Why Nuclear Energy Costs Keep Rising — And Whether SMRs Can Reverse the Curve

A Wright's Law Analysis · 20 MECE Experts · 1950–2040

BOTTOM LINE UP FRONT · Nuclear is the only major energy technology with a negative learning curve (–23%). Costs rose 5× in real terms (1960–2024) while deployment grew 400×. Ten historical drivers explain why. Looking forward, SMRs promise to activate Wright's Law through factory fabrication and standardization, but the first operational evidence — NuScale's cancelled CFPP at $20,139/kW — is not encouraging. NOAK SMR targets of $3,600/kW require 50-200 serial builds at learning rates never achieved for nuclear. By 2040, solar+storage LCOE may be 3× cheaper than SMR NOAK. Nuclear's value proposition is shifting from cost competitiveness to dispatchability, industrial heat, and grid reliability — a viable but narrower role.

PART I · Historical Analysis (1950–2025)

PART II · Future Projections (2025–2040)

16. **Nuclear Finance Analyst** — NuScale CFPP Post-Mortem
17. **Project Finance Expert** — Financing Cost Multiplier
18. **Deployment Pipeline Analyst** — Aspirations vs Reality
19. **Technology Competition Analyst** — Exponential vs Flat Curves
20. **Strategic Integration Analyst** — Wright's Law Precondition Scorecard

Sources: EIA, WNA, IAEA-PRIS, Lovering et al. 2016, Grubler 2010, NREL ATB 2024, BNEF, IEA, Fraunhofer ISE, Carlino et al. 2025, CATF, IEEFA, EY-Parthenon 2024, Nøland et al. 2024.

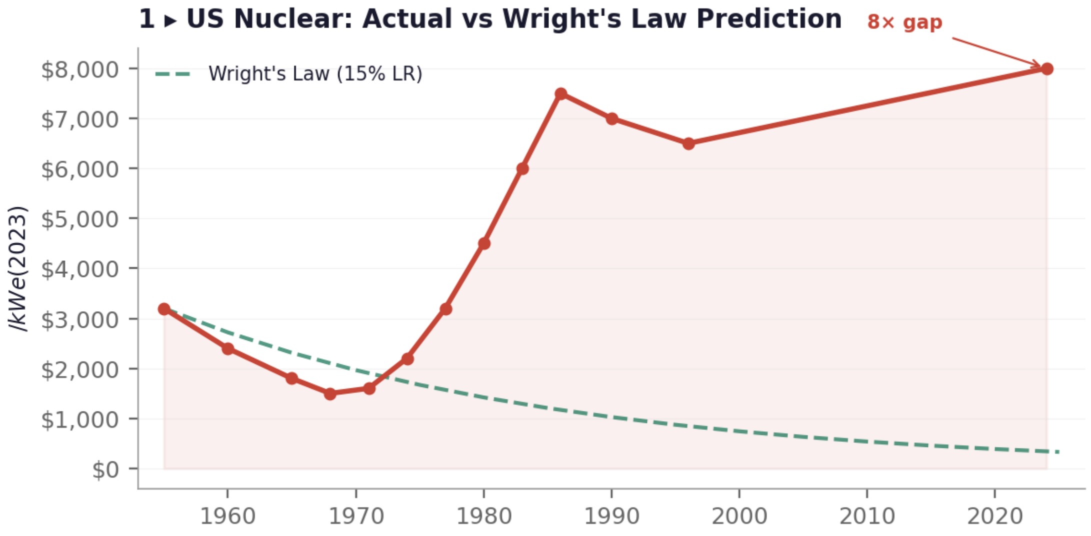
PART I

Historical Analysis: Why Wright's Law Failed (1950–2025)

01 Energy Economist

Overnight Cost Trajectory

BLUF: US nuclear costs rose from ~$1,500/kWe (1960s) to ~$8,000/kWe (2024) — a 5× real increase. Wright's Law predicted 90% decline. The gap is 8×.



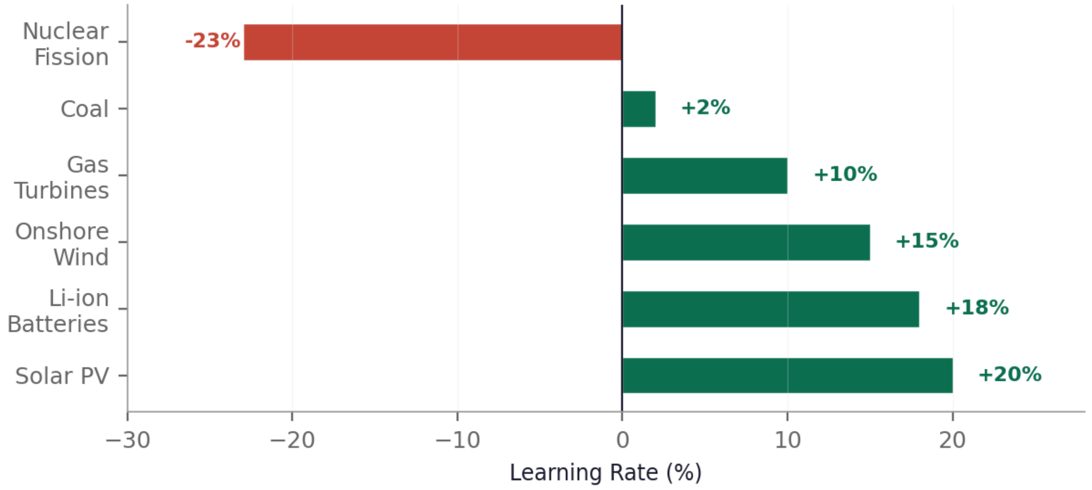
1 ▸ US Nuclear: Actual vs Wright's Law Prediction

Wright's Law posits costs decline a fixed percentage per cumulative production doubling. Nuclear defied this comprehensively. The EIA documented overnight costs growing from $1,500/kWe in the early 1960s to $4,000/kWe by the mid-1970s. The latest AP1000 estimate stands at $7,821/kWe. Had nuclear followed even a modest 15% learning rate, costs would be under $500/kWe today. This represents the most dramatic failure of learning-curve economics in industrial history.

02 Technology Forecaster

Learning Rate Benchmarking

BLUF: Nuclear exhibits –23% learning rate — costs rise 23% per capacity doubling. Solar PV achieves +20%. This is the defining number in energy economics.

