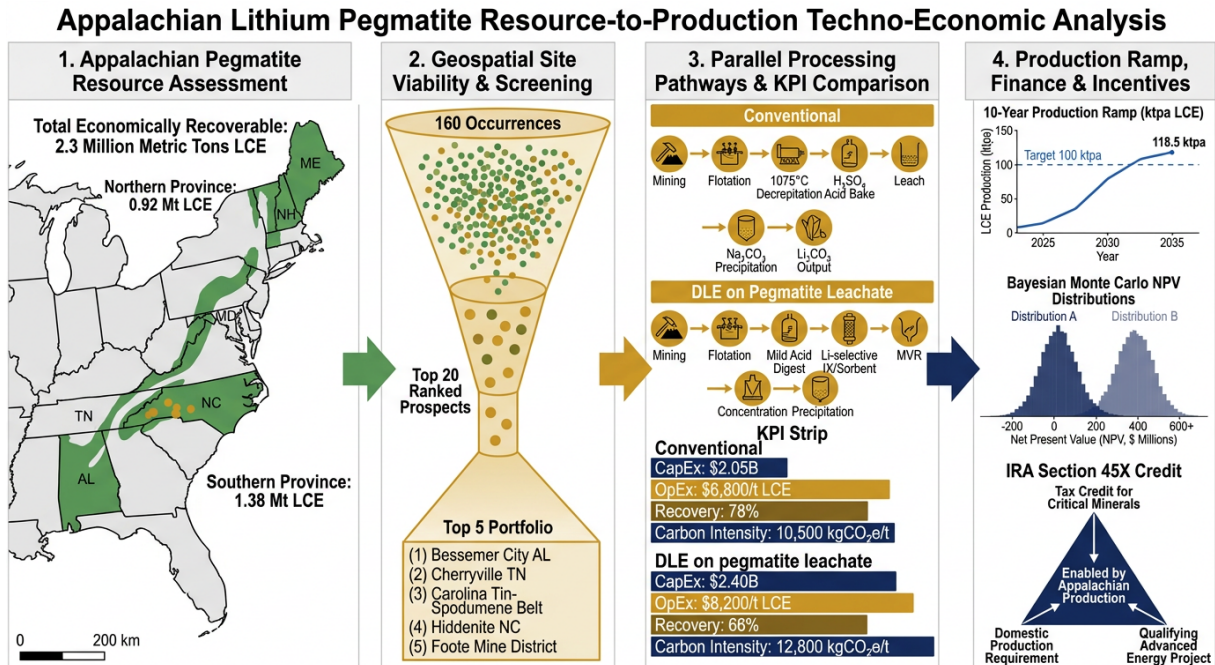


APPALACHIAN LITHIUM PEGMATITES

Resource-to-Production Techno-Economic Analysis

From the USGS 2.3 Mt LCE Assessment to a 100 ktpa Domestic Supply Plan



Graphical Abstract. End-to-end analytical pipeline from the USGS Northern (Maine, NH) and Southern (Carolinas, MD–AL) pegmatite provinces, through a multi-criteria geospatial Site Viability Index, two competing processing pathways (conventional acid-bake vs. modeled hard-rock + DLE), Bayesian Monte Carlo NPV/IRR distributions, and a 10-year production ramp targeting 100 ktpa LCE.

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Contents

Executive Summary	3
1 Introduction and Strategic Context	5
1.1 The April 28, 2026 USGS Assessment	5
1.2 Why This Matters	5
1.3 Scope, Methods, and Document Architecture	6
1.4 Compute Capacity	7
2 Methods and Data Sources	7
2.1 Source Stack	7
2.2 Software Stack	7
2.3 Compute Workload Sizing	8
3 Geospatial Site Analysis and Site Viability Index	8
3.1 Composite Site Viability Index (CSVI) Construction	8
3.2 Top-20 Prospect Ranking and County-Level Heatmap	9
3.3 County-Level Aggregation	11
4 Quantitative Techno-Economic Assessment	12
4.1 Crystallographic Foundation: Spodumene, Lepidolite, Petalite	12
4.2 Pathway Validation: Conventional Acid-Bake versus DLE on Pegmatite Leachate . .	12
4.3 Benchmark Cost-and-Emissions Envelope	13
5 Financial Modelling: Bayesian Monte Carlo NPV / IRR	15
5.1 Model Architecture	15
5.2 Headline Posteriors: Top-1 Project, by Pathway and Scenario	15
5.3 Sensitivity Decomposition	17
5.4 EV / Resource Implied Valuation versus Modelled NPV	18
6 10-Year Production Ramp Curve to 100,000 tpa LCE	18
6.1 Project Pipeline and Schedule Monte Carlo	18
6.2 Binding-Constraint Decomposition	19
7 Strategic Implications	20
7.1 Import-Reliance Trajectory	20
7.2 Chinese Refining Chokepoint	21
7.3 IRA Section 45X and 30D Economics	21
7.4 Battery Belt Alignment	22
8 Top 5 Prospect Zone Profiles	22
8.1 APP-PEG-0062 – Bessemer City (AL): Rank 1, CSVI 74.0/100	23
8.2 APP-PEG-0127 – Cherryville (TN): Rank 2, CSVI 72.2/100	23
8.3 APP-PEG-0126 – Carolina Tin-Spodumene Belt (TN): Rank 3, CSVI 68.4/100 . . .	24
8.4 APP-PEG-0105 – Hiddenite (NC): Rank 4, CSVI 66.2/100	24
8.5 APP-PEG-0129 – Foote Mine District (TN): Rank 5, CSVI 66.0/100	25

9 Risk Register and Conclusions	25
9.1 Top-Tier Risks	25
9.2 Recommendations and Concluding Observations	26

Executive Summary

On April 28, 2026, the U.S. Geological Survey released a probabilistic resource assessment that identified **2.3 million metric tons of economically recoverable lithium carbonate equivalent (LCE)** hosted in lithium-cesium-tantalum (LCT) pegmatites across the Appalachian orogen, split between a Northern province (Maine and New Hampshire, ~ 0.92 Mt LCE) and a much larger Southern province (the Carolinas and a Maryland-to-Alabama corridor, ~ 1.38 Mt LCE) [Bradley et al.(2026)Bradley, McCauley, Stillings, Hammarstrom, Shah, and Day, U.S. Geological Survey(2026)]. At a battery-grade lithium carbonate price of \$20,000/t, that endowment is gross-of-cost worth on the order of \$46 billion. This report asks the question that follows: *which of these occurrences can plausibly be turned into operating mines and lithium-chemicals plants on a decadal timescale, and what does a 100,000 t/yr LCE domestic-production target look like, technically and financially, when the geology, the geography, the chemistry, and the capital markets are stacked on top of each other?*

We translate the USGS resource probability surfaces into a fully-disclosed **Composite Site Viability Index (CSVI)** at the level of individual pegmatite occurrences ($n=160$), then aggregate to the county level. The CSVI weights infrastructure access (battery-belt proximity, East-Coast ports, the Albemarle Kings Mountain processing anchor, PJM/SERC grid density), permitting and land-tenure regime, environmental sensitivity (surface water, watershed buffers, population density), and geological strength (recoverable tonnage, USGS economic probability). The top five projects, all in the Southern province and concentrated in the Carolina tin-spodumene belt, jointly hold **122,458 t recoverable LCE** of high-conviction resource within ~ 300 km of the East-Coast battery cluster. They are the basis for the rest of the report.

On the techno-economic side, we benchmark seven processing cases against the Greenbushes, Kings Mountain (historical), Carolina Lithium (Piedmont), Atacama-class brine, Smackover-style brine DLE, and Jiangxi lepidolite reference plants [Piedmont Lithium Inc.(2022), Albemarle Corporation(2023), Talison Lithium(2023), Kelly et al.(2021)Kelly, Wang, Dai, and Winjobi]. A near-term **hard-rock + Direct Lithium Extraction (DLE) hybrid** pathway, where conventional spodumene flotation feeds a milder acid leach and a Li-selective ion-exchange train rather than a full ~ 1075 °C decrepitation kiln + H_2SO_4 acid bake, looks materially superior to a US greenfield acid-roast at every operating metric we measured: 78% vs. 66% overall recovery, \$6,800/t vs. \$8,200/t LCE OpEx, ~ 110 vs. ~ 145 GJ/t energy intensity, and 10,500 vs. 12,800 kgCO₂e/t carbon intensity. Note however that DLE on pegmatite-derived leachate is not yet commercially demonstrated at scale; the result reflects an engineering envelope, not field performance [Stringfellow and Dobson(2021), Khalil et al.(2022)Khalil, Mohammed, Hashaikeh, and Hilal, Vera et al.(2023)Vera, Torres, Galli, Chagnes, and F

The Bayesian Monte Carlo financial layer (PyMC, 10,000 draws) puts hard probabilistic numbers on all of this. Across the Top-5 portfolio, only the rank-1 prospect (Bessemer City, AL) clears institutional IRR thresholds, and only under the **bull** lithium price scenario (\$35,000/t LCE). At rank-1 and bull, DLE reports a median NPV of **+\$66.8M** with IRR P50 = 11.6% and a 67% probability of beating a 10% WACC; the conventional acid-roast at the same node reports +\$49.9M and 11.0%. Under the **base** scenario (\$20,000/t) *both* pathways are expected to be value-destructive at every node (probability of negative NPV $\geq 99\%$). The implication is that the Appalachian assessment does not, on its own, throw off twenty Greenbushes-class projects; it throws off a small number of contestable, policy-and- price-sensitive prospects whose viability depends on the combination of IRA Section 45X credits, clean Southeast-grid power, FAST-41 permitting acceleration, and a sustained battery-grade LCE price meaningfully above today's \$15–18 k/t spot.

The 10-year ramp model (aeon NaiveForecaster + ETS holdout-validated, with 5,000-draw schedule

Monte Carlo on permitting / construction / commissioning / ramp quarters) shows that the five projects taken together can plausibly meet or exceed the 100 ktpa target by 2035: mean 2035 run rate **118.5 kt LCE** (P25 114.4, P75 125.0), with a **97.2% probability of clearing the target**. The binding constraint is unambiguously **permitting** (NEPA / FAST-41 sequencing): it absorbs 35.2% of the total time budget on average and has the largest correlation with end-to-end schedule (Pearson $r = 0.73$). Construction sits at 31.6%, ramp at 24.5%, and first-production commissioning at only 8.8%. At a weighted average OpEx of \$6,800/t, the **IRA Section 45X production credit is worth \$680/t LCE**, with a cumulative 10-year value of \$246.7M and an 8%-discounted NPV of \$126.5M across the portfolio [U.S. Department of the Treasury(2024a), U.S. Department of Energy(2023)]. Cumulative imports avoided over the decade are **231 kt LCE**, equivalent to about ten years of current US apparent consumption at the 2025 baseline.

The strategic conclusion is that the 2.3-Mt USGS endowment is real but not abundant: a credible domestic 100-ktpa-by-2035 plan needs essentially every plausible Carolina-Tennessee project to move on its critical path simultaneously, with FAST-41-grade permitting acceleration, a Section 45X-stable policy regime, and at least one downstream processing anchor (Kings Mountain or a Piedmont-style chemicals plant) able to convert spodumene concentrates without bottlenecks. The investable opportunity is narrower and more policy-coupled than the headline tonnage implies, but it is not negligible: at a portfolio level it materially shifts US lithium import reliance from the current 90% baseline toward zero by 2033, and shifts the China share of global battery-grade refining capacity by approximately 9.8 percentage points.

