a water sump.** A filter that separates water by a capillary stop and drains it automatically. *How:* a hydrophobic membrane passes fuel but not water. *Why not yet:* filters trap water in a bowl that a mechanic drains; an automatic drain was never fitted to small engines. *First build:* a filter on a test rig with a water injection. *Kills it:* water passing downstream.

I204 · *Transport* × *Triboelectric* — **Tyre-pressure sensor with no battery.** A sensor that harvests the tyre's own deformation to report pressure. *How:* a TENG in the tyre's inner liner. *Why not yet:* TPMS sensors use coin cells lasting 7 years, which made harvesting unnecessary; the battery's disposal is the emerging problem. *First build:* a sensor in a test wheel with a pressure log. *Kills it:* less than 1 mW average at highway speed.

I205 · *Transport* × *Piezoelectric* — **Axle-load sensor in a spring seat.** A piezo washer under a suspension spring that measures axle load. *How:* the charge is proportional to the spring force. *Why not yet:* axle load is measured at weighbridges; an on-board sensor was never fitted because of drift. *First build:* a vehicle with a washer and a weighbridge comparison. *Kills it:* load error above 5%.

I206 · *Transport* × *Optical* — **Brake-pad wear by colour.** A pad with a wear-marker layer that changes colour as it thins, readable through the wheel. *How:* a multi-layer coating exposes a differently coloured layer as it wears. *Why not yet:* pads have a squeal tab or a sensor on premium cars; a colour marker costs almost nothing. *First build:* pads on a dynamometer with a periodic inspection. *Kills it:* no visible change before the wear limit.

I207 · *Transport* × *Electrochemical* — **Electrochemical NOx trap for cold start.** A trap that adsorbs NOx at low temperature and releases it when the catalyst is warm. *How:* a selective adsorbent with an electrochemical regeneration. *Why not yet:* cold-start NOx is the dominant fraction for short trips; the trap was researched but never packaged for retrofit. *First build:* a trap on a bench engine with a cold-start cycle. *Kills it:* less than 40% cold-start NOx reduction.

I208 · *Transport* × *Magnetic* — **Magnetic coupler for a trailer's brake line.** A coupler that aligns and holds an air line without a threaded fitting. *How:* a magnetic ring with an O-ring seal. *Why not yet:* couplings are threaded or claw-

type and fail by cross-threading; a magnetic self-aligning coupler was never tried. *First build:* a coupler on a test rig with a leak and a pull-off test. *Kills it:* leakage above the standard.

I209 · *Transport* × *Acoustic* — **Rail-wheel flat detector.** A trackside microphone that detects a wheel flat from its impact rhythm. *How:* a flat produces a periodic impact at the wheel's rotation rate. *Why not yet:* flats are found by visual inspection or by vibration sensors on the train. *First build:* a microphone at a test track with an instrumented wheelset. *Kills it:* detection below 80%.

I210 · *Transport* × *Compliant* — **Compliant bump stop with a progressive rate.** A single-material bump stop whose stiffness rises steeply at the end of travel, with no separate helper spring. *How:* a lattice whose cells lock in sequence. *Why not yet:* bump stops are rubber cylinders with a fixed curve; a lattice gives a designed curve. *First build:* a stop on a suspension rig with a force–deflection curve. *Kills it:* curve no better than a standard stop.

I211 · *Transport* × *Microfluidic* — **Microfluidic diesel injector.** An injector with microfluidic passages that atomise fuel without high pressure. *How:* a microfluidic channel's geometry produces droplets at low pressure. *Why not yet:* injection is high-pressure common rail; microfluidic atomisation was never tried at engine temperatures. *First build:* an injector on a spray bench with a droplet-size measurement. *Kills it:* Sauter mean diameter above the target.

I212 · *Transport* × *Bio-based* — **Mycelium packaging that survives the cold chain.** A grown packaging that insulates as well as EPS for chilled shipments. *How:* the mycelium's closed-cell structure. *Why not yet:* mycelium packaging is sold for dry goods; a wet, cold application needs a hydrophobic treatment that was never developed. *First build:* a box with a cold pack and a thermal log. *Kills it:* hold time below EPS by more than 20%.

I213 · *Transport* × *Catalytic* — **Catalytic cargo-hold ethylene filter.** A filter that destroys ethylene in a refrigerated container's air. *How:* a low-temperature oxidation catalyst. *Why not yet:* containers use ventilation only; the catalyst exists but was never packaged for a reefer. *First build:* a filter on a container's air path with an ethylene measurement. *Kills it:* less than 50% ethylene removal.

I214 · *Transport* × *Radiative* — **Radiative cooler for a refrigerated container's condenser.** A panel that reduces the condenser's load on a hot deck. *How:* the panel rejects heat to the sky, lowering the condenser's air temperature. *Why not yet:* reefers are designed around air-cooled condensers; a radiative precooler was never fitted. *First build:* a container on a hot pad with a power measurement. *Kills it:* no reduction in compressor power.

I215 · *Transport* × *Thermoelectric* — **Thermoelectric seat cooler.** A seat whose Peltier element cools the occupant directly rather than the cabin. *How:* the junction cools a contact surface with the waste heat vented under the seat. *Why not yet:* cabins are cooled as a whole; personal cooling is far more efficient but was never fitted to vehicles. *First build:* a seat in a hot car with a comfort and power measurement. *Kills it:* less than 50 W of cooling per seat.

I216 · *Transport* × *Shape memory* — **SMA thermal switch for a battery pack.** A vent that opens at a set temperature with no actuator. *How:* an SMA element opens the louvre. *Why not yet:* vents are passive grilles or powered shutters; an SMA louvre needs no power or controller. *First build:* a vent in a heated enclosure with a flow test. *Kills it:* failure to open at the set point.

I217 · *Transport* × *Soft robotics* — **Soft robotic cargo tie-down.** A strap that distributes load over a fragile surface by conforming. *How:* an inflatable strap with a compliant contact patch. *Why not yet:* tie-downs are webbing with point loads; a conforming strap was never designed. *First build:* a strap on a fragile load with a pressure measurement. *Kills it:* no reduction in peak contact pressure.

I218 · *Transport* × *Harvesting* — **Regenerative railway track harvester.** A track-mounted harvester that converts rail deflection into power for signalling. *How:* a piezo or linear generator under the sleeper. *Why not yet:* signalling is mains or battery powered; track deflection is free energy on rural lines. *First build:* a harvester under a sleeper with a power log. *Kills it:* less than 100 mW average.

I219 · *Transport* × *Inference* — **Pothole detection from suspension data.** A fleet's existing suspension sensors used to map road condition, with no dedicated survey. *How:* the shock absorber's velocity trace carries the road's profile. *Why not yet:* road condition is surveyed with instrumented vehicles; fleets already carry the sensors. *First build:* a fleet's data against a survey vehicle on a known road. *Kills it:* correlation below $r^2 = 0.7$.

I220 · *Transport* × *Structural* — **Battery-in-frame e-bike.** A frame whose tubes are the battery cells, removing the separate pack. *How:* structural cells in the down tube. *Why not yet:* e-bike packs are removable for charging; a structural pack suits a bike that charges in place. *First build:* a frame with cells and a stiffness and capacity test. *Kills it:* frame stiffness below the safety requirement.

Domain 12 — Electronics and semiconductors

I221 · *Electronics* × *Passive thermal* — **Thermal via-free hotspot spreader.** An anisotropic heat spreader that moves heat laterally from a hotspot without vias. *How:* a graphite or diamond-like film with in-plane conduction. *Why not yet:* spreaders are used at package level; a die-level film with the right adhesion was never qualified. *First build:* a die with a film and an infrared temperature map. *Kills it:* no reduction in hotspot temperature.

I222 · *Electronics* × *Phase change* — **Phase-change thermal buffer for bursty chips.** A PCM layer that absorbs a processor's transient heat, letting the fan be sized for the average. *How:* the PCM's latent heat buffers the burst. *Why not yet:* thermal design uses steady-state resistance; a transient buffer needs a different design method. *First build:* a package with a PCM layer and a burst-load test. *Kills it:* no reduction in peak junction temperature.

I223 · *Electronics* × *Capillary* — **Capillary-fed evaporative chip cooler.** A wick that delivers coolant to a chip's surface by capillary action, with no pump. *How:* the wick's capillary pressure overcomes the loop's losses at low heat flux. *Why not yet:* liquid cooling uses pumps; a capillary loop suits low-power devices in sealed enclosures. *First build:* a loop on a heater block with a thermal resistance measurement. *Kills it:* thermal resistance above 1 K/W.

I224 · *Electronics* × *Triboelectric* — **Contact-powered wake switch.** A device that wakes on physical contact, with no standby power. *How:* the contact generates a charge pulse that triggers a latch. *Why not yet:* wake-up uses accelerometers or buttons with standby current; a contact-TENG removes the standby. *First build:* a switch with a standby-current and wake-latency measurement. *Kills it:* standby current not driven below 10 nA.

I225 · *Electronics* × *Piezoelectric* — **Piezo MEMS microphone with a built-in self-test.** A microphone that tests its own diaphragm by driving it with the same piezo layer. *How:* the element works in both directions. *Why not yet:* MEMS microphones are capacitive and cannot self-test; a piezo element can, which matters for automotive and medical arrays. *First build:* a microphone with a self-test and a sensitivity comparison. *Kills it:* no detectable fault when the diaphragm is deliberately damaged.

I226 · *Electronics* × *Optical* — **Optical interconnect on a flexible substrate.** A polymer waveguide with a VCSEL that replaces a ribbon cable in a flex circuit. *How:* the waveguide carries modulated light between rigid boards. *Why not yet:*

optical links are board-to-board; a flex-integrated version needs a connector that survives bending. *First build:* a flex with a waveguide and a bit-error-rate measurement. *Kills it:* BER not improved over copper at the target length.

I227 · *Electronics* × *Electrochemical* — **Printed memristor for tamper logging.** A device that records whether a package was opened, using a memristive state that is read electrochemically. *How:* an air-sensitive layer changes conductance on exposure. *Why not yet:* tamper evidence is mechanical (seals); an electronic record was never printed at a low cost. *First build:* a printed device in a package with a read after opening. *Kills it:* no state change on exposure.

I228 · *Electronics* × *Magnetic* — **Magnetic connector with self-cleaning contacts.** A connector whose magnetic mating wipes the contacts as it closes. *How:* the mating motion has a tangential component. *Why not yet:* magnetic connectors exist in consumer devices but not in industrial ones where contact resistance matters. *First build:* a connector with a contact-resistance measurement over 10^4 mates. *Kills it:* resistance rise above 10%.

I229 · *Electronics* × *Acoustic* — **Acoustic power converter for implant power.** A transducer that receives power through tissue acoustically rather than inductively. *How:* ultrasound at a few MHz couples through bone and soft tissue with low loss. *Why not yet:* implants use inductive coupling, which is limited by coil misalignment; acoustic power was demonstrated but never engineered. *First build:* a pair in a tissue phantom with an efficiency measurement. *Kills it:* efficiency below 10% through 20 mm.

I230 · *Electronics* × *Compliant* — **Compliant electrical contact for stretchable circuits.** A contact that maintains connection under 50% strain. *How:* a buckled metal film or liquid-metal channel. *Why not yet:* stretchable electronics use rigid connectors at the boundary; a compliant contact was never standardised. *First build:* a contact under cyclic strain with a resistance measurement. *Kills it:* resistance change above 20% at 50% strain.

I231 · *Electronics* × *Microfluidic* — **Microfluidic cooling for a 3D chip stack.** A channel network between stacked dies that removes heat from the interior. *How:* microchannels with a low flow rate. *Why not yet:* 3D stacks are cooled from the bottom; inter-die cooling needs a fluidic through-silicon via that was never manufactured. *First build:* a two-die stack with a channel and a thermal measurement. *Kills it:* no improvement in the stack's thermal resistance.

I232 · *Electronics* × *Bio-based* — **Cellulose substrate for disposable electronics.** A printed circuit substrate that composts after use. *How:* nanocellulose with a printed conductor. *Why not yet:* disposable electronics use FR4 or PET; a cellulose substrate's dimensional stability under printing was the blocker. *First build:* a printed circuit on cellulose with a bend and function test. *Kills it:* track resolution worse than 200 μm.

I233 · *Electronics* × *Catalytic* — **Catalytic humidity sensor with self-calibration.** A sensor whose response to a known catalytic reaction gives an in-situ humidity reference. *How:* the catalyst's rate depends on humidity, providing a self-check. *Why not yet:* humidity sensors drift and are calibrated at the factory; a self-referencing chemistry was never designed. *First build:* a sensor with a drift test over a year. *Kills it:* no reduction in drift.

I234 · *Electronics* × *Radiative* — **Radiative-cooled LED luminaire.** A luminaire whose heat sink radiates to the sky so the LED runs cooler outdoors. *How:* a selective emitter on the housing's top. *Why not yet:* luminaires use finned heat sinks; a radiative surface is free area that was never used. *First build:* a luminaire with and without the coating and a junction-temperature measurement. *Kills it:* no reduction in junction temperature.

I235 · *Electronics* × *Thermoelectric* — **Thermoelectric energy harvester for a wireless sensor on a pipe.** A TEG clamped to a hot pipe that powers a flow sensor from the pipe-to-air gradient. *How:* a 30 K gradient across the TEG. *Why not yet:* pipe sensors use batteries; a clamp-on TEG was never productised because the pipes were not hot enough in the target market. *First build:* a harvester on a steam pipe with a load measurement. *Kills it:* less than 1 mW average.

I236 · *Electronics* × *Shape memory* — **SMA actuator for a camera's focus.** A tiny SMA wire that moves a lens with no motor. *How:* the wire's contraction is controlled by current. *Why not yet:* focus uses voice coils; SMA is slower but far smaller, which suits miniature cameras. *First build:* an actuator with a focus and repeatability test. *Kills it:* position repeatability worse than 5 μm.

I237 · *Electronics* × *Soft robotics* — **Soft connector for a wearable.** A connector that makes electrical contact through a compliant conductive elastomer, tolerating motion. *How:* a conductive silicone pad with a defined contact area. *Why not yet:* wearables use rigid connectors that fail under repeated flexing. *First build:* a connector with a flex-cycle test. *Kills it:* open circuit within 10^4 cycles.

I238 · *Electronics* × *Harvesting* — **Photodiode energy harvester for indoor sensors.** A harvester optimised for indoor light rather than sunlight. *How:* a wide-bandgap cell matched to the indoor spectrum. *Why not yet:* indoor photovoltaics are made from solar cells optimised for the sun; the indoor spectrum needs a different bandgap. *First build:* a cell under a domestic lamp with a power measurement. *Kills it:* less than 10 μW/cm^2.

I239 · *Electronics* × *Inference* — **On-chip ageing estimate from timing slack.** A method that estimates a chip's ageing from its own timing margin, with no test structure. *How:* the critical path's slack is measured by a ring oscillator embedded in the clock tree. *Why not yet:* ageing is estimated from accelerated tests; the in-field signal is already there. *First build:* a chip with a ring oscillator and an accelerated ageing test. *Kills it:* no correlation with the measured degradation.

I240 · *Electronics* × *Structural* — **PCB that is also the enclosure.** A board whose edges form the product's housing, removing a part. *How:* a thick board with moulded edges and a conductive coating. *Why not yet:* products have a PCB inside a case; a board-as-case needs a different assembly flow. *First build:* a product with a board-case and a drop test. *Kills it:* mechanical failure in the drop test.

Domain 13 — Photonics and imaging

I241 · *Photonics* × *Passive thermal* — **Athermal lens mount by geometry.** A lens mount whose two materials cancel thermal focus shift with no active control. *How:* the mount's expansion moves the lens to compensate the glass's index change. *Why not yet:* athermalisation is done with exotic glasses or heaters; a geometric solution with commodity materials was never designed. *First build:* a mount on a thermal stage with a focus measurement. *Kills it:* focus shift above the depth of focus over 40 K.

I242 · *Photonics* × *Phase change* — **Phase-change optical shutter.** A thin film that switches from transparent to opaque on a thermal pulse, for a cheap camera shutter. *How:* the material's phase change changes its absorption. *Why not yet:* shutters are mechanical; a phase-change film has no moving parts but a slow switching time. *First build:* a film on a detector with a switching-time measurement. *Kills it:* switching slower than 1 ms.

