

Research Paper

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Assessing the Potential of Bio-Based Battery Material Innovations: Evidence from an Expert Survey

Bio-based materials could reduce the environmental and supply-chain burdens of batteries, but their technical and economic consequences remain uncertain. This paper addresses these uncertainties by eliciting judgments from 35 experts who evaluated six bio-based battery innovations across various dimensions, including specific energy, lifetime, material cost, production cost, carbon-dioxide emissions, and recycling capability. Across 210 innovation ratings, favorable impacts were most frequently expected for carbon-dioxide emissions (81.9%), material cost (70.5%), recycling (61.9%), and production cost (53.8%). By contrast, 55.7% of ratings anticipated negative impacts on specific energy and lifetime. An exploratory ordinal scoring exercise identified bio-based anode binders as having the most favorable overall profile, whereas bio-based cathode active material presented the greatest performance concerns. Most maturity assessments placed the innovations within ten years of practical readiness. These findings reveal a consistent tension between environmental promise and electrochemical performance, identifying priorities for laboratory validation, lifecycle assessment, and targeted research investment.

Keywords: Battery research, Bio-based battery materials, Expert elicitation, Technology assessment, Innovation management.

1. Introduction

Rapid growth in battery deployment is increasing demand for raw materials, energy-intensive manufacturing, and effective end-of-life management (Ihlbrock et al., 2025). Although battery electrification can reduce emissions during vehicle or device operation, these benefits do not eliminate environmental burdens

associated with material extraction, component production and recycling (Gutsch and Leker, 2024). Substituting renewable, biologically derived or bio-processed materials for conventional battery components could reduce lifecycle emissions, facilitate material recovery and diversify supply chains (Liedel,

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2020; Liu et al., 2021). Bio-based materials may be relevant to electrodes, binders, separators, electrolytes and supporting components, but their suitability depends on more than renewable origin. They must also satisfy demanding requirements for energy density, stability, manufacturability, cost, and safety (Dühnen et al., 2020).

Research in this area is therefore confronted by a prioritization problem. Many candidate technologies appear environmentally attractive, yet comparative evidence remains limited and maturity varies substantially among pathways. Decisions about which concepts should proceed to laboratory development, pilot manufacturing, or system-level assessment often must be made before reliable engineering and lifecycle data are available. Expert elicitation cannot replace those data, but it can expose shared expectations, uncertainty, and potential trade-offs at an early stage (for more details on the expert elicitation method, see e.g. Morgan, 2014 and Hanea et al., 2021).

In this study, we elicited expert assessments of six proposed bio-based battery innovations: (I) Bio-based graphite, (II) bio-based cathode active material (CAM), (III) bio-based separators, (IV) bio-based electrolytes, (V) bio-based anode binders, and (VI) bio-based cathode binders. Respondents evaluated the expected direction and magnitude of each innovation's impact across several assessment dimensions: specific energy, battery lifetime or cycling stability, material cost, production cost, carbon-dioxide (CO₂) emissions, and recycling capability. We also asked the experts to estimate the time required for each innovation to reach maturity. More specifically, we posed three questions: First, whether experts anticipated systematic environmental, economic or performance effects. Second, whether any innovation presented a comparatively favorable balance across these dimensions. Third, and finally, whether perceived benefits were aligned with expectations of near-term maturity.

This study was conducted as part of the interdisciplinary research project BIOSTORE ("Biologization of Batteries and Materials: Developing the Battery of the Future"), located at the University of Münster, Germany. The BIOSTORE project addresses the pivotal challenge of sustainability in the battery sector. More specifically, it

investigates the potential of the so-called biologization of batteries – a technique through which some commonly used battery components are replaced by bio-based alternatives. This process potentially enables the development of more sustainable energy storage devices while ensuring comparable performance. The BIOSTORE project comprises experts from a wide range of disciplines, including biology, chemistry, engineering, political science, economics, and law. At the time the expert survey and data analysis were conducted, the authors of this study were postdoctoral researchers within this research project. For more information on this project, see Schmid et al. (2025) and Bröker & Flothkötter (2026).

The paper proceeds as follows. Section 2 outlines the methods, detailing the survey design and the data analysis approach. Section 3 presents the results of the study. Finally, Section 4 offers a discussion of the findings along with an outlook on future research.

