

# Nuclear Energy in the Build Economy

*Prerequisites, Constraints, and the AI Imperative*

**DOE Targets:** 200 GW by 2050 | 35 GW by 2035 | 15 GW/Yr by 2040 [1]

## Fuel Constraints: LEU vs HALEU vs Fusion

Pathway	Players	Fuel Requirement	Near-Term Gating
LEU (<5% U-235)	NuScale (LWR SMR) [2]	Standard LEU supply chain	Licensing, components, EPC capacity
HALEU (5-19.75% U-235)	TerraPower [3], X-energy [4], Oklo* [5]	HALEU production ramp	<b>Fuel supply</b> + licensing + components
Fusion	Helion, CFS	No HALEU	Technical/timeline uncertainty

\*Oklo: HALEU required for initial deployments [5]; recycling strategy is long-term [5].

**Critical nuance:** Avoiding HALEU ≠ U.S.-only supply chain. LEU/HALEU enrichment, fabrication, and components can involve global suppliers. DOE prioritizes domestic [10], but it's a strategic choice, not a technical constraint.

**Valar Atomics:** Fuel enrichment **TBD**—treat as unverified until primary source confirmation.

## Market Segmentation

Market	Size	Timeline	Key Players	Pricing
Data Centers	35 GW by 2030 [6]	Near-term	Valar, Oklo, Helion, NuScale	Premium, long-term contracts
Hydrogen	50 GW eq by 2050 [6]	Medium-term	Valar (800-900°C advantage [12])	Premium (high-temp exclusive)
Industrial Heat	25 GW by 2050 [6]	Medium-term	Valar (800-900°C advantage [12])	Premium (high-temp exclusive)
Electricity	~90 GW by 2050 [6]	Long-term	All players (once HALEU available)	Competitive

## DOE Goal Reality Check

Target	Goal	Realistic	Gap	What's Required
2035	35 GW [1]	20-28 GW [7]	⚠ Challenging	LEU deployments + HALEU ramp + execution capacity
2040	15 GW/Yr [1]	8-12 GW/Yr [7]	⚠ Challenging	Repeatable delivery (modularization + AI) + fuel availability
2050	200 GW [1]	280-350 GW [7]	✅ Achievable	Portfolio approach at scale

## The 5x Productivity Math

U.S. labor cost disadvantage:

- U.S.: \$30/hr | China: \$6/hr [8] | **5x productivity required**

AI/automation is not optional—it's mathematically necessary for competitiveness.

Application	Impact	Stage
Construction automation (welding, inspection)	Labor reduction, quality consistency	Build
Predictive maintenance	Forced outage reduction, uptime	Operations
Fuel/plasma optimization	Efficiency, cost reduction	Operations
Safety systems	Risk reduction, compliance	All stages

**Fusion:** AI is foundational. Plasma control requires AI/ML—fusion cannot function without it.

## Heartbeat AI: Nuclear Value Chain Targets

Nuclear Consulting Services Market: \$461M Deloitte opportunity over next decade [9] | High-value stages: Development (licensing, construction), Operations (optimization, outage planning) [9]

Stage	Market Size	Deloitte Opportunity	Heartbeat AI Impact
Development (Next 10 Years)	\$6.22-9.33B professional services [9]	\$311-467M Deloitte capture [9]	Licensing acceleration, QA throughput, construction automation
Operations (Annual)	\$102-235M professional services [9]	\$5-12M/year Deloitte capture [9]	Operations optimization, outage planning, predictive maintenance

**Value proposition:** Heartbeat AI addresses technical bottlenecks (licensing delays, QA bottlenecks, operations inefficiency) that limit nuclear deployment speed and cost competitiveness. By enabling faster licensing, higher QA throughput, and optimized operations, Heartbeat AI directly supports Deloitte's ability to capture the \$461M consulting opportunity in nuclear development and operations [9].

**Deloitte ER&I alignment:** ER&I's 5 service categories (Design & Development, Financial Planning, Program Planning, Operations Planning, Workforce Transformation) target the \$6.22-9.33B professional services market. Heartbeat AI provides the AI/automation capability that enables delivery of these services at scale, addressing the 5x productivity requirement and technical prerequisites (licensing acceleration, QA throughput) that unlock nuclear deployment.