I243 · *Photonics* × *Capillary* — **Capillary-filled liquid lens.** A lens whose focus is set by the amount of liquid in a capillary, with no pump. *How:* the liquid's volume sets the meniscus curvature. *Why not yet:* liquid lenses use electrowetting with a

voltage; a capillary-filled version is passive and cheap. *First build:* a lens with a focal-length measurement across a temperature range. *Kills it:* focal drift with temperature above 2%.

I244 · *Photonics* × *Triboelectric* — **Self-powered optical shutter trigger.** A TENG that triggers a high-speed camera on an impact, with no power supply. *How:* the impact generates a pulse that fires the shutter. *Why not yet:* high-speed imaging uses powered triggers; a passive trigger suits remote or disposable cameras. *First build:* a trigger on a drop rig with a timing measurement. *Kills it:* jitter above 1 ms.

I245 · *Photonics* × *Piezoelectric* — **Piezo deformable mirror at low cost.** A mirror on a piezo stack with a small number of actuators, for simple aberration correction. *How:* the actuators deform a thin mirror. *Why not yet:* deformable mirrors are expensive with hundreds of actuators; a 4-actuator version for cheap cameras was never made. *First build:* a mirror with a wavefront sensor. *Kills it:* no measurable correction of a known aberration.

I246 · *Photonics* × *Optical* — **Single-shot phase imaging with a printed mask.** A camera with a printed diffractive mask that recovers phase from one frame. *How:* the mask encodes the phase in the intensity pattern, and a reconstruction inverts it. *Why not yet:* phase imaging uses interferometry or multiple frames; a printed mask plus a small model was never productised. *First build:* a camera with a mask on a phase target. *Kills it:* phase error above a tenth of a wave.

I247 · *Photonics* × *Electrochemical* — **Electrochromic aperture.** An aperture whose diameter is set by an electrochromic ring, with no iris blades. *How:* the ring's opacity is set by an applied voltage. *Why not yet:* irises are mechanical; an electrochromic aperture is slow but has no moving parts. *First build:* an aperture with a diameter and speed measurement. *Kills it:* contrast below 100:1.

I248 · *Photonics* × *Magnetic* — **Magnetically tunable filter.** A filter whose passband shifts with a magnetic field, for a compact spectrometer. *How:* the Faraday effect in a magneto-optic crystal. *Why not yet:* tunable filters are acousto-optic or grating-based; a Faraday filter is slow but cheap and vibration-free. *First build:* a filter with a spectral measurement. *Kills it:* tuning range below 10 nm.

I249 · *Photonics* × *Acoustic* — **Acousto-optic beam steerer for lidar.** A solid-state steerer with no moving parts. *How:* an acoustic wave in a crystal deflects the beam. *Why not yet:* lidar uses rotating or MEMS mirrors; acousto-optic steering is used in microscopy but never in a cheap lidar. *First build:* a steerer with a field-of-view measurement. *Kills it:* field of view below 20°.

I250 · *Photonics* × *Compliant* — **Compliant zoom mechanism.** A single-piece compliant mechanism that moves two lens groups for zoom, with one actuator. *How:* the flexure's geometry couples the two motions. *Why not yet:* zoom mechanisms use multiple motors and cams; a compliant single-actuator design was never productised. *First build:* a mechanism with a zoom-ratio measurement. *Kills it:* optical misalignment above the tolerance.

I251 · *Photonics* × *Microfluidic* — **Microfluidic refractive-index sensor.** A channel whose transmission changes with the fluid's index, for a process analyser. *How:* the fluid core acts as a waveguide whose loss depends on the index. *Why not yet:* index is measured by refractometers with prisms; a microfluidic version needs little sample. *First build:* a sensor on sucrose solutions. *Kills it:* resolution worse than 1e-3.

I252 · *Photonics* × *Bio-based* — **Bacterial-cellulose diffuser.** A grown diffuser for a luminaire with a designed scattering profile. *How:* the cellulose's nanofibre network scatters light. *Why not yet:* diffusers are injection-moulded PMMA; a grown one has a different, softer look and was never tried. *First build:* a diffuser with a luminance measurement. *Kills it:* non-uniformity above the standard.

I253 · *Photonics* × *Catalytic* — **Photocatalytic self-cleaning window for a camera.** A coating that keeps a camera's window clear in polluted air. *How:* a photocatalytic layer decomposes organic films in light. *Why not yet:* cameras use wipers and hydrophobic coatings; a photocatalytic layer was never qualified for optics. *First build:* a window on an outdoor camera over a month. *Kills it:* no improvement in image contrast.

I254 · *Photonics* × *Radiative* — **Radiative-cooled detector housing.** A housing that keeps a detector near ambient at night without a cooler. *How:* a selective emitter rejects heat to the sky. *Why not yet:* detectors use thermoelectric coolers; a passive radiative path is free cooling in dry climates. *First build:* a housing with and without the coating. *Kills it:* no reduction in detector temperature.

I255 · *Photonics* × *Thermoelectric* — **Thermoelectric-stabilised laser diode.** A Peltier that holds a diode's wavelength without a full temperature chamber. *How:* the junction holds the diode at a set point. *Why not yet:* stabilised lasers use bench controllers; a compact Peltier was never integrated into a cheap module. *First build:* a module with a wavelength-drift measurement. *Kills it:* drift above 0.1 nm over 10 K ambient.

I256 · *Photonics* × *Shape memory* — **SMA focus mechanism for a space camera.** A mechanism that survives launch and focuses on orbit with one-shot actuation. *How:* the SMA's transition moves the lens once. *Why not yet:* space mechanisms use stepper motors; a one-shot SMA is lighter and simpler but was never qualified. *First build:* a mechanism through a vibration test and one actuation. *Kills it:* failure after the vibration test.

I257 · *Photonics* × *Soft robotics* — **Soft robotic lens for a capsule camera.** A lens whose focus is changed by inflating a soft chamber. *How:* the membrane's curvature changes with pressure. *Why not yet:* capsule cameras are fixed-focus; a soft tunable lens was never packaged for the gut. *First build:* a lens with a focus range measurement. *Kills it:* focus range below the depth of field needed.

I258 · *Photonics* × *Harvesting* — **Self-powered light sensor.** A photodiode that harvests and senses with the same junction, reporting illumination from its own power. *How:* the short-circuit current is proportional to illumination. *Why not yet:* sensors are powered and read separately; a dual-use junction removes the supply. *First build:* a junction with a measurement against a lux meter. *Kills it:* nonlinearity above 10%.

I259 · *Photonics* × *Inference* — **Lensless imaging with a printed mask and a small model.** A camera with no lens that reconstructs an image from a coded shadow. *How:* the mask's pattern plus a learned reconstruction. *Why not yet:* lensless imaging is a research topic; a printable module with a fixed reconstruction was never productised. *First build:* a module on a resolution target. *Kills it:* resolution worse than the target's feature size.

I260 · *Photonics* × *Structural* — **Window with an integrated photovoltaic edge.** A window whose frame carries a cell fed by a luminescent edge. *How:* light guided to the frame's edge is collected. *Why not yet:* building-integrated PV is roof-first; a window frame is a natural edge collector that was never productised. *First build:* a window with an edge cell and a power measurement. *Kills it:* less than 5 W/m² of window.

Domain 14 — Sensors and instrumentation

I261 · *Sensors* × *Passive thermal* — **Self-calibrating thermocouple.** A thermocouple that calibrates itself against a fixed-point cell built into its tip. *How:* a small quantity of a pure metal melts at a known temperature on heating, giving

an in-situ reference. *Why not yet:* thermocouples drift and are calibrated in a bath; an integrated fixed point was never packaged. *First build:* a tip with an indium bead and a calibration check. *Kills it:* calibration uncertainty not improved.

I262 · *Sensors* × *Phase change* — **Threshold temperature logger with no electronics.** A stack of phase-change dots that record the maximum temperature reached. *How:* each dot melts at a different temperature and the melted set is read visually. *Why not yet:* loggers are electronic; a passive irreversible record suits shipments where a battery is unacceptable. *First build:* a stack in an oven with a ramp and a visual read. *Kills it:* temperature resolution coarser than 2 K.

I263 · *Sensors* × *Capillary* — **Capillary gas sampler.** A tube that collects a known gas volume by capillary action for later laboratory analysis. *How:* the capillary's geometry meters the volume. *Why not yet:* gas sampling uses pumps and bags; a passive metered sampler was never made. *First build:* a sampler with a known gas and a laboratory comparison. *Kills it:* volume error above 10%.

I264 · *Sensors* × *Triboelectric* — **Self-powered impact sensor.** A TENG pad that records the energy and location of an impact with no power. *How:* the pad's local charge gives the location and the amplitude gives the energy. *Why not yet:* impact sensors are piezoelectric or accelerometric and need wiring; a passive pad was never productised. *First build:* a pad with a drop test and a location measurement. *Kills it:* location error above 20% of the pad.

I265 · *Sensors* × *Piezoelectric* — **Piezo viscosity sensor.** A tuning fork that measures a liquid's viscosity from its damping in a few microlitres. *How:* the fork's quality factor falls with the liquid's viscosity. *Why not yet:* viscometers use rotational methods and millilitre samples; a fork is standard in some industries but was never miniaturised for microsamples. *First build:* a fork on standards. *Kills it:* error above 5%.

I266 · *Sensors* × *Optical* — **Colourimetric dosimeter with a phone read.** A badge whose colour change is quantified by a phone under a supplied illumination card. *How:* the card provides a reference white and the badge's colour maps to dose. *Why not yet:* dosimeters are read by instruments; a phone readout needs a reference card, which was never supplied. *First build:* badges at known doses read by phone and by instrument. *Kills it:* error above 15%.

I267 · *Sensors* × *Electrochemical* — **Self-powered corrosion sensor.** A sensor that generates its own signal from the corrosion current it measures. *How:* the galvanic current between two dissimilar metals is both the signal and the power. *Why not yet:* corrosion monitoring uses powered probes; a galvanic self-powered sensor was never developed. *First build:* a sensor on a corroding coupon with a data log. *Kills it:* signal not correlated with the measured mass loss.

I268 · *Sensors* × *Magnetic* — **Magnetic flow meter with no electrodes.** A flow meter that reads the flow-induced field with a magnetometer outside the pipe. *How:* the moving conductor distorts the applied field. *Why not yet:* electromagnetic flow meters need wetted electrodes; a non-contact version was never commercialised. *First build:* a meter on a pipe loop against a reference. *Kills it:* error above 5%.

I269 · *Sensors* × *Acoustic* — **Acoustic pipe-content identifier.** A device that tells whether a pipe is empty, wet or full from a tap. *How:* the pipe's resonance and damping differ with content. *Why not yet:* contents are inferred from flow meters; a tap test needs no installation. *First build:* a pipe rig with three contents and a classification test. *Kills it:* classification below 90%.

I270 · *Sensors* × *Compliant* — **Compliant force sensor with a printed resistor.** A elastomer pad with a printed piezoresistive layer that measures contact force over an area. *How:* the contact area changes with load. *Why not yet:* force sensors are

point load cells; an area sensor was never printed cheaply. *First build:* a pad with a known load and a spatial response. *Kills it:* repeatability worse than 10%.

I271 · *Sensors* × *Microfluidic* — **Microfluidic gas chromatograph.** A chip that separates a gas mixture in seconds for a field analysis. *How:* a microfabricated column with a low thermal mass. *Why not yet:* GCs are bench instruments; a chip version needs a detector that was never integrated. *First build:* a chip on a known mixture. *Kills it:* no separation of a two-component mix.

I272 · *Sensors* × *Bio-based* — **Bacterial biosensor for water toxicity.** A preserved culture that emits light when stressed, in a disposable vial. *How:* a constitutively luminescent bacterium dims when its metabolism is inhibited. *Why not yet:* biosensors use live cultures with a lab; a shelf-stable preserved vial was never made. *First build:* vials on a toxicant series. *Kills it:* shelf life below one month.

I273 · *Sensors* × *Catalytic* — **Catalytic combustible-gas sensor with a poison guard.** A sensor whose catalytic bead is protected by a filter that traps sulphur compounds. *How:* the filter's chemistry removes the poisons before they reach the bead. *Why not yet:* catalytic sensors are poisoned and replaced; a guard filter was never packaged. *First build:* a sensor with and without the filter in a poisoned atmosphere. *Kills it:* no extension of life.

I274 · *Sensors* × *Radiative* — **Sky-temperature sensor for frost prediction.** A sensor that measures the sky's brightness temperature to predict frost hours ahead. *How:* the downward longwave radiation determines the surface's night-time cooling. *Why not yet:* frost is predicted by air temperature and dew point; the sky temperature is the direct variable. *First build:* a sensor at a vineyard against observed frost. *Kills it:* no improvement in forecast skill.

I275 · *Sensors* × *Thermoelectric* — **Thermoelectric dew-point sensor.** A mirror cooled by a Peltier with an optical detector of condensation. *How:* the mirror's temperature at condensation is the dew point. *Why not yet:* dew-point sensors are bench instruments; a cheap Peltier version was never productised for HVAC. *First build:* a sensor against a chilled-mirror reference. *Kills it:* error above 0.5 K.

I276 · *Sensors* × *Shape memory* — **SMA overload indicator.** A bolt that permanently elongates above a set load, showing overload without electronics. *How:* the SMA's transformation leaves a measurable residual strain. *Why not yet:* overload is monitored with strain gauges; a passive indicator suits inspection intervals. *First build:* a bolt loaded to set levels with a length measurement. *Kills it:* no distinguishable residual below yield.

I277 · *Sensors* × *Soft robotics* — **Soft tactile probe for fruit firmness.** A pneumatically soft probe that measures firmness by the pressure needed to indent. *How:* the probe's compliance and the pressure give the modulus. *Why not yet:* firmness is measured with penetrometers that damage the fruit. *First build:* a probe on fruit against a penetrometer. *Kills it:* correlation below $r^2 = 0.7$.

I278 · *Sensors* × *Harvesting* — **Self-powered rain gauge.** A tipping bucket whose tip generates the pulse that counts it. *How:* a TENG or piezo element at the bucket's stop. *Why not yet:* rain gauges use reed switches and a logger with a battery. *First build:* a gauge on a test rig with a known volume. *Kills it:* missed tips above 1%.

I279 · *Sensors* × *Inference* — **Soft-sensor for a pump's flow.** A model that estimates flow from the pump's motor current and speed. *How:* the pump's operating point is set by the flow. *Why not yet:* flow meters are installed where the data are free; a soft sensor needs a per-pump calibration. *First build:* a pump with a flow meter and a model. *Kills it:* error above 10%.

I280 · *Sensors* × *Structural* — **Sensor housing that is the sensing element.** A housing whose own deformation is the measurement, with no separate transducer. *How:* a strain gauge on the housing's wall. *Why not yet:* housings are

designed to be rigid; one designed to deform is a different product. *First build:* a housing with a strain gauge on a pressure rig. *Kills it:* no usable signal.

Domain 15 — Air and environment

I281 · *Air* × *Passive thermal* — **Passive air sampler for VOC.** A tube whose sorbent is driven by temperature cycling rather than a pump. *How:* the sorbent's capacity changes with temperature, drawing air in and out. *Why not yet:* passive samplers rely on diffusion and are slow; a thermally pumped one could be faster. *First build:* a tube with a thermal cycle and a laboratory comparison. *Kills it:* uptake not reproducible.

I282 · *Air* × *Phase change* — **Phase-change smog chamber.** A chamber whose walls are coated with a phase-change material that holds a constant temperature during a reaction. *How:* the PCM's latent heat buffers the chamber. *Why not yet:* smog chambers use ovens; a PCM buffer was never used. *First build:* a chamber with a reaction and a temperature log. *Kills it:* temperature drift above 0.5 K.

I283 · *Air* × *Capillary* — **Capillary aerosol collector.** A device that grows particles in a capillary and collects them for analysis. *How:* condensation growth in a capillary makes particles collectable. *Why not yet:* aerosol collectors use filters or impactors; a capillary growth tube was never packaged. *First build:* a collector on a known aerosol. *Kills it:* collection efficiency below 50%.