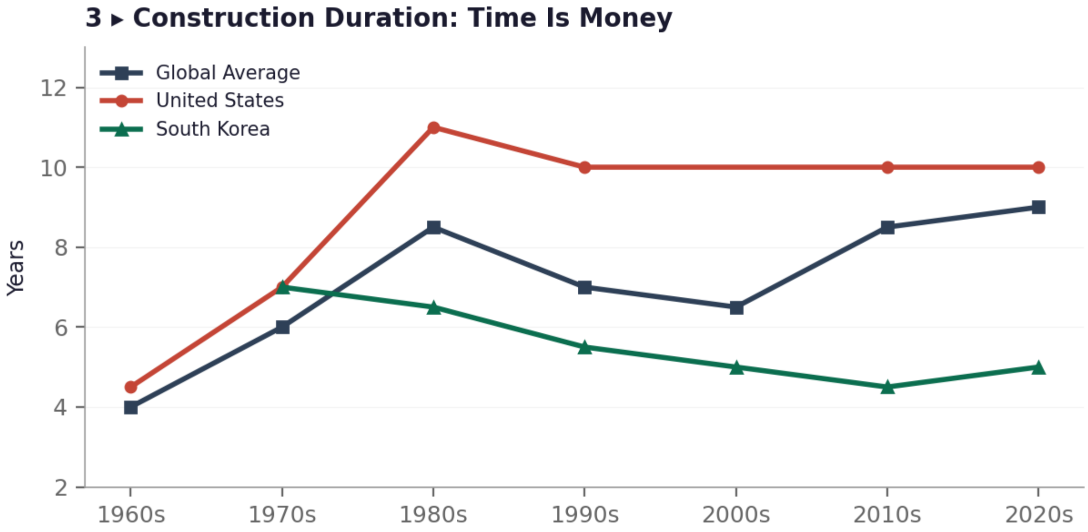

2 ▸ Learning Rates: Nuclear Is the Outlier

Grubler's landmark analysis of the French program revealed negative learning across all major nuclear nations. Solar PV has maintained a stable 20% learning rate for four decades; batteries show 18%. Nuclear's negative rate means building more reactors has been associated with higher costs. This signals that forces outside production — regulation, complexity growth, workforce disruption — overwhelm whatever manufacturing learning occurs.

03 Construction Manager

Duration Escalation

BLUF: US build times ballooned from ~5 years (1960s) to 10+ years (1980s). Every additional year adds ~$1B in financing and escalation costs.

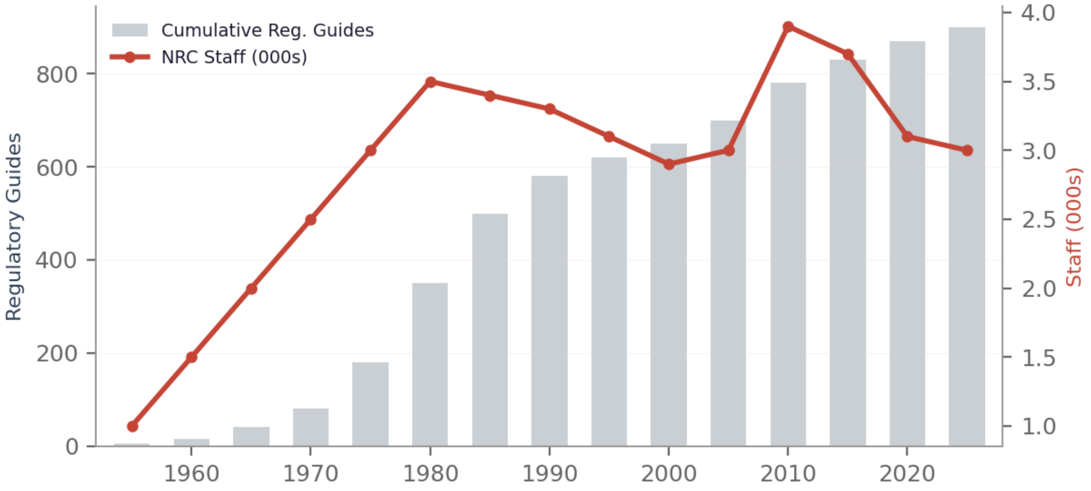


The EIA documented average build times growing from 7 years (1965-70 licenses) to 11 years (1973-77 licenses). Vogtle 3&4 took ~10 years. Time compounds costs through financing, inflation, and opportunity cost. South Korea maintained 5-year schedules through standardized designs and continuous programs. The correlation between schedule discipline and cost performance is near-perfect across countries.

Regulatory Ratcheting

BLUF: NRC regulatory guides grew from a handful in 1955 to 900+ by 2025. Rules only tighten; obsolete ones are never removed.

4 ▸ Regulatory Complexity: The Ratchet Effect

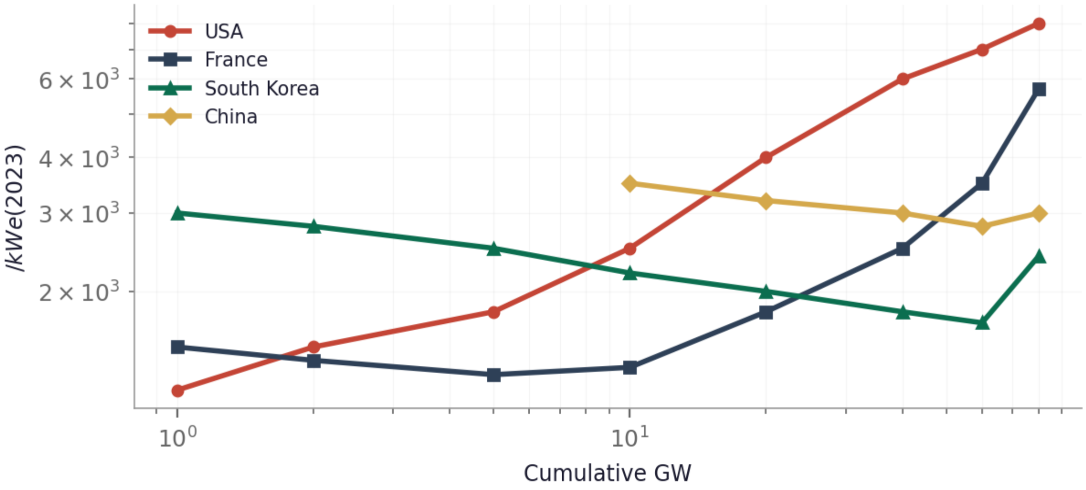


Between 1954 and 1978, the US authorized 133 reactors; since 1978, exactly two entered commercial operation. The shift from ad hoc to prescriptive regulation in the late 1970s transformed nuclear licensing from engineering into legal-administrative process. Executive Order 14300 (2025) represents the first serious attempt to reverse this ratchet, mandating NRC reform for a fourfold capacity expansion by 2050.

05 Comparative Industrialist

Cross-Country Divergence

BLUF: South Korea achieved sustained cost reductions through standardization. The US saw 5× escalation building unique reactors. Same technology, opposite outcomes.