2. Methods

To assess how selected bio-based battery innovations could potentially affect performance, costs, and the environmental footprint, we conducted an online expert survey between December 2025 and January 2026. The survey provides the empirical basis for this study. Regarding the survey design, as briefly mentioned in the introduction, the questionnaire described the following six candidate bio-based battery innovations:

(I) Bio-based graphite is an alternative to conventional graphite used in lithium-ion batteries. Unlike traditional graphite sourced from fossil resources, bio-based graphite is derived from renewable biomass, such as vegetable carbon (biochar). This material aims to reduce environmental impact while offering comparable performance.

(II) Bio-based cathode active materials are innovative alternatives to conventional metal-based cathodes in lithium-ion batteries. Instead of relying on mined metals like cobalt or nickel, these materials utilize organic compounds derived from renewable biomass sources. They aim to reduce dependence on critical raw materials while providing stable electrochemical performance and improved environmental sustainability.

(III) Bio-based separators are a novel alternative to conventional battery separators made from fossil-derived polymers such as polyethylene (PE). These innovative materials are produced from renewable sources such as polysaccharides (e.g., cellulose or chitosan). They aim to maintain or improve battery safety and performance while reducing environmental impact and dependence on fossil resources.

(IV) Bio-based electrolytes represent an emerging class of electrolyte solvents designed to replace conventional fossil-derived mixtures such as ethylene carbonate (EC) and ethyl methyl carbonate (EMC) in lithium-ion batteries. These alternatives are derived from renewable feedstocks and aim to match or exceed the electrochemical stability, ionic conductivity, and safety performance of standard solvents. The substitution may influence overall system performance, cost structures, and environmental impact.

(V / VI) Bio-based binders serve as renewable alternatives to traditional polymer binders in lithium-ion batteries. Sourced from natural materials such as polysaccharides (starch, alginate) or lignin, these binders aim for strong adhesion of active materials to current collectors while maintaining flexibility and conductivity. By replacing petroleum-derived binders, they contribute to greener and more sustainable battery manufacturing. The type of binder also affects the processing of electrodes. As this can differ for anodes and cathodes, the experts were questioned separately regarding the anode and cathode side, resulting in a total of six different innovations.

The full descriptions of these battery innovations were provided to the survey participants in the questionnaire, which can be found in the Appendix to this paper. Participants rated each innovation across several criteria: specific energy, lifetime or cycling stability, material cost, production cost, carbon-dioxide emissions, and recycling capability.

For each dimension, responses comprised strong negative impact (>15%), moderate negative impact (5–15%), weak negative impact (<5%), weak positive impact (<5%), moderate positive impact (5–15%), and strong positive impact (>15%). Alternatively, the participants could choose “I don’t know”. Positive responses indicated improvement relative to NMC811-graphite lithium-ion

battery cells which served as a reference point/cell; for cost and emissions, improvement meant a reduction. “I don’t know” represented insufficient knowledge and was not treated as a neutral judgment.

Participants also assessed time to maturity as under five years, five to ten years, more than ten years, never, or “I don’t know”. As mentioned above, the survey was administered online. Participants were recruited through e-mail and were eligible if they self-identified as experts in the battery field. Regarding the data analysis, it should be noted that all data processing and visualizations were conducted using Python. The data analyzed in this study are available from the authors upon request.

3. Results

3.1 Environmental promise accompanied by performance concerns

Thirty-five participants completed the survey, comprising 26 respondents from academia, six from industry, and three reporting other professional roles. Since each participant evaluated all six innovations, the survey yielded 210 innovation-level ratings. To account for this structure, analyses distinguished between the 35 participants as the independent observational units (i.e., 35 participant-level observations) and the individual ratings (i.e., 210 innovation-level ratings). Finally, response distributions were summarized descriptively by impact dimension and innovation.

Across the complete set of ratings, experts expressed the greatest optimism about carbon-dioxide emissions. Of the 210 assessments, 81.9% classified the expected emissions effect as positive, meaning that the innovation was expected to reduce emissions relative to an NMC811-graphite cell. Material cost received favorable assessments in 70.5% of ratings, recycling capability in 61.9%, and production cost in 53.8%. These responses suggest that experts regarded the principal value of bio-based battery materials as being environmental and resource-related rather than serving as an immediate route to improved electrochemical performance.

Performance assessments were substantially less favorable. Negative impacts were reported in 55.7% of ratings for specific energy and in 55.7% for lifetime or

cycling stability. Thus, the same innovation portfolio that was widely expected to improve emissions, costs or end-of-life management was also expected to create performance penalties. This pattern represents the central result of the elicitation: experts did not interpret biological origin as an unqualified sustainability advantage. Rather, they anticipated a trade-off in which upstream and end-of-life benefits might be achieved at the expense of energy storage performance or durability.