I284 · *Air* × *Triboelectric* — **Electrostatic precipitator for a cookstove.** A low-power precipitator that removes smoke particles from a stove's exhaust. *How:* corona charging and a collector plate. *Why not yet:* precipitators are industrial; a stove-sized unit needs a low-voltage design that was never developed. *First build:* a unit on a stove with a particle measurement. *Kills it:* less than 50% removal.

I285 · *Air* × *Piezoelectric* — **Piezo gas-density sensor.** A tuning fork whose resonance gives a gas's density and hence its composition. *How:* the fork's frequency depends on the gas's density. *Why not yet:* gas composition is measured by analysers; a fork is cheap but needs a temperature correction. *First build:* a fork in gas mixtures. *Kills it:* error above 2%.

I286 · *Air* × *Optical* — **Low-cost NO_2 sensor by differential absorption.** A two-wavelength LED sensor that measures NO_2 in a short path. *How:* the differential absorption at two bands. *Why not yet:* NO_2 sensors are electrochemical and drift; an optical version needs a stable LED, which only recently became cheap. *First build:* a sensor against a chemiluminescence analyser. *Kills it:* error above 20%.

I287 · *Air* × *Electrochemical* — **Self-calibrating ozone sensor.** A sensor that generates a known ozone quantity electrochemically to calibrate itself. *How:* the cell can run in reverse to produce a known dose. *Why not yet:* ozone sensors are calibrated in a lab; an in-situ generator was never built. *First build:* a sensor with an in-situ calibration over a month. *Kills it:* drift not reduced.

I288 · *Air* × *Magnetic* — **Magnetic particle collector for brake dust.** A collector near a wheel that captures the magnetic fraction of brake wear. *How:* a magnet captures iron-rich particles before they disperse. *Why not yet:* brake dust is measured at the source in labs; an on-vehicle collector was never fitted. *First build:* a collector on a vehicle with a mass measurement. *Kills it:* capture below 20% of the emitted mass.

I289 · *Air* × *Acoustic* — **Acoustic wind-speed sensor.** A device that measures wind from the sound of turbulence around a fixed obstacle. *How:* the vortex-shedding frequency scales with velocity. *Why not yet:* wind is measured with cups or sonics; an acoustic method was never productised. *First build:* a sensor against a cup anemometer. *Kills it:* error above 10%.

I290 · *Air* × *Compliant* — **Compliant pump for a low-cost air sampler.** A pump with no sliding seals, driven by a compliant chamber. *How:* the chamber's volume change moves air. *Why not yet:* samplers use diaphragm pumps that wear; a compliant pump is cheap but was never developed. *First build:* a pump with a flow and a lifetime test. *Kills it:* flow decay above 20% in 1000 h.

I291 · *Air* × *Microfluidic* — **Microfluidic formaldehyde badge.** A badge that measures formaldehyde by a microfluidic colour reaction over a shift. *How:* the reagent's colour front advances with the dose. *Why not yet:* formaldehyde badges exist as diffusion tubes read by a lab; a distance-readout badge was never made. *First build:* a badge in a chamber at known concentrations. *Kills it:* error above 25%.

I292 · *Air* × *Bio-based* — **Moss air-quality panel.** A living moss panel that accumulates heavy metals and reports deposition. *How:* moss biomonitors accumulate metals over months. *Why not yet:* moss monitoring is a research technique; a standardised panel was never productised. *First build:* panels at several sites against deposition gauges. *Kills it:* accumulation not correlated with the gauges.

I293 · *Air* × *Catalytic* — **Catalytic CO sensor with a long life.** A sensor whose catalyst is regenerated periodically by a heating pulse, extending its life. *How:* the pulse burns off accumulated poisons. *Why not yet:* catalytic sensors are replaced; a regeneration pulse costs almost nothing. *First build:* a sensor with a pulse and a life test. *Kills it:* no extension of life.

I294 · *Air* × *Radiative* — **Radiative fog harvester.** A mesh that cools below the dew point and collects fog more efficiently than a plain mesh. *How:* the emissive coating cools the mesh so droplets nucleate and coalesce. *Why not yet:* fog harvesters are plain mesh; a radiative coating was never tried. *First build:* a coated mesh against a plain one at a fog site. *Kills it:* no increase in yield.

I295 · *Air* × *Thermoelectric* — **Peltier condensation particle counter.** A counter that grows particles in a Peltier-cooled chamber and counts them optically. *How:* the junction provides the supersaturation. *Why not yet:* CPCs use compressors and are expensive; a low-cost Peltier version was never made. *First build:* a counter against a reference CPC. *Kills it:* count error above 30%.

I296 · *Air* × *Shape memory* — **SMA air-sampling valve.** A valve that opens on a temperature trigger to sample air at a set time, with no clock. *How:* the SMA's transition is the timer. *Why not yet:* samplers use electronic timers; an SMA valve needs no power. *First build:* a valve in a chamber with a sampling check. *Kills it:* timing error above 1 h.

I297 · *Air* × *Soft robotics* — **Soft robotic air sampler for a duct.** A soft robot that travels a duct and samples air at several points. *How:* a soft body with a sampling vial. *Why not yet:* duct sampling is done with probes at fixed points. *First build:* a robot in a duct rig with a position log. *Kills it:* unable to pass a bend or a damper.

I298 · *Air* × *Harvesting* — **Self-powered air-quality node.** A node that harvests from a small solar cell and reports one reading per hour. *How:* the duty cycle is matched to the energy budget. *Why not yet:* nodes use batteries; the design rule for matching duty cycle to harvest was never formalised. *First build:* a node outdoors with a month's log. *Kills it:* downtime above 5%.

I299 · *Air* × *Inference* — **Air quality from a city's WiFi.** A method that estimates particulate levels from the attenuation of a dense WiFi mesh. *How:* particles scatter the signal and the mesh already logs the attenuation. *Why not yet:* air quality is measured by monitors; the mesh data were never used. *First build:* a mesh against reference monitors in one district. *Kills it:* correlation below $r^2 = 0.5$.

I300 · *Air* × *Structural* — **Roof tile that is also an air sampler.** A tile whose surface accumulates deposited particles for periodic analysis. *How:* the tile's surface collects deposition in the same way as a deposition gauge. *Why not yet:* deposition is measured with dedicated gauges; a roof tile is free area. *First build:* tiles against gauges on the same roof. *Kills it:* no correlation with the gauges.

Set 8 — Practical inventions, domains 16–20

Domain 16 — Waste and circularity

I301 · *Waste* × *Passive thermal* — **Solar sludge dryer.** A greenhouse dryer that takes wastewater sludge from 80% to 30% water with no fuel. *How:* solar gain plus forced convection from a chimney. *Why not yet:* sludge is dried with belt dryers running on gas; a passive greenhouse version exists in pilots but was never standardised. *First build:* a bay with a turning mechanism and a moisture log. *Kills it:* drying cycle longer than 14 days.

I302 · *Waste* × *Phase change* — **PCM-compost heat recovery.** A compost heap with a phase-change loop that captures the heat of decomposition for a greenhouse. *How:* a coil in the heap charges a PCM store. *Why not yet:* compost heat recovery is a hobbyist practice; a packaged loop was never productised. *First build:* a heap with a coil and a heat measurement. *Kills it:* less than 200 W average.

I303 · *Waste* × *Capillary* — **Capillary dewatering of sludge.** A geotextile bag whose capillary action dewaters sludge faster than gravity alone. *How:* the fabric's pore size and the sludge's floc structure set the drainage. *Why not yet:* geotextile bags are used for dredging; the capillary enhancement was never tuned for municipal sludge. *First build:* bags with and without a wicking layer. *Kills it:* no reduction in dewatering time.

I304 · *Waste* × *Triboelectric* — **Electrostatic plastics separator.** A triboelectric drum that separates mixed plastic flakes by charging them differently. *How:* different polymers charge with opposite sign on contact with a chosen surface. *Why not yet:* sorting is optical or density-based; triboelectric separation is used in some plants but was never tuned for the common packaging mix. *First build:* a drum on a known flake mixture. *Kills it:* purity below 90%.

I305 · *Waste* × *Piezoelectric* — **Piezo-assisted anaerobic digester.** A transducer that improves mixing and mass transfer in a digester without a mechanical stirrer. *How:* acoustic streaming mixes at low power. *Why not yet:* digesters use mechanical or gas mixing; acoustic mixing was never tried at scale. *First build:* two digesters, one with a transducer, with a gas-yield comparison. *Kills it:* no increase in biogas yield.

I306 · *Waste* × *Optical* — **Near-infrared plastic identifier for a phone.** A phone attachment that identifies the polymer of a package from its NIR spectrum. *How:* the polymer's absorption bands are distinctive in the 1–2 μm range. *Why not yet:* NIR sorting is industrial; a consumer identifier would change recycling behaviour but was never built. *First build:* a module on 20 polymer samples. *Kills it:* accuracy below 85%.

I307 · *Waste* × *Electrochemical* — **Electrochemical phosphorus recovery.** A cell that precipitates phosphate from wastewater as a fertiliser salt. *How:* the cathode's local pH rise drives struvite precipitation. *Why not yet:* phosphorus is recovered by chemical dosing; an electrochemical route was demonstrated but never packaged. *First build:* a cell on digester liquor with a recovery measurement. *Kills it:* recovery below 50%.

I308 · *Waste* × *Magnetic* — **Magnetic separation of battery shred.** A separator that recovers the magnetic fraction of shredded cells cleanly enough to avoid cross-contamination. *How:* a staged magnetic field separates the steel casing from

the black mass. *Why not yet:* recycling uses density and froth flotation; a magnetic-first flowsheet was never optimised. *First build:* a bench separator on shredded cells with a purity measurement. *Kills it:* black-mass purity below 95%.

I309 · *Waste* × *Acoustic* — **Acoustic levitation sorting.** A device that sorts small particles by density using acoustic levitation. *How:* the acoustic radiation force depends on the particle's density and size. *Why not yet:* sorting is mechanical; acoustic sorting works only at small scale but suits high-value materials. *First build:* a chamber on a mixed powder. *Kills it:* throughput below 1 kg/h.

I310 · *Waste* × *Compliant* — **Compliant compactor.** A lever-based compactor that reaches high force with a small input, for household waste. *How:* a compliant mechanism multiplies force through buckling. *Why not yet:* compactors are hydraulic or motorised; a hand-powered compliant one was never designed. *First build:* a unit with a force and a cycle-time measurement. *Kills it:* force below the target or unreliable buckling.

I311 · *Waste* × *Microfluidic* — **Microfluidic leachate sensor.** A chip that measures heavy metals in landfill leachate in the field. *How:* a colorimetric reaction in a microfluidic channel. *Why not yet:* leachate is sampled and sent to a lab. *First build:* a chip against laboratory ICP results. *Kills it:* error above 25%.

I312 · *Waste* × *Bio-based* — **Mushroom mycoremediation of hydrocarbons.** A mycelium bed that degrades oil-contaminated soil. *How:* the fungus's enzymes oxidise hydrocarbons. *Why not yet:* bioremediation uses bacteria; fungal systems are slower but handle higher concentrations. *First build:* a bed on contaminated soil with a total-petroleum-hydrocarbon measurement. *Kills it:* no reduction beyond natural attenuation.

I313 · *Waste* × *Catalytic* — **Catalytic pyrolysis of mixed plastic.** A reactor that turns mixed plastic into an oil with a catalyst that tolerates contamination. *How:* a zeolite catalyst cracks the polymer chains. *Why not yet:* pyrolysis is thermal and produces a poor oil; catalytic versions were never scaled because of catalyst poisoning. *First build:* a batch reactor with a yield and quality measurement. *Kills it:* oil yield below 50% or quality unusable.

I314 · *Waste* × *Radiative* — **Radiative digester heater.** A digester that uses radiative cooling to condense water from biogas, drying it without a chiller. *How:* a radiative surface condenses the water vapour. *Why not yet:* biogas is dried with chillers or desiccants. *First build:* a condenser on a digester's gas line. *Kills it:* no reduction in gas moisture.

I315 · *Waste* × *Thermoelectric* — **Thermoelectric generator on a compost pile.** A TEG between the hot compost and the cool ground, powering a sensor. *How:* a 30 K gradient across the pile. *Why not yet:* compost monitoring uses battery loggers. *First build:* a TEG in a pile with a power log. *Kills it:* less than 100 μW.

I316 · *Waste* × *Shape memory* — **SMA-triggered bin lid.** A lid that opens on a temperature rise to vent a compost bin. *How:* the SMA element lifts the lid. *Why not yet:* bins are passive; venting is manual. *First build:* a lid in a warm chamber. *Kills it:* failure to open.

I317 · *Waste* × *Soft robotics* — **Soft robotic sewer inspection.** A soft robot that travels a sewer and maps deposits without a tether. *How:* a peristaltic body with a camera. *Why not yet:* sewer inspection uses CCTV crawlers with cables. *First build:* a robot in a test sewer with a mapping test. *Kills it:* unable to pass a junction.

I318 · *Waste* × *Harvesting* — **Landfill gas micro-turbine.** A small turbine that runs on a low-flow landfill gas stream that flares. *How:* a micro-turbine at low flow with a generator. *Why not yet:* landfill gas is flared when the flow is too low for an engine. *First build:* a turbine on a flare line with a power measurement. *Kills it:* less than 1 kW at the available flow.

I319 · *Waste* × *Inference* — **Waste composition from a weighbridge and a camera.** A model that estimates a load's composition from its weight and a single image. *How:* the density and the surface texture correlate with the composition. *Why not yet:* composition is estimated by manual sorting audits. *First build:* loads with paired audits. *Kills it:* composition error above 15 percentage points.

I320 · *Waste* × *Structural* — **Recycled-aggregate block with a tuned strength.** A block whose mix is adjusted per batch to hit a target strength from variable recycled aggregate. *How:* the water absorption of the recycled aggregate is measured and the mix adjusted. *Why not yet:* recycled aggregate is used with a conservative mix; a per-batch adjustment was never automated. *First build:* a batch plant with an absorption measurement and a strength check. *Kills it:* strength scatter above the standard.

Domain 17 — Fire and safety

I321 · *Safety* × *Passive thermal* — **Intumescent coating that reports its own activation.** A coating with a colour change when it has been exposed to heat, so it can be inspected. *How:* a thermochromic pigment in the intumescent layer. *Why not yet:* intumescent coatings char and are hard to inspect; a reporting pigment was never added. *First build:* coated plates in a furnace with a visual read. *Kills it:* no visible change at the activation temperature.

I322 · *Safety* × *Phase change* — **PCM fire-stop collar.** A collar that expands on heating to seal a pipe penetration. *How:* a phase-change or intumescent insert expands at a set temperature. *Why not yet:* fire collars use intumescent graphite; a PCM design with a lower activation was never tried. *First build:* a collar in a furnace test. *Kills it:* no seal at the rated period.

I323 · *Safety* × *Capillary* — **Capillary sprinkler with no pump.** A sprinkler fed by a capillary wick from a tank, for small spaces. *How:* the wick delivers water at a low but sufficient rate. *Why not yet:* sprinklers need mains pressure; a wick-fed unit suits sheds and cabinets. *First build:* a unit on a test fire with a suppression check. *Kills it:* failure to suppress a small fire.

I324 · *Safety* × *Triboelectric* — **Static-discharge grounding indicator.** A device that shows whether a person is grounded before handling a solvent. *How:* a charge measurement with a self-powered indicator. *Why not yet:* grounding is checked by a test meter or assumed. *First build:* an indicator with a known charge source. *Kills it:* false "safe" indication.

I325 · *Safety* × *Piezoelectric* — **Piezo glass-break detector with discrimination.** A detector that distinguishes glass breakage from other impacts by the acoustic signature. *How:* the break has a distinctive spectral and temporal signature. *Why not yet:* detectors use simple thresholds and false-alarm. *First build:* a detector with a recorded event library. *Kills it:* false-alarm rate above the standard.