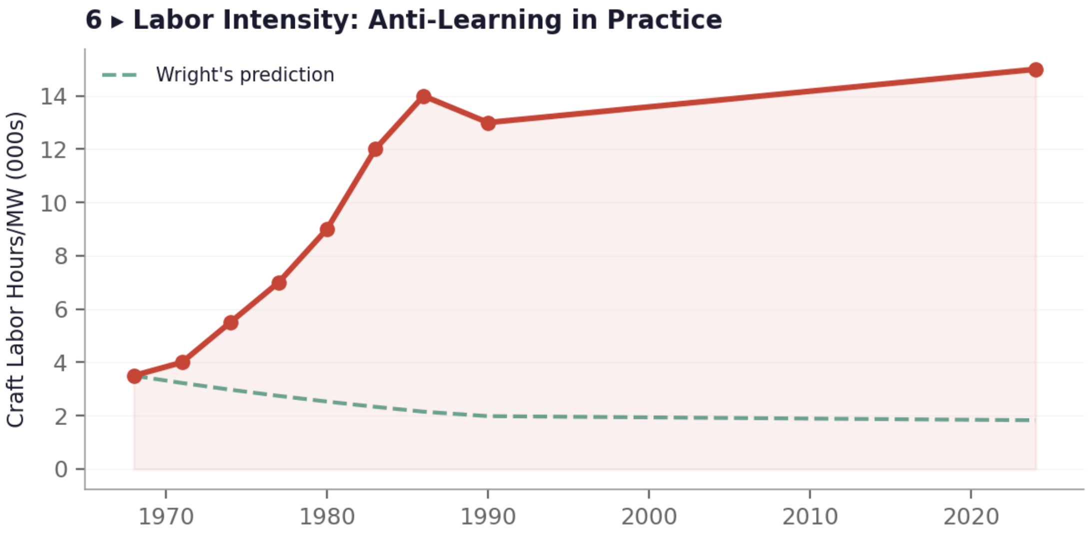
5 ▸ Log-Log Learning Curves by Country

The Breakthrough Institute's 2016 study of 349 reactors across seven countries found cost trends varied enormously. South Korea is the sole sustained decliner through identical OPR-1000 and APR-1400 builds. France's early standardized 900 MW series held costs flat, but the EPR shift produced massive escalation — Flamanville 3 at ~€23.7B. Wright's Law works when its preconditions are met. Most nuclear programs violated all three.

06 Workforce Analyst

Labor Productivity Collapse

BLUF: Craft labor hours per MW quadrupled from the 1960s to 1980s. Nuclear lost its workforce during two decades of zero construction and never rebuilt it.



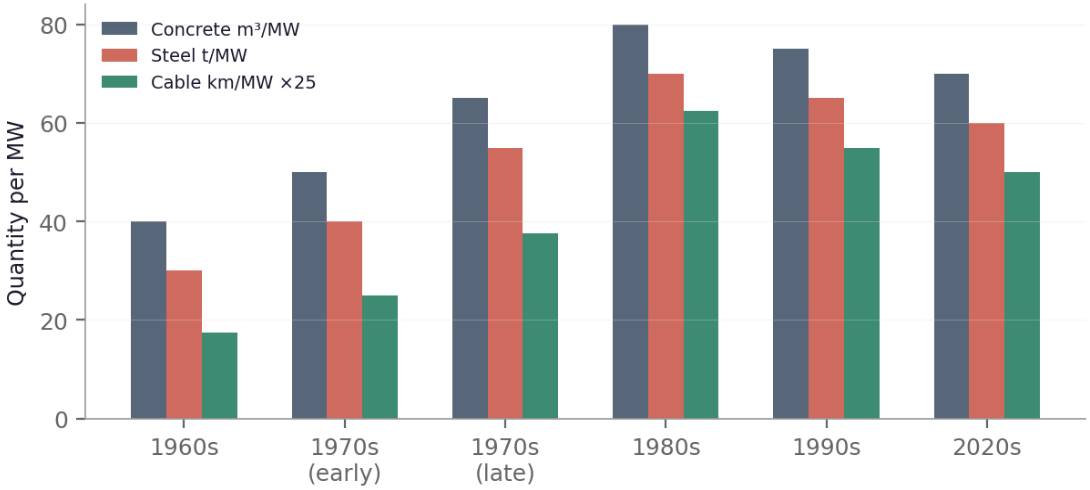
Wright's original insight came from watching aircraft workers get faster with repetition. Nuclear experienced the opposite. Vogtle 3&4 were the first US construction in 30 years — welders and pipefitters trained from scratch. The stop-start pattern ensures Wright's mechanism never activates: you cannot learn by doing if you stop doing for 30 years.

07 Nuclear Engineer

Material Complexity Growth

BLUF: Concrete, steel, and cabling per MW all increased substantially as safety systems were added. Modern reactors contain 2-3× the material of 1960s plants.

7 ▸ Material Intensity: More Stuff Per Megawatt

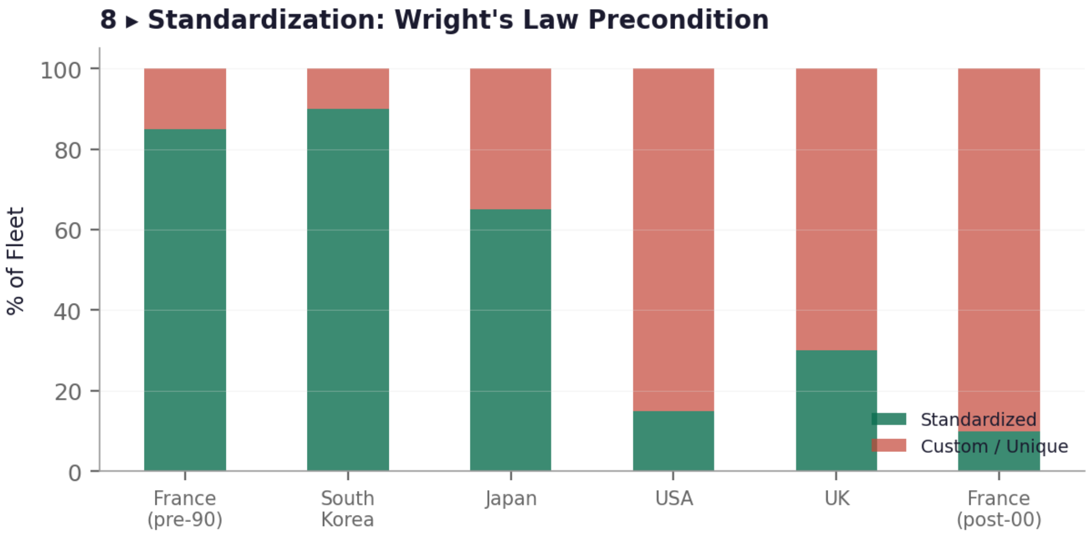


Each safety generation added redundant cooling, containment hardening, seismic reinforcement. Grubler identified the core paradox: increasing application led to increasing complexity, which reversed learning effects. The technology matured into greater complexity rather than greater simplicity — the inverse of normal Wright's Law dynamics.

08 Manufacturing Expert

Standardization Failure

BLUF: The US built 100+ reactors using 50+ distinct designs. ~85% were unique. Wright's Law requires identical units — nuclear rarely delivered them.

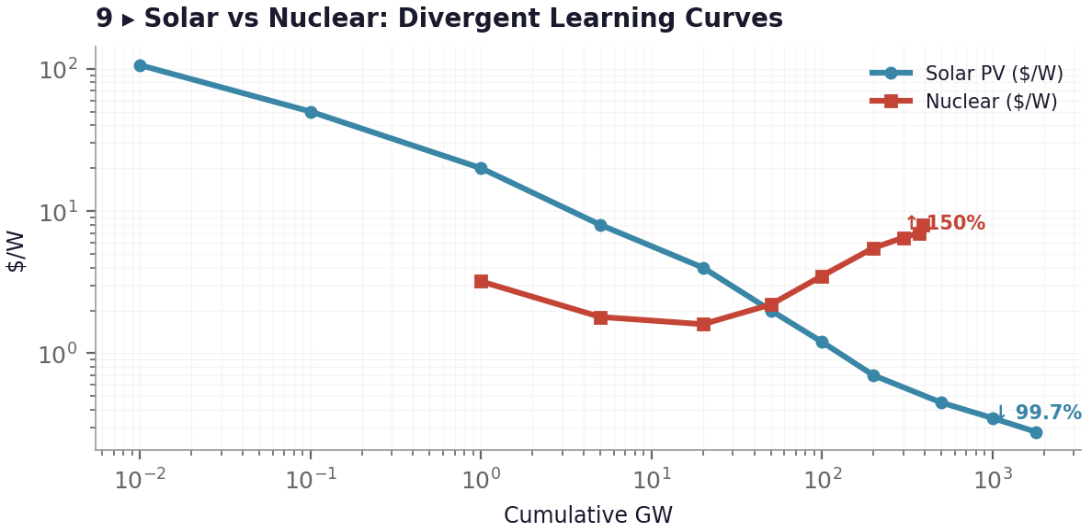


The US treated each reactor as bespoke construction. Compare South Korea (90% repeat designs) or early France (single standardized 900 MW series). When France shifted to EPR, it immediately encountered massive overruns — confirming that first-of-a-kind projects reset the learning clock to zero.

09 Investment Analyst

Solar-Nuclear Divergence

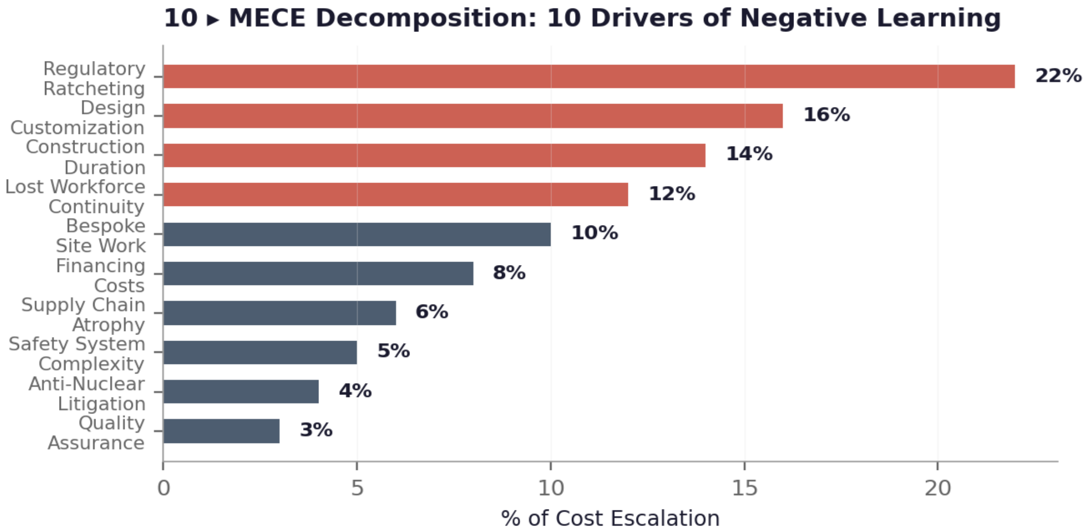
BLUF: Solar PV costs fell 99.7% over four decades. Nuclear costs rose 150%. This divergence permanently reshaped global energy capital flows.



Solar satisfies every Wright's Law precondition: mass factory production, high standardization, rapid iteration, minimal per-unit regulation. Nuclear violates every one. Capital flows to declining cost curves, creating self-reinforcing cycles that accelerate solar learning while nuclear atrophies.

MECE Decomposition

BLUF: Ten MECE factors explain negative learning. Regulatory ratcheting (22%), design customization (16%), and construction delays (14%) top the list.



Synthesizing the committee: regulatory ratcheting is the largest single factor. Design customization prevented repetition. Duration extensions multiplied financing costs. Workforce atrophy erased institutional learning. Reversing nuclear's cost trajectory requires addressing all ten simultaneously — which is why SMR advocates emphasize factory fabrication.

PART II

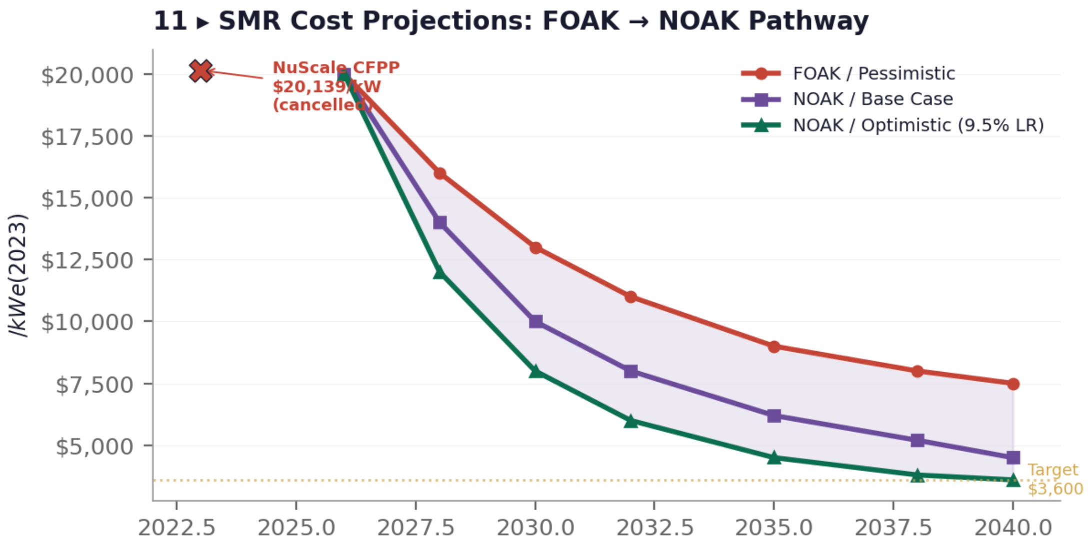
Future Projections: Can SMRs Activate Wright's Law? (2025–2040)

BLUF: SMRs represent the first credible structural attempt to satisfy Wright's Law preconditions for nuclear: factory fabrication, standardized designs, and shorter build times. But the evidence so far — NuScale's $20,139/kW FOAK cancellation, zero operational Western SMRs, and no factory in existence — suggests this is a 2035-2040 story at best. The learning rate assumption (9.5% vs historical –23%) is the entire bet.

11 SMR Cost Modeler

FOAK-to-NOAK Cost Pathway

BLUF: SMR FOAK costs are ~$15,000-20,000/kW — higher than large reactors. The NOAK target of $3,600/kW requires 10-20 deployments and a 9.5% learning rate, which has never been demonstrated for nuclear.

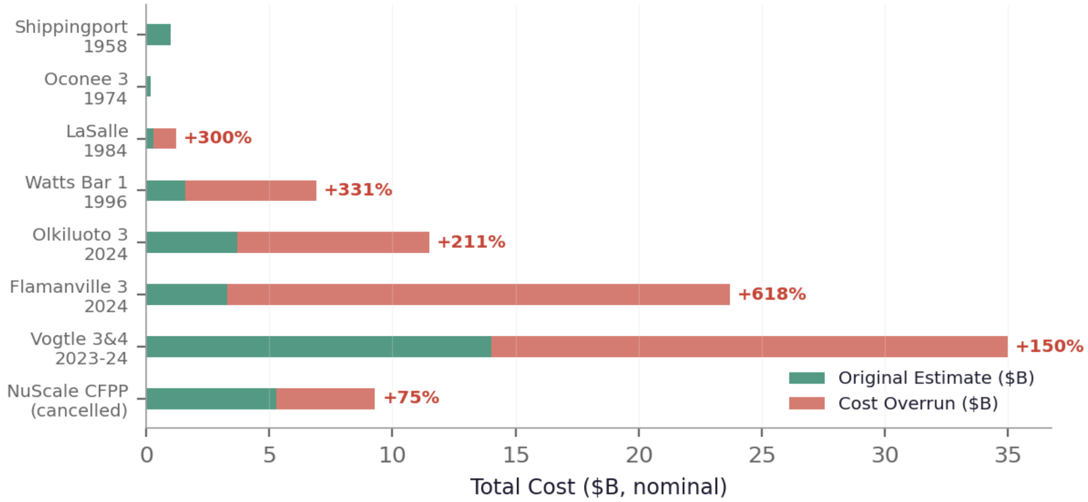


NREL's 2024 ATB recommends an 8% learning rate for large reactors and 9.5% for SMRs. NuScale's cancelled CFPP reached $20,139/kW — comparable to Vogtle on a per-kW basis, contradicting the 'SMRs will be cheaper' claim. The optimistic NOAK pathway requires serial factory production at a scale not yet attempted. Even with an aggressive 9.5% learning rate, reaching $3,600/kW requires building 100+ units. The base case suggests $5,000-7,000/kW by 2040 — competitive with large reactors but not with renewables.

12 Megaproject Risk Analyst

Cost Overrun Patterns

BLUF: Nuclear megaprojects have averaged 117% cost overruns historically. NuScale's CFPP escalated 75% before cancellation. FOAK SMRs face the same risk pattern at smaller absolute scale.



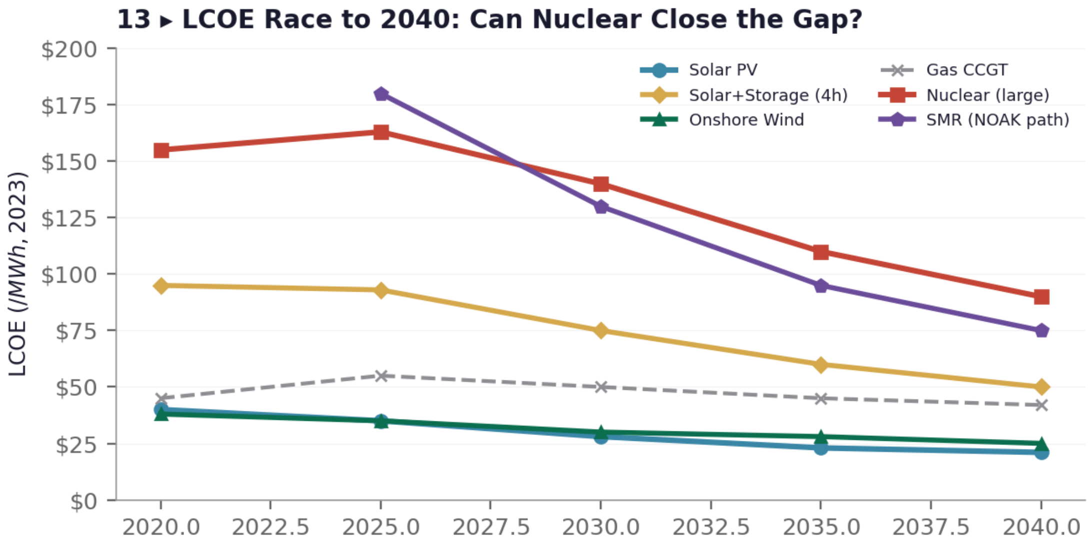
12 ▸ Nuclear Megaproject Cost Overruns: A Pattern

The pattern is consistent across decades and countries: Olkiluoto 3 went from €3.7B to €11.5B (+211%). Flamanville 3 from €3.3B to €23.7B (+618%). Vogtle 3&4 from $14B to $35B (+150%). NuScale CFPP from $5.3B to $9.3B (+75%) before cancellation. Smaller SMR scale reduces absolute overrun magnitude but not the percentage risk. Until serial production proves schedule discipline, investors must price in 50-100% contingency on any FOAK nuclear project.

13 Energy Systems Modeler

LCOE Multi-Technology Comparison

BLUF: By 2040, solar PV LCOE is projected at ~$21/MWh, solar+storage at ~$50/MWh, and SMR NOAK at ~$75-90/MWh. Nuclear must compete on dispatchability value, not levelized cost.

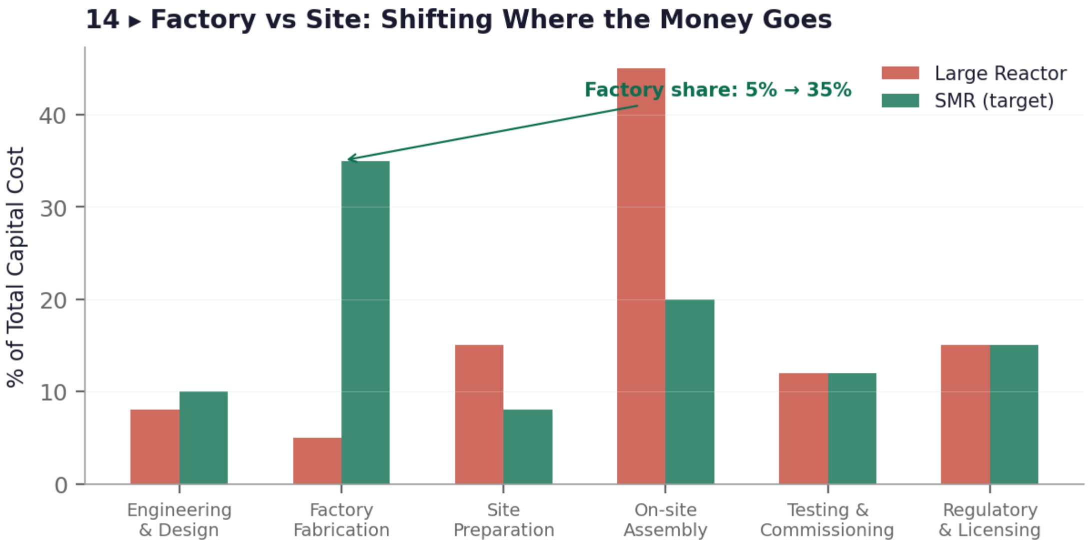


BloombergNEF projects solar LCOE declining to ~$25/MWh by 2035. Battery storage LCOE is falling ~11% annually. The gap between renewables and nuclear widens every year. SMRs' economic case rests not on LCOE parity but on dispatchability premium, industrial heat, and load-following capability. For grid applications, SMRs must demonstrate LCOE below $80/MWh to attract deployment — achievable only at NOAK scale with sustained build programs.

14 Manufacturing Strategy Expert

Factory Fabrication Shift

BLUF: SMRs promise to move 35% of capital cost into factory settings vs 5% for large reactors. This is the structural precondition for activating Wright's Law — but no factory exists yet.



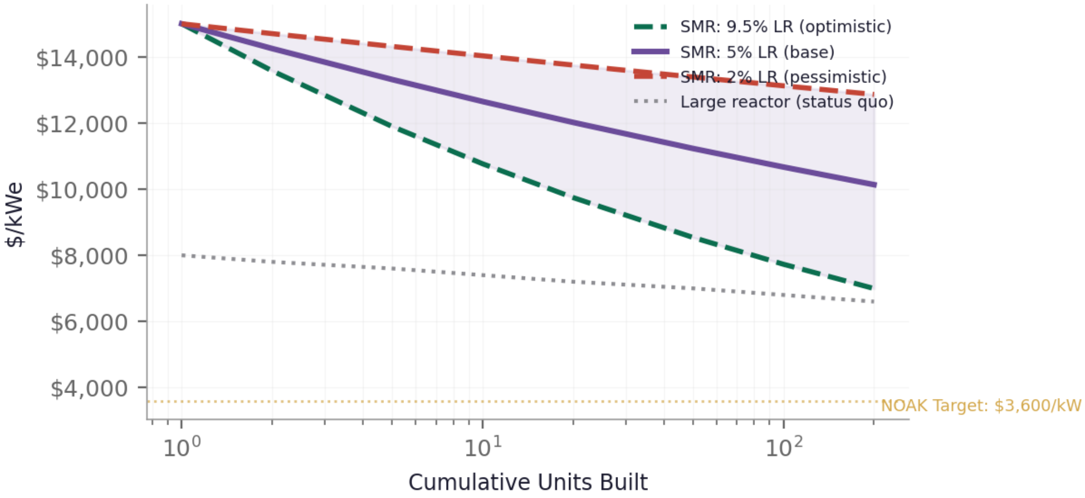
The core SMR proposition is shifting from bespoke site construction to factory fabrication. This moves work into controlled environments with standardized processes, quality control, and worker continuity — exactly the conditions under which Wright's Law operates. But this requires building SMR factories at $1-2B investment before demand is proven. The chicken-and-egg problem: factories need order books to justify investment, but orders need cost certainty that only factories can provide.

15 Economies of Scale Analyst

Learning Rate Sensitivity

BLUF: At 9.5% learning rate, SMRs reach cost parity after ~50 units. At 5%, it takes 200+. At 2% (nuclear's historical average), they never get there. The learning rate assumption is the entire bet.

15 ▸ Scale: How Many SMRs to Reach Cost Competitiveness?

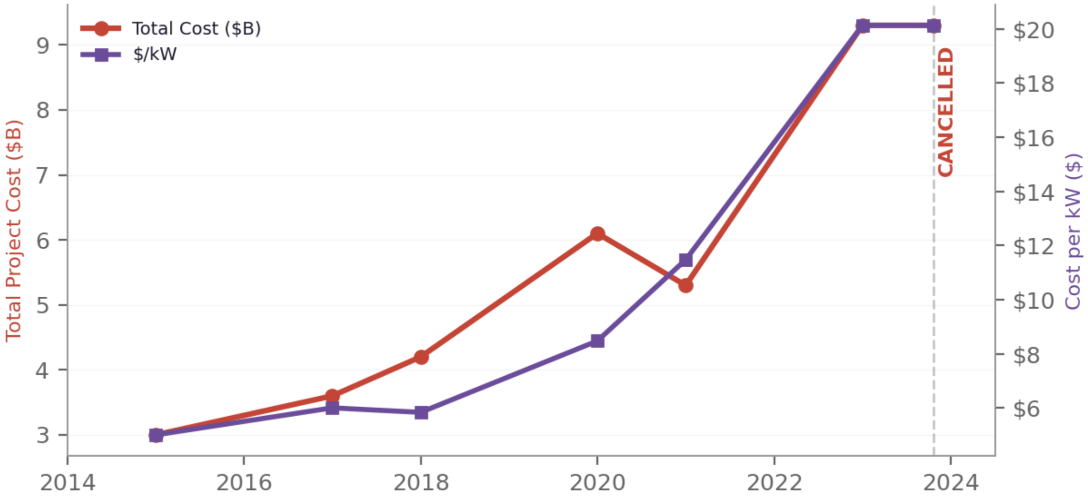


NREL recommends 9.5% for SMRs — roughly half the solar PV rate but far above nuclear's historical performance. Monte Carlo analysis shows SMR OCC with mean $5,233/kW and standard deviation $658/kW. The learning rate assumption drives all economic projections. If SMRs achieve even 5% learning (which would be unprecedented for nuclear), costs decline meaningfully. If they replicate the historical –23%, the technology fails commercially. The first 10-20 units will reveal which trajectory prevails.

