

## Reporting Summary

Nature Portfolio wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Portfolio policies, see our [Editorial Policies](#) and the [Editorial Policy Checklist](#).

### Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a Confirmed

- ☒ ☐ The exact sample size ( $n$ ) for each experimental group/condition, given as a discrete number and unit of measurement
- ☒ ☐ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
- ☒ ☐ The statistical test(s) used AND whether they are one- or two-sided  
*Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
- ☒ ☐ A description of all covariates tested
- ☐ ☒ A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
- ☐ ☒ A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
- ☒ ☐ For null hypothesis testing, the test statistic (e.g.  $F$ ,  $t$ ,  $r$ ) with confidence intervals, effect sizes, degrees of freedom and  $P$  value noted  
*Give  $P$  values as exact values whenever suitable.*
- ☒ ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
- ☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
- ☒ ☐ Estimates of effect sizes (e.g. Cohen's  $d$ , Pearson's  $r$ ), indicating how they were calculated

*Our web collection on [statistics for biologists](#) contains articles on many of the points above.*

### Software and code

Policy information about [availability of computer code](#)

Data collection

Data analysis

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio [guidelines for submitting code & software](#) for further information.

### Data

Policy information about [availability of data](#)

All manuscripts must include a [data availability statement](#). This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our [policy](#)

The authors declare that the main data supporting the findings of this study are available within the article and its Supplementary Information files.

## Research involving human participants, their data, or biological material

Policy information about studies with [human participants or human data](#). See also policy information about [sex, gender \(identity/presentation\), and sexual orientation](#) and [race, ethnicity and racism](#).

Reporting on sex and gender n/a

Reporting on race, ethnicity, or other socially relevant groupings n/a

Population characteristics n/a

Recruitment n/a

Ethics oversight n/a

Note that full information on the approval of the study protocol must also be provided in the manuscript.

## Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☒ Behavioural & social sciences ☐ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see [nature.com/documents/nr-reporting-summary-flat.pdf](https://nature.com/documents/nr-reporting-summary-flat.pdf)

## Behavioural & social sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description

The data are quantitative: leveled production costs derived from secondary, feasibility-stage engineering and economic data reported in company technical reports (NI 43-101 filings) for seven clay-based projects, benchmarked against published brine and hard-rock cost data. It is cross-sectional in that costs are compared across projects and technologies at a single point in time rather than tracked longitudinally, and non-experimental — the analysis is model-based (cost benchmarking plus sensitivity and scenario analysis), with no primary data collection or intervention.

Research sample

Research sample. The study analyzes seven clay-based (sedimentary) lithium extraction projects: Angel Island, TLC Lithium, Thacker Pass, Rhyolite Ridge, Tonopah Flats, and Bonnie Claire in Nevada, USA, and the Sonora Lithium Project in Sonora, Mexico. Together these span the three principal clay-extraction routes, hydrochloric acid leaching, sulfuric acid leaching, and sulfate salt roasting. These are benchmarked against global brine and hard-rock operations (operating, under-development, and announced) used as comparison cases.

Representativeness and rationale. The sample is a purposive near-census rather than a random sample: it comprises essentially all clay-based lithium projects for which publicly available, sufficiently granular project-level cost data existed at the time of analysis. Projects were included on the basis of data availability and disclosure quality, and known clay projects lacking published cost data (e.g., the Jadar Project in Serbia and various Chinese clay deposits) were necessarily excluded. As such, the sample is representative of the three dominant clay-extraction technologies and of the current North American clay-development pipeline, but it is geographically concentrated (six of seven projects in Nevada/Sonora closed-basin systems) and therefore not fully representative of the global distribution of clay resources. This is the appropriate and defensible sample because the study's aim is a like-for-like process-based cost benchmark, which requires the detailed, standardized engineering-economic disclosures that only these reports provide.

Datasets and sources. The analysis uses existing secondary datasets rather than primary data collection. Project cost data are drawn from company technical reports — preliminary economic assessments, pre-feasibility and definitive feasibility studies, mineral resource estimates, and NI 43-101 technical reports prepared by certified qualified persons and filed with the U.S. Securities and Exchange Commission. Benchmark costs for conventional sources come from S&P Global Market Intelligence (2019) lithium cost outlook data and from a prior compilation of publicly available mining-company reports (Wesselkaemper et al., 2025). Where reports lacked specific cost line items, missing values were filled using process-based techno-economic back-calculation from disclosed operating parameters (e.g., reactor sizes, throughput, retention times, reaction stoichiometry), as described in the Methods.

Sampling strategy

Sampling procedure. The sampling is best described as purposive, complete-enumeration (total-population / census) sampling — not random, snowball, or stratified. Rather than drawing a probabilistic sample from a larger frame, we included the entire accessible population: every clay-based lithium project for which publicly available, sufficiently granular project-level cost data existed at the time of analysis. Selection was therefore driven by two purposive inclusion criteria — (i) presence of a filed technical/feasibility report and (ii) cost disclosure detailed enough to support process-step decomposition — applied to the known universe of clay projects. It has a stratification-like feature only in that the resulting seven projects collectively cover all three principal extraction technologies, but projects were not sampled to fill technology strata; the technology coverage is an outcome of enumerating the available population.

Sample size determination. No statistical sample-size or power calculation was performed, and none is applicable: the study is a deterministic techno-economic cost analysis, not an inferential study estimating a population parameter or testing a hypothesis, so there is no sampling distribution against which to power an n. The sample size (seven projects) was not chosen a priori but was fixed by data availability — it represents the near-complete set of clay projects meeting the disclosure criteria above. Rationale for sufficiency. The seven projects are sufficient for the study's aim because they (i) constitute essentially the full accessible population rather than a subsample, (ii) span all three dominant clay-extraction routes, allowing complete cross-technology comparison, and (iii) draw on seven independently prepared reports from different corporate sponsors, so process-technology averages reflect inter-project variation rather than any single forecast. Because the objective is a like-for-like cost benchmark and optimization-pathway analysis rather than statistical generalization, robustness is established not through sample size but through individual, bilateral, and multi-driver sensitivity and scenario analyses (20–70% variation of each major cost driver), which characterize how conclusions hold across a wide range of plausible input values. Qualitative data / saturation. Not applicable — the study uses quantitative cost data and does not involve qualitative data collection, coding, or thematic analysis, so data-saturation criteria were not relevant. The conceptual analogue we did apply is coverage completeness: sampling was bounded by exhausting the population of projects with adequate public cost data and by covering all three available extraction technologies, at which point no further eligible cases remained to include.

Data collection

n/a

Timing

n/a

Data exclusions

n/a

Non-participation

n/a

Randomization

n/a

## Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

### Materials & experimental systems

### Methods

- n/a
- Involved in the study
- ☒ ☐ Antibodies
- ☒ ☐ Eukaryotic cell lines
- ☒ ☐ Palaeontology and archaeology
- ☒ ☐ Animals and other organisms
- ☒ ☐ Clinical data
- ☒ ☐ Dual use research of concern
- ☒ ☐ Plants

- n/a
- Involved in the study
- ☒ ☐ ChIP-seq
- ☒ ☐ Flow cytometry
- ☒ ☐ MRI-based neuroimaging

### Plants

Seed stocks

n/a

Novel plant genotypes

n/a

Authentication

n/a