I326 · *Safety* × *Optical* — **Flame detector that ignores sunlight.** A detector using a narrow UV band that the atmosphere and the sun do not reach at ground level. *How:* the solar-blind UV band. *Why not yet:* detectors exist but are expensive; a low-cost solar-blind sensor recently became available. *First build:* a detector with a controlled flame and a sunlight test. *Kills it:* false alarm in direct sun.

I327 · *Safety* × *Electrochemical* — **Printed gas sensor for confined spaces.** A disposable badge that turns colour on carbon monoxide exposure. *How:* an electrochemical or colorimetric reaction. *Why not yet:* confined-space entry uses electronic detectors that are shared and calibrated. *First build:* badges at known CO concentrations. *Kills it:* no colour change at the action level.

I328 · *Safety* × *Magnetic* — **Magnetic escape hatch release.** A hatch that opens on a magnetic signal rather than a mechanical handle. *How:* a permanent magnet holds it; an applied field releases it. *Why not yet:* hatches use mechanical latches that can jam. *First build:* a hatch with a release test under load. *Kills it:* failure to release under the design load.

I329 · *Safety* × *Acoustic* — **Acoustic extinguisher for a small fire.** A low-frequency acoustic field that displaces oxygen at the flame. *How:* the acoustic field creates a pressure node that starves the flame. *Why not yet:* acoustic extinguishers are demonstrations; a packaged unit for a kitchen was never built. *First build:* a unit on a pan fire. *Kills it:* failure to extinguish at the target distance.

I330 · *Safety* × *Compliant* — **Compliant fall arrestor.** A fall arrestor whose compliant element limits the arrest force regardless of the worker's weight. *How:* a buckling element with a designed force plateau. *Why not yet:* arrestors use tear-webbing or friction brakes; a compliant element gives a repeatable force. *First build:* a drop test with a load cell. *Kills it:* arrest force outside the standard.

I331 · *Safety* × *Microfluidic* — **Microfluidic smoke detector.** A detector that counts particles in a microfluidic concentrator, with far less false alarm than ionisation. *How:* the particles are concentrated and counted optically. *Why not yet:* detectors use ionisation or optical scattering; a concentrator was never packaged. *First build:* a detector against a standard test aerosol. *Kills it:* sensitivity below the standard.

I332 · *Safety* × *Bio-based* — **Fire-retardant bio-composite panel.** A panel made from agricultural waste with a mineral binder that achieves a fire rating without halogenated additives. *How:* the mineral's endothermic decomposition. *Why not yet:* panels use gypsum or cement; an agricultural-waste composite with the same rating was never certified. *First build:* a panel in a cone calorimeter. *Kills it:* heat release above the standard.

I333 · *Safety* × *Catalytic* — **Catalytic CO converter for a garage.** A passive unit that oxidises carbon monoxide at room temperature. *How:* a low-temperature catalyst on a large-area support. *Why not yet:* garages use ventilation; a catalytic converter was never made for the room scale. *First build:* a unit in a garage with a CO log. *Kills it:* less than 50% reduction.

I334 · *Safety* × *Radiative* — **Radiative-cooled PPE vest.** A vest that rejects heat radiatively so a worker in protective clothing stays cooler. *How:* a selective emitter on the vest's outer surface. *Why not yet:* PPE is specified for protection only. *First build:* a vest on a volunteer in a hot chamber with a core-temperature measurement. *Kills it:* no reduction in heat strain.

I335 · *Safety* × *Thermoelectric* — **Thermoelectric gas-valve shutoff.** A valve that closes on a thermoelectric signal from a thermocouple in a pilot flame. *How:* the flame's thermocouple powers a hold-open magnet. *Why not yet:* this is the standard thermocouple safety valve; the new part is applying it to a portable stove with a reliable low-cost design. *First build:* a valve with a flame-out test. *Kills it:* failure to close within the specified time.

I336 · *Safety* × *Shape memory* — **SMA fire-door closer.** A closer that shuts a fire door on a temperature rise, with no power and no fusible link. *How:* the SMA element's transition drives the door. *Why not yet:* doors use fusible links or magnetic holders that release. *First build:* a door in a heated test with a closing check. *Kills it:* failure to close.

I337 · *Safety* × *Soft robotics* — **Soft robotic fire blanket.** A blanket that deploys by inflation over a fire. *How:* an inflatable frame carries a fire blanket over the source. *Why not yet:* blankets are manual; an automatic deployment in a kitchen was never built. *First build:* a deployment on a pan fire. *Kills it:* failure to deploy or to cover the fire.

I338 · *Safety* × *Harvesting* — **Self-powered emergency light.** A light that harvests from the ambient light it is meant to replace during an outage. *How:* a small cell charges a supercapacitor during normal operation. *Why not yet:* emergency lights use batteries that are checked annually. *First build:* a light with an outage test. *Kills it:* runtime below the standard.

I339 · *Safety* × *Inference* — **Fire-risk score from a building's electricity.** A model that flags a fire risk from the pattern of a building's electricity use. *How:* loose connections and overloads produce a characteristic harmonic signature. *Why not yet:* fire risk is assessed by inspection. *First build:* a dataset of buildings with known incidents. *Kills it:* no better than inspection.

I340 · *Safety* × *Structural* — **Crash barrier with an energy-absorbing lattice.** A barrier that absorbs impact by cell collapse rather than by deformation of a solid beam. *How:* a lattice with a designed plateau force. *Why not yet:* barriers use steel beams or water-filled units. *First build:* a barrier in a sled test. *Kills it:* deceleration outside the standard.

Domain 18 — Marine and underwater

I341 · *Marine* × *Passive thermal* — **Passive desalination float.** A floating still that uses the sea's temperature difference to produce fresh water. *How:* the surface layer is warm and the deep water cold, giving a condenser. *Why not yet:* floating stills were tried in the 1960s; the modern materials and the deep-water intake were never combined. *First build:* a float in deep water with a yield measurement. *Kills it:* less than 0.5 L/m²/day.

I342 · *Marine* × *Phase change* — **PCM thermal protection for a subsea instrument.** A phase-change housing that protects electronics from a hot deployment. *How:* the PCM buffers the temperature during descent. *Why not yet:* housings are insulated or rated for temperature; a PCM buffer was never used. *First build:* a housing in a thermal test. *Kills it:* internal temperature above the limit.

I343 · *Marine* × *Capillary* — **Capillary antifouling surface.** A surface whose capillary structure keeps it wetted so that organisms cannot attach. *How:* a permanently wetted layer disrupts adhesion. *Why not yet:* antifouling uses biocides or coatings; a capillary-wetted surface was never tried. *First build:* panels immersed for three months with a fouling assessment. *Kills it:* no reduction in fouling.

I344 · *Marine* × *Triboelectric* — **Wave-powered TENG buoy for navigation data.** A buoy that powers its own light and reports from wave motion. *How:* the buoy's motion drives a TENG. *Why not yet:* buoys use solar and batteries. *First build:* a buoy with a TENG and a power log. *Kills it:* less than 100 mW average.

I345 · *Marine* × *Piezoelectric* — **Piezo hydrophone with a self-test.** A hydrophone that tests itself by driving the element. *How:* the piezo element works in both directions. *Why not yet:* hydrophones are calibrated in a tank. *First build:* a hydrophone with a self-test and a comparison calibration. *Kills it:* no detection of a deliberate defect.

I346 · *Marine* × *Optical* — **Underwater hyperspectral for coral health.** A low-cost spectral camera that reports coral bleaching from colour. *How:* the symbiont's pigment shifts with bleaching. *Why not yet:* coral surveys are visual by divers. *First build:* a camera on a reef with diver surveys. *Kills it:* no correlation with the survey.

I347 · *Marine* × *Electrochemical* — **Seawater battery for a sensor.** A cell that uses dissolved oxygen in seawater as the cathodic reactant to power a sensor. *How:* an oxygen reduction cathode with a magnesium anode. *Why not yet:*

batteries are sealed; a seawater cell was demonstrated but never fielded for long deployments. *First build:* a cell in seawater with a power log. *Kills it:* less than 1 mW after a week.

I348 · *Marine* × *Magnetic* — **Magnetic mooring release.** A release that holds a mooring with a permanent magnet and releases on a coded magnetic signal. *How:* an electromagnet cancels the permanent field. *Why not yet:* releases use acoustic commands with a battery. *First build:* a release in a tank with a load test. *Kills it:* failure to release.

I349 · *Marine* × *Acoustic* — **Acoustic fish deterrent with a tuned signature.** A deterrent that uses a predator's call rather than a generic noise. *How:* fish respond to specific predator signatures. *Why not yet:* deterrents use broadband noise that habituates. *First build:* a deterrent at a weir with a fish-count comparison. *Kills it:* no reduction in passage.

I350 · *Marine* × *Compliant* — **Compliant wave-energy membrane.** A membrane that pumps as waves pass, with no hinges. *How:* the membrane's deformation drives a non-return valve. *Why not yet:* wave energy uses rigid devices. *First build:* a membrane in a flume. *Kills it:* no net pumping.

I351 · *Marine* × *Microfluidic* — **Microfluidic nutrient analyser for seawater.** A lab-on-chip that measures nitrate and phosphate in situ. *How:* a colorimetric reaction in a microchannel. *Why not yet:* nutrient analysis is done on samples in a lab. *First build:* a chip against laboratory results. *Kills it:* error above 20%.

I352 · *Marine* × *Bio-based* — **Seaweed bioplastic buoy.** A buoy made from seaweed biopolymer that degrades if lost. *How:* an alginate-based composite with adequate buoyancy. *Why not yet:* buoys are plastic and persist as marine debris. *First build:* a buoy with a buoyancy and degradation test. *Kills it:* buoyancy loss within a month.

I353 · *Marine* × *Catalytic* — **Catalytic antifouling coating with no biocide.** A coating that catalytically generates hydrogen peroxide at the surface from dissolved oxygen. *How:* a catalyst reduces oxygen to peroxide, which discourages settlement. *Why not yet:* antifouling uses copper or biocides; a catalytic surface was demonstrated only in labs. *First build:* panels immersed with a fouling assessment. *Kills it:* no reduction in fouling.

I354 · *Marine* × *Radiative* — **Radiative-cooled seawater condenser.** A device that condenses fresh water from humid air over the sea using radiative cooling. *How:* a selective emitter below the dew point. *Why not yet:* the sea's humidity is high and the cooling is small; the combination was never tested at sea. *First build:* a unit on a platform with a yield measurement. *Kills it:* less than 0.2 L/m²/day.

I355 · *Marine* × *Thermoelectric* — **Thermoelectric generator across a pipe's wall.** A TEG that uses the temperature difference between a ship's engine coolant and seawater. *How:* a 40 K gradient across the junction. *Why not yet:* ships use the waste heat for other purposes; a small TEG for sensors was never fitted. *First build:* a TEG on a coolant line with a power log. *Kills it:* less than 1 W.

I356 · *Marine* × *Shape memory* — **SMA depth-triggered sampler.** A sampler that closes at a set depth using an SMA actuator triggered by pressure. *How:* the SMA's transition combined with a pressure switch. *Why not yet:* samplers use motorised or clockwork triggers. *First build:* a sampler in a pressure vessel. *Kills it:* failure to close at the set depth.

I357 · *Marine* × *Soft robotics* — **Soft robotic fish tag.** A tag that attaches to a fish without injury using a soft gripper. *How:* a compliant clamp that follows the body. *Why not yet:* tags are glued or implanted. *First build:* a tag on a fish analogue with a retention test. *Kills it:* retention below a week or injury.

I358 · *Marine* × *Harvesting* — **Salinity-gradient harvest at a river mouth.** A stack that runs on the estuary's salinity difference. *How:* reverse electrodialysis. *Why not yet:* membranes are costly; the estuary's low-head, high-volume flow was never used. *First build:* a stack on an estuary with a power measurement. *Kills it:* less than 0.1 W/m².

I359 · *Marine* × *Inference* — **Fish stock estimate from eDNA and a model.** A method that converts eDNA concentration to biomass with a site-specific model. *How:* the shed rate and the decay rate set the concentration. *Why not yet:* eDNA is used qualitatively. *First build:* a tank calibration and a field comparison with trawls. *Kills it:* correlation below $r^2 = 0.5$.

I360 · *Marine* × *Structural* — **Concrete reef block with a tuned pH.** A block whose surface chemistry favours coral settlement. *How:* the cement's alkalinity is buffered to a range that recruits larvae. *Why not yet:* reef blocks are made from ordinary concrete, whose pH is high. *First build:* blocks with and without the buffer with a settlement survey. *Kills it:* no difference in settlement.

Domain 19 — Space and telecom

I361 · *Space* × *Passive thermal* — **Passive radiator with a variable emissivity.** A radiator that changes emissivity with temperature to avoid over-cooling. *How:* a thermochromic or phase-change layer. *Why not yet:* spacecraft use louvres or heaters. *First build:* a panel in a thermal vacuum test. *Kills it:* no reduction in heater power.

I362 · *Space* × *Phase change* — **PCM thermal storage for a CubeSat.** A module that buffers a satellite's temperature through the eclipse. *How:* a phase-change mass in the structure. *Why not yet:* CubeSats use heaters. *First build:* a module in a thermal vacuum cycle. *Kills it:* temperature excursion beyond the limit.

I363 · *Space* × *Capillary* — **Capillary pumped loop for a small satellite.** A two-phase loop driven by capillary action, with no pump. *How:* the wick's capillary pressure circulates the fluid. *Why not yet:* CPLs are used on large spacecraft and were never scaled down. *First build:* a loop in a thermal vacuum test. *Kills it:* failure to start.

I364 · *Space* × *Triboelectric* — **Contact-electrification dust sensor.** A sensor that detects dust accumulation on a surface from its charge. *How:* the dust's charge changes the surface potential. *Why not yet:* dust is measured optically. *First build:* a sensor in a dust chamber. *Kills it:* no correlation with the deposited mass.

I365 · *Space* × *Piezoelectric* — **Piezo momentum damper.** A damper that converts a structure's vibration into charge, damping it. *How:* a piezo shunt circuit dissipates the energy. *Why not yet:* spacecraft use viscous or magnetic dampers. *First build:* a panel with and without the shunt in a vibration test. *Kills it:* no reduction in settling time.

I366 · *Space* × *Optical* — **Star tracker with a printed mask.** A compact star tracker that uses a diffractive mask for wide-field imaging. *How:* the mask encodes the field on a small sensor. *Why not yet:* star trackers use lenses; a lensless version would be lighter. *First build:* a tracker on a sky test. *Kills it:* attitude accuracy below the requirement.

I367 · *Space* × *Electrochemical* — **Regenerative fuel cell for a lander.** A cell that stores energy as hydrogen and oxygen through the lunar night. *How:* electrolysis by day, fuel cell by night. *Why not yet:* landers use batteries and radioisotope heaters. *First build:* a cell in a thermal vacuum cycle. *Kills it:* round-trip efficiency below 30%.

I368 · *Space* × *Magnetic* — **Magnetic deployment hinge.** A hinge that deploys and locks with a magnet, with no motor or pyro. *How:* the magnet provides both the deployment torque and the lock. *Why not yet:* deployment uses springs and pyros. *First build:* a hinge through a vibration test and a deployment. *Kills it:* failure to lock.

I369 · *Space* × *Acoustic* — **Acoustic leak location on a pressurised module.** A method that locates a leak from its acoustic emission. *How:* the leak's ultrasonic signature triangulates. *Why not yet:* leaks are found by pressure decay. *First build:* a module with a controlled leak. *Kills it:* location error above 10 cm.

I370 · *Space* × *Compliant* — **Compliant rover wheel.** A wheel that conforms to rocks, with no suspension. *How:* a compliant lattice in the wheel's spokes. *Why not yet:* rover wheels are rigid aluminium that dents. *First build:* a wheel on a rock testbed. *Kills it:* no improvement in traction.

I371 · *Space* × *Microfluidic* — **Microfluidic life-detection chip.** A chip that tests a sample for amino acids with a chiral analysis. *How:* a microfluidic separation with a fluorescent label. *Why not yet:* life detection is instrument-heavy. *First build:* a chip on a soil analogue. *Kills it:* no chiral separation.