NuScale CFPP Post-Mortem

BLUF: NuScale's CFPP cost spiral — from $3B/600MW in 2015 to $9.3B/462MW at cancellation — demonstrates that SMR economics remain unproven. FOAK risk was the primary killer.

16 ▸ NuScale CFPP: Anatomy of an SMR Cost Spiral

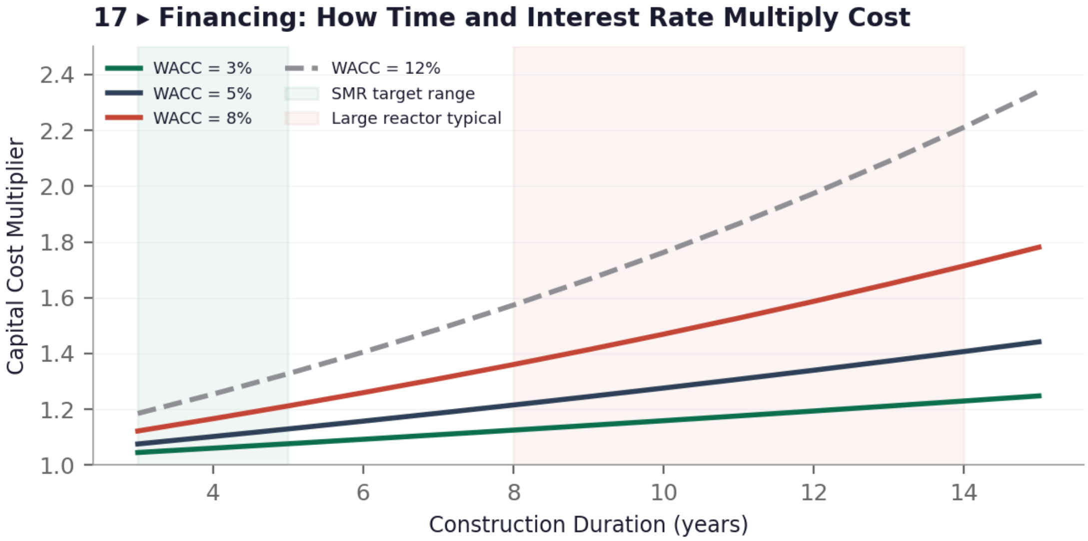


The CFPP's escalation had technology-specific and structural causes. The VOYGR design required a large reactor pool with fixed civil works costs regardless of module count — limiting true modularity. Reducing from 12 to 6 modules raised per-unit costs. UAMPS lacked nuclear experience and couldn't absorb cost risk. Only 116 MW of 462 MW capacity was subscribed at cancellation. The lesson: FOAK SMR projects need experienced nuclear utilities, not municipal cooperatives, as anchor customers. Romania's Nuclearelectrica and other experienced operators represent better deployment paths.

17 Project Finance Expert

Financing Cost Multiplier

BLUF: At 8% WACC and 10-year build, financing doubles the overnight cost. SMRs' 3-5 year target build time could cut this multiplier from 2× to 1.15× — worth more than any learning curve.

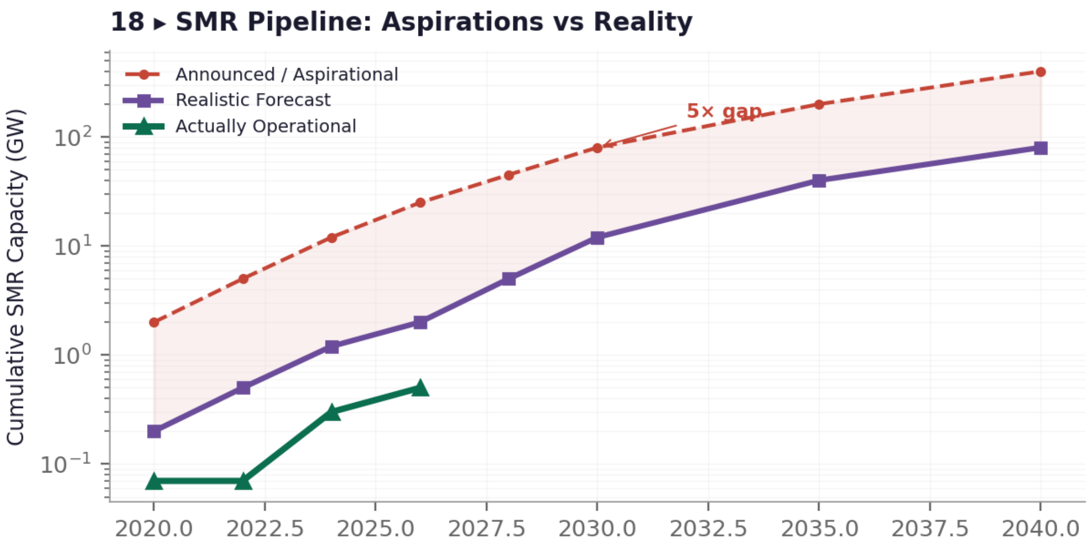


Nuclear's capital intensity means financing costs are the hidden multiplier. A $6,600/kW overnight cost becomes $13,721/kW with 15-year construction at 5% WACC. An SMR at $10,000/kW overnight becomes only $12,763/kW with 5-year build at the same rate. Shorter construction time alone can make SMRs cheaper than large reactors — even at higher overnight costs. This is the underappreciated advantage: speed reduces financial risk, which lowers cost of capital, which further reduces total cost. The virtuous cycle depends entirely on schedule discipline.

18 Deployment Pipeline Analyst

Aspirations vs Reality

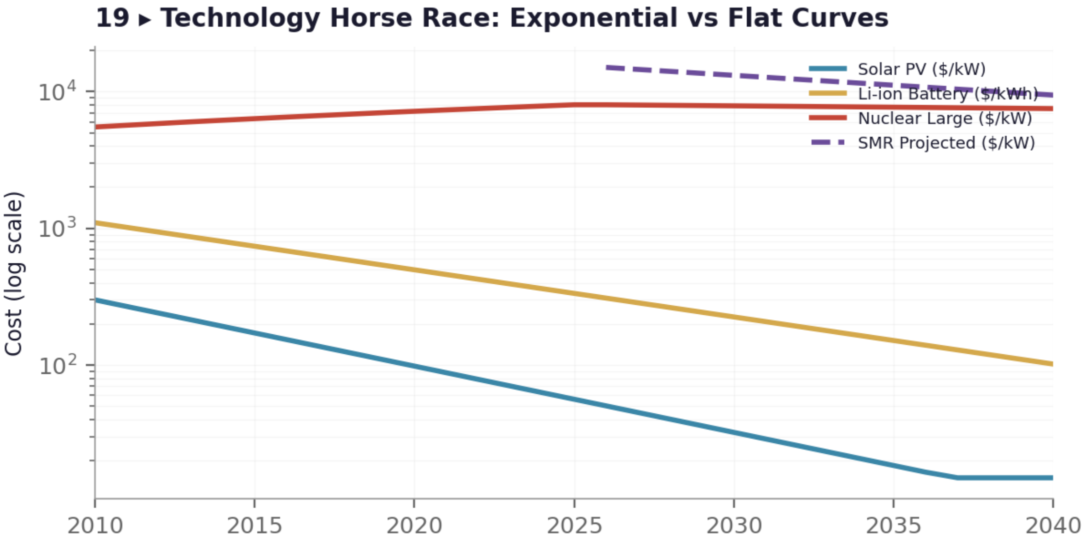
BLUF: Global SMR announcements total 400+ GW by 2040. Realistic deployment: ~80 GW. Only ~0.3 GW is operational today (China's HTR-PM, Russia's Akademik Lomonosov).


18 ▸ SMR Pipeline: Aspirations vs Reality

The gap between announcements and operational capacity is enormous. As of 2025, only China's 210 MW HTR-PM and Russia's 70 MW floating reactor are commercially operational. EY-Parthenon projects 400-700 SMR units (60-100 GW) by 2050 under accelerated scenarios. The IEA and others project first SMR demonstrators around 2030, with real acceleration in the 2040s when Gen IV designs emerge. The pipeline is aspirational; the constraint is not demand but the ability to actually build, license, and deliver units on time and on budget.

Exponential vs Flat Curves

BLUF: Solar and battery costs are falling exponentially. Nuclear costs are flat-to-rising. By 2040, the solar+storage LCOE advantage over nuclear may exceed 3×, making nuclear's value proposition purely about dispatchability.



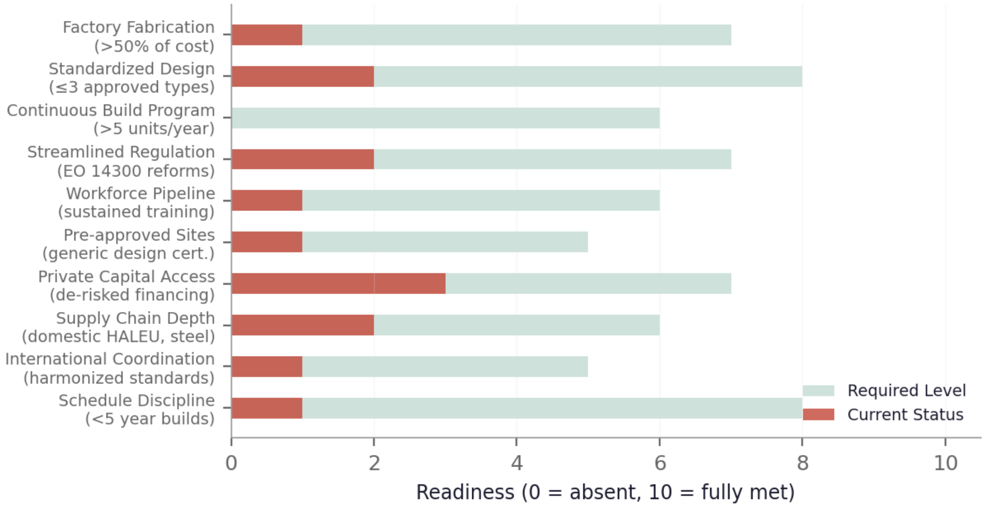
The technology competition is asymmetric. Solar PV follows a steep exponential decline; batteries are on a similar trajectory. Nuclear's cost curve is flat at best. By 2040, ground-mounted solar PV may reach $19-35/MWh (Fraunhofer ISE). Solar+storage at $50/MWh. SMR NOAK at best $75/MWh. Nuclear's remaining value proposition is firm dispatchable power, industrial process heat, and hydrogen production — applications where intermittent renewables cannot substitute. The honest case for nuclear is not cost competitiveness but complementarity.

20 Strategic Integration Analyst

Wright's Law Precondition Scorecard

BLUF: Of 10 preconditions required to activate Wright's Law for nuclear, current readiness averages 1.4 out of 10. No single condition is close to the required threshold. This is a decade-long institutional rebuild.

20 ▸ Scorecard: 10 Preconditions to Activate Wright's Law for Nuclear



The scorecard is sobering. Factory fabrication: no SMR factory exists (1/10). Standardized design: only NuScale has NRC certification (2/10). Continuous build program: zero SMRs under serial construction in the West (0/10). Streamlined regulation: EO 14300 issued but reforms pending (2/10). The gap between current status and required thresholds suggests Wright's Law activation for nuclear is a 2035-2040 event at earliest — contingent on sustained political will, capital commitment, and successful FOAK demonstrations. The first 10 units will determine whether nuclear can join the exponential age or remains permanently in the bespoke era.

Synthesis: The Wright's Law Verdict on Nuclear

	Large Reactor (historical)	SMR (projected)	Solar PV (actual)
Learning Rate	–23%	9.5% (target)	+20%
FOAK → NOAK	Costs rose	$15K → $3.6K/kW	N/A (all NOAK)
Build Time	7-15 years	3-5 years (target)	Months
Factory Share	5%	35% (target)	95%+
Standardization	50+ US designs	≤3 designs	Identical panels
Units for Learning	Built 400+, no learning	Need 50-200	Billions produced
2040 LCOE	$140-180/MWh	$75-90/MWh	$21/MWh
Key Risk	Regulatory ratchet	FOAK cost spiral	Intermittency
Value Proposition	Baseload (legacy)	Dispatchable + heat	Lowest cost kWh

The honest conclusion: nuclear's path to Wright's Law activation exists in theory but requires an institutional revolution — factory production, regulatory reform, continuous build programs, and sustained political commitment. The first 10-20 FOAK SMR units globally will reveal whether this is achievable or aspirational. Meanwhile, solar and storage continue their exponential descent, narrowing the window in which nuclear can establish its role. The smart bet is not nuclear-or-renewables but nuclear-and-renewables — with nuclear earning its place through dispatchability, industrial heat, and grid reliability rather than competing on levelized cost.

— CarbonSig Research, February 2026