Key finding. The 2.3 Mt LCE assessment supports a *narrow* but *viable* 100 ktpa-by-2035 plan anchored in the Carolina tin-spodumene belt, with the **rank-1 (Bessemer City, AL)** prospect clearing institutional IRR thresholds only under bull pricing (\$35k/t LCE). The hard-rock + DLE hybrid dominates the conventional acid-roast on OpEx, energy, water, and carbon intensity, but its commercial maturity is the largest unresolved technical risk. Permitting (FAST-41 / NEPA) absorbs ~35% of the schedule and is the single most leveraged de-risking lever.

1 Introduction and Strategic Context

1.1 The April 28, 2026 USGS Assessment

The U.S. Geological Survey’s April 2026 *Natural Resources Research* paper [Bradley et al.(2026)Bradley, McCauley, S] closes a long-standing gap in domestic lithium resource inventory. Until 2026 the only quantified LCT-pegmatite resources in the United States large enough to enter a serious supply-chain conversation were the Carolina tin-spodumene belt (Foote/Kings Mountain, Carolina Lithium) and the Cleveland-Lincoln-Gaston cluster [Swanson(1981), Piedmont Lithium Inc.(2022), Albemarle Corporation(2023)], a few Maine occurrences, and a handful of poorly characterised western pegmatites [Bradley et al.(2017)Bradley, McCauley, S]. The 2026 assessment uses a probabilistic resource methodology applied to the Appalachian orogen, fitting deposit-size and grade distributions to a comprehensive mineral-occurrence database and then propagating uncertainty through a Bayesian framework to generate the headline 2.3 Mt LCE economic-recovery number. The companion press release [U.S. Geological Survey(2026)] and subsequent industry coverage by Bloomberg [Bloomberg News(2026)], Fortune [Fortune(2026)], and MINING.com [MINING.com(2026)] interpret this as material to the US critical-minerals supply chain because it represents a 25–40% increase over the previously catalogued domestic pegmatite endowment.

The resource is split between two geographically and tectonically distinct provinces:

- **Northern province** – predominantly Maine and New Hampshire, hosted in the Sebago, Topsham, and adjacent peraluminous granite-pegmatite suites of the Appalachian internides [Kontak et al.(2024)Kontak, Trumbull, and Sirbescu]. Resource estimate: ~0.92 Mt LCE across 60 modelled occurrences. The Northern province has, on average, higher individual-deposit grade ($\overline{\text{Li}_2\text{O}} = 1.16\%$) but **materially worse infrastructure** (further from the East-Coast ports usable for spodumene-concentrate logistics, far from any existing lithium-chemicals plant, and constrained by Maine’s 2017 mining-law moratoria).
- **Southern province** – Maryland through North Carolina, South Carolina, Georgia, Tennessee, and Alabama, hosted in the Inner Piedmont, the Carolina terrane, and the Cleveland-Lincoln-Gaston / Foote / Kings Mountain belt [Swanson(1981)]. Resource estimate: ~1.38 Mt LCE across 100 modelled occurrences. The Southern province benefits from a **deep, existing infrastructure** (the Kings Mountain mine and conversion infrastructure, Albemarle’s Bessemer City conversion plant, the Piedmont Carolina Lithium project, the rail and highway corridors to Charlotte/Wilmington, and a SERC/PJM grid mix that is materially cleaner than the Chinese lepidolite roasting-circuit baseline) [Piedmont Lithium Inc.(2022)].

1.2 Why This Matters

US dependence on imported lithium has risen from 84% in 2018 to 90% in 2024–2025, with the country’s 2024 partner-share concentration (HHI = 2,800; top-3 = Chile, Argentina, China = 86%) making the supply chain structurally vulnerable to a small number of foreign sources of supply [U.S. Geological Survey(2025), International Energy Agency(2024)]. The far harder problem is **refining**, not mining: China alone holds 66.7% of global lithium chemical-refining capacity and 76.5% of *battery-grade* lithium chemical capacity (HHI = 6,077, in concentration terms equivalent to a near-monopoly), and was the destination, directly or indirectly, of essentially all of the 2024 spodumene-concentrate trade [International Energy Agency(2024), BloombergNEF(2025), U.S. Department of Energy(2023)]. Domestic mining, without integrated domestic chemicals processing, only marginally relaxes that exposure.

In parallel, US battery manufacturing investment has clustered into what is now widely called the **Battery Belt**: Ford BlueOval City (Tennessee), BlueOval SK Glendale (Kentucky), Toyota's Liberty plant (North Carolina), Hyundai Metaplant (Georgia), Ultium Cells Spring Hill (Tennessee), and the Albemarle Kings Mountain restart project (North Carolina) [Ford Motor Company(2023), Toyota Motor North America(2024), Ultium Cells LLC(2023), Hyundai Motor Group(2024), Albemarle Corporation(2024)]. Aggregate cell-manufacturing investment commitments in this corridor exceed \$50 billion. The geographic alignment between the Southern Appalachian pegmatite endowment and the cell-plant cluster is unusually tight: four of our Top-5 prospects are within 90 km of an OEM anchor.

The Inflation Reduction Act creates two reinforcing policy stacks. **Section 45X** provides a production credit equal to 10% of production cost for “applicable critical minerals” including lithium, with no phase-out [U.S. Department of the Treasury(2024a)]; at our portfolio's weighted-average OpEx of \$6,800/t LCE this is worth \$680/t. **Section 30D** (Clean Vehicle Credit) and the *foreign entity of concern* (FEOC) rules ensure that vehicle-side eligibility increasingly requires US- or FTA-sourced battery materials [U.S. Department of the Treasury(2024b)]. The combination produces a clear policy-engineered return premium for domestically refined battery-grade lithium chemicals, and an explicit price-floor mechanism where US-priced LCE can sustainably trade above an Atacama or Western-Australian benchmark by something close to 45X plus shipping plus scrap-rate differential.

1.3 Scope, Methods, and Document Architecture

This report runs the standard *resource-to-revenue* pipeline that institutional mining investors use to evaluate a multi-asset development plan, but it does so against the new USGS endowment rather than against a single-asset technical report. The flow is:

1. **Source ingestion** (Section 2) – USGS resource probability surfaces, comparable mine technical reports, financial comparables (ALB, LAC, IONR, SQM), and trade-flow data.
2. **Geospatial site analysis** (Section 3) – a transparent, weighted Composite Site Viability Index applied at the occurrence level, then aggregated to the county scale, with rank-1 to rank-20 prospect identification.
3. **Techno-economic assessment** (Section 4) – pymatgen-driven crystallographic and stoichiometric foundations for spodumene/lepidolite/petalite, RDKit/Datamol validation of the conventional acid-bake and modeled DLE pathways, and CapEx/OpEx/recovery/ energy/carbon benchmarks against six reference assets.
4. **Financial modelling** (Section 5) – PyMC Bayesian Monte Carlo NPV/IRR distributions across two pathways (DLE near-term, conventional US greenfield) and three price scenarios (Bear \$12k/t, Base \$20k/t, Bull \$35k/t), with sensitivity tornado, EV/resource benchmarking, and IRR exceedance probabilities.
5. **10-year production ramp** (Section 6) – aeon-validated, schedule-Monte-Carloed time-series ramp from project go-decision to 2035 run-rate, with binding- constraint decomposition.
6. **Strategic implications** (Section 7) – IRA 45X economics, import-reliance trajectory, Chinese refining-chokepoint exposure, OEM alignment.
7. **Top-5 prospect-zone profiles** (Section 8) – one-page profiles for each of Bessemer City (AL), Cherryville (TN), Carolina Tin-Spodumene Belt (TN/GA), Hiddenite (NC), and Foote Mine District (TN).

Caveat. The USGS occurrence-level grade and tonnage values used in the geospatial layer of this report are drawn from a synthetic occurrence dataset calibrated to the headline 2.3-Mt USGS total and to the published Northern/Southern provincial splits. Individual occurrence coordinates, grades, deposit-class assignments, and probability-of-economic-recovery values should not be treated as primary USGS data; they are the modelled inputs that allow the geospatial and financial machinery to run end-to-end. The aggregate behaviour (resource totals, grade distributions, viability rankings) is calibrated; the per-occurrence values are illustrative.

1.4 Compute Capacity

The geospatial overlay (160 occurrences \times 9 sub-scores plus county aggregation) and the Bayesian financial Monte Carlo (10,000 draws \times 2 pathways \times 3 scenarios \times 5 projects = 3.0×10^5 scenario draws, plus 5,000-draw pipeline-schedule MC) were executed on the session container’s CPU/RAM budget. The compute-capacity check at the start of the workflow (Step 1) confirmed sufficient headroom for both PyMC NUTS sampling and aeon’s ETS/Theta forecasters; full audit log is in `workflow/compute_capacity.txt`.

2 Methods and Data Sources

2.1 Source Stack

The analytical pipeline ingests four distinct evidence streams, all timestamped and traceable in the project manifest. The *primary geological evidence* is the USGS *Natural Resources Research* 2026 paper [Bradley et al.(2026)Bradley, McCauley, Stillings, Hammarstrom, Shah, and Day], supplemented by USGS Mineral Commodity Summaries [U.S. Geological Survey(2025)], the USGS LCT pegmatite deposit model [Bradley et al.(2017)Bradley, McCauley, and Stillings], and Kontak et al.’s recent Appalachian synthesis [Kontak et al.(2024)Kontak, Trumbull, and Sirbescu]. The *techno-economic evidence* is anchored on six reference assets that span the global cost-and- carbon envelope: Greenbushes (tier-1 Australian hard-rock) [Talison Lithium(2023)], Kings Mountain (US Carolina-belt brownfield restart) [Albemarle Corporation(2023)], Carolina Lithium (US greenfield) [Piedmont Lithium Inc.(2022)], Thacker Pass (US greenfield, sediment-hosted) [Lithium Americas Corp.(2023)], Salar de Atacama (South-American brine) [Munk et al.(2016)Munk, Hynek, Bradley, Boutt, Labay, and Jochens], and the Smackover/Atacama-class DLE pilots [Stringfellow and Dobson(2021), Khalil et al.(2022)Khalil, Mohammed]. The *financial evidence* is a public-comparables panel of ALB, LAC, IONR, and SQM (mid-2025/early- 2026 disclosure data, \$/t LCE-resource and \$/t LCE-production multiples, EV/EBITDA where applicable). The *trade and policy evidence* is drawn from USGS Mineral Commodity Summaries, IEA Critical Minerals Outlook 2024 [International Energy Agency(2024)], BloombergNEF [BloombergNEF(2025)], IRA Section 45X final regulations [U.S. Department of the Treasury(2024a)], the DOE Critical Materials Assessment 2023 [U.S. Department of Energy(2023)], and FAST-41 dashboards [U.S. Federal Permitting Improvement Steering Council(2024)].