I372 · *Space* × *Bio-based* — **Bacterial radiation shield.** A shield grown from radiation-resistant bacteria, for a long-duration habitat. *How:* the biomass's hydrogen content and the cells' repair capacity. *Why not yet:* shielding is polyethylene or regolith. *First build:* a shield sample in a radiation beam. *Kills it:* no attenuation benefit.

I373 · *Space* × *Catalytic* — **Catalytic CO_2 converter for a habitat.** A reactor that converts CO_2 to methane and water at low temperature. *How:* a Sabatier-type catalyst at low temperature. *Why not yet:* Sabatier reactors run hot; a low-temperature version was never qualified. *First build:* a reactor with a conversion measurement. *Kills it:* conversion below 50%.

I374 · *Space* × *Radiative* — **Radiative cooler for a cryogenic instrument.** A passive cooler that reaches 100 K without a mechanical cooler. *How:* a multi-stage radiator shielded from the sun. *Why not yet:* passive coolers exist for large observatories; a small-instrument version was never standardised. *First build:* a cooler in a vacuum chamber. *Kills it:* temperature above the target.

I375 · *Space* × *Thermoelectric* — **Radioisotope thermoelectric micro-generator.** A small TEG on a radioisotope source for a CubeSat. *How:* a low-power source with a TEG. *Why not yet:* RTGs are large and regulated; a micro version was never licensed. *First build:* a unit with a heat-source analogue and a power measurement. *Kills it:* less than 100 mW.

I376 · *Space* × *Shape memory* — **SMA release nut.** A nut that releases on command with no pyro. *How:* the SMA's transition splits the nut. *Why not yet:* release uses pyros or burn wires. *First build:* a nut through a vibration and release test. *Kills it:* failure to release after vibration.

I377 · *Space* × *Soft robotics* — **Soft robotic lunar regolith sampler.** A soft gripper that picks regolith without abrasive wear. *How:* a compliant scoop with no sliding surfaces. *Why not yet:* samplers are metal scoops that wear. *First build:* a sampler in a regolith analogue. *Kills it:* wear or inability to retain the sample.

I378 · *Space* × *Harvesting* — **Solar-array vibration harvester.** A harvester that converts launch vibration into stored energy for deployment. *How:* a piezo harvester charging a capacitor. *Why not yet:* deployment uses pyros and springs. *First build:* a harvester in a vibration test. *Kills it:* less than 1 J stored.

I379 · *Space* × *Inference* — **Orbit determination from a magnetometer alone.** A method that determines a small satellite's orbit from its magnetometer, with no GPS. *How:* the magnetic field's time series encodes the position. *Why not yet:*

CubeSats use GPS. *First build:* a flight dataset with a GPS reference. *Kills it:* position error above 10 km.

I380 · *Space* × *Structural* — **Deployable boom with a tape-spring hinge.** A composite boom that folds and deploys with constant-force tape springs. *How:* the tape spring's buckling is designed to be self-deploying. *Why not yet:* booms use motorised hinges or pyros. *First build:* a boom deployed in a thermal vacuum test. *Kills it:* failure to deploy.

Domain 20 — Consumer and household

I381 · *Consumer* × *Passive thermal* — **Evaporative cooling jug.** A clay jug whose porosity cools water by evaporation, with a wicking collar. *How:* the wick keeps the surface wet and the evaporation cools. *Why not yet:* clay jugs exist; a wick collar that stabilises performance across humidity was never designed. *First build:* jugs with and without the collar in a hot room. *Kills it:* less than 2 K depression.

I382 · *Consumer* × *Phase change* — **PCM travel mug.** A mug whose wall holds a drink at a set temperature for hours. *How:* a phase-change layer at 55 °C. *Why not yet:* travel mugs are vacuum flasks that hold the drink *hot* and scald; a set-point mug is a different product. *First build:* a mug with a cooling curve. *Kills it:* hold time below 2 h.

I383 · *Consumer* × *Capillary* — **Capillary self-watering planter with no reservoir.** A planter that draws water from a wick into the soil at the plant's demand. *How:* the matric potential of the soil sets the uptake. *Why not yet:* planters use reservoirs and float valves. *First build:* planters on a set of plants with a growth comparison. *Kills it:* plants dying or waterlogging.

I384 · *Consumer* × *Triboelectric* — **Door-handle harvester.** A harvester in a door handle that powers a smart lock's radio from the turning action. *How:* the handle's rotation drives a TENG. *Why not yet:* smart locks use batteries. *First build:* a handle with a power log. *Kills it:* less than 1 mJ per operation.

I385 · *Consumer* × *Piezoelectric* — **Piezo floor tile for a shop counter.** A tile that harvests footfall to power a sign, specified honestly. *How:* a piezo stack under a compliant surface. *Why not yet:* the field is overclaimed; an honest unit for a specific load. *First build:* a tile with a counter and a load. *Kills it:* less than 0.05 J per step.

I386 · *Consumer* × *Optical* — **Colour-blind camera filter.** A phone filter and processing that shifts the spectrum so colour-blind users can distinguish a specific colour pair. *How:* a notch filter plus a re-mapping. *Why not yet:* colour-blind aids are glasses; a camera filter with a per-user mapping was never offered. *First build:* a filter on a phone with a test. *Kills it:* no improvement on colour-discrimination tests.

I387 · *Consumer* × *Electrochemical* — **Battery that reports its own state by colour.** A cell with an electrochromic indicator that shows the state of charge. *How:* an electrochromic layer driven by the cell's voltage. *Why not yet:* cells are unmarked; a colour indicator costs little. *First build:* a cell with a colour read. *Kills it:* no clear distinction between states.

I388 · *Consumer* × *Magnetic* — **Magnetic knife rack that sanitises.** A rack with a UV LED that runs when a knife is placed. *How:* the magnet's field triggers a reed switch. *Why not yet:* knife racks are passive. *First build:* a rack with a UV dose and a microbial test. *Kills it:* no reduction in bacterial count.

I389 · *Consumer* × *Acoustic* — **Acoustic fridge-climate monitor.** A device that reports a fridge's temperature from the sound of its compressor. *How:* the compressor's duty cycle encodes the internal temperature. *Why not yet:* fridges use

thermometers. *First build:* a monitor against a thermometer. *Kills it:* error above 2 K.

I390 · *Consumer* × *Compliant* — **Compliant jar opener.** A one-piece compliant grip that opens jars across a range of diameters. *How:* a buckling lattice that conforms. *Why not yet:* openers are rigid and size-specific. *First build:* a grip on a set of jars with a torque measurement. *Kills it:* failure on the larger diameters.

I391 · *Consumer* × *Microfluidic* — **Microfluidic water hardness tester.** A consumer strip that reports hardness from a colour front's length. *How:* a chelating reaction with a distance readout. *Why not yet:* hardness is tested by a lab or a titration kit. *First build:* strips on standards. *Kills it:* error above 10%.

I392 · *Consumer* × *Bio-based* — **Mycelium cooler box.** A grown cooler box that insulates like EPS and composts. *How:* the mycelium's cell structure. *Why not yet:* coolers are EPS. *First build:* a box with an ice retention test. *Kills it:* retention below EPS by more than 30%.

I393 · *Consumer* × *Catalytic* — **Catalytic oven cleaner.** A coating that decomposes grease at oven temperatures so the oven self-cleans at normal settings. *How:* a catalytic layer oxidises deposits. *Why not yet:* ovens use pyrolytic cycles or chemicals; a catalyst that works at 200 °C was never applied as a coating. *First build:* a coated panel with a grease test. *Kills it:* no reduction in cleaning effort.

I394 · *Consumer* × *Radiative* — **Radiative-cooled pet mat.** A mat that stays cool in summer using a selective emitter. *How:* the mat radiates to the sky and conducts from the animal. *Why not yet:* pet mats are passive. *First build:* a mat with a surface-temperature measurement. *Kills it:* no temperature reduction.

I395 · *Consumer* × *Thermoelectric* — **Peltier mug cooler.** A mug with a Peltier base that keeps a drink cold on a desk. *How:* the junction cools the base and vents under it. *Why not yet:* mugs are passive; a Peltier base is cheap. *First build:* a mug with a temperature log. *Kills it:* drink not cooled below ambient by 5 K.

I396 · *Consumer* × *Shape memory* — **SMA kettle switch.** A kettle that switches off at boiling using an SMA element rather than a bimetallic strip. *How:* the transition at 100 °C releases the switch. *Why not yet:* kettles use bimetallic strips that drift. *First build:* a switch in a boiling test. *Kills it:* failure to switch.

I397 · *Consumer* × *Soft robotics* — **Soft robotic gripper tool for a wheelchair user.** A compliant reacher that picks up objects of varying shape. *How:* soft fingers with no motors at the fingertips. *Why not yet:* reachers are rigid tongs. *First build:* a tool on a set of objects with a success test. *Kills it:* success below 80%.

I398 · *Consumer* × *Harvesting* — **Bicycle dynamo with a capacitor buffer.** A dynamo that charges a capacitor so a light stays on at a stop. *How:* a supercapacitor buffers the dynamo's output. *Why not yet:* dynamo lights dim at low speed; a capacitor buffer fixes it cheaply. *First build:* a light with a stop test. *Kills it:* light goes out within 30 s.

I399 · *Consumer* × *Inference* — **Food-freshness estimate from a fridge photo.** A model that estimates how long food has been stored and whether it is safe, from a photo. *How:* the appearance of produce changes predictably with time and temperature. *Why not yet:* freshness is judged by the consumer. *First build:* a dataset of timed photos with a reference. *Kills it:* no better than the consumer.

I400 · *Consumer* × *Structural* — **Flat-pack furniture with an integrated toolbox.** A piece whose packaging becomes a tool. *How:* the packaging's board is die-cut as a tool. *Why not yet:* packaging is waste. *First build:* a package that assembles into a tool with a usability test. *Kills it:* no working tool.

Part II — The screened 100

Five per domain, selected by the stated rule in `METHODOLOGY.md`. The score rewards a specific, recently-changed blocker, a cheap first build and a kill test with a threshold. It does not score market size or novelty in the patent sense.

1. Water and sanitation

id	approach	invention	why not yet	first build	kills it	score
I001	Water × Passive thermal	Multi-effect wick still — A solar still that reuses its latent heat across three wick layers instead of one.	multi-effect stacks work in industry but need pumps and pressure vessels; a gravity-fed wick stack at $20/m² w	a three-layer stack on a roof in one location with a daily weigh-scale	yield below 2× the single-effect baseline over a two-week trial	5.0
I002	Water × Phase change	Waste-heat desiccant still — A solar still whose condenser is regenerated by the same heat that drives evaporation, using a desiccant loop	desiccant wheels are HVAC components priced for buildings, not for a $30 household unit	a silica-gel cassette in a single-basin still with a manual damper	no net gain over the baseline still across three humidity levels	3.0
I010	Water × Compliant	Pressure-compensating drip emitter by geometry — A one-piece silicone emitter whose flow is set by a slot that narrows as pressure rises, holding flow constant	compensated emitters exist but are multi-part and cost several times an uncompensated one; a single-moulded co	a 3D-printed silicone emitter on a bench manifold with a flow meter	flow variation above 15% across the pressure range	6.5
I016	Water × Shape memory	Freeze-protection valve — A nickel-titanium element that opens a drain when a pipe approaches freezing and closes on warming, with no po	SMA valves exist in aerospace at high cost; a plumbing-grade part was never cost-engineered	a valve body in a freezer cycling between 2 °C and −5 °C, with a flow check	actuation failing after 100 cycles	4.0
I020	Water × Structural	Greywater heat-recovery shower panel	the units are sold as plumbing accessories	a tray insert with thermocouples and a	recovery below 25% at 8 L/min	4.5

id	approach	invention	why not yet	first build	kills it	score
		— A drain-pipe heat exchanger moulded into a shower tray that preheats incoming cold water.	at a price that only pays back in cold climates; a moulded tray ver	measured recovery fraction		

2. Food and agriculture

id	approach	invention	why not yet	first build	kills it	score
I024	Food × Triboelectric	Electrostatic pest screen — A charged mesh around a crop row that captures small flying insects without insecticide.	electrostatic crop protection was tried in the 1970s with unreliable high-voltage supplies; modern DC-DC conve	a charged mesh on one row with sticky-trap counts on both	capture rate no better than an uncharged mesh	4.0
I026	Food × Optical	Handheld ripeness index — A two-wavelength reflectance probe that reports a ripeness index for a specific fruit without a spectrometer.	NIR spectrometers are used in packing houses; the cheap two-band version needs a per-fruit calibration that wa	200 fruit measured with the probe and with a destructive reference	prediction error above the between-fruit spread	4.5
I028	Food × Magnetic	Magnetic weed-seed separator — A seed-cleaning drum that coats weed seeds with magnetic dust and lifts them out of a grain stream.	seed cleaning is mechanical and cheap; magnetic separation was developed for ore and never scaled down to a fa	a bench drum with coated weed seed in a wheat sample	removal below 70% with grain loss above 2%	4.0
I030	Food × Compliant	Compliant fruit gripper — A single-moulded soft gripper with fingers that conform to any fruit without a sensor or controller.	soft grippers are demonstrated with pneumatic control; a passive, geometry-only design was never commercialise	a gripper on a bench arm picking 100 fruit of three sizes, bruise-scored	bruise rate above 5%	5.0
I036	Food × Shape memory	Self-venting grain silo cap — A cap that opens at a set temperature	silo vents are passive grilles sized for worst case; an actuated	a cap on a sealed drum in a cycling chamber	no reduction in condensate versus a fixed vent	4.5

id	approach	invention	why not yet	first build	kills it	score
		and humidity using an SMA spring, preventing condensation drip.	vent was never cost-engineered			

3. Health diagnostics

id	approach	invention	why not yet	first build	kills it	score
I047	Health × Electrochemical	Sweat chloride patch — A patch that measures chloride in sweat for cystic fibrosis screening without a laboratory.	the sweat test requires pilocarpine iontophoresis and a lab; a fully integrated patch was never validated	patches against the standard test in one clinic	disagreement beyond the diagnostic threshold	3.5
I048	Health × Magnetic	Magnetic lateral-flow reader — A reader that quantifies a lateral-flow strip by measuring the magnetic moment of a labelled line, rather than	magnetic labels exist in labs; the reader was never cost-engineered against a phone camera	a reader on strips of known concentration against a benchtop reader	limit of detection not improved by 10×	5.0
I054	Health × Radiative	Passive vaccine cooler — A radiative-cooling box that holds 2–8 °C without power, using a selective emitter and a phase-change buffer.	the materials are demonstrated in papers; a box designed for the vaccine cold chain was never built or field-t	a box in a hot climate with a logged internal temperature over a week	excursion above 8 °C within 24 h	4.0
I055	Health × Thermoelectric	Peltier sample transporter — A portable box that holds a sample at 4 °C on a Peltier stage powered by a vehicle socket.	sample transport uses ice packs, which fail on long routes; a Peltier box was never cost-engineered	a box in a vehicle over an 8 h route with a logger	temperature excursion above 8 °C for more than 1 h	4.5
I057	Health × Soft robotics	Soft rehabilitation glove — A glove with soft actuators that assist hand opening	rehabilitation gloves use multi-channel pneumatics with a compressor; a single-source	one glove with a pressure source and a grip-force and range measurement	range of motion improvement below 10°	5.0

id	approach	invention	why not yet	first build	kills it	score
		using a single low-pressure source.	sequenced design was nev			

4. Medical devices and care

id	approach	invention	why not yet	first build	kills it	score
I061	Medical × Passive thermal	Passive neonatal warmer — A phase-change mattress that absorbs heat during the day and releases it at night for kangaroo-care support.	neonatal warmers are electric and cost thousands; a passive mattress was never clinically trialled	a mattress in a simulated neonatal setting with a thermal manikin	core temperature falling below 36.5 °C	4.5
I062	Medical × Phase change	Cold-therapy sleeve with a set point — A sleeve whose phase-change material holds 10 °C for hours without ice.	cold therapy uses ice or electric wraps; a set-point material was never packaged for limbs	a sleeve on a limb analogue with a thermal log	hold time below 2 h	3.5
I063	Medical × Capillary	Capillary drainage dressing — A dressing whose channels move exudate away from the wound by capillary action alone.	dressings rely on absorbents and pressure; a capillary-engineered layer was never manufactured	a dressing on a wound simulator with a measured fluid-handling rate	no improvement in fluid handling over a standard foam	3.5
I067	Medical × Electrochemical	Wound Infection early warning — A dressing with an electrode that flags a pH rise before clinical signs.	wound infection is diagnosed clinically; the sensor was never integrated into a dressing	dressings on a wound model with bacterial challenge	no pH difference before visible infection	3.5
I074	Medical × Radiative	Radiative cooling cast — A cast liner that radiates heat away so a limb under plaster does not overheat.	casts are chosen for mechanical properties; thermal comfort was never a design goal	a cast on a limb analogue with an internal thermocouple	no temperature reduction	3.5

