The hidden engineering of scaling electrolysers.

A single cell that works on the bench is a lab result, not a product. What changes on the way to the megawatt — in the cell, the stack, and the plant around them.

THE CELL

THE STACK

THE SYSTEM

100 cm^2

the area a cell is often proven at — before scaling to thousands

100s

of cells wired in series; the worst repeat unit rules the stack

1

weak cell is all it takes — a stack performs like its worst, not its best

THE THESIS

Scaling is *not* inventing.

The chemistry can be excellent and the project can still fail on things nobody publishes — how heat leaves a stack, how gas moves through a manifold, how a coating survives ten thousand hours instead of ten.

> **The physics does not break at scale.**
>
> *The engineering does.*

These challenges come from R&D and technical due-diligence work — the region where most scale-up budgets are actually spent.

THE MAP

Six places scale-up quietly breaks

Three live in the cell and stack. Three in the system around them. None show up on a polarisation curve.

01 **Current density**

Efficient when small, hot and lossy when large

02 **Heat & water**

Thermal and mass transport the bench never tested

03 **Sealing & mechanics**

Compression, gaskets, tolerances across a big stack

04 **Materials & coatings**

Degradation that only appears over thousands of hours

05 **Balance of plant**

The unglamorous 60% of cost that decides reliability

06 **Manufacturing**

A hand-built cell is not a repeatable production part

CELL & STACK

SYSTEM & PRODUCTION

BY TECHNOLOGY

Every chemistry has a different weak point

ALKALINE

Mature, cheap, load-limited

Under variable renewables H_2 crosses into O_2; systems shut at ~2% HTO, forcing a ~10–40% minimum load.

PEM

High performance, precious metals

Anode needs iridium — only ~7–9 t mined a year. Loadings must fall ~40× while surviving a 10-year life.

AEM

Promising, still early

Cells exceed 1 A/cm^2 but often last under 200 hours; strong cells, little long-duration stack data.

SOLID OXIDE

Efficient, hot and brittle

Runs at 700–850 °C: ceramics crack on cycling, chromium poisons the electrode. Target: 40,000 h+ life.

The efficiency that doesn't survive scale

THE NUMBER THAT GETS SOLD vs THE NUMBER THAT SHIPS

WHAT THE LAB REPORTS

84%

efficiency, measured on a slow low-load sweep

Gentle current · few cells · ideal conditions · the number on the pitch deck

−22
points

WHAT THE PLANT OPERATES AT

62%

efficiency, at the current density you actually sell at

High current · hundreds of cells · bubbles, ohmic loss and hot spots all rising

Illustrative · the gap is where the business case quietly moves against you.

THE TEST Quote efficiency at the current density you will actually sell at — not the flattering one from a slow lab sweep.

The bench never tested the plumbing

THE INLET

Feed water and current must arrive evenly at every cell. On one cell that is automatic; across a tall stack it is a manifold problem.

THE MIDDLE

Heat is generated unevenly and must leave. Gas must escape without starving the reaction. The centre cell lives in a different world.

THE EDGE

The worst-fed, hottest, most starved cell sets the ceiling. The stack degrades at the pace of its unhappiest repeat unit.

Most stack failures are not electrochemistry failures.

They are heat, water and pressure distribution failures wearing an electrochemical mask.

The failure that only shows up in year five

~80,000 h

the lifetime a commercial electrolyser is often sold on

Nobody has watched most designs run that long. The number is a model, extrapolated from a few thousand hours.

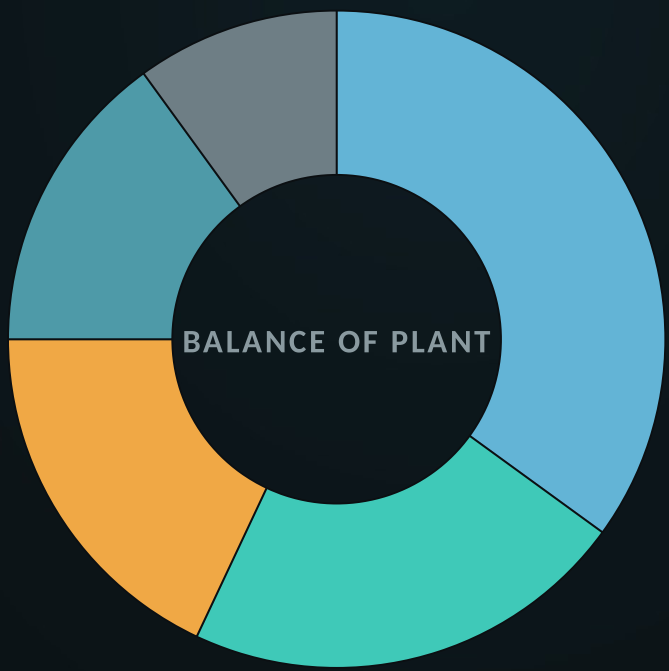
WHAT ACTUALLY DEGRADES — AND IT DIFFERS BY CHEMISTRY

PEM	iridium dissolves at OER voltage into the membrane
SOEC	degrades faster stack-than-cell; Cr poisoning at 800 °C
AEM	OH^- and radicals strip the membrane's cationic groups
ALKALINE	shutdown reverse-current oxidises the Ni electrodes

The scale-up error

Validate performance, then assume durability — different experiments, and the slow one gets cut first when the timeline gets tight.

The stack is not the expensive part



Stack	35%
Power electronics	22%
Gas processing	18%
Water & thermal	15%
Controls & integration	10%

Illustrative split for a deployed system. The exact shares vary — the lesson does not.

> **A perfect stack strapped to an unreliable system** is an unreliable product. Scale-up means designing the whole thing as one machine.

THE CLOCK

Scaling has a speed limit, and it is physical

You cannot compress a degradation curve into a quarter. The slowest necessary experiment sets the schedule — not the funding round.

1	**Single cell**	Chemistry & performance
2	**Short stack**	Distribution & sealing
3	**Full stack**	Heat, gas & mechanics at scale
4	**System**	Balance of plant & controls
5	**Plant**	Duty cycles & durability

Each rung must prove out before the next is funded. Skip one and you meet its problem later, at ten times the cost.

LISTEN NOW

The cell is the easy part.

A megawatt is not a big cell — it is a different machine, governed by heat, water, mechanics, materials and manufacturing. Respect that gap early and it is an engineering programme. Ignore it, and it becomes a post-mortem.

The full breakdown is in Episode 5

Link in the comments.

Where have you seen the bench lie? Tell me which of the six you'd fix first — before you listen.

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