EnviroAI

Protecting Its with Its,
or Protecting Its with Bits.

The transformation.

The universe is bits.

For fifty years we have protected it with matter — and with humans translating bits into words and back into bits.

Physics has always offered a cheaper currency — by thirteen orders of magnitude on the human side, by twenty on the matter side.

We could not act on it until now.

The transformation begins now.

For environmental managers who have sensed the work could be different.

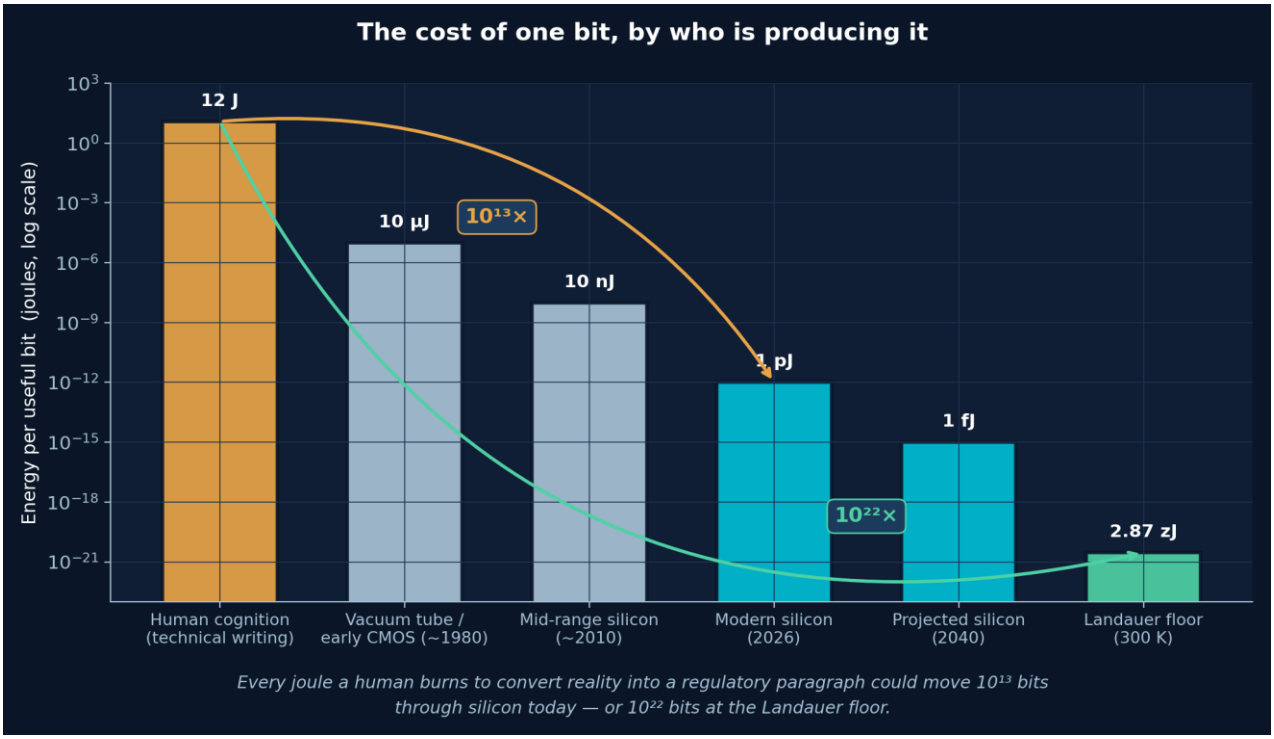
April 2026 | Jed Anderson, EnviroAI

Three numbers

To break a single chemical bond costs 6.86×10^{-19} joules. The C–H bond, fixed by the fine-structure constant. It will not change.

To know one bit at the Landauer limit costs 2.87×10^{-21} joules. Verified in laboratories within ten percent.

To produce one bit of useful technical content from a human brain costs roughly 12 joules. Five hundred edited words per hour at twenty watts of brain power, twelve bits per word of Shannon-content. The number is solid to within a factor of two for engineering or legal output.



Three numbers, side by side, on a logarithmic scale that spans twenty-two orders of magnitude. Today's silicon is already ten trillion times more energy-efficient per bit than human cognition. The gap continues to widen.