# DOE Strategy: Domestic Supply Chain Priority

## DOE Actions:

- Defense Production Act consortium (domestic nuclear fuel supply chain) [10]
- Nuclear Fuel Security Initiative [10]
- HALEU Availability Program [10]
- Explicit goal: Reduce reliance on foreign sources (especially Russia) [10]

**Impact:** While imports are technically possible, DOE strategy makes domestic production a strategic prerequisite.

## DOE-NE Programs

Program	Focus	Relevance
ARDP	Advanced Reactor Demonstration Program [10]	Near-term FOAK delivery amplifies schedule/QA bottlenecks
HALEU Availability	Fuel supply chain [10]	Gating for HALEU-dependent players
Licensing Support	Cost-shared grants [10]	Aligns with Heartbeat AI documentation/review compression
Workforce Training	\$100M program [10]	EPC/QA capacity dependency
GAIN	Gateway for Accelerated Innovation [10]	National lab access, partner ecosystem
Genesis Mission	AI + computing acceleration [10]	Validates AI as national acceleration layer (licensing, design, operations)

## Constraints Taxonomy

Constraint Type	Examples	Can Import?	DOE Priority
Hard Technical	NRC licensing, N-stamp certification, U.S. certifications	No (regulatory requirement)	Must meet
Fuel Gating	HALEU production	Yes (France), but DOE prioritizes domestic	Strategic priority
Strategic Supply Chain	Component manufacturing, fuel fabrication	Yes (with delays/certifications)	Strategic priority

**Insight:** Not all gaps are equal. Hard constraints must be met; fuel/component gaps are strategic priorities that DOE is actively addressing.

## Player Optimization Matrix

Player	Fuel Exposure	Regulatory	Market Fit	2050 Projection	Deloitte Engagement
NuScale	LEU (low) [2]	NRC certified	Electricity	40-50 GW [11]	ER&I client [13]
TerraPower	HALEU [3]	Grid focus	Electricity/coal replacement	40-55 GW [11]	ER&I client [13]
X-energy	HALEU/TRISO [4]	TRISO supply chain	Electricity	Not quantified	ER&I client [13]
Oklo	HALEU (near-term) [5]	Public company	Data centers/remote	35-45 GW [11]	ER&I client [13]
Valar	TBD	Early stage	Hydrogen/industrial/data centers	50-70 GW [11]	Opportunity
Helion	None (fusion)	High uncertainty	Data centers	35-50 GW [11]	Opportunity
CFS	None (fusion)	High uncertainty	Electricity	40-60 GW [11]	Opportunity

**Total realistic 2050: 280-350 GW** [7] (exceeds 200 GW target [1])

**Deloitte engagement context:** ER&I has existing client relationships with NuScale, TerraPower, X-energy, and Oklo [13]. These relationships provide foundation for Heartbeat AI delivery and expansion of ER&I service offerings. Valar, Helion, and CFS represent new opportunities where Deloitte can establish early positioning.

**Insight:** Fuel supply constraints differentiate timelines, but "fuel independence" must be defined precisely (LEU vs HALEU vs fusion). It does not replace other gating items (regulatory, components, EPC capacity, execution). Existing Deloitte relationships with HALEU-dependent players (TerraPower, X-energy, Oklo) position us to support their deployment once fuel is available, while new opportunities (Valar, Helion) represent early-mover advantage in fuel-independent pathways.

## Strategic Recommendations

Player	Realistic 2050	Key Markets
Valar	50-70 GW	Hydrogen/high-temp, Industrial/high-temp, Data centers
Oklo	35-45 GW	Data centers, Remote/Military, Electricity
TerraPower	40-55 GW	Electricity, Coal replacement
NuScale	40-50 GW	Electricity
Helion	35-50 GW	Data centers, Electricity
CFS	40-60 GW	Electricity
Others	30-50 GW	Various

**Total: 280-350 GW** (exceeds 200 GW target)

**Insight:** Portfolio approach required. No single player can achieve 200 GW alone; early progress depends on **least-constrained near-term pathways** plus **ramping enabling supply chains** (fuel, components, construction).

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## 9. Strategic Recommendations

### For 2035 target:

- Support LEU-based LWR pathways (NuScale) to reduce HALEU exposure
- Treat Valar "no-HALEU" as hypothesis until validated
- Treat Oklo as HALEU-dependent near-term
- Support fusion pilots selectively (high uncertainty)

### For 2040-2050:

- Portfolio approach (all players)
- Address HALEU bottleneck for advanced designs
- Enable fuel recycling (Oklo model)
- Accelerate fusion (multiple approaches)

### For Deloitte/SFL:

- **Leverage existing ER&I relationships** (NuScale, TerraPower, X-energy, Oklo [13]) to expand Heartbeat AI services
- **Pursue new opportunities** (Valar, Helion, CFS) for early positioning in fuel-independent pathways
- Address domestic supply chain (DOE alignment)
- **Heartbeat AI services** (enables \$461M consulting opportunity [9])
- Data center market (high-value, early)

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## Bottom Line

**Fuel constraints are real but not the only gating item.** HALEU availability is a major schedule driver for many advanced reactors, but LEU-based LWR SMRs avoid this bottleneck (while still requiring licensing, components, EPC capacity).

**Portfolio approach achieves 200 GW.** No single player can do it alone. Early progress comes from least fuel-gated pathways plus improved execution capacity. HALEU-dependent designs contribute once fuel is available.

**AI/automation is not optional.** 5x productivity required to offset labor costs. Mathematically necessary for competitiveness. Foundational for fusion (plasma control).

**DOE goals are challenging but achievable.** 2035/2040 targets are challenging (20-28 GW, 8-12 GW/Yr realistic). 2050 target is achievable (280-350 GW realistic).

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### Sources:

[1] DOE Strategic Targets: U.S. Department of Energy, "Pathways to Commercial Liftoff: Advanced Nuclear," April 2024; DOE Office of Nuclear Energy strategic planning documents (200 GW by 2050, 35 GW by 2035, 15 GW/Yr by 2040).

[2] NuScale LEU: NuScale Power, "NuScale Fuel Design," technical specifications and NRC Design Certification Application; NuScale public materials confirming LEU (<5% U-235) fuel requirements.

[3] TerraPower HALEU: TerraPower, "Natrium Reactor Technology," company materials; DOE ARDP award documentation; public statements on HALEU dependency and fuel supply chain requirements.

[4] X-energy HALEU/TRISO: X-energy, "Xe-100 Advanced Nuclear Reactor," technical specifications; DOE ARDP documentation; public materials on TRISO fuel and HALEU requirements.

[5] Oklo HALEU: Oklo Inc., SEC filings and public investor materials; DOE reporting on Aurora reactor fuel requirements; Oklo public statements on HALEU for initial deployments and long-term recycling strategy.

[6] Market Sizing: ER&I Infrastructure Nuclear Jumpstart Kit analysis; industry market research on data center power demand (35 GW by 2030), hydrogen production capacity (50 GW eq by 2050), industrial process heat (25 GW by 2050), and electricity generation market (~90 GW by 2050).

[7] Realistic Projections: Deloitte analysis based on fuel availability timelines, construction capacity constraints, and historical deployment rates. 2035: 20-28 GW realistic; 2040: 8-12 GW/Yr realistic; 2050: 280-350 GW achievable with portfolio approach.

- [8] Labor Cost Comparison: U.S. Bureau of Labor Statistics (BLS) manufacturing wage data; international labor cost comparisons (China manufacturing wages); industry analysis of nuclear construction labor costs (\$30/hr U.S. vs. \$6/hr China equivalent).
- [9] Nuclear Consulting Services Market & Heartbeat AI Value Chain: ER&I Infrastructure Nuclear Jumpstart Kit, "Nuclear Consulting Services Market Sizing" slide. Market sizing based on Argonne and Idaho National Labs research: Development market (next 10 years) = \$6.22-9.33B professional services (2-3% of \$311B capital costs for 35GW new nuclear), Deloitte capture = \$311-467M (5% of professional services market); Operations market (annual) = \$102-235M professional services (2-3% of capital costs), Deloitte capture = \$5-12M/year. Total Deloitte opportunity = \$461M over next decade. Assumptions: 3.5GW/year deployment until 2035, utility-scale nuclear including SMRs, excludes pre-deployment startups. Heartbeat AI targets high-value stages (Development: licensing acceleration, QA throughput; Operations: optimization, outage planning) that enable Deloitte service delivery and market capture.
- [10] DOE-NE Programs: U.S. Department of Energy, Office of Nuclear Energy, "Advanced Reactor Demonstration Program (ARDP)"; "HALEU Availability Program"; "Nuclear Safety Training and Workforce Development" (\$100M program); "Gateway for Accelerated Innovation in Nuclear (GAIN)"; DOE "Genesis Mission" (November 2025) AI + computing acceleration initiative; Defense Production Act consortium on domestic nuclear fuel supply chain; Nuclear Fuel Security Initiative.
- [11] Player 2050 Projections: Deloitte analysis based on company deployment timelines, market positioning, and fuel supply constraints. Projections reflect realistic scaling scenarios: Valar (50-70 GW), Oklo (35-45 GW), TerraPower (40-55 GW), NuScale (40-50 GW), Helion (35-50 GW), CFS (40-60 GW).
- [12] High-Temperature Advantage: Industry technical specifications for high-temperature electrolysis efficiency (800-900°C enables 2-3x efficiency gains); HTGR (High-Temperature Gas Reactor) technology specifications; Valar Atomics public materials on temperature capabilities.
- [13] Deloitte ER&I Client Relationships: ER&I Infrastructure Nuclear Jumpstart Kit, client engagement list. Deloitte has existing client relationships with NuScale, TerraPower, X-energy, and Oklo, providing foundation for service expansion and Heartbeat AI delivery. These relationships position Deloitte to support HALEU-dependent players once fuel is available, while new opportunities (Valar, Helion, CFS) represent early-mover advantage in fuel-independent pathways.

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