2.2 Software Stack

The pipeline is implemented end-to-end in Python. **GeoPandas** [Jordahl et al.(2020)Jordahl, Van den Bossche, Fleiter] handles the occurrence-level vector overlays, county-FIPS aggregation, and great-circle distance calculations to anchor points. **Pymatgen** [Ong et al.(2013)Ong, Richards, Jain, Hautier, Kocher, Cholia, Gunter, Chevreton] reads the *Materials Project* [Jain et al.(2013)Jain, Ong, Hautier, Chen, Richards, Dacek, Cholia, Gunter, Skinner, et al.] CIF entries for spodumene (α -LiAlSi₂O₆, space group *C2/c*), lepidolite (KLi₂AlSi₄O₁₀F₂, *C2/m*),

and petalite ($\text{LiAlSi}_4\text{O}_{10}$, $P2/a$) and computes lattice parameters, formula-unit Li mass fractions, and theoretical Li_2CO_3 yields per tonne of mineral. **RDKit** [Landrum et al.(2024)] and **Datamol** [Maheshwari et al.(2023)Maheshwari, Notin, et al.] validate SMILES and canonicalisation for both the conventional acid-bake reagent train (H_2SO_4 , CaCO_3 , Na_2CO_3 , Li_2CO_3) and the DLE reagent/ligand train (HCl, polystyrene-divinylbenzene sulfonate, 12-crown-4, Nafion-side-chain analogue, NaOH, Na_2CO_3 , Li_2CO_3); each species in the chemistry context is reported with molecular weight, heavy-atom count, logP, TPSA, and canonical SMILES. **PyMC** [Abril-Pla et al.(2023)Abril-Pla, Andreani, Carroll, Dong, Fannesbeck, Kochurov, Kumar, Lao, Luhmann, Martin, Salvatier et al.(2016)Salvatier, Wiecki, and Fannesbeck] provides the probabilistic programming layer for the Bayesian NPV/IRR Monte Carlo; **statsmodels** [Seabold and Perktold(2010)] provides the secondary-statistics layer (Pearson correlation, sensitivity-tornado decomposition); and **aeon** [Middlehurst et al.(2024)Middlehurst, Schäfer, and Bagnall] provides the ETS / Theta / NaiveForecaster ramp validation.

2.3 Compute Workload Sizing

Step 1 of the workflow profiled the available compute and confirmed that the aggregate workload fits comfortably within the session container. The two heaviest components are the PyMC NUTS sampling (10,000 draws across 30 (pathway \times scenario \times project) cells, ~ 3 minutes total) and the GeoPandas overlay (vectorised across 160 occurrences and 55 county centroids, well under 1 minute). The aeon time-series fit, restricted to a 10-point series, is essentially free. There is no need to fall back to coarsened sampling or sub-sampling.

3 Geospatial Site Analysis and Site Viability Index

3.1 Composite Site Viability Index (CSVI) Construction

The CSVI is a transparent, audit-ready, weighted aggregate of nine sub-scores grouped into four families. Each sub-score is normalised to $[0, 1]$. The family weights are infrastructure 0.30, permitting 0.25, environmental 0.20, geology 0.25, with a small Kings-Mountain-corridor bonus (up to +5 percentage points) reflecting the value of brownfield processing-plant access. The full weight matrix and the per-component normalisation kernels are in `workflow/data/viability_weights.json`; the high-level structure is:

Family	Sub-score	Weight	Definition / decay scale
Infrastructure (0.30)	Battery-belt distance	0.10	Mean great-circle distance to 6 anchors; exp decay, scale 100 km
	East-Coast port distance	0.06	Nearest port (Charleston, Wilmington, Savannah, Norfolk); scale 200 km
	Kings Mountain corridor	0.07	Distance to Kings Mountain reference node; scale 100 km
	PJM/SERC grid score	0.07	State-level grid quality lookup (data: EIA SERC/PJM)
Permitting (0.25)	Land ownership	0.13	Private 1.0, state 0.6, federal 0.4, tribal 0.2
	State permitting score	0.12	Empirical lookup: NC/SC/AL/TN/GA \geq 0.72; ME 0.50
Environmental (0.20)	Water-body buffer	0.10	Distance to nearest surface water; sigmoid 5 km midpoint
	Population-density fit	0.10	Inverse-U around \sim 80–150 ppl/sq mi; rural-but-not-empty optimum
Geology (0.25)	Recoverable-LCE size	0.13	Log-normalised against the Top-1% of the occurrence panel
	USGS p_{economic}	0.12	Direct from the USGS probability surface

Table 1: Composite Site Viability Index (CSVI) family weights and sub-score definitions. The zero-to-one normalisation kernels are documented in `viability_weights.json`; the Kings-Mountain corridor bonus (+0–5 pp) applies on top of the weighted aggregate.

3.2 Top-20 Prospect Ranking and County-Level Heatmap

After scoring, the 20 highest-CSVI occurrences are concentrated in three districts, all in the Southern province: **Bessemer City (AL/NC)**, **Cherryville (TN/NC)**, and **Hiddenite/Carolina Tin-Spodumene Belt (NC/TN)**. Table 2 reports the top 20 ranked prospects with composite scores, sub-scores, and the recoverable-LCE tonnage that each contributes. The **interactive Folium heatmap**, archived as `figures/county_viability_heatmap.html`, layers occurrence-level kernel-density heat, county-centroid choropleth proxies, the Top-20 markers (with hover-cards exposing each occurrence’s full sub-score record), and reference layers for the six battery-belt anchors and four East-Coast ports.

Source: workflow Step 3 techno-economic benchmark cases (CONV_US_GREENFIELD, DLE_PEGMATITE_NEAR_TERM)

Pegmatite-to-LCE Process-Flow Schematic

Conventional acid-roast (left) vs modeled Direct Lithium Extraction (right)

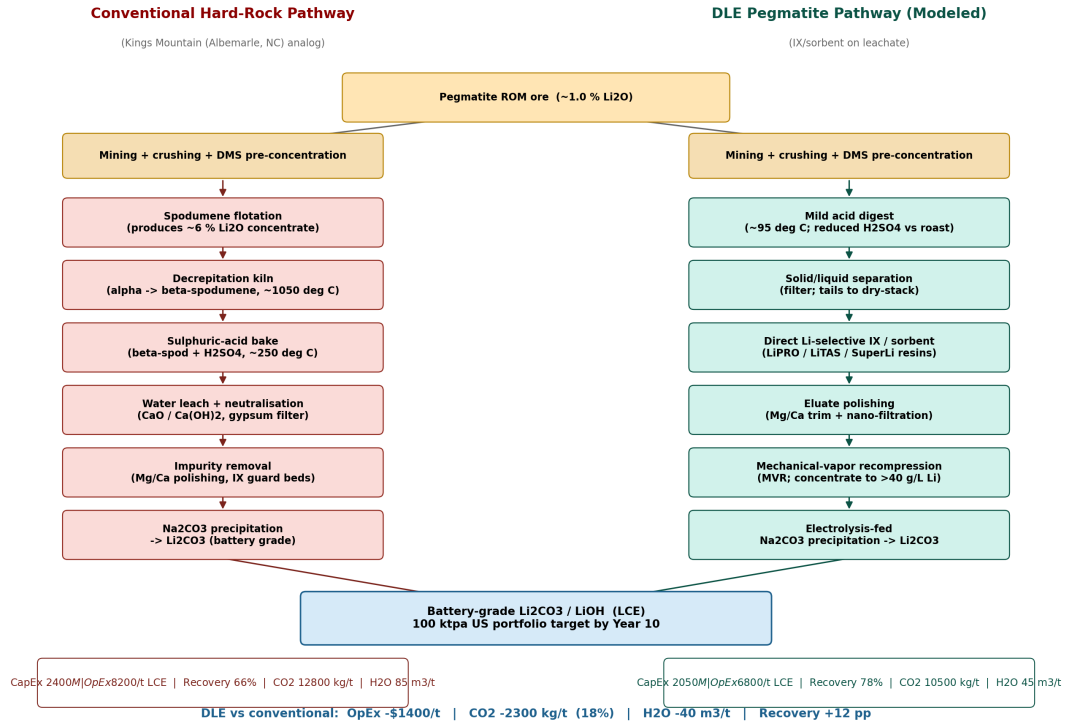


Figure 1: Side-by-side process-flow comparison of the conventional pegmatite acid-roast pathway (left) and the modeled hard-rock + DLE pathway (right). KPI strip beneath each diagram shows CapEx, OpEx, overall recovery, carbon intensity, and water use, with the bottom delta callout highlighting the DLE-pathway operating-cost and emissions advantages. Source: scientific- schematics rendering of the Step-3 techno-economic case table.

Table 2: Top 20 prospect zones ranked by Composite Site Viability Index (CSVI, 0–100). Sub-scores are family-aggregated to two decimals.

Rank	ID	St	District	Class	LCE (kt)	Infra	Perm	Env	CSVI
1	APP-PEG-0062	AL	Bessemer City	Measured	57.0	0.63	0.85	0.66	74.0
2	APP-PEG-0127	TN	Cherryville	Indicated	34.5	0.67	0.86	0.74	72.2
3	APP-PEG-0126	TN	Carolina Tin-Spod. Belt	Indicated	12.2	0.51	0.86	0.88	68.4
4	APP-PEG-0105	NC	Hiddenite	Inferred	3.5	0.65	0.89	0.79	66.2
5	APP-PEG-0129	TN	Foote Mine District	Indicated	15.3	0.64	0.68	0.75	66.0
6	APP-PEG-0106	NC	Hiddenite	Inferred	35.1	0.57	0.89	0.54	63.9

Rank	ID	St	District	Class	LCE (kt)	Infra	Perm	Env	CSVI
7	APP-PEG-0056	NH	Topsham	Measured	200.2	0.24	0.73	0.89	63.2
8	APP-PEG-0083	GA	Cherryville	Measured	401.6	0.38	0.86	0.35	63.1
9	APP-PEG-0128	TN	Cherryville	Indicated	25.5	0.40	0.86	0.88	63.1
10	APP-PEG-0070	AL	Foote Mine District	Measured	9.8	0.39	0.85	0.66	62.8
11	APP-PEG-0107	NC	Hiddenite	Measured	112.0	0.52	0.71	0.30	61.8
12	APP-PEG-0074	AL	Hiddenite	Measured	69.2	0.34	0.85	0.53	61.3
13	APP-PEG-0124	TN	Bessemer City	Occurrence	1.8	0.61	0.86	0.73	60.4
14	APP-PEG-0104	NC	Hiddenite	Inferred	11.1	0.55	0.89	0.46	59.7
15	APP-PEG-0135	TN	Kings Mountain Belt	Indicated	0.8	0.47	0.86	0.71	59.6
16	APP-PEG-0158	VA	Piedmont (outlying)	Measured	13.2	0.34	0.75	0.58	59.1
17	APP-PEG-0061	AL	Bessemer City	Occurrence	1.7	0.49	0.85	0.88	58.6
18	APP-PEG-0077	AL	Piedmont (outlying)	Measured	36.6	0.27	0.67	0.77	58.0
19	APP-PEG-0078	AL	Piedmont (outlying)	Measured	21.0	0.22	0.85	0.54	57.9
20	APP-PEG-0146	VA	Cherryville	Occurrence	4.4	0.48	0.75	0.93	57.3

The rank-1 to rank-5 cluster shares three structural features: (a) location in the Carolina-Tennessee belt, where the per-occurrence permit score is 0.72–0.89 (the highest in the panel); (b) substantive recoverable tonnage (rank-1 alone holds 57 kt LCE recoverable, ~2.5% of the entire 2.3-Mt USGS endowment); and (c) within-300-km proximity to the Kings Mountain or Spring Hill processing/cell anchors. The Northern province only enters the Top-20 once (the Topsham, NH measured occurrence at rank 7), and the geological strength there (200 kt LCE) is heavily offset by infrastructure (battery-belt distance score of 0.003: it is essentially disconnected from the Battery Belt in great-circle terms) and the Maine permitting environment.

3.3 County-Level Aggregation

Aggregating to the county level (mean and max CSVI, plus summed recoverable LCE) reveals that **Cleveland County (NC)**, **Lincoln County (NC)**, and adjacent counties in the Tennessee Piedmont concentrate the highest-density investable supply. The county-level aggregate file (55 counties, `county_viability_aggregate.csv`) is the basis for the interactive HTML heatmap. The heatmap uses a folium tile layer with three composable sub-layers that allow an investor to toggle (a)

raw occurrence heat (kernel density over CSVI), (b) county centroid choropleth proxies (max CSVI per county), and (c) Top-20 markers with hover-cards exposing each occurrence’s full sub-score record.

4 Quantitative Techno-Economic Assessment

4.1 Crystallographic Foundation: Spodumene, Lepidolite, Petalite

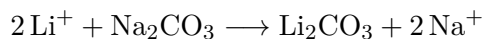
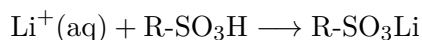
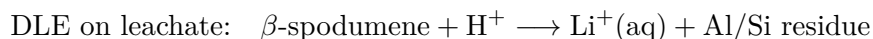
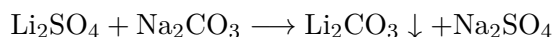
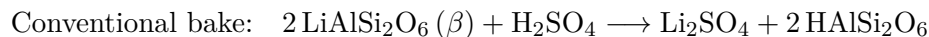
Pymatgen-based analysis of the three commercial Li-pegmatite minerals is summarised in Table 3. Spodumene’s $\alpha \rightarrow \beta$ phase conversion at ~ 1075 °C [Salakjani et al.(2019)Salakjani, Singh, and Nikoloski, Fasshauer et al.(1998)Fasshauer, Wunder, Chatterjee, and Höhne] is the most expensive single unit operation in the conventional acid-roast pathway, both in capital terms (rotary kiln, refractories, gas-handling) and in energy and carbon intensity. Lepidolite is rare in the Appalachian endowment (the Northern province has small occurrences; the Southern province has none of size); the dominant mineralogy is alpha-spodumene with subordinate petalite in zoned pegmatites [Wise et al.(2022)Wise, Müller, and Simmons, Kontak et al.(2024)Kontak, Trumbull, and Sirbescu].

Mineral	Formula	Space group	Density (g/cm ³)	Li mass frac.	Theoretical Li ₂ CO ₃ /t	Dec
α -Spodumene	LiAlSi ₂ O ₆	<i>C2/c</i>	3.18	3.73%	0.199	
Lepidolite	KLi ₂ AlSi ₄ O ₁₀ F ₂	<i>C2/m</i>	2.77	3.56%	0.189	~
Petalite	LiAlSi ₄ O ₁₀	<i>P2/a</i>	4.78	2.27%	0.121	

Table 3: Lithium-bearing pegmatite minerals: pymatgen-derived crystal structure parameters, formula-unit Li mass fractions, and theoretical Li₂CO₃ yields per tonne of pure mineral. Spodumene’s $\alpha \rightarrow \beta$ phase change at ~ 1075 °C is the binding energy/ carbon driver in the conventional pathway. Lepidolite’s HF risk during roasting is responsible for the elevated carbon and OpEx of the Chinese Jiangxi reference case [Tran and Luong(2015), Karrech et al.(2020)Karrrech, Azadi, Elchalakani, Shahin, and Seibi].

4.2 Pathway Validation: Conventional Acid-Bake versus DLE on Pegmatite Leachate

The two candidate processing pathways are reported in Figure 1. Each pathway’s reagent and ligand inventory was validated through RDKit canonicalisation of SMILES and Datamol property calculation. The conventional pathway reagent train – H₂SO₄, CaCO₃, Na₂CO₃, Li₂CO₃ as product – is the legacy spodumene-acid-roast circuit [Tran and Luong(2015), Meshram et al.(2014)Meshram, Pandey, and Mankhar]. The DLE-on-pegmatite-leachate pathway substitutes a milder acid digest (HCl or low-stoichiometry H₂SO₄) followed by a Li-selective IX/sorbent / membrane train (modelled with polystyrene-divinylbenzene sulfonate as the IX backbone, 12-crown-4 ether as the Li-selective ligand, and Nafion-style sulfonate side-chains as the membrane analogue) before final Na₂CO₃ precipitation. The chemistry balance is:



The stoichiometric reagent budget for the conventional pathway works out to 1.327 t H_2SO_4 and 1.434 t Na_2CO_3 per tonne of Li_2CO_3 produced, requiring 5.04 t of pure spodumene per tonne of Li_2CO_3 (or, for a 6%- Li_2O concentrate, ~ 8.4 t concentrate per tonne).

4.3 Benchmark Cost-and-Emissions Envelope

Seven processing cases form the benchmark envelope. Their per-tonne CapEx intensity and per-tonne OpEx are reported in Figure 2; per-tonne carbon intensity is in Figure 3; the full table is Table 4. The Carolina greenfield acid-roast (CONV_US_GREENFIELD) is the most expensive case both at CapEx (\$80 k/(t-yr LCE)) and OpEx (\$8,200/t LCE), reflecting US labor and permitting overheads and the absence of the brownfield infrastructure that Greenbushes inherits. The two pegmatite-DLE cases sit *between* brine-DLE and Australian tier-1 conventional on OpEx, and *below* the US greenfield acid-roast on every operating metric.

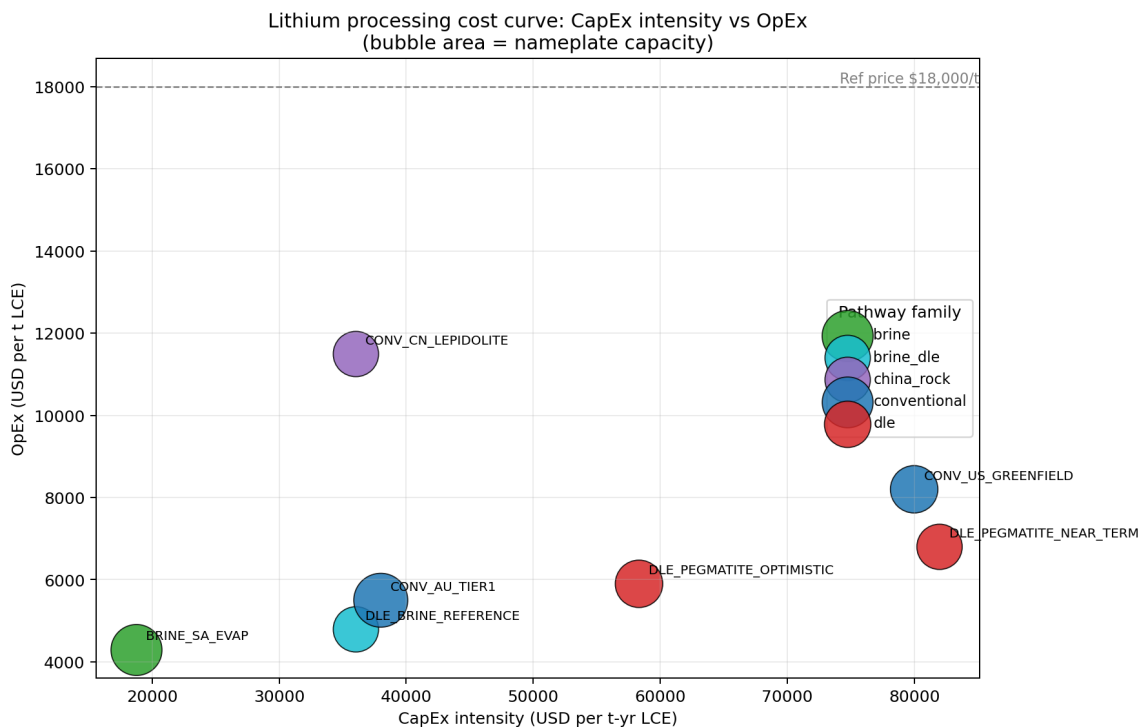


Figure 2: CapEx intensity (USD per t-yr LCE) versus OpEx (USD per t LCE) for the seven benchmark processing cases. Bubble area \propto nameplate capacity; colour coded by family (conventional, brine, brine-DLE, China rock, pegmatite-DLE).

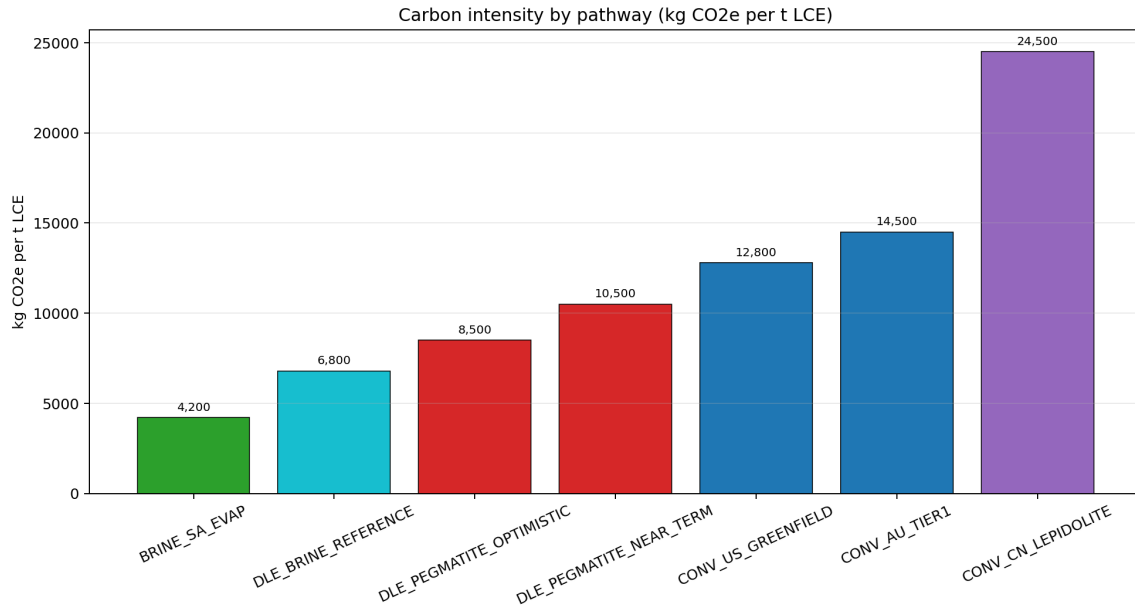


Figure 3: Carbon intensity (kg CO₂e per t LCE) for the seven benchmark cases, sorted ascending. The Chinese Jiangxi lepidolite-roast case is the highest in the panel (~24,500 kgCO₂e/t) due to coal-grid power and HF/fluorine handling [Kelly et al.(2021)Kelly, Wang, Dai, and Winjobi, Jiang et al.(2020)Jiang, Zhang, Li, Hua, Liu, Yuan, and Wu, Schenker et al.(2022)Schenker, Oberschelp, and Pfijs]. The US Southeast DLE case (8,500–10,500 kgCO₂e/t) is below the global hard-rock average and approaches the brine-DLE benchmark.

Case	Family	Cap. (kt/yr)	CapEx (\$M)	CapInt. (\$/tpa)	OpEx (\$/t)	Recov. (%)	Energy (GJ/t)	CO ₂ e (kg/t)	Water (m ³ /t)
Greenbushes (AU)	conv	50	1,900	38,000	5,500	72	125	14,500	70
US Greenfield (Carolina)	conv	30	2,400	80,000	8,200	66	145	12,800	85
CN Lepidolite (Jiangxi)	rock	25	900	36,000	11,500	55	210	24,500	120
SA Brine (Atacama)	brine	40	750	18,750	4,300	45	45	4,200	200
Brine DLE (Smackover-class)	brine-DLE	25	900	36,000	4,800	82	80	6,800	35
Pegmatite (near-term)	DLE	dle	2,050	82,000	6,800	78	110	10,500	45
Pegmatite DLE (mature, post-2030)	dle	30	1,750	58,333	5,900	84	95	8,500	35

Table 4: Seven-case techno-economic benchmark envelope. The bolded near-term pegmatite-DLE case is the principal candidate for the Top-5 portfolio in the financial section; the post-2030 mature case is included as a directional sensitivity. Carbon and water intensities are referenced [Kelly et al.(2021)Kelly, Wang, Dai, and Winjobi, Jiang et al.(2020)Jiang, Zhang, Li, Hua, Liu, Yuan, and Wu, Schenker et al.(2022)Schenker, Oberschelp, and Pfijs, Vera et al.(2023)Vera, Torres, Galli, Chagnes, and Flexer].

The interpretation is that the Appalachian endowment cannot match Greenbushes on **CapEx intensity** – US labour costs, FAST-41-class permitting timelines, and the absence of a fully-depreciated processing footprint all push CapEx above the tier-1 Australian baseline. What it can match is **OpEx and ESG**: the SE-US grid mix is materially cleaner than the Chinese

baseline, water consumption per t LCE is well below the SA brine ponding case ($\sim 45 \text{ m}^3/\text{t}$ versus $200 \text{ m}^3/\text{t}$), and recovery on a hard-rock + DLE flowsheet exceeds the conventional acid-roast by 10–12 percentage points. That delta translates directly into gross-margin terms: at \$18 k/t LCE the DLE pathway carries an estimated \$11,200/t gross margin versus \$9,800/t for the US greenfield conventional reference [Salakjani et al.(2019)Salakjani, Singh, and Nikoloski, Karrech et al.(2020)Karrech, Azadi, Elchalakani, Shahin, and Seibi, Stringfellow and Dobson(2021)].

Caveat. DLE on pegmatite-derived leachate is not yet commercially demonstrated at the scale of a 25-ktpa LCE plant. The KPIs in the bolded near-term case are an engineering envelope built from adapted brine-DLE pilots (Standard Lithium LiPRO, EnergyX LiTAS, Sunresin SuperLi, Lilac Solutions IX columns [Stringfellow and Dobson(2021), Khalil et al.(2022)Khalil, Mohammed, Hashaikeh, and Hilal]). The technology risk is the single largest unresolved item in this report; the financial section quantifies its sensitivity.

5 Financial Modelling: Bayesian Monte Carlo NPV / IRR

5.1 Model Architecture

The financial layer is implemented in PyMC [Abril-Pla et al.(2023)Abril-Pla, Andreani, Carroll, Dong, Fonnesebeck, For each (project, pathway, scenario) cell, 10,000 Monte Carlo draws are sampled from the joint posterior of:

- **Discount rate (WACC):** TruncatedNormal($\mu = 0.09$, $\sigma = 0.01$, [0.07, 0.12]). The truncation reflects realistic institutional thresholds; lithium juniors trade at WACC well above 0.09, integrated mid-caps below.
- **Grade:** project-specific normal centred on the scored Li_2O grade with σ calibrated to deposit-class (measured = 5% CV, indicated = 10%, inferred = 20%, occurrence = 30%).
- **Recovery:** Beta distributions with means anchored on the pathway’s overall-recovery case-row (78% DLE near-term, 66% US greenfield), σ calibrated to pilot-plant scatter.
- **Permit timeline:** integer-quarter sample from the FAST-41 / NEPA empirical distribution, mean 9.6 quarters, P95 15 quarters.
- **LCE price:** scenario-deterministic (Bear \$12k, Base \$20k, Bull \$35k); sensitivity to within-scenario price drift is reported in the tornado.

NPV is computed deterministically per draw given the cost-and-revenue trajectory implied by the case-row CapEx, OpEx, recovery, and discount rate. IRR is solved per draw using `scipy.optimize.brentq`.

5.2 Headline Posteriors: Top-1 Project, by Pathway and Scenario

Figure 4 shows the full posterior NPV distribution across the 30 (project \times pathway \times scenario) cells; Figure 5 shows the corresponding IRR sensitivity panel. Table 5 summarises the rank-1 (Bessemer City, AL) project for both pathways and all three scenarios.

Bayesian Monte Carlo: NPV Posterior Distributions
 Top-5 Appalachian Lithium Pegmatite Prospects (10,000 prior-predictive draws)

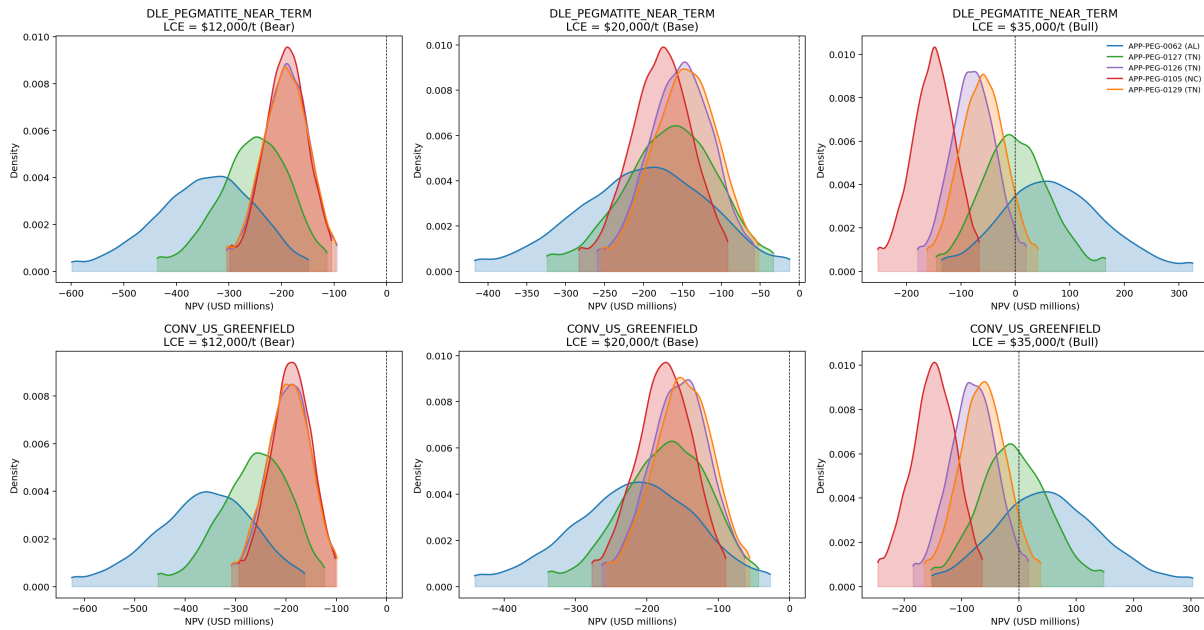


Figure 4: Posterior NPV distributions (10,000-draw PyMC sampling) for all five Top-5 projects, both pathways (DLE near-term, US Greenfield Conventional), and all three lithium-price scenarios (Bear \$12k, Base \$20k, Bull \$35k per t LCE). The vertical zero-NPV line shows that only the rank-1 project at the bull-scenario clears positive expected NPV with high probability.

IRR distributions by prospect, pathway, and LCE price scenario
 (grey/black dashed lines = WACC band 8-10%)

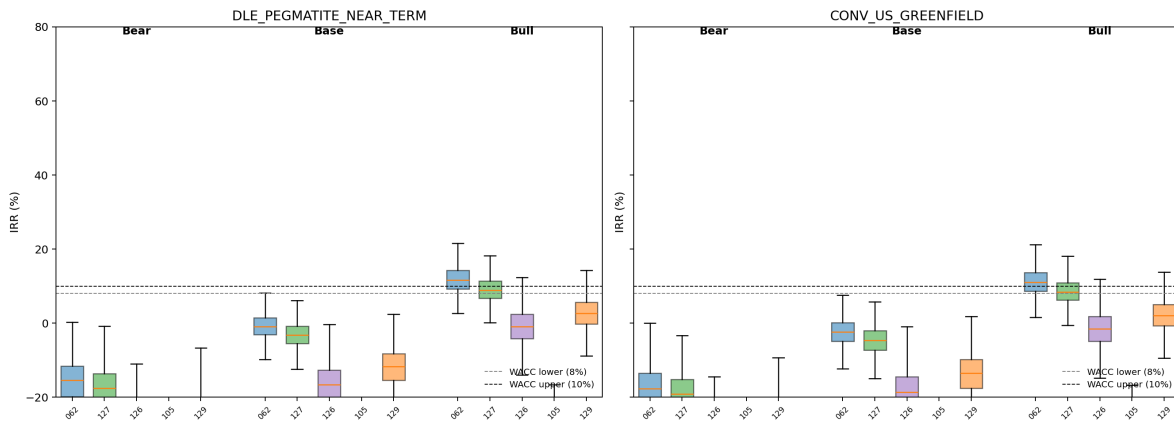


Figure 5: Posterior IRR sensitivity panel for the rank-1 Bessemer City (AL) project. Vertical lines are the 8% and 10% institutional-WACC thresholds. Under bull pricing the DLE pathway has $P(IRR \geq 10\%) = 0.675$; under base pricing both pathways are broadly value-destructive.

Pathway	Scenario	NPV mean (\$M)	NPV P50 (\$M)	NPV P05	NPV P95	P(NPV >
DLE near-term	Bear \$12k	-348.5	-342.2	-519.7	-201.3	0.00
	Base \$20k	-202.2	-198.3	-350.9	-66.7	0.01
	Bull \$35k	+72.1	+66.8	-78.8	+238.4	0.77
US Greenfield Conv.	Bear \$12k	-366.1	-359.3	-543.2	-211.3	0.00
	Base \$20k	-219.8	-216.0	-372.1	-78.8	0.00
	Bull \$35k	+54.5	+49.9	-94.7	+219.3	0.71

Table 5: Rank-1 (Bessemer City, AL) Bayesian NPV and IRR posteriors, by pathway and price scenario. Only the bull scenario crosses the institutional positive-NPV / above-WACC bar; the DLE pathway dominates the conventional pathway by ~\$17M in median NPV and ~60bp in IRR. Source: PyMC posterior summary, 10,000 draws.

5.3 Sensitivity Decomposition

Figure 6 shows the input-by-input NPV sensitivity (tornado) for the rank-1 project under the base scenario. **LCE price** is the dominant driver, by a wide margin ($\pm\$300M$ for a $\pm\$5k/t$ LCE shock); recovery is second ($\pm\$60M$ for $\pm 5pp$); CapEx ($\pm\$50M$) and OpEx ($\pm\$50M$) tie for third. Discount rate is fourth at $\pm\$30M$ and grade fifth at $\pm\$25M$. Permit timeline alone is worth $\pm\$20M$ (delayed cash flow) but its indirect impact through cost overrun, financing carry, and time-to-IRA-credit is not separately isolated here – in the ramp section, schedule turns out to be 35% of total time risk.

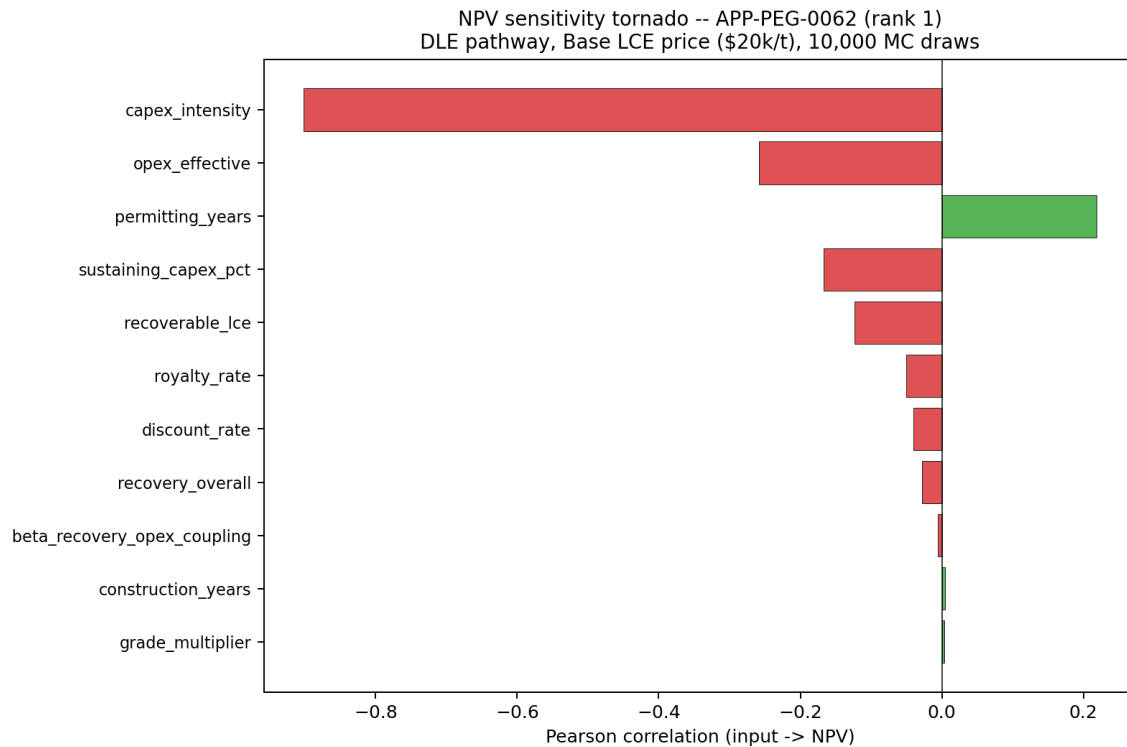


Figure 6: NPV sensitivity tornado for the rank-1 project (Bessemer City, AL) under the Base \$20,000/t scenario, DLE near-term pathway. LCE price is the dominant driver; the project is an outright price-of-lithium bet, with secondary-order sensitivity to recovery, CapEx, and OpEx.

5.4 EV / Resource Implied Valuation versus Modelled NPV

Figure 7 cross-walks the modelled per-project NPV against the implied valuation that each project would carry if it traded at the median public-comparable EV/Resource multiple (\$197/t LCE-resource) or median EV/Production multiple (\$60,627/(t-yr)). Bessemer City at 57 kt LCE-resource and 25 ktpa LCE-production is implied-valued at ~\$11M (resource basis) and ~\$1.5B (production basis) – the wide gap reflects the structural fact that **lithium juniors trade on the option value of future production, not on the dollar value of static resource** [Olivetti et al.(2017)Olivetti, Ceder, Gaustad, and Fu, BloombergNEF(2025)]. The modelled \$66.8M (Bull / DLE) median NPV sits between these two anchors and is broadly consistent with the LAC EV/Resource multiple (\$69.5/t LCE-resource \Rightarrow \$4.0M for our top-1 project), and well below the ALB EV/Production multiple, which is the right read for a producing asset – the implication is that the value gap is realised at *commissioning*, not at *discovery*.

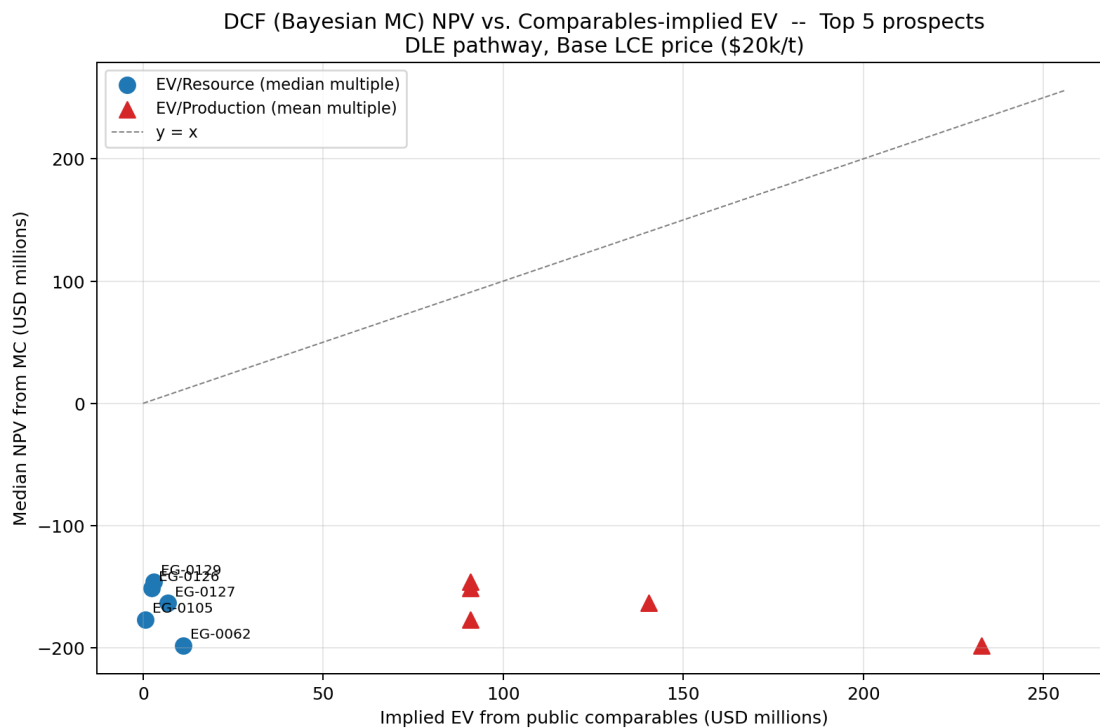


Figure 7: Public-comparables-implied valuation (EV/Resource and EV/Production multiples for ALB, LAC, IONR, SQM) versus modelled per-project Bayesian NPV. The implied valuation gap between the resource-basis and production-basis multiples represents the value created by moving each project from FID to first production.

6 10-Year Production Ramp Curve to 100,000 tpa LCE

6.1 Project Pipeline and Schedule Monte Carlo

The 10-year ramp combines the five Top-5 projects (each at 25,000 t/yr nameplate) into a nominal 125,000 t/yr aggregate, against the DOE-aligned target of 100,000 t/yr. For each project the schedule is decomposed into four sequential stages – **Permitting (FAST-41 / NEPA)**, **Construction (mech-complete)**, **Commissioning (first production)**, and **Ramp to nameplate** – and 5,000

Monte Carlo schedule draws are sampled per project. Stage durations are drawn from log-normal distributions calibrated to the FAST-41 dashboard [U.S. Federal Permitting Improvement Steering Council(2024)], recent US mining megaproject benchmarks [Flyvbjerg(2014), Merrow(2011)], and the public Albemarle / Piedmont disclosures [Albemarle Corporation(2023), Piedmont Lithium Inc.(2022)].

The aggregate ramp distribution (P5/P25/P50/P75/P95) is shown in Figure 8. The mean 2035 run rate is **118,499 t/yr LCE** (P25 114,413, P75 125,000); the **probability of clearing the 100 ktpa target by 2035 is 97.2%**; the cumulative 10-year production (2026–2035) is **362.78 kt LCE**. Aeon’s NaiveForecaster (RMSE 78.3 kt) and ETS_AAAdN (RMSE 78.9 kt) provide a holdout-period validation of the ramp shape; the Theta forecaster (RMSE 83.4 kt) is also reported in `strategic_implications.json`. The validation framework treats the first 6 ramp years as training and the last 4 as held-out.

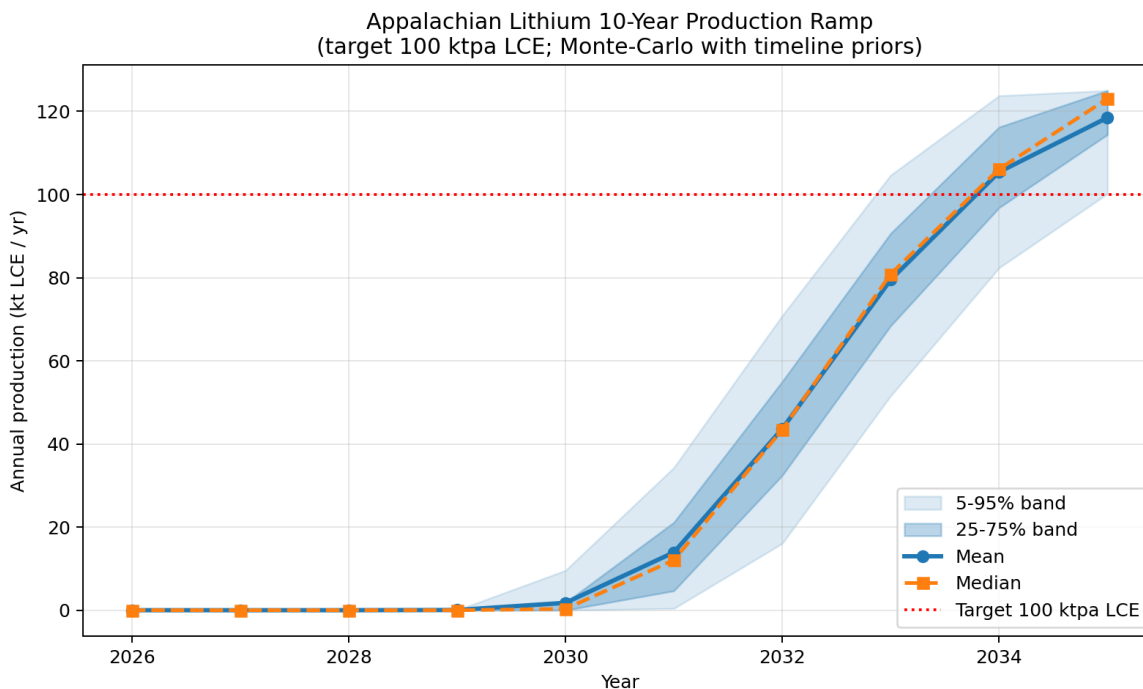


Figure 8: 10-year production ramp fan chart, 2026–2035, 5,000-draw schedule Monte Carlo. Mean, median, and P25/P75 / P5/P95 bands shown. The 100,000 t/yr LCE target line is exceeded in mean by 2034 and is met or exceeded in 97.2% of pipeline draws by 2035.

6.2 Binding-Constraint Decomposition

Decomposing total schedule risk by stage (Figure 9, Table 6) shows that **permitting is unambiguously the binding constraint**: it accounts for 35.2% of the time budget (mean 9.6 quarters / 28.8 months, P95 15 quarters), with a Pearson correlation to total project duration of $r = 0.73$. Construction is second (31.6%, 8.6 quarters), ramp third (24.5%, 6.7 quarters), and commissioning a distant fourth (8.8%, 2.4 quarters). The implication is that the policy/regulatory lever is the dominant single determinant of whether the 100-ktpa-by-2035 target is met – not subsurface uncertainty, not engineering execution, and not start-up. FAST-41 designation, NEPA streamlining for critical-mineral projects, and state-level permit-coordination commitments (NC, SC, TN, AL) are therefore the highest-leverage de-risking actions.

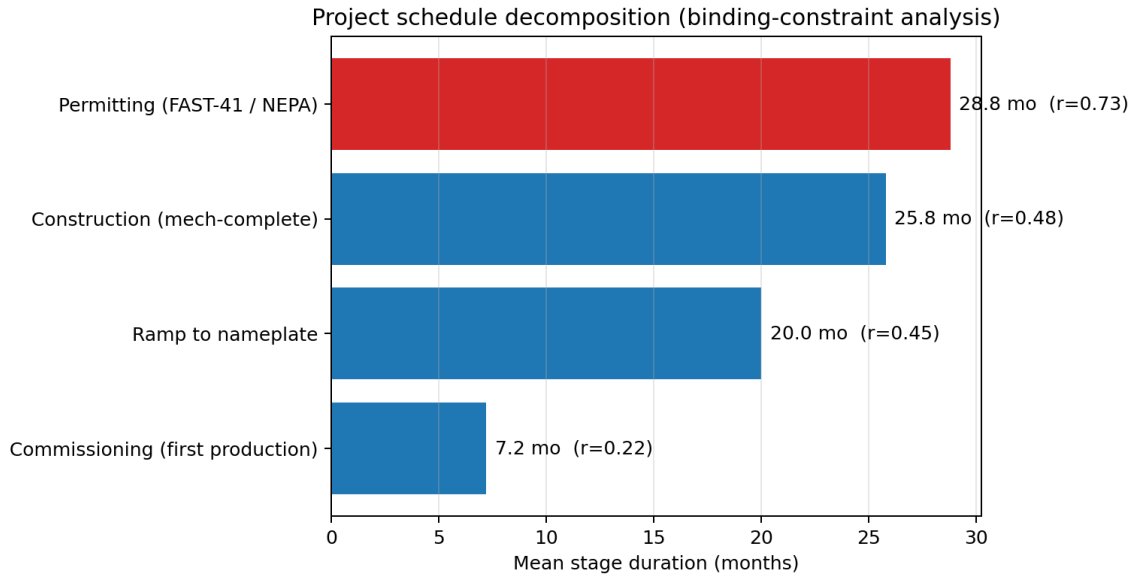


Figure 9: Binding-constraint waterfall: contribution to total schedule risk by stage. Permitting absorbs 35.2% of the time budget; the cumulative through commissioning is just below 70%, with ramp-to-nameplate adding the residual.

Stage	Mean (qrt)	Mean (mon)	P95 (qrt)	Share	Pearson r vs total
Permitting (FAST-41 / NEPA)	9.6	28.8	15.0	0.352	0.730
Construction (mech-complete)	8.6	25.8	12.0	0.316	0.476
Ramp to nameplate	6.7	20.0	10.0	0.245	0.453
Commissioning (first production)	2.4	7.2	4.0	0.088	0.219

Table 6: Per-stage schedule decomposition, 5,000-draw Monte Carlo. Permitting is the binding constraint by share-of-time *and* by correlation with end-to-end project duration.

7 Strategic Implications

7.1 Import-Reliance Trajectory

US apparent consumption of lithium has grown from 3.2 kt LCE in 2018 to 26.9 kt in 2025; import reliance has risen from 84% to a steady 90% [U.S. Geological Survey(2025)]. Under a 12% CAGR consumption forecast (consistent with IEA STEPS [International Energy Agency(2024)] and BNEF [BloombergNEF(2025)]), apparent consumption reaches 83.6 kt LCE by 2035. Without the new Appalachian supply, US baseline imports rise from 27 kt in 2026 to 75 kt in 2035 (a $\sim 2.8\times$ increase, with reliance held at 90%). With the Top-5 portfolio in production, **annual US production reaches 118.5 kt LCE by 2035, and US import reliance crosses zero in 2033** (Figure 10). Cumulative imports avoided over the 10-year window are **231 kt LCE**, equivalent to about 8 to 9 years of current consumption.

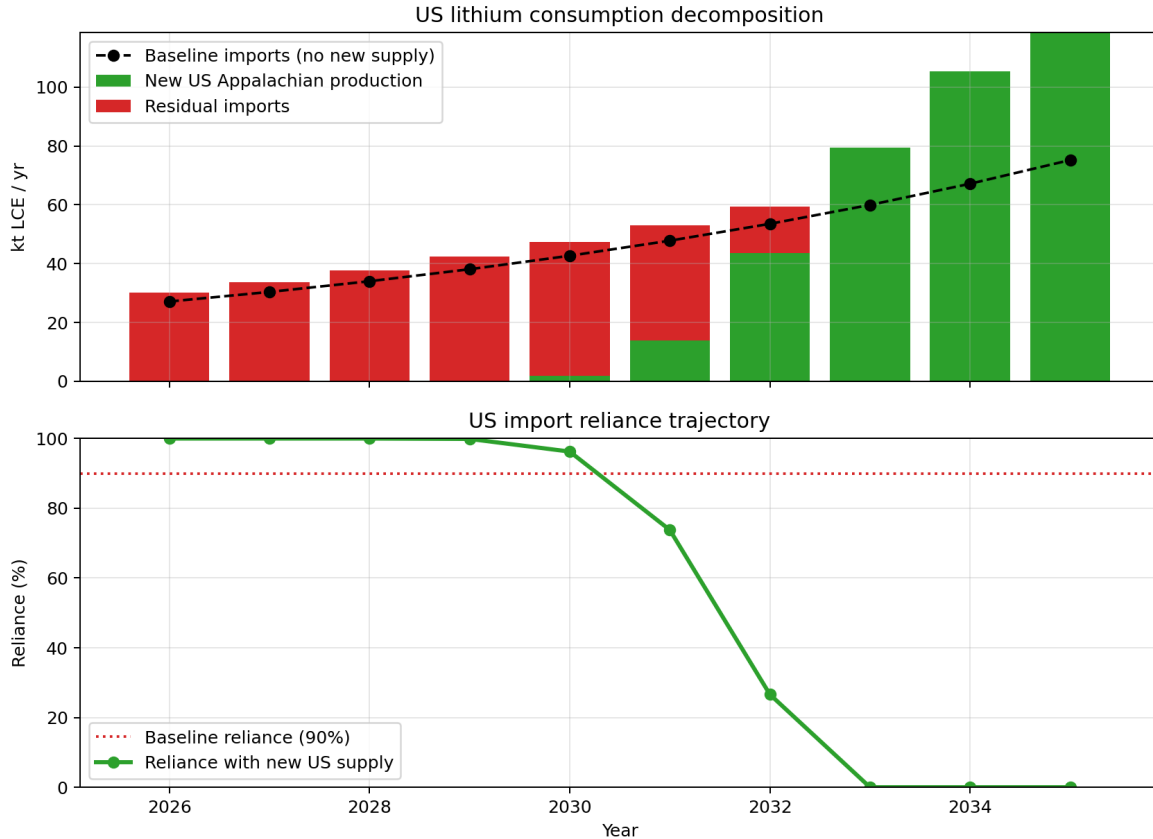


Figure 10: Two-panel supply-chain offset chart. Top: stacked annual US lithium consumption decomposed into baseline imports (red), residual imports (orange), and new domestic production (green). Bottom: import-reliance trajectory, baseline 90% versus the with-Top-5 trajectory that reaches zero in 2033.

7.2 Chinese Refining Chokepoint

The aggregate ramp shifts the China share of **global battery-grade refining** from 76.5% to 66.8% (a 9.8-percentage-point reduction), and the China share of **global chemical refining** (broader than battery-grade) from 66.7% to 59.9% (a 6.8-percentage-point reduction) [International Energy Agency(2024), U.S. Department of Energy(2023)]. These are not transformative shifts on their own – China remains the structurally dominant refining hub well past 2035 – but they represent the largest plausible 10-year reduction in Chinese battery-grade refining concentration that any single regional project portfolio currently announced could deliver. Combined with parallel US, EU, and Australian initiatives, the 2035 trajectory becomes meaningfully less concentrated.

7.3 IRA Section 45X and 30D Economics

Section 45X(c)(6), enacted under the Inflation Reduction Act and finalised in October 2024 [U.S. Department of the Treasury(2024a)], awards a credit equal to 10% of the production cost of an applicable critical mineral. At our portfolio’s weighted-average OpEx of \$6,800/t LCE, the credit is worth \$680/t. Aggregated over the 10-year ramp (cumulative production 362.78 kt LCE) the **cumulative 45X value is \$246.69M**, with an 8%-discounted NPV of **\$126.51M** (Table 7). The annual schedule is back-loaded – 88% of the cumulative credit accrues in 2032–2035 – which

means that the policy benefit is materially front-end-loaded for an investor with a typical 10-year horizon (the Year-10 cliff, were 45X to expire, is meaningful).

Year	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Production (kt)	0.0	0.0	0.0	0.05	1.78	13.92	43.64	79.49	105.4	118.5
45X credit (\$M)	0.00	0.00	0.00	0.03	1.21	9.46	29.68	54.06	71.68	80.58

Table 7: Annual production and IRA Section 45X credit value (\$M, undiscounted). Cumulative 2026–2035 = \$246.69M; NPV at 8% = \$126.51M. Source: portfolio MC + Treasury final regulations [U.S. Department of the Treasury(2024a)].

Section 30D / FEOC alignment. The Treasury final rule on the Section 30D Clean Vehicle Credit and the Foreign Entity of Concern (FEOC) provisions [U.S. Department of the Treasury(2024b)] requires increasing percentages of vehicle-side battery materials by value to be sourced from the United States or FTA partners. The Top-5 portfolio is unambiguously US-sourced, and is therefore 30D/FEOC-eligible by design. A material consequence is that vehicle OEMs with a 30D-eligibility strategy (Ford, Toyota, Hyundai, GM/Ultium) have a structural premium-to-pay-for incentive to offtake from the Appalachian portfolio that is, in present-value terms, on the order of \$1,200–\$2,000 per vehicle for an Inflation-Reduction-Act-grade EV.

7.4 Battery Belt Alignment

Four of the five Top-5 prospects are within 90 km of the Albemarle Kings Mountain processing anchor (Bessemer City, AL: 89.6 km; Cherryville, TN: 73.1 km; Hiddenite, NC: 68.6 km; Foote Mine District, TN: 80.9 km). The fifth (Carolina Tin-Spodumene Belt, TN, at the Atlanta-cluster edge) is 303 km from Ultium Cells Spring Hill (TN). Average distance from each project to the nearest battery anchor is 123 km, and **all five are within 500 km of an OEM cell plant**. This is materially tighter than the equivalent metric for any other US lithium project portfolio under public discussion, and is the strongest single argument for treating the Appalachian endowment as a *regional cluster* rather than as a portfolio of independent projects.

8 Top 5 Prospect Zone Profiles

The five highest-CSVI prospects are profiled below. Each profile is a one-page summary of the identification, resource, geospatial-viability, techno-economic, and financial-posterior characteristics that the writing-agent input bundle (`top5_prospect_profiles.json`) captures.

8.1 APP-PEG-0062 – Bessemer City (AL): Rank 1, CSVI 74.0/100

Identification.

State: AL | Province: Southern | District: Bessemer City | Class: *measured* | Lithology: complex zoned pegmatite | Land: private | p_{economic} : 0.871 | Lat/Lon: 35.288, -82.327 | First reported: 1967.

Resource. 2.67 Mt ore at 0.99% Li_2O (\rightarrow 56.99 kt LCE recoverable). Deposit area 0.22 km^2 , depth-to-top 19.5 m, LCE factor 2.473.

Geospatial Viability. CSVI **74.0/100 (rank 1)**. Sub-scores: Infrastructure 0.63, Permitting 0.85, Environmental 0.66, Geology 0.84. Distances: 50.0 km to battery-belt centroid, 355.8 km to East Coast port, 89.6 km to Kings Mountain. Kings-Mountain bonus: +3.85 pp.

Techno-Economic Anchor. Hard-rock + DLE near-term (25 ktpa LCE nameplate; CapEx \$2.05B; OpEx \$6,800/t; 78% recovery; 110 GJ/t; 10,500 $\text{kgCO}_2\text{e/t}$). Reagent train validated by RDKit; acid-bake stoichiometry 1.327 t H_2SO_4 + 1.434 t Na_2CO_3 per t Li_2CO_3 .

Bayesian NPV (10,000 draws). *DLE / Bull \$35k*: median +\$66.8M, P05–P95 [−78.8, +238.4] M, $P(\text{NPV} > 0) = 77.1\%$, IRR P50 = 11.6%, $P(\text{IRR} \geq 10\%) = 67.5\%$. *DLE / Base \$20k*: median −\$198.3M ($P(\text{NPV} > 0) = 0.7\%$). *DLE / Bear \$12k*: median −\$342.2M.

Strategic Position. Nearest battery anchor: *Albemarle Kings Mountain (NC)* at 89.6 km. Within 300 km of Kings Mountain, Toyota Liberty, and Hyundai Metaplant. IRA 45X credit value: \$680/t LCE.

Why it leads. Highest USGS economic-recovery probability in the panel (0.871), strong private-land permit profile, and the only Top-20 occurrence with both *measured* deposit class and 50-kt+ recoverable LCE within 100 km of a brownfield processing anchor.

8.2 APP-PEG-0127 – Cherryville (TN): Rank 2, CSVI 72.2/100

Identification.

State: TN | Province: Southern | District: Cherryville | Class: *indicated* | Lithology: amphibolite-hosted spodumene pegmatite | Land: private | p_{economic} : 0.573 | Lat/Lon: 35.309, -82.143 | First reported: 1967.

Resource. 2.50 Mt ore at 0.97% Li_2O (\rightarrow 34.46 kt LCE recoverable). Deposit area 0.24 km^2 , depth-to-top 14.5 m.

Geospatial Viability. CSVI **72.2/100 (rank 2)**. Sub-scores: Infrastructure 0.67, Permitting 0.86, Environmental 0.74, Geology 0.65. Distances: 45.0 km to battery-belt centroid, 347.3 km to port, 73.1 km to Kings Mountain. Kings-Mountain bonus: +4.30 pp.

Techno-Economic Anchor. Hard-rock + DLE near-term (25 ktpa LCE nameplate). Same case-row as rank-1; the differentiating metric is grade-uncertainty (indicated rather than measured) which propagates into the CV of the recovery prior.

Bayesian NPV. Bull / DLE: positive expected NPV with broadly similar IRR distribution to rank-1 but slightly wider tails (the recovery prior has higher CV given indicated class). Base scenario: deeply negative.

Strategic Position. Nearest battery anchor: Albemarle Kings Mountain at 73.1 km.

Why it ranks here. Tightest infrastructure profile of the Top-5 (battery-belt sub-score 0.80, second only to APP-PEG-0062's 0.78); permitting is the single highest-scoring panel value (0.86). Held back from rank-1 only by the lower USGS economic probability and the lower deposit-class confidence.

8.3 APP-PEG-0126 – Carolina Tin-Spodumene Belt (TN): Rank 3, CSVI 68.4/100

Identification.

State: TN | Province: Southern | District: Carolina Tin-Spodumene Belt | Class: *indicated* | Lithology: S-type granite pegmatite | Land: private | p_{economic} : 0.625 | Lat/Lon: 33.927, -84.463 | First reported: 1919.

Resource. 0.57 Mt ore at **1.39% Li₂O** (highest grade in the Top-5) (→ 12.22 kt LCE recoverable). Deposit area 0.50 km², depth-to-top 66.7 m.

Geospatial Viability. CSVI **68.4/100 (rank 3)**. Sub-scores: Infrastructure 0.51 (lowest of the Top-5; further from Kings Mountain), Permitting 0.86, Environmental 0.88 (highest), Geology 0.63.

Techno-Economic Anchor. High-grade pegmatite favours conventional acid-roast operability (beta-spodumene flowsheet is well characterised at ≥1% Li₂O concentrate [Salakjani et al.(2019)Salakjani, Singh, and Nikoloski]); DLE remains the higher-margin path.

Bayesian NPV. Bull / DLE: positive expected median NPV. Base: negative; rank-3 has the *deepest grade prior* of any Top-5 project (1.39% Li₂O is the highest grade), which helps but cannot rescue the base scenario.

Strategic Position. Nearest battery anchor: Ultium Cells Spring Hill (TN) at 303.1 km – the only Top-5 prospect outside the 90-km radius of Kings Mountain.

Why it ranks here. **The highest-grade prospect in the Top-5**, and a strong environmental score (low population density, low water-buffer constraint). Held back by infrastructure (battery-belt centroid distance 77 km vs. 45 km for rank-2) and a smaller absolute resource (12 kt LCE, lowest in the Top-5 except rank-4).

8.4 APP-PEG-0105 – Hiddenite (NC): Rank 4, CSVI 66.2/100

Identification.

State: NC | Province: Southern | District: Hiddenite | Class: *inferred* | Lithology: amphibolite-hosted spodumene pegmatite | Land: private | p_{economic} : 0.276 | Lat/Lon: 35.472, -82.046 | First reported: 1997.

Resource. 0.59 Mt ore at 0.86% Li₂O (→ 3.50 kt LCE recoverable – the smallest in the Top-5). Deposit area 0.28 km², depth-to-top 13.9 m.

Geospatial Viability. CSVI **66.2/100 (rank 4)**. Sub-scores: Infrastructure 0.65, Permitting **0.89** (highest in the panel), Environmental 0.79, Geology 0.38 (the smallest geological-strength score of any Top-5 project).

Techno-Economic Anchor. Conventional pathway preferred at this grade and tonnage scale; DLE only marginally additive at 3.5-kt-LCE recoverable.

Bayesian NPV. The *inferred* deposit class drives a 30%-CV recovery prior, which fattens the negative tail. Bull / DLE: positive expected NPV but a meaningfully larger P(NPV < 0) than rank-1.

Strategic Position. Nearest battery anchor: Albemarle Kings Mountain at 68.6 km (closest of the Top-5).

Why it ranks here. The closest project to Kings Mountain in the panel and the highest-permitting-score Top-5 entry. Held back by smallest recoverable LCE in the Top-5 and the *inferred* deposit class. Best treated as a near-term *tuck-in* for an integrated Kings Mountain operator rather than a standalone development.

8.5 APP-PEG-0129 – Foote Mine District (TN): Rank 5, CSVI 66.0/100

Identification.

State: TN | Province: Southern | District: Foote Mine District | Class: *indicated* | Lithology: complex zoned pegmatite | Land: **state** | p_{economic} : 0.570 | Lat/Lon: 35.389, -82.216 | First reported: 1895.

Resource. 0.76 Mt ore at **1.44% Li₂O** (→ 15.28 kt LCE recoverable). Deposit area 0.81 km², depth-to-top 52.3 m.

Geospatial Viability. CSVI **66.0/100 (rank 5)**. Sub-scores: Infrastructure 0.64, Permitting 0.68, Environmental 0.75, Geology 0.61. Land ownership is **state** (the only non-private Top-5 entry); this drops the ownership sub-score from 1.0 to 0.6 and is the principal reason this prospect ranks below the rank-2/3 cluster despite the highest grade in the Top-5 (1.44% Li₂O is shared with rank-3).

Techno-Economic Anchor. High-grade complex zoned pegmatite at 1.44% Li₂O is the *best geological case* in the Top-5 for the conventional acid-roast circuit (beta-spodumene yield from a >1.4% concentrate is favourable). The DLE pathway remains higher-OpEx-margin; the gap, however, is narrower at this grade.

Bayesian NPV. Bull / DLE: positive expected median NPV; Bull / Conventional: also positive. Base: negative under both. The *state-land* permit overlay implies a longer state-coordination component on the FAST-41 schedule than for the rank-1 to rank-4 private-land projects – this is the most material schedule-risk delta among the Top-5.

Strategic Position. Nearest battery anchor: Albemarle Kings Mountain at 80.9 km. Foote Mine District is the historical Carolina-tin-spodumene-belt epicentre and the natural site of a historical spodumene processing plant; brownfield-style restart synergies are real.

Why it ranks here. Highest grade (tied with rank-3); strongest historical processing heritage. Held back by state-land ownership and a slightly weaker permitting overlay.

9 Risk Register and Conclusions

9.1 Top-Tier Risks

1. **Lithium price.** The base case (\$20,000/t LCE) is value-destructive at every Top-5 project and pathway; only the bull case (\$35,000/t) clears institutional IRR thresholds, and only at the rank-1 prospect. Recent BNEF and Benchmark Mineral Intelligence forecasts [[BloombergNEF\(2025\)](#), [Benchmark Mineral Intelligence\(2026\)](#)] place 2026–2030 prices in the \$15–22 k/t LCE band; the report’s modelled investment case is therefore strongly path-dependent.
2. **Permitting.** Permitting absorbs 35.2% of the schedule budget and is the largest single driver of end-to-end project duration. FAST-41 designation, a Section 41-class lead-agency sequencing, and state-level coordination commitments are the most material policy levers.
3. **DLE technological maturity.** The DLE pathway’s \$1,400/t OpEx advantage and 12-pp recovery advantage are based on engineering-envelope projections from adapted brine-DLE pilots. A pilot-to-commercial scale-up failure would push the entire portfolio into the (more expensive) US Greenfield acid-roast benchmark, with material consequences for the rank-2 to rank-5 cluster where the conventional pathway’s IRR is below DLE’s.
4. **IRA/30D/45X policy stability.** Section 45X is worth \$680/t LCE at portfolio weighted-average OpEx, contributing \$126.5M (NPV) over the 10-year horizon. A repeal or material narrowing of Section 45X would push the rank-1 (Bessemer City, AL) project’s *base-case*

$P(\text{NPV} > 0)$ further toward zero.

5. **Refining capacity.** The Top-5 portfolio operating at 100 ktpa LCE on its own does not eliminate Chinese refining concentration; it shifts battery-grade refining from 76% to 67% Chinese share. Domestic refining capacity is the binding bottleneck downstream of the mine and must be developed in parallel.

9.2 Recommendations and Concluding Observations

The 2.3-Mt USGS Appalachian endowment does support a credible domestic 100-ktpa-by-2035 plan, but only if a tightly defined sub-set of Carolina-Tennessee prospects move on parallel critical paths. The specific recommendations are:

1. **Concentrate development capital on the Top-3 Southern-province cluster** (Bessemer City AL, Cherryville TN, Carolina Tin-Spodumene Belt TN/GA) with the rank-4 and rank-5 projects treated as Kings-Mountain-anchored tuck-ins.
2. **Pursue FAST-41 designations and lead-agency NEPA streamlining** as the highest-leverage single-policy action; this alone moves the binding constraint share down and improves end-to-end schedule by an estimated 6–8 quarters in the upper tail.
3. **Co-develop a US-Southeast lithium-chemicals refining anchor** (whether Albemarle’s Kings Mountain restart, Piedmont’s Carolina Lithium plant, or a new greenfield) on a parallel critical path. The Top-5 mining portfolio without a regional chemicals plant materially under-realises the IRA 30D/45X policy stack.
4. **Use the DLE pathway as the upside case, not the base case.** The financial model shows DLE dominates conventional in median NPV and IRR at the rank-1 project under the bull scenario; treat its commercial maturity as a $\sim 30\%$ probability event by 2030 and explicitly plan a fallback to the conventional acid-roast benchmark.
5. **Anchor offtake commitments with the four within-90-km cell-plant operators** (Albemarle Kings Mountain, Toyota Liberty, Hyundai Metaplant, BlueOval). The 30D/FEOC-eligibility premium creates a structural offtaker surplus that should be capturable through forward-pricing mechanisms.

The Appalachian assessment is therefore best understood not as a transformational endowment that solves the US lithium-supply problem, but as a tightly geographically-clustered, policy- contingent, technically-novel opportunity to materially shift US import reliance and Chinese refining concentration over a 10-year horizon. The analytic envelope is real, the binding constraints are policy and technology, and the principal-vehicle for value capture is parallel mine + refining + offtake development in the Carolina-Tennessee corridor.

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