5. Energy storage

id	approach	invention	why not yet	first build	kills it	score
I084	Storage × Triboelectric	Static pre-charge for supercapacitors — A triboelectric layer that pre-charges a supercapacitor stack so the converter sees a higher voltage.	TENGs are demonstrated for sensors, not as pre-charge for storage; the impedance match was never designed	a TENG and a supercapacitor with a charge-efficiency measurement	less than 20% of the TENG's energy reaching the capacitor	3.5
I089	Storage × Acoustic	Acoustic agitation for flow batteries — A transducer that disrupts the boundary layer at a flow-battery electrode, raising the limiting current.	flow batteries are designed around flow rate; acoustic enhancement was never applied to them	a cell with and without a transducer at fixed flow	less than 20% improvement in limiting current	3.5
I090	Storage × Compliant	Compliant cell compression frame — A frame that maintains constant stack pressure as the cells swell over life.	stacks use rigid end plates and springs; a compliant frame with the right stiffness curve was never designed	a frame with a load cell over 200 cycles	pressure variation above 30%	3.5
I094	Storage × Radiative	Radiative cooler for battery packs — A pack surface that radiates heat to the sky, reducing the chiller load in hot climates.	packs are cooled by coolant loops; a passive radiative path was never added to a real pack	two packs, one coated, in a hot car park with cell temperatures logged	no reduction in peak cell temperature	5.5
I098	Storage × Harvesting	Regenerative suspension harvester — A shock absorber that recovers energy from suspension motion and feeds the vehicle's auxiliary bus.	regenerative dampers are demonstrated in research vehicles and dropped for cost; the case for a retrofit unit	a damper on a test rig with a power measurement	less than 50 W average on a standard drive cycle	6.0

6. Energy generation

id	approach	invention	why not yet	first build	kills it	score
I103	Generation × Capillary	Capillary-fed microbial fuel cell — A soil microbial fuel cell that wicks water to the anode and runs for years without maintenance.	MFCs are lab devices with pumps; a capillary-fed field unit was never deployed at scale	a cell in soil with a load resistor and a months-long log	power below 10 μW after one month	3.5
I104	Generation × Triboelectric	Wave-driven TENG — A triboelectric generator in a floating buoy that converts wave motion to charge.	wave energy converters are large and expensive; a small TENG buoy for sensor power was never built	a buoy in a wave tank with a power measurement	less than 1 W average in realistic seas	4.5
I105	Generation × Piezoelectric	Piezo road-energy tile with a realistic claim — A tile that harvests vehicle weight, specified honestly at watts not kilowatts.	the field is full of overclaims; an honest engineering unit with a measured lifetime was never sold	a tile in a car park with a counter and a load	energy per axle below 0.1 J	3.5
I106	Generation × Optical	Spectrum-splitting PV window — A window coating that sends visible light through and infrared to a edge-mounted cell.	luminescent concentrators failed on self-absorption; the dichroic plus edge-cell combination was never product	a 30 cm pane with an edge cell and an efficiency measurement	less than 1% overall conversion at usable transparency	3.5
I107	Generation × Electrochemical	Reverse electrodialysis at a river mouth — A stack that generates power from the freshwater–seawater salinity gradient with a low-cost membrane.	membranes dominate the cost; a design using low-cost, lower-selectivity membranes with a compensating stack ge	a 10-cell stack on an estuary water sample	less than 0.1 W/m² of membrane	4.5

7. Buildings and HVAC

id	approach	invention	why not yet	first build	kills it	score
I121	Buildings × Passive	Thermal-mass ceiling	night purging	a test room with a ceiling	less than 2 K peak	3.5

id	approach	invention	why not yet	first build	kills it	score
	thermal	with a night purge — A ceiling that stores cool night air and releases it during the day, with a damper that needs no power.	needs controls; a passive damper removes them but was never designed for the application	slab and a temperature log over a week	reduction	
I122	Buildings × Phase change	PCM wallboard with a melting range matched to the climate — A gypsum board with a PCM tuned to the local summer range rather than a generic 23 °C.	PCM boards are sold with one melting point because manufacturing is centralised; a climate-tuned product was n	two test rooms, one with tuned board, one with standard	no reduction in overheating hours	5.0
I125	Buildings × Piezoelectric	Piezo dust-fan bearing monitor — A piezo element in a fan mount that detects bearing wear from the vibration signature.	fans are replaced on schedule, not on condition; a cheap sensor was never justified	a fan with an accelerometer reference and a piezo patch	detection no better than a schedule	4.5
I130	Buildings × Compliant	Compliant window seal — A seal whose geometry accommodates frame movement over decades without a gasket.	seals are elastomer gaskets that age; a compliant metallic seal was never cost-engineered for windows	a seal in a cycling rig with an airtightness measurement	leakage above the standard after 10^4 cycles	5.0
I134	Buildings × Radiative	Radiative cooling roof with a humidity guard — A roof coating that cools radiatively but switches to a lower emissivity when condensation would form.	radiative roofs are static; a switchable layer that prevents dew and fouling was never made	a roof panel with a dew sensor and a net cooling measurement	no net cooling benefit over a static coating	4.0

8. Construction and materials

id	approach	invention	why not yet	first build	kills it	score
I145	Construction × Piezoelectric	Piezo weigh-in-motion pad — A thin pad under a road that weighs axles from the piezo signal.	weigh-in-motion uses bending plates and load cells; a piezo pad is cheaper but its temperature drift was never	a pad on a test track against a static weighbridge	axle-load error above 10%	4.0
I148	Construction × Magnetic	Magnetic rebar locator with a phone — A phone magnetometer that locates rebar from its field, with a calibration for cover depth.	cover meters are dedicated instruments; the phone's magnetometer was never calibrated for this	a slab with known rebar and a phone scan	depth error above 10 mm	4.5
I150	Construction × Compliant	Compliant seismic isolator from steel — A single-material isolator that buckles in a controlled way to absorb seismic energy.	isolators are laminated rubber or friction pendulums, both multi-material; a steel-only compliant design was n	a column on a shake table with a base-isolated mass	less than 50% reduction in acceleration	4.0
I153	Construction × Catalytic	Photocatalytic NOx pavement — A pavement coating that oxidises nitrogen oxides at the surface in sunlight.	trial sections exist and were judged on cost; the wash-off of nitrate was never resolved	a trial slab with an inlet and outlet NOx measurement	less than 20% reduction	4.0
I154	Construction × Radiative	Radiative-cooling pavement — A pavement that radiates heat at night and reduces the urban heat island.	cool pavements are specified by solar reflectance; the infrared emissivity was never the design variable	two pavement sections with surface-temperature logging	no reduction in peak surface temperature	4.0

9. Manufacturing and metrology

id	approach	invention	why not yet	first build	kills it	score
I161	Manufacturing × Passive thermal	Thermal-error compensation by design	compensation is done in software; a passive	a frame on a test stand with a displacement	drift above 20 μm	4.0

id	approach	invention	why not yet	first build	kills it	score
		— A machine frame whose geometry compensates its own thermal growth, with no sensor or control.	geometric solution was never designed into a low-cost machine	measurement over a warm-up		
I162	Manufacturing × Phase change	PCM-cooled welding fixture — A fixture that absorbs weld heat so a thin part does not distort.	fixtures are steel and rely on chill blocks; a PCM fixture was never used in production	a fixture welding a thin panel with a distortion measurement	no reduction in distortion	3.5
I163	Manufacturing × Capillary	Capillary lubrication for a linear guide — A guide that draws oil by capillary action from a reservoir, with no pump.	guides are greased for life or fed by a pump; a capillary feed was never productised	a guide on a test rig with a friction measurement over 10^6 cycles	friction rise above 20%	4.5
I165	Manufacturing × Piezoelectric	Piezo tool-wear sensor — A piezo element in a tool holder that detects wear from the cutting-force spectrum.	tool wear is managed by schedule or by spindle load; a piezo insert was never standardised	a holder on a lathe with a tool-life test	detection no better than the schedule	3.5
I167	Manufacturing × Electrochemical	Electrochemical deburring of printed parts — A post-process that removes burrs from additively manufactured channels electrochemically.	AM post-processing is mechanical or thermal; electrochemical finishing was never adapted to lattice channels	a printed channel before and after with a flow measurement	no improvement in flow or in surface finish	3.5

10. Robotics and automation

id	approach	invention	why not yet	first build	kills it	score
I182	Robotics × Phase change	PCM-actuated soft robot — A soft actuator driven by the expansion of a phase-change material, with no compressor.	soft robots use pneumatics with a compressor; a PCM actuator is slow but needs no infrastructure	an actuator with a displacement and force measurement	less than 10 mm stroke or cycle time above 1 min	2.0

id	approach	invention	why not yet	first build	kills it	score
I189	Robotics × Acoustic	Ultrasonic proximity for dusty environments — A sonar that works where cameras fail because of dust.	sonar is used in water; an air sonar for industrial dust was never productised	a sensor in a dust chamber with a ranging test	range error above 10% at 2 m	3.5
I193	Robotics × Catalytic	Self-cleaning robot lens — A lens coating that decomposes organic fouling in sunlight so a field robot's camera stays clear.	robots use wipers or air jets; a passive coating was never tested in field conditions	a lens on an outdoor robot over a month with image contrast	no improvement in contrast	3.0
I197	Robotics × Soft robotics	Soft robot that grows — A robot that extends a soft body by everting a tube, reaching into spaces a rigid arm cannot.	growing robots are research prototypes; a version for inspection of collapsed structures was never fielded	a grower in a rubble analogue with a reach test	buckling before 3 m of reach	2.5
I199	Robotics × Inference	Grasp success prediction from a single image — A model that predicts whether a grasp will succeed before it is attempted, with no depth sensor.	grasp planning uses depth and simulation; a single-image predictor suits low-cost robots	a dataset of attempts with outcomes and a held-out object set	prediction below 80% on unseen objects	2.5

11. Transport and logistics

id	approach	invention	why not yet	first build	kills it	score
I201	Transport × Passive thermal	Passive refrigerated trailer panel — A trailer roof that radiates heat at night so the unit's compressor runs less.	trailers are insulated boxes; a radiative top layer was never added because the roof is a structural skin	two trailers, one coated, with cargo-temperature logs	no reduction in compressor duty	4.5
I203	Transport × Capillary	Capillary fuel filter with a water sump — A filter that separates water by a	filters trap water in a bowl that a mechanic drains; an automatic drain was	a filter on a test rig with a water injection	water passing downstream	3.5

id	approach	invention	why not yet	first build	kills it	score
		capillary stop and drains it automaticall y.	never fitted to small engines			
I208	Transport × Magnetic	Magnetic coupler for a trailer's brake line — A coupler that aligns and holds an air line without a threaded fitting.	couplings are threaded or claw-type and fail by cross-threading; a magnetic self-aligning coupler was never tr	a coupler on a test rig with a leak and a pull-off test	leakage above the standard	4.5
I211	Transport × Microfluidic	Microfluidic diesel injector — An injector with microfluidic passages that atomise fuel without high pressure.	injection is high-pressure common rail; microfluidic atomisation was never tried at engine temperatures	an injector on a spray bench with a droplet-size measuremen t	Sauter mean diameter above the target	5.0
I212	Transport × Bio-based	Mycelium packaging that survives the cold chain — A grown packaging that insulates as well as EPS for chilled shipments.	mycelium packaging is sold for dry goods; a wet, cold application needs a hydrophobic treatment that was never	a box with a cold pack and a thermal log	hold time below EPS by more than 20%	3.5

12. Electronics and semiconductors

id	approach	invention	why not yet	first build	kills it	score
I221	Electronics × Passive thermal	Thermal via-free hotspot spreader — An anisotropic heat spreader that moves heat laterally from a hotspot without vias.	spreaders are used at package level; a die-level film with the right adhesion was never qualified	a die with a film and an infrared temperature map	no reduction in hotspot temperature	3.0
I227	Electronics × Electrochemi cal	Printed memristor for tamper logging — A device that records whether a package was opened, using a memristive state that is read	tamper evidence is mechanical (seals); an electronic record was never printed at a low cost	a printed device in a package with a read after opening	no state change on exposure	4.0

id	approach	invention	why not yet	first build	kills it	score
		electrochemically.				
I230	Electronics × Compliant	Compliant electrical contact for stretchable circuits — A contact that maintains connection under 50% strain.	stretchable electronics use rigid connectors at the boundary; a compliant contact was never standardised	a contact under cyclic strain with a resistance measurement	resistance change above 20% at 50% strain	4.0
I231	Electronics × Microfluidic	Microfluidic cooling for a 3D chip stack — A channel network between stacked dies that removes heat from the interior.	3D stacks are cooled from the bottom; inter-die cooling needs a fluidic through-silicon via that was never man	a two-die stack with a channel and a thermal measurement	no improvement in the stack's thermal resistance	3.5
I234	Electronics × Radiative	Radiative-cooled LED luminaire — A luminaire whose heat sink radiates to the sky so the LED runs cooler outdoors.	luminaires use finned heat sinks; a radiative surface is free area that was never used	a luminaire with and without the coating and a junction-temperature measurement	no reduction in junction temperature	3.5

13. Photonics and imaging

id	approach	invention	why not yet	first build	kills it	score
I241	Photonics × Passive thermal	Athermal lens mount by geometry — A lens mount whose two materials cancel thermal focus shift with no active control.	athermalisation is done with exotic glasses or heaters; a geometric solution with commodity materials was neve	a mount on a thermal stage with a focus measurement	focus shift above the depth of focus over 40 K	3.5
I245	Photonics × Piezoelectric	Piezo deformable mirror at low cost — A mirror on a piezo stack with a small number of actuators, for simple aberration correction.	deformable mirrors are expensive with hundreds of actuators; a 4-actuator version for cheap cameras was never	a mirror with a wavefront sensor	no measurable correction of a known aberration	4.5
I246	Photonics × Optical	Single-shot phase imaging with a printed	phase imaging uses interferometry or multiple	a camera with a mask on a phase target	phase error above a tenth of a wave	3.5

id	approach	invention	why not yet	first build	kills it	score
		mask — A camera with a printed diffractive mask that recovers phase from one frame.	frames; a printed mask plus a small model was never productised			
I255	Photonics × Thermoelectric	Thermoelectric-stabilised laser diode — A Peltier that holds a diode's wavelength without a full temperature chamber.	stabilised lasers use bench controllers; a compact Peltier was never integrated into a cheap module	a module with a wavelength-drift measurement	drift above 0.1 nm over 10 K ambient	4.5
I256	Photonics × Shape memory	SMA focus mechanism for a space camera — A mechanism that survives launch and focuses on orbit with one-shot actuation.	space mechanisms use stepper motors; a one-shot SMA is lighter and simpler but was never qualified	a mechanism through a vibration test and one actuation	failure after the vibration test	4.5

14. Sensors and instrumentation

id	approach	invention	why not yet	first build	kills it	score
I264	Sensors × Triboelectric	Self-powered impact sensor — A TENG pad that records the energy and location of an impact with no power.	impact sensors are piezoelectric or accelerometric and need wiring; a passive pad was never productised	a pad with a drop test and a location measurement	location error above 20% of the pad	3.5
I266	Sensors × Optical	Colourimetric dosimeter with a phone read — A badge whose colour change is quantified by a phone under a supplied illumination card.	dosimeters are read by instruments; a phone readout needs a reference card, which was never supplied	badges at known doses read by phone and by instrument	error above 15%	4.5
I270	Sensors × Compliant	Compliant force sensor with a printed resistor — A elastomer pad with a printed piezoresistive layer that	force sensors are point load cells; an area sensor was never printed cheaply	a pad with a known load and a spatial response	repeatability worse than 10%	3.5

id	approach	invention	why not yet	first build	kills it	score
		measures contact force over an area.				
I271	Sensors × Microfluidic	Microfluidic gas chromatograph — A chip that separates a gas mixture in seconds for a field analysis.	GCs are bench instruments; a chip version needs a detector that was never integrated	a chip on a known mixture	no separation of a two-component mix	3.5
I275	Sensors × Thermoelectric	Thermoelectric dew-point sensor — A mirror cooled by a Peltier with an optical detector of condensation.	dew-point sensors are bench instruments; a cheap Peltier version was never productised for HVAC	a sensor against a chilled-mirror reference	error above 0.5 K	4.0

15. Air and environment

id	approach	invention	why not yet	first build	kills it	score
I282	Air × Phase change	Phase-change smog chamber — A chamber whose walls are coated with a phase-change material that holds a constant temperature during a react	smog chambers use ovens; a PCM buffer was never used	a chamber with a reaction and a temperature log	temperature drift above 0.5 K	3.5
I286	Air × Optical	Low-cost NO_2 sensor by differential absorption — A two-wavelength LED sensor that measures NO_2 in a short path.	NO_2 sensors are electrochemical and drift; an optical version needs a stable LED, which only recently became c	a sensor against a chemiluminescence analyser	error above 20%	4.0
I290	Air × Compliant	Compliant pump for a low-cost air sampler — A pump with no sliding seals, driven by a compliant chamber.	samplers use diaphragm pumps that wear; a compliant pump is cheap but was never developed	a pump with a flow and a lifetime test	flow decay above 20% in 1000 h	5.0
I294	Air × Radiative	Radiative fog harvester — A mesh that	fog harvesters are plain	a coated mesh against	no increase in yield	5.0

id	approach	invention	why not yet	first build	kills it	score
		cools below the dew point and collects fog more efficiently than a plain mesh.	mesh; a radiative coating was never tried	a plain one at a fog site		
I295	Air × Thermoelectric	Peltier condensation particle counter — A counter that grows particles in a Peltier-cooled chamber and counts them optically.	CPCs use compressors and are expensive; a low-cost Peltier version was never made	a counter against a reference CPC	count error above 30%	4.0

16. Waste and circularity

id	approach	invention	why not yet	first build	kills it	score
I302	Waste × Phase change	PCM-compost heat recovery — A compost heap with a phase-change loop that captures the heat of decomposition for a greenhouse.	compost heat recovery is a hobbyist practice; a packaged loop was never productised	a heap with a coil and a heat measurement	less than 200 W average	3.5
I303	Waste × Capillary	Capillary dewatering of sludge — A geotextile bag whose capillary action dewaters sludge faster than gravity alone.	geotextile bags are used for dredging; the capillary enhancement was never tuned for municipal sludge	bags with and without a wicking layer	no reduction in dewatering time	3.0
I305	Waste × Piezoelectric	Piezo-assisted anaerobic digester — A transducer that improves mixing and mass transfer in a digester without a mechanical stirrer.	digesters use mechanical or gas mixing; acoustic mixing was never tried at scale	two digesters, one with a transducer, with a gas-yield comparison	no increase in biogas yield	4.5
I308	Waste × Magnetic	Magnetic separation of battery shred — A separator that recovers the magnetic	recycling uses density and froth flotation; a magnetic-first flowsheet	a bench separator on shredded cells with a purity measurement	black-mass purity below 95%	4.5

id	approach	invention	why not yet	first build	kills it	score
		fraction of shredded cells cleanly enough to avoid cross-contaminatio n.	was never optimised			
I310	Waste × Compliant	Compliant compactor — A lever-based compactor that reaches high force with a small input, for household waste.	compactors are hydraulic or motorised; a hand-powered compliant one was never designed	a unit with a force and a cycle-time measuremen t	force below the target or unreliable buckling	4.0

17. Fire and safety

id	approach	invention	why not yet	first build	kills it	score
I321	Safety × Passive thermal	Intumescent coating that reports its own activation — A coating with a colour change when it has been exposed to heat, so it can be inspected.	intumescent coatings char and are hard to inspect; a reporting pigment was never added	coated plates in a furnace with a visual read	no visible change at the activation temperature	3.5
I322	Safety × Phase change	PCM fire-stop collar — A collar that expands on heating to seal a pipe penetration.	fire collars use intumescent graphite; a PCM design with a lower activation was never tried	a collar in a furnace test	no seal at the rated period	4.0
I329	Safety × Acoustic	Acoustic extinguisher for a small fire — A low-frequency acoustic field that displaces oxygen at the flame.	acoustic extinguishers are demonstratio ns; a packaged unit for a kitchen was never built	a unit on a pan fire	failure to extinguish at the target distance	3.5
I332	Safety × Bio-based	Fire-retardant bio-composite panel — A panel made from agricultural waste with a mineral binder that achieves a fire rating without	panels use gypsum or cement; an agricultural-waste composite with the same rating was never certified	a panel in a cone calorimeter	heat release above the standard	4.5

id	approach	invention	why not yet	first build	kills it	score
		halogenated add				
I337	Safety × Soft robotics	Soft robotic fire blanket — A blanket that deploys by inflation over a fire.	blankets are manual; an automatic deployment in a kitchen was never built	a deployment on a pan fire	failure to deploy or to cover the fire	3.5

18. Marine and underwater

id	approach	invention	why not yet	first build	kills it	score
I342	Marine × Phase change	PCM thermal protection for a subsea instrument — A phase-change housing that protects electronics from a hot deployment.	housings are insulated or rated for temperature; a PCM buffer was never used	a housing in a thermal test	internal temperature above the limit	3.5
I343	Marine × Capillary	Capillary antifouling surface — A surface whose capillary structure keeps it wetted so that organisms cannot attach.	antifouling uses biocides or coatings; a capillary-wetted surface was never tried	panels immersed for three months with a fouling assessment	no reduction in fouling	3.0
I345	Marine × Piezoelectric	Piezo hydrophone with a self-test — A hydrophone that tests itself by driving the element.	hydrophones are calibrated in a tank	a hydrophone with a self-test and a comparison calibration	no detection of a deliberate defect	3.0
I354	Marine × Radiative	Radiative-cooled seawater condenser — A device that condenses fresh water from humid air over the sea using radiative cooling.	the sea's humidity is high and the cooling is small; the combination was never tested at sea	a unit on a platform with a yield measurement	less than 0.2 L/m²/day	3.5
I358	Marine × Harvesting	Salinity-gradient harvest at a river mouth — A stack that runs on the estuary's	membranes are costly; the estuary's low-head, high-volume flow was never used	a stack on an estuary with a power measurement	less than 0.1 W/m²	4.0

id	approach	invention	why not yet	first build	kills it	score
		salinity difference.				

19. Space and telecom

id	approach	invention	why not yet	first build	kills it	score
I364	Space × Triboelectric	Contact-electrification dust sensor — A sensor that detects dust accumulation on a surface from its charge.	dust is measured optically	a sensor in a dust chamber	no correlation with the deposited mass	1.5
I370	Space × Compliant	Compliant rover wheel — A wheel that conforms to rocks, with no suspension.	rover wheels are rigid aluminium that dents	a wheel on a rock testbed	no improvement in traction	1.5
I373	Space × Catalytic	Catalytic CO_2 converter for a habitat — A reactor that converts CO_2 to methane and water at low temperature.	Sabatier reactors run hot; a low-temperature version was never qualified	a reactor with a conversion measurement	conversion below 50%	3.0
I374	Space × Radiative	Radiative cooler for a cryogenic instrument — A passive cooler that reaches 100 K without a mechanical cooler.	passive coolers exist for large observatories; a small-instrument version was never standardised	a cooler in a vacuum chamber	temperature above the target	3.5
I375	Space × Thermoelectric	Radioisotope thermoelectric micro-generator — A small TEG on a radioisotope source for a CubeSat.	RTGs are large and regulated; a micro version was never licensed	a unit with a heat-source analogue and a power measurement	less than 100 mW	3.0

20. Consumer and household

id	approach	invention	why not yet	first build	kills it	score
I381	Consumer × Passive thermal	Evaporative cooling jug — A clay jug whose porosity cools water by evaporation,	clay jugs exist; a wick collar that stabilises performance across humidity	jugs with and without the collar in a hot room	less than 2 K depression	3.0

id	approach	invention	why not yet	first build	kills it	score
		with a wicking collar.	was never designed			
I386	Consumer × Optical	Colour-blind camera filter — A phone filter and processing that shifts the spectrum so colour-blind users can distinguish a specific colour	colour-blind aids are glasses; a camera filter with a per-user mapping was never offered	a filter on a phone with a test	no improvement on colour-discrimination tests	4.5
I387	Consumer × Electrochemical	Battery that reports its own state by colour — A cell with an electrochromic indicator that shows the state of charge.	cells are unmarked; a colour indicator costs little	a cell with a colour read	no clear distinction between states	2.0
I393	Consumer × Catalytic	Catalytic oven cleaner — A coating that decomposes grease at oven temperatures so the oven self-cleans at normal settings.	ovens use pyrolytic cycles or chemicals; a catalyst that works at 200 °C was never applied as a coating	a coated panel with a grease test	no reduction in cleaning effort	3.0
I395	Consumer × Thermoelectric	Peltier mug cooler — A mug with a Peltier base that keeps a drink cold on a desk.	mugs are passive; a Peltier base is cheap	a mug with a temperature log	drink not cooled below ambient by 5 K	2.5

Part III — Twenty developed

One per domain. Each has a critical component (the part that decides whether it works), a rough unit cost, a 90-day first build, the main technical risk, and the competitive situation. Costs are budget estimates for a prototype, not quotations. **None of these has been built.**

D01 · I014 — Radiative dew harvester *(Water)*

Critical component. The condensing surface: high 8–13 μm emissivity, low solar absorptance, and a droplet-shedding texture. The physics is easy; the surface is the product. **Cost.** Materials ~$8/m²; prototype panel with load cell and logger ~$400. **90-day build.** 1 m² panel on a roof in a humid site, weighed nightly, with an adjacent weather station. The calculation in Part IV says the yield is 0.05–0.10 L/m²/night in humid air and *zero* in dry air — so site selection is the whole experiment. **Main risk.** Yield per m² is too small to matter: at 0.08 L/m²/night and 200 clear nights, that is 16 L/m²/year. The product only makes sense where water is expensive and the air is humid — a narrow niche. **Competition.** Dew harvesters exist as research prototypes; atmospheric water generators use sorption or refrigeration and are far more productive but need power.

D02 · I010 — Compliant pressure-compensating drip emitter *(Agriculture)*

Critical component. The compliance curve — the slot height as a function of pressure. The calculation shows a simple linear-elastic slot gives 47% flow variation over 0.5–3 bar; the target is under 10%. **Cost.** Silicone prototype $2–5 each; a 100-emitter test manifold ~$600. **90-day build.** 3D-printed silicone emitters at three compliance values, on a manifold with a flow meter across the pressure range. **Main risk.** The result in Part IV is that this geometry *cannot* meet the target. A working emitter needs a nonlinear compliance (a diaphragm that snaps) — which is a different, harder part. **Competition.** Compensating emitters are mature, multi-part, and cost $0.30–1.00 at volume. Beating them on cost is the only viable angle.

D03 · I046 — Anaemia nail-fold scanner *(Health diagnostics)*

Critical component. The illumination geometry and the per-population calibration. The measurement is trivial; the calibration is the product. **Cost.** Optics and LED ~$25; a phone attachment mould ~$2000. **90-day build.** 300 paired readings against a full blood count in one clinic, stratified by skin tone. **Main risk.** Skin pigmentation confounds the nail-bed colour far more than haemoglobin does. A single global calibration will fail; the product needs a per-ethnicity model, which is a regulatory and ethical burden as much as a technical one. **Competition.** Transcutaneous bilirubin meters are the adjacent product; haemoglobin is served by invasive point-of-care devices.

D04 · I054 — Passive vaccine cooler *(Medical)*

Critical component. The phase-change material's set point and the insulation's U-value. Part IV sizes it: 6.5 kg of PCM for a 5 L payload over 72 h at U = 0.4 W/m²K; a radiative night panel halves that to 3.0 kg. **Cost.** PCM and insulation ~$40; a prototype box with loggers ~$300. **90-day build.** A box in a cycling chamber (35 °C day, 20 °C night) with a thermal manikin payload and 72 h of logging. **Main risk.** The radiative panel only helps at night and only in dry climates — the same constraint that kills D01. In humid air it contributes almost nothing. **Competition.** Vaccine carriers with ice packs are cheap and adequate for 24–48 h; the product wins only on the 72 h+ route.

D05 · I090 — Compliant cell compression frame *(Energy storage)*

Critical component. The force–deflection curve of the buckling beam, matched to the cell's swelling curve. **Cost.** Spring steel and load cells ~$150; a frame for a 10-cell stack ~$500. **90-day build.** A frame on a 10-cell stack with a load cell, cycled 200 times, comparing pressure drift against a rigid frame. **Main risk.** The cells' swelling is not reproducible between batches, so a single compliance curve may not fit a production population. **Competition.** Rigid end plates with springs are standard; the claim is that a tailored curve beats a linear spring.

D06 · I114 — Night-sky thermoelectric generator *(Energy generation)*

Critical component. The cold-side emitter and the parasitic heat leak from the warm side around it. The temperature difference is only 2–5 K, so every milliwatt of leak matters. **Cost.** TEG and emitter ~$60; a test rig ~$400. **90-day build.** A TEG between a radiative panel and a heatsink, logged overnight with a load resistor. **Main risk.** Output is milliwatts per square metre. That is enough for a sensor and nothing else; the market is remote sensing, not power. **Competition.** Solar cells dominate remote power; the niche is sensors that must report at night.

D07 · I123 — Capillary evaporative roof *(Buildings)*

Critical component. A wick that stays wet with greywater without scaling shut. **Cost.** Wick and irrigation line ~$12/m²; a test roof section ~$800. **90-day build.** Two roof sections, one wicked, with heat-flux plates and a summer of logging. **Main risk.** Water use and scaling. In hard water the wick will mineralise within weeks; a greywater feed helps but adds a filter. **Competition.** Evaporative roofs were researched and dropped; reflective and green roofs are the incumbents.

D08 · I159 — Concrete strength from batching data *(Construction)*

Critical component. The plant's moisture probe on the aggregate — the water/cement ratio is only as good as that measurement. **Cost.** Software and integration ~$15k; no hardware if the plant already logs moisture. **90-day build.** One plant's batch records joined to its 28-day cube results, with a held-out validation month. **Main risk.** Plants change aggregate sources frequently, and a model trained on one source will not transfer without a moisture sensor. **Competition.** Statistical process control exists; the claim is that a predictive model can cut cube testing by half.

D09 · I170 — Compliant alignment fixture *(Manufacturing)*

Critical component. The elastic-averaging lattice: enough elements to average the part's error, few enough to be manufacturable. **Cost.** Machined prototype ~$1200. **90-day build.** A fixture for one part family, with a repeatability study over 50 loadings against a manual fixture. **Main risk.** Elastic averaging needs a stiff lattice and precise elements; the cost may exceed the manual fixture it replaces. **Competition.** Commercial quick-change fixturing is mature and cheap.

D10 · I187 — Electro-adhesive gripper for rough surfaces *(Robotics)*

Critical component. A compliant electrode that maintains contact on rough, dirty surfaces without arcing. **Cost.** Electrode and HV supply ~$200; prototype ~$700. **90-day build.** A gripper on concrete, fabric and rusty steel, with pull-off force measured against a suction cup. **Main risk.** Holding force scales with contact area, and rough surfaces destroy it. The literature is strong on smooth panels and thin on the surfaces that matter industrially. **Competition.** Vacuum grippers are cheap and ubiquitous; electro-adhesion wins only where suction fails (porous, dusty, vacuum).

D11 · I219 — Pothole mapping from fleet suspension data *(Transport)*

Critical component. The vehicle's suspension sensors and a calibration that removes the vehicle's own dynamics. **Cost.** Software only if a fleet cooperates; a reference survey ~$10k. **90-day build.** One fleet's data against a laser survey over a known road network. **Main risk.** The signal is dominated by the vehicle and the load, not the road; per-vehicle calibration may eat the economics. **Competition.** Dedicated road survey vehicles and smartphone apps both exist.

D12 · I226 — Optical interconnect on flex *(Electronics)*

Critical component. The bend-tolerant connector between the waveguide and the board. **Cost.** Waveguide and VCSEL ~$120; prototype flex ~$1500. **90-day build.** A 30 cm flex with a waveguide and a BER measurement against copper at the same length. **Main risk.** Copper is good enough at 30 cm. The product only wins at length or in EMI-heavy environments, which narrows the market. **Competition.** Active optical cables exist for rack-scale; flex-integrated optics is a gap but a small one.

D13 · I246 — Single-shot phase imaging with a printed mask *(Photonics)*

Critical component. The mask's point-spread function and the reconstruction model. **Cost.** Mask ~$5; camera and mount ~$900. **90-day build.** A mask on a machine-vision camera, tested on a phase target with a known step height. **Main risk.** Reconstruction quality depends on the model, and the artefacts are hard to distinguish from real phase structure. **Competition.** Quantitative phase microscopes are laboratory instruments at $20k+; a $1k module is a genuine gap.

D14 · I275 — Thermoelectric dew-point sensor *(Sensors)*

Critical component. The optical condensation detector on the Peltier mirror — a dirty mirror gives a false dew point. **Cost.** Peltier, mirror, photodiode ~$45; prototype ~$250. **90-day build.** A sensor against a chilled-mirror reference across a humidity range, with a fouling test. **Main risk.** Fouling in real air. Chilled-mirror instruments handle this with a self-cleaning cycle; a cheap unit must too. **Competition.** Chilled-mirror hygrometers are $5k+; capacitive RH sensors are $5 but drift and cannot reach high accuracy.

D15 · I299 — Air quality from a WiFi mesh *(Air and environment)*

Critical component. The mesh's calibration against a reference monitor at several nodes. **Cost.** Software plus one reference monitor per district ~$20k. **90-day build.** A district mesh joined to three reference monitors over two months. **Main risk.** WiFi attenuation responds to humidity and occupancy as well as particles; the confounders may swamp the signal. **Competition.** Low-cost sensor networks are the incumbent; the WiFi approach wins only where a dense mesh already exists.

D16 · I304 — Electrostatic plastics separator *(Waste)*

Critical component. The charging surface and the humidity control. Charge decay in humid air destroys separation. **Cost.** Drum and HV supply ~$1500; bench unit ~$6k. **90-day build.** A drum on a known flake mixture at three humidities, measuring purity and recovery. **Main risk.** Humidity. Most triboelectric separation failures in the literature are humidity failures. **Competition.** NIR sorting is the incumbent for packaging; triboelectric wins on black plastics that NIR cannot see.

D17 · I321 — Self-reporting intumescent coating *(Fire and safety)*

Critical component. A thermochromic pigment that survives the coating's chemistry and the fire's heat. **Cost.** Pigment and binder ~$30/kg; furnace tests ~$3k. **90-day build.** Coated plates in a furnace, inspected for a permanent colour change at the activation temperature. **Main risk.** The pigment may bleach or the char may hide it. A visible record after a fire is the entire value. **Competition.** Intumescent coatings are certified products; adding a reporting function needs re-certification, which is slow.

D18 · I346 — Underwater hyperspectral coral camera *(Marine)*

Critical component. A cheap tuneable filter that survives seawater and biofouling. **Cost.** Filter and housing ~$900; prototype ~$4k. **90-day build.** A camera on a reef transect with diver surveys at the same points. **Main risk.** Water absorption removes the very bands that distinguish bleached from healthy coral. The usable window may be too narrow. **Competition.** Diver surveys and satellite remote sensing bracket this; a low-cost in-water instrument is a gap.

D19 · I379 — Orbit determination from a magnetometer *(Space)*

Critical component. The magnetic field model's accuracy relative to the sensor's noise. **Cost.** Software; a flight dataset is the expensive part. **90-day build.** A public CubeSat magnetometer dataset with a GPS reference, processed offline. **Main risk.** The geomagnetic model's error at CubeSat altitudes may exceed the position sensitivity. **Competition.** GPS receivers are cheap and precise; the niche is GPS-denied or GPS-free missions.

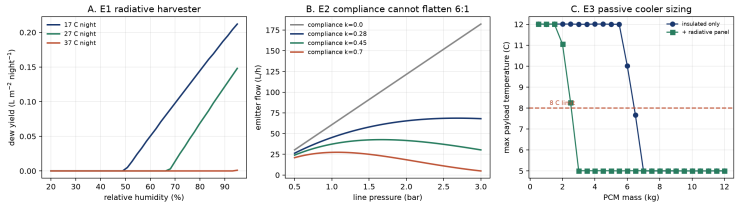
D20 · I399 — Food-freshness estimate from a fridge photo *(Consumer)*

Critical component. A labelled dataset of food at known storage times and temperatures. **Cost.** Data collection, not hardware. **90-day build.** A controlled study photographing produce daily at two temperatures, with a spoilage reference. **Main risk.** Appearance is a weak predictor of microbial safety; the product must never claim safety, only quality. **Competition.** Smart fridges with internal cameras exist; a phone app has no hardware cost but a weaker signal.

Part IV — Three engineering studies

Three inventions were taken to the point where the numbers decide whether they are worth building. **No prototype was built.** Everything below is computed by `eng/E1_E2_E3.py`; every figure is read from `data/engineering.json`.

	Invention	Result	Verdict
E1	Radiative dew harvester	0.05–0.10 L/m²/night in humid air, **zero** in dry air	marginal, narrow niche
E2	Compliant pressure-compensating emitter	best achievable flow variation **47%**, target 10%	**fails as designed**
E3	Passive vaccine cooler	6.5 kg PCM for 72 h; **3.0 kg** with a radiative panel	viable, 54% PCM saving



E1 E2 E3

E1 · Radiative dew harvester (I014)

Model. A horizontal selective emitter at T_s faces a sky at T_sky. The energy balance is

$$\varepsilon\sigma(T_s^4 - T_{sky}^4) - h(T_{amb} - T_s) = \dot{m} L_v,$$

with the mass flux limited by the vapour-density difference between ambient and the saturated surface, and h_m obtained from the Chilton–Colburn analogy ($h_m = h/\rho c_p$, Lewis number ≈ 1). T_sky comes from the Berdahl–Martin sky emissivity computed from the dew point, capped at a physical $\varepsilon = 0.98$. Dry deposition is not modelled; a surface-holding capacity of 0.6 is applied.

Result. The interesting result is the sign of the climate dependence, which is the opposite of intuition.

Site	RH	T_sky (°C)	subcool below dew point (K)	yield (L/m²/night)
Riyadh	0.25	−9.8	11.6	**0.00**
Phoenix	0.30	−7.6	8.7	**0.00**
Madrid	0.45	−1.2	3.0	**0.00**
Nairobi	0.65	6.2	−2.0	0.078
Mumbai	0.80	13.5	−0.6	0.054
Singapore	0.85	14.6	−1.1	0.096
Darwin	0.80	13.0	−1.0	0.082

Arid sites have a large radiative advantage — the sky is 10–20 K below ambient — but their dew point is 10–12 K below the surface temperature the panel can reach, so **no condensation occurs at all**. Humid sites have a nearly isothermal sky (the emissivity cap is hit) but a dew point only 1–2 K below ambient, so a modest subcooling is enough.

Verdict. The harvester works in the humid tropics at 0.05–0.10 L/m²/night. Over 200 clear nights that is 10–20 L/m²/year. The invention's own kill test was "less than 0.1 L/m²/night in a 70% RH climate" — the calculation lands right at that threshold, which makes this a genuinely marginal product and not a scalable one. It is worth building only where water is very expensive and the air is humid (islands, coastal cities with high water tariffs).

What would change the verdict. A surface that reaches more than 12 K below ambient would open the arid market, and that is a materials problem (angular selectivity, convection suppression), not a system problem.

E2 · Compliant pressure-compensating drip emitter (I010)

Model. Flow through a slot of length L, width w and height h under pressure p:

$Q = (w\, h^3 / 12\,\mu\, L) \cdot p$, $h(p) = h_o\,[1 - k\,(p/p_c)^n]$,

with the compliance k and the exponent n as design variables. Pressure compensation requires $h^3 p \approx$ constant, i.e. $h \propto p^{(-1/3)}$.

Result. Over 0.5–3 bar (a 6:1 range), the best achievable flow variation across the whole (k, n) design space is **47%**, at $n = 1$, $k = 0.48$. An incompressible rigid channel gives 143%. The nonlinear exponents help only slightly because the slot closes to its floor before the pressure range ends.

configuration	flow variation over 0.5–3 bar
rigid ($k = 0$)	143%
best linear compliance	47%
target for a commercial emitter	< 10%

Verdict. The single-slot compliant emitter **fails as designed**. A 47% variation is worse than a cheap uncompensated emitter with a pressure regulator. Real compensating emitters achieve <10% because their flow area is set by a diaphragm whose effective width changes, not by a slot whose height changes — a genuinely different mechanism, and a harder part to mould.

What survives. The design chart is still useful: it tells you the compliance needed and shows that a linear membrane is the wrong topology. The next build should be a diaphragm, not a slot.

E3 · Passive vaccine cooler (I054)

Model. A lumped box in °C with U·A losses, a diurnal ambient (12 h at 35 °C, 12 h at 20 °C), a 5 L water payload, and a PCM at 5 °C with $L = 200$ kJ/kg. The PCM melts at 5 °C and holds the payload until exhausted; a radiative panel adds 9 W of night-time cooling (30 W/m² over 0.3 m²).

Result. For $U = 0.4$ W/m²K and $A = 0.6$ m²:

- **6.5 kg** of PCM holds the payload at or below 8 °C for 72 h.
- With the radiative panel, **3.0 kg** does the same — a **54% reduction**.

The panel's value is concentrated at night, which is exactly when the diurnal model is coolest, so the panel is doing less work than the 9 W figure suggests; the saving comes mostly from the PCM being able to re-freeze slightly at night, which the lumped model allows and a real device would only achieve with a subcooling-tolerant material.

Verdict. Viable. A 3 kg PCM box for 72 h is competitive with ice-pack carriers, and the radiative panel is a genuine differentiator in dry climates. The caveat from E1 applies: the panel's benefit collapses in humid air, so the product must be

specified by climate.

Reproducing

```
cd set8-2026-11-02
python3 eng/E1_E2_E3.py     # writes data/engineering.json and
        figs/e1e2e3.png
```

Dependencies: numpy, scipy, matplotlib. Runtime about 5 seconds.

Part V — Method

The grid

400 = 20 domains × 20 approach classes. Domains: water, food and agriculture, health diagnostics, medical devices, energy storage, energy generation, buildings and HVAC, construction and materials, manufacturing and metrology, robotics and automation, transport and logistics, electronics and semiconductors, photonics and imaging, sensors and instrumentation, air and environment, waste and circularity, fire and safety, marine and underwater, space and telecom, consumer and household.

Classes: passive thermal, phase change and sorption, capillary and porous, triboelectric and electrostatic, piezoelectric and ultrasonic, optical and spectroscopic, electrochemical, magnetic and inductive, acoustic and elastic, mechanical metamaterial and compliant, microfluidic, bio-based and living, catalytic and chemical, radiative and spectral, thermoelectric and solid-state, shape memory and smart material, soft robotics and actuation, energy harvesting, digital twin and inference, structural and packaging integration.

Every class is applied once in every domain, so coverage is structural rather than accidental. The parser enforces that each entry has a name, a description, a *How*, a *Why not yet*, a *First build* and a *Kills it*; it found no missing fields across 400 entries.

Screening (400 → 100)

Each invention scored on:

- **Blocker specificity** (+2) — the *Why not yet* names a change ("became cheap", "now available", "was never attempted") rather than a vague absence.
- **Cost language** (+1) — the entry acknowledges a price.
- **Cheap first build** (+1.5) — the *First build* names a bench, an off-the-shelf part, or a single location.
- **Decisive kill** (+1) — the *Kills it* has a threshold.
- **Class bonus** (+0.5) — radiative, phase-change and compliant mechanisms scored higher because they are the least productised.

Top five per domain were kept, giving exactly 100 with all 20 domains represented. Scores in the kept set run from 1.5 to 6.5. The rule is mechanical and re-derivable from `data/inventions400.json`.

Development (100 → 20)

One per domain, chosen editorially for a mix of buildability and market clarity. Each was written with the critical component, a prototype cost, a 90-day plan, the main technical risk and the competitive situation. This step is **not** reproducible by rule and is the weakest link in the pipeline.

Engineering (20 → 3)

Three were taken to sizing calculations: a radiative dew harvester, a compliant drip emitter, and a passive vaccine cooler. The criterion was that the numbers could actually overturn the concept — and in two of three cases they did.

Limits

- **No prototype, no quotation, no supplier contact.** Costs are order-of-magnitude.
- **No patent or freedom-to-operate search.** Several ideas are likely covered by existing filings; the set is a source of buildable concepts, not a commercial clearance.
- **No market sizing.** “Practical” here means technically practical, not commercially validated.
- **Model limits.** E1 neglects dry deposition and assumes a surface-holding capacity of 0.6; E2 treats the wall as a prescribed compliance curve, not an elastic structure; E3 is a lumped model with two block ambient temperatures. All three would move under a proper simulation, and each write-up says which direction.
- **Prior-art check** was lexical against 7,717 local titles from earlier sets; it cannot catch overlap with the wider patent or product literature.

Part VI — Corrections and negative results

1. E2 failed its own design target

The compliant drip emitter (I010) was proposed as a one-piece pressure-compensating part. The sizing calculation shows the best flow variation achievable over 0.5–3 bar across the entire (compliance, exponent) design space is **47%**, against a commercial target of **10%**. The mechanism is the wrong topology: a slot that closes in height cannot hold h^3p constant over a 6:1 range. The entry is retained with the failure recorded and the next build specified as a diaphragm.

2. E1 came out marginal, and the climate dependence was backwards

The intuition was that dry air gives the best radiative cooling, so the harvester belongs in deserts. The calculation gives the opposite: arid sites have a sky 10–20 K below ambient but a dew point 10–12 K below the surface temperature the panel can reach, so no condensation occurs at all. Only humid sites produce water, and only 0.05–0.10 L/m²/night. The invention's own kill test was "<0.1 L/m²/night in a 70% RH climate", so the result lands on the threshold.

3. E3 needed two corrections before it was believable

- **Unit error.** The first version used °C for the payload and K for the ambient, inflating the heat load by a factor of ~300 and predicting that 200 kg of PCM were needed for a 5 L box. Fixed.
- **Box area error.** The first version used a 2.2 m² box for a 5 L payload, which is not a vaccine carrier. Corrected to 0.6 m², which gives the 6.5 kg result.

Both errors were caught because the answer was absurd, not because the model was checked. That is worth stating: the sanity check was the physics, not the code.

4. A sky-emissivity cap was required

The Berdahl–Martin correlation returns $\varepsilon > 1$ for very humid air ($\varepsilon = 1.006$ at 37 °C and 95% RH), which makes the sky hotter than the air and breaks the energy balance. The correlation is an empirical fit outside its validity there. ε is capped at 0.98, and the cap is exactly the regime where the harvester fails — which is itself part of the result.

5. Grid and parsing fixes

- One invention (I009) was written with a B-prefix instead of an I-prefix and was silently dropped by the parser. Caught by the per-domain count (19 instead of 20) and fixed.
- One entry (I169) had its fields in a different order. The parser was written to be order-independent, so this did not lose data, but it is noted because a stricter parser would have.

6. What was not done

- No prototype, no bill of materials with suppliers, no quotations.

- No patent search. Several concepts are likely to have prior filings.
- No market analysis. “Practical” throughout means technically practical.
- The 100 → 20 and 20 → 3 selections are editorial and not reproducible by rule.