3.2 Innovation profiles reveal different research priorities

To compare the six innovation profiles in Figure 1, the ordered response categories were transformed into an exploratory score as follows: strong negative impact (-2), moderate negative (-1), weak negative (-0.5), weak positive (+0.5), moderate positive (+1), and strong positive impact (+2). The response "I don't know" was excluded from the data evaluation, reducing the number of evaluated responses to 24-34 answers per category (indicated by the number (n) in Figure 1).

The heatmap in Figure 1 demonstrates that expected environmental benefits were comparatively consistent across the innovation portfolio, particularly for carbon-dioxide emissions. By contrast, specific energy and lifetime varied more strongly among innovations and generated most of the negative scores. Innovation V, bio-based anode binders, had the most favorable aggregate profile under the exploratory scoring convention. Its relative advantage arose from favorable emissions,

recycling and cost assessments with comparatively limited performance penalties. Innovation II, bio-based cathode active material, received the least favorable assessments for specific energy and lifetime.

These profiles should not be mistaken for a definitive league table. The innovation identifiers are nominal, the assigned scores are not measurements on a continuous scale, and the sample does not support precise population estimates. More usefully, Figure 1 distinguishes three possible development strategies. Innovations with favorable environmental assessments and limited performance penalties are candidates for accelerated validation. Innovations with substantial environmental promise but pronounced energy or lifetime penalties require coupled materials and cell-engineering research. Innovations characterized by uncertainty across several dimensions require better definition and preliminary evidence before comparative prioritization is meaningful.

3.3 Most pathways are expected to mature within a decade

Respondents also estimated the time required for each pathway to reach maturity using the following categories: less than five years, five to ten years, more than ten years, never, and "I don't know". Across all 210 assessments, five to ten years was the most common response, accounting for 38.1% of ratings, while 30.5% anticipated maturity in under five years. Taken together, 68.6% of ratings placed maturity within ten years.

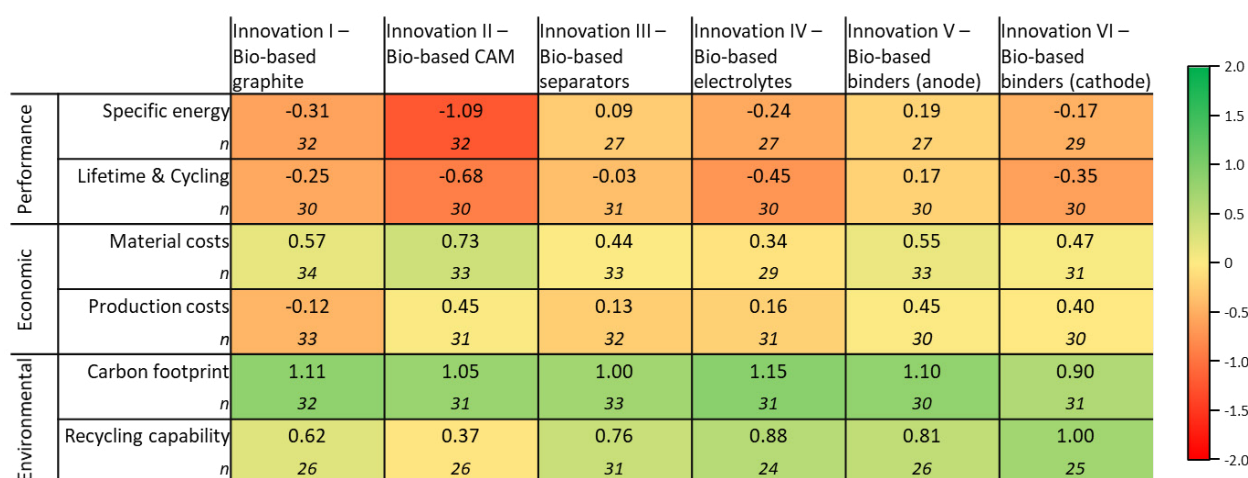


Figure 1. Heatmap of mean ordered scores by innovation and impact field (green = positive, red = negative, n = number of evaluated responses).