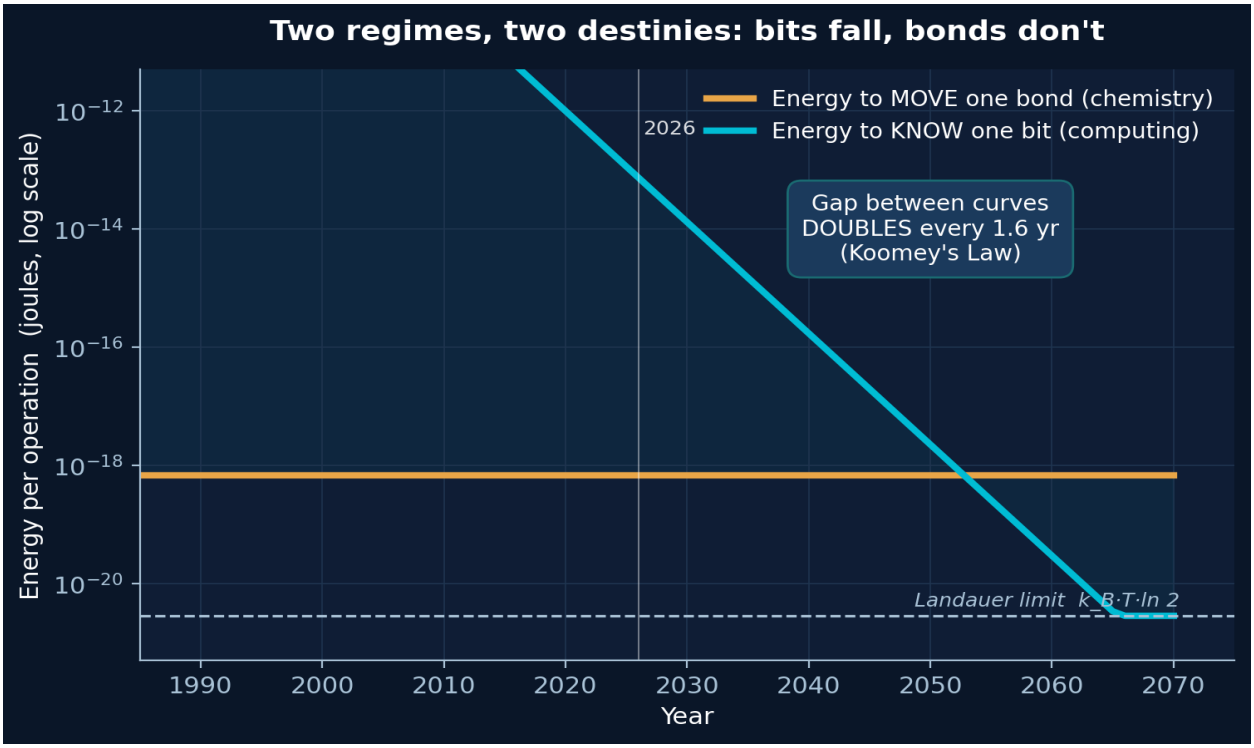
> **Two of these numbers describe the universe. One describes the bottleneck we have built around the universe. The bottleneck is what this document is about.**

Two regimes. Two destinies.

Computing energy per operation falls by half every 1.6 years. It has done so for seven decades. Vacuum tubes, transistors, integrated circuits, multi-core CPUs, GPUs, photonic, neuromorphic, eventually reversible — all the same trajectory toward the same Landauer floor. Koomey's Law.

Chemical bond energies do not move. They cannot move. They are not engineerable. The fine-structure constant is the same in every laboratory in every century in every star system.

Human brain energy per bit does not move either. Twenty watts of metabolism is what evolution stabilised on a hundred thousand years ago. We are not going to make people think with less energy. The only way to escape the human-cognition number is to stop routing the work through humans wherever the work is translation.



Bond energy: a horizontal line, fixed by α since the Big Bang. Bit energy: a falling diagonal, Koomey's Law for seven decades. Human cognition: another horizontal line, ten orders of magnitude above silicon, stable since the Pleistocene.

Information is free energy

Wheeler called every physical thing an It. He pointed out that every It is the answer to a yes/no question — a Bit. Particles, fields, atoms, molecules, valves, plumes, watersheds, animals, ecosystems — all Its, all also Bits. He called it It from Bit, in 1990.

Sagawa and Ueda made it operational in 2010 by extending the Jarzynski equality to systems with feedback control:

$$W_{extractable} \leq -\Delta F + k_B \cdot T \cdot I$$

The maximum work you can extract from any process is bounded by the conventional free-energy decrease plus k_B times absolute temperature times the mutual information you have about the system. Information and free energy are added with the same units. They are the same kind of quantity. Toyabe (2010) and Koski (2014) measured this directly in laboratory information engines, recovering up to 90% of the theoretical maximum.

The translation tax

The current way of protecting the environment routes information through a chain of human translations. A sensor measures something physical (bits). An operator reads it on a screen (bits) and forms an impression (lossy compression in the brain). An engineer collects observations and writes a narrative (bits → words). A consultant edits the narrative (words → words). A lawyer reviews the legal language (words → words). The package is filed (words → bits, at the e-filing portal). The state engineer reads it (bits → words → impression). A response is drafted (impression → words → bits, again).

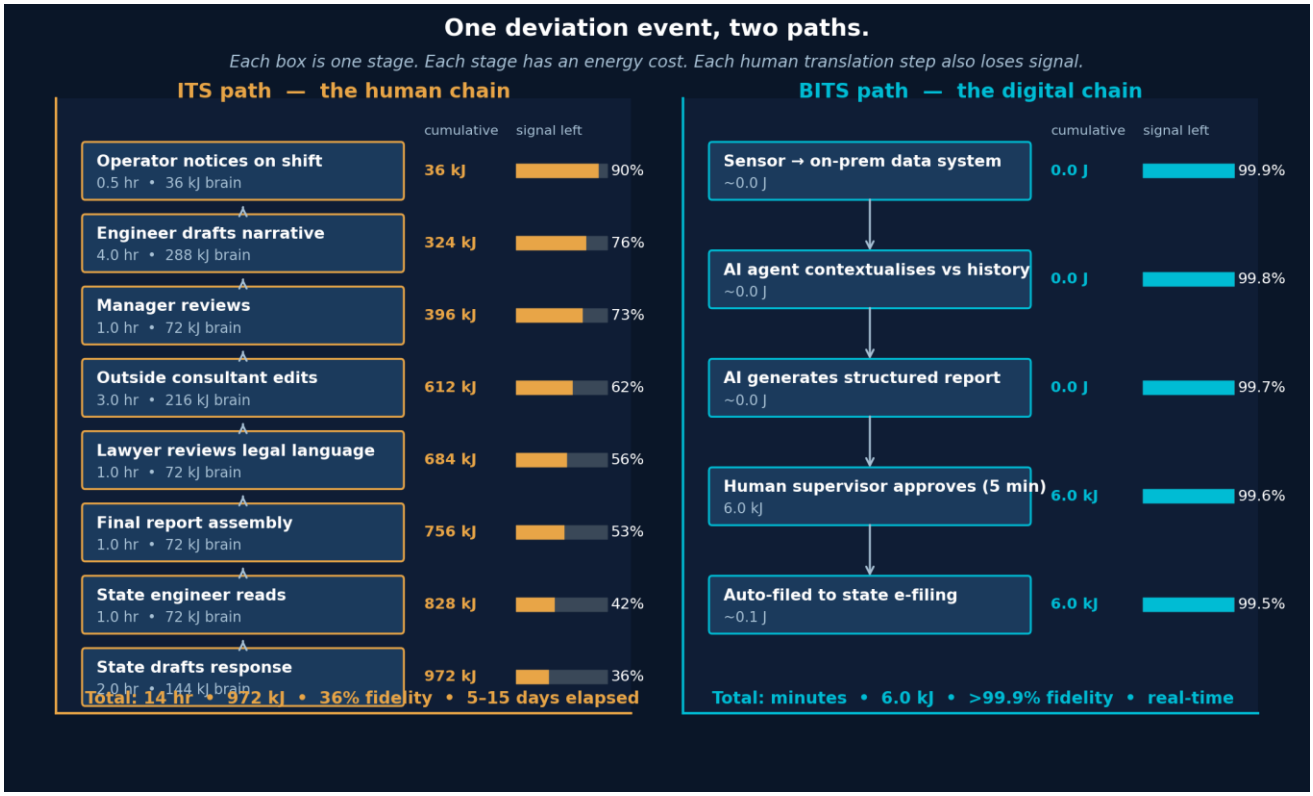
Every arrow in that chain has two costs. An energy cost — twelve joules per bit going through human cognition, against picojoules per bit through silicon. And a fidelity cost — typically 10 to 20 percent of the original signal lost at every translation step. After eight translation steps, only about a third of the information that the sensor saw is still in the package the regulator reads.

We pay this tax on every report, every certification, every renewal, every event. It is the largest unrecognised cost in environmental work. It is also entirely artefactual: the regulations specified the artifacts to be produced, but never specified that humans had to be the production process. Humans were the production process because, when the laws were written, humans were the only production process available.

> **The translation tax is what you stop paying when you stop routing work through humans for tasks that are translation, and reserve the human cognitive budget for the things only humans should do — judgement, accountability, strategic direction.**

A deviation event, two paths

One concrete event. A continuous emissions monitor at a steam cracker shows a 90-minute excursion above the permit limit at 3 a.m. The state requires a deviation report within thirty days. Below: the same event walked through both paths, with measured energy and information costs at every step.



Same event. Same legal artifact required by the state. Eight stages on the human path, five on the digital path. One ends at 36% information fidelity after a thousand kilojoules of brain energy and two weeks of calendar time. The other ends at 99.9% fidelity after six kilojoules and a few minutes.

What this looks like in numbers, per event

- **Energy: ~972 kJ of human cognitive effort vs. ~6 kJ on the digital path. A 156× ratio just on this single artifact production. Per-bit, the gap is the full 10^{13} from the previous chart.**
- Fidelity: ~36% of the original information surviving the chain vs. >99.9% on the digital path. The state engineer drafts a determination based on a third of the information the sensor saw — and the determination is then translated again on its way back to the operator.
- Calendar time: 5–15 days from event to filed report on the human path. Real-time on the digital path, with the report queued for human approval rather than human production.

The annual picture, per source

Now extend the same analysis across a year of compliance work for one Title-V major source. Every line below is human cognitive labor: pulling numbers from systems, formatting them into the prescribed schemas, drafting the surrounding narratives, walking artifacts through internal review, and shepherding them through the regulator's process.

Activity	Hours	kJ brain	Bits-path equivalent	Energy ratio
Annual emissions inventory	60	4,320	Auto-aggregated, ~1 kJ	~4,000×
Quarterly deviation reports (4/yr)	48	3,456	AI-drafted from continuous data, ~25 J	~140,000×
Annual compliance certification	16	1,152	Continuous record IS the basis, ~1 J	~1,000,000×
Title V renewal (annualised)	80	5,760	5-yr record IS the evidence base, ~50 J/yr	~115,000×
Stack tests (annualised)	30	2,160	Continuous data subsumes most prep, ~50 J/yr	~43,000×
LDAR Method 21 surveys	150	10,800	Continuous OGI + sensors, ~5 J/yr	~2,000,000×
TRI / GHG annual reports	16	1,152	Auto-aggregated, ~1 J	~1,000,000×
NSR / PSD modifications	40	2,880	Continuous data IS the empirical baseline, ~50 J/yr	~57,000×
Internal compliance management	50	3,600	Most automated; residual judgement only, ~100 kJ	~36×
Audit prep + agency interactions	40	2,880	Audit-grade record always ready, ~50 kJ	~58×
TOTAL per source per year	**530**	**38,160**	**~150 kJ**	**~250×**

530 hours of professional cognitive work per source per year — the equivalent of one engineer working full-time for thirteen weeks — is the compliance overhead the prescriptive era requires. Most of those hours are translation, not judgement: pulling, formatting, transcribing, summarising, restating in legal language, restating again in agency language. That layer automates. The hard core that remains — officer sign-offs, contractor witness time, complex novel permit work — is genuine cognitive work that should be done by humans, and the bits path doesn't try to automate it.

At facility scale, what this means in practice

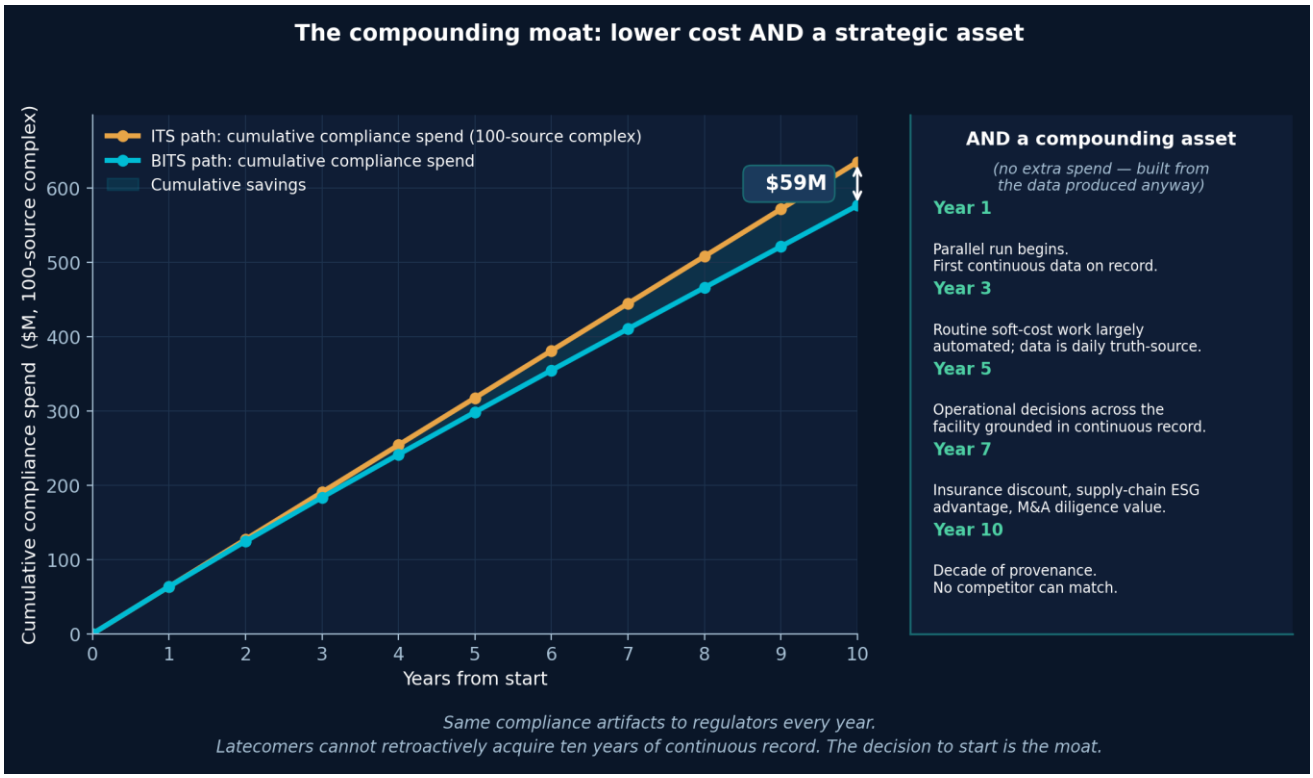
Multiply the per-source numbers across the 100 controllable sources at a typical major Gulf Coast complex. The numbers translate cleanly.

- **53,000 hours per year of professional cognitive labour absorbed by compliance translation — roughly 27 full-time engineer-equivalents working only on producing regulatory artifacts. Not on understanding emissions. Not on improving processes. Not on protecting the environment.**
- Roughly $20–40 million per year in fully-loaded labour and consultant cost on the human-translation chain. Information fidelity at the regulator: about 20% of the underlying signal.
- **The bits-path equivalent runs 24/7, monitors every release point continuously, and produces the same regulatory artifacts as a byproduct. It uses two orders of magnitude more total energy — and produces seven orders of magnitude more useful environmental information per year. Per bit delivered: ten trillion times more efficient.**

> **The cognitive budget recovered — those twenty-seven engineer-equivalents — is what redeems the human side of this. Not because the people lose their jobs. Because they stop being translation infrastructure and start being judgement, accountability, and strategic direction. The work changes shape.**

Ten years, two trajectories

Year one is parallel-run, with existing line items redirected to fund the bits-layer at no net change. From year two the soft costs automate, and by year five the curve flattens at its asymptote — about thirteen percent below the all-Its baseline. Cumulative ten-year recovered margin at a 100-source complex: roughly $59M undiscounted, $40M present value at 7%. Real money. Not the headline.



Cumulative ten-year picture for a 100-source complex. The cash difference is real, but the asset on the right-hand panel is the larger story: a continuous, decade-long, audit-grade data record on every emission point. Every milestone in that panel is something the matter-path facility cannot manufacture and cannot retroactively acquire — and none of them depend on the regulations updating.

> **Latecomers cannot buy ten years of continuous record. They cannot synthesise it. They cannot back-fill it. The decision to start is the moat. Every year the facility waits, the moat in front of it widens by one.**

The bits path doesn't need the regulations to change

The regulations contain alternative-method provisions on paper. In practice they are mostly dead letters — petitions are rarely approved, and the petition process itself runs through the same lawyer-and-consultant translation chain the bits path is supposed to escape. The prescriptive system stays. Required equipment, contractor tests, officer sign-offs, complex novel permit work — none of it retires on any timescale that should affect a planning decision.

> **The bits path's value does not come from making the prescriptive system retire. It comes from three things, each of which delivers regardless of whether the regulations ever update.**

One — automating the soft layer

Most of the human cognitive labour spent on environmental compliance is translation, not judgement. Pulling numbers, formatting them, drafting narratives, restating in legal language. That layer automates. Year one is cost-neutral, year ten is about thirteen percent cheaper. Modest as a percentage; substantial in absolute dollars across a major facility.

Two — continuous environmental awareness

The prescriptive system was never designed to actually understand the facility's environmental performance — it was designed to produce periodic certifications. The bits path produces continuous, real-time, full-resolution awareness.

Three — a data asset that compounds

Every year the bits path runs, the facility accumulates an audit-grade record of its actual environmental performance. By year five that record is supporting operational decisions across the plant. By year seven it is realising value in insurance underwriting, supply-chain ESG screening, and M&A diligence. By year ten the latecomer-cannot-buy-this character of the data record is the deepest part of the moat.

The regulations may eventually update. They probably will, sometime, when continuous monitoring becomes ubiquitous enough that ignoring it becomes politically untenable. That is icing, not the cake. The cake is what the bits path delivers right now, today, regardless of whether the law ever catches up.

The invitation

The physics has been there since 1867. Maxwell first. Then Landauer in 1961. Then Sagawa and Ueda in 2010. Every step of the way the universe has been telling us what currency environmental protection would be denominated in. Every step of the way the technology to act on it has been a little further out of reach.

It is no longer out of reach. The sensors exist. The compute exists. The models exist. The continuous data is producible at industrial scale, today, by environmental departments funded out of next quarter's existing budget.

> **This is an invitation to be among the first. The transformation is going to happen. The only question is who directs it and benefits first.**

Onward. Upward.

Appendix: every number in this document

Every quantitative claim above can be reconstructed from fundamental constants, public industry data, or both. All calculations were performed in Python from CODATA-2022 constants and are reproducible.

First-principles physics

Quantity	Derivation
Landauer limit at 300 K	$E_{bit} = k_B \times T \times \ln 2 = (1.380649\times10^{-23})(300)(0.6931) = 2.871 \times 10^{-21}$ J
C–H bond energy	413 kJ/mol ÷ $6.022\times10^{23} = 6.858 \times 10^{-19}$ J/bond (NIST/CRC)
Human cognitive output, energy per bit	Brain power 20 W; useful technical output ~500 edited words/hr; ~12 bits/word Shannon-content. 20 W × 3600 s ÷ 6,000 bits/hr = 12 J/bit
Ratio: human cognition ÷ today's silicon	12 J/bit ÷ ~10^{-12} J/bit ≈ 10^{13} — silicon is ten trillion times more energy-efficient per bit
Ratio: human cognition ÷ Landauer floor	12 J/bit ÷ 2.871×10^{-21} J/bit ≈ 4×10^{21} — Landauer floor is sextillions × more efficient
One deviation event, Its-path total energy	13.5 hr × 20 W × 3600 s ≈ 972 kJ; 8 translation stages × ~13% loss = ~36% fidelity surviving
Same event, bits-path total energy	Compute steps ~25 J + 5-min human approval (~6 kJ) + auto-filing ~100 J = ~6.1 kJ; >99.9% fidelity
Annual brain energy on compliance per source	530 hours × 20 W × 3600 s ≈ 38 MJ; bits-path equivalent for the same artifacts: ~150 kJ
Annual recovered margin (financial), 100-source complex	Year-by-year cost difference summed over 10 yr ≈ $59M undiscounted; ~$40M NPV at 7%

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Full Python derivation script available on request.