As summarized in Figure 2, these maturity distributions nevertheless differed substantially among the innovations. Bio-based graphite, bio-based separators and bio-based anode binders attracted the largest proportions of assessments within the shorter maturity categories, whereas bio-based CAM and bio-based electrolytes received more assessments of over ten years or “I don’t know”. These differences matter because a favorable environmental profile has limited immediate relevance if the underlying technology remains technically immature. Conversely, a moderately beneficial pathway that can be integrated into existing manufacturing processes may deliver earlier cumulative sustainability gains than a more ambitious but distant alternative.

Maturity judgments should not be interpreted as deployment forecasts. Respondents were asked to summarize expectations rather than construct probabilistic forecasts from technical-readiness, manufacturing and market evidence. The distributions are therefore better understood as indicators of perceived development difficulty. They can guide the sequencing of follow-up work but cannot establish commercialization dates.

3.4 Professional groups provide only exploratory contrasts

Figure 3 presents normalized impact-response distributions separately for academic and industry respondents. While both groups showed broadly favorable expectations for environmental dimensions alongside shared concerns about specific energy and lifetime, some apparent descriptive differences are visible across roles. However, because the industry (n=6) and “Other” (n=3) subsamples were too small compared to academia (n=26), these role comparisons were not tested inferentially.

The role comparison is consequently descriptive. Normalization prevents the larger academic group from dominating the visual display, but it does not overcome the uncertainty associated with small group sizes. No claim of systematic academic–industry disagreement is warranted from these data. A larger, deliberately stratified elicitation would be needed to determine whether views differ by sector, disciplinary background, battery expertise or position within the innovation chain.

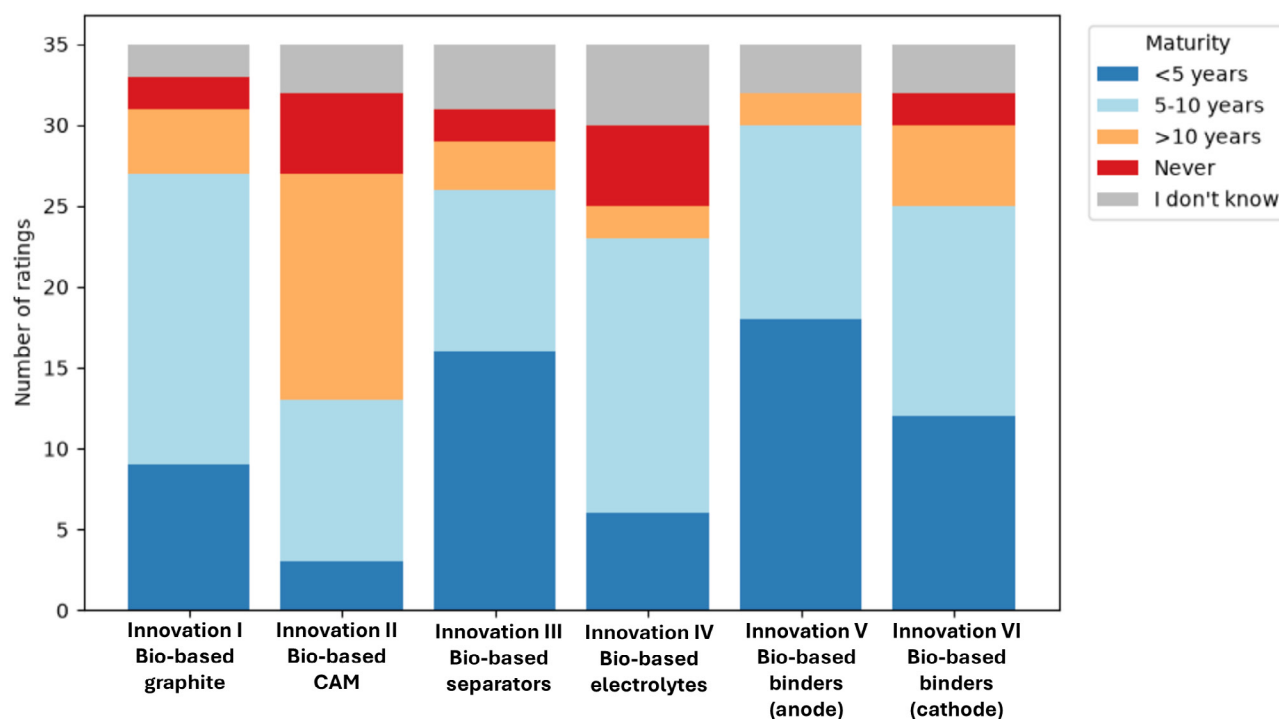


Figure 2. Maturity expectation distributions by innovation.

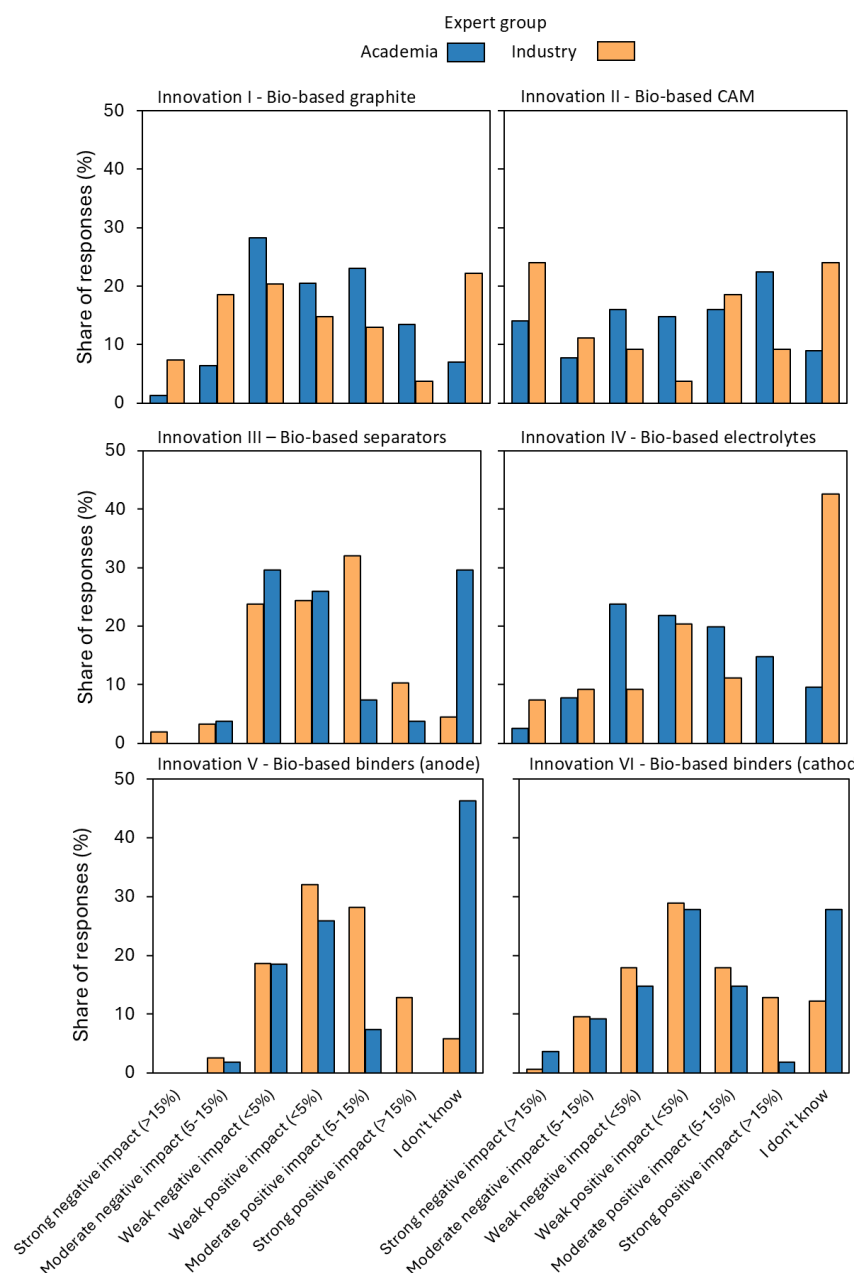


Figure 3. Role split normalized impact response distributions (Academia vs Industry).

4. Discussion and Outlook

Our results identify a clear asymmetry in expert expectations. Bio-based battery innovations were primarily valued for prospective reductions in carbon emissions, material costs, and end-of-life burdens, while their principal perceived liabilities concerned specific energy and lifetime. This finding has a straightforward but important implication: renewable material origin alone is an inadequate criterion

for research prioritization. A material that reduces production emissions but shortens battery lifespan may increase replacement frequency and offset part—or conceivably all—of its initial environmental advantage. Likewise, improved recyclability offers limited system-level benefit if lower energy density increases material requirements per unit of delivered storage.

The dimensions assessed here are increasingly regulatory as well as technical criteria, as the EU

Batteries Regulation (see European Union, 2023), currently the most comprehensive framework of its kind, illustrates (Carratta, 2025). First, the Batteries Regulation requires carbon footprint declarations and foresees performance classes and maximum thresholds for electric-vehicle, light-means-of-transport and larger rechargeable industrial batteries (Art. 7). Because the carbon footprint is expressed per kWh of total energy delivered over the battery's expected service life, the emission reductions experts anticipated will count in regulatory terms only if they are not eroded by the specific-energy and lifetime penalties experts also expected. Second, the Regulation introduces minimum performance and durability requirements (Art. 10), so that lifetime penalties become a question not only of competitiveness but potentially of market access. Third, recycling targets and recycled-content obligations (Arts. 8 and 71) reward the recovery of specific metals, to which bio-based binders, separators and electrolytes contribute little (Schlehuber et al., 2026). As comparable requirements emerge in other jurisdictions, research prioritization should consider not only expected technical and environmental performance but also how each innovation would fare under the regulatory metrics that govern market entry.

At the technical level, research programs should therefore evaluate bio-based components at cell and lifecycle levels rather than treating component substitution as an isolated materials problem. For relatively mature pathways such as bio-based anode binders, bio-based separators, or bio-based graphite the next step should be comparative testing against a clearly specified conventional benchmark, accompanied by prospective lifecycle and techno-economic assessment. Critical outcomes include energy and power density, degradation, safety, manufacturing yield, feedstock variability, energy demand, and recovery efficiency. For less mature pathways, funding should focus on resolving the mechanisms underlying the anticipated performance penalties.

The findings also support a portfolio rather than winner-takes-all funding strategy. Near-term investment can prioritize pathways combining environmental benefit, manageable performance risk, and expected maturity within ten years. Longer-term funding should preserve potentially transformative concepts whose present

technical limitations may be addressed through hybrid materials, protective interfaces, electrode architecture, or cell-level redesign. Figure 1 should consequently be used to formulate research questions, not to terminate work on low-ranked innovations.

However, several limitations warrant a cautious interpretation of the results. First, 35 participants are sufficient for an exploratory elicitation but not for representative estimates of a heterogeneous global expert community. The sample was dominated by academics, and recruitment may have introduced professional, geographic, or network selection bias. Second, expertise was represented only through broad occupational categories; future surveys should document disciplinary specialization, years of experience, battery component expertise, and familiarity with each innovation. Third, respondents assessed short innovation descriptions rather than standardized technical specifications. Differences in assumed feedstocks, processing routes, system boundaries, or reference technologies may therefore explain part of the observed variation. Fourth, the response categories combine direction and approximate percentage magnitude, but respondents may not have applied those thresholds consistently. Fifth, the ordered-score ranking depends on an arbitrary numerical mapping. The number of evaluated responses is further decreased by the exclusion of the "I don't know" answers from the ordered-score ranking. Finally, elicited expectations are hypotheses, not empirical demonstrations of sustainability performance.

Despite these limitations, the survey offers a useful early-stage diagnosis. Experts consistently identified environmental opportunities but were unwilling to assume that bio-based materials would preserve battery performance. Innovation V, bio-based anode binders, emerged as the most balanced candidate under the exploratory comparison, whereas Innovation II, bio-based CAM, requires particular attention to specific energy and lifetime. The immediate priority is not to declare a universal winner, but to convert these judgments into testable comparisons. Coordinated electrochemical testing, lifecycle assessment, techno-economic analysis and pilot manufacturing can determine whether the anticipated environmental gains survive real-world performance constraints.

Funding

This study was supported by the Ministry of Culture and Science (MKW) of the State of North Rhine-Westphalia (NRW) as part of the research project BIOSTORE (no. PB22-014).

Statement of AI Usage

Generative artificial intelligence (AI) tools were used solely for language editing and manuscript refinement. All scientific content, analyses, interpretations, and conclusions remain the sole responsibility of the authors.

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Appendix : BIOSTORE Expert Survey Questionnaire

Assessing the potential of bio-advanced battery innovations

Dear participant,

we invite you to share your expertise by taking part in this 10-minute survey. The aim of the survey is to find out how a set of battery innovations could potentially impact performance, costs and environmental impacts.

As a reference point, we define the status quo as an **NMC811-graphite lithium-ion battery cell** with ethylene carbonate (EC) and ethyl methyl carbonate (EMC) in a 3:7 ratio as electrolyte containing 1M LiPF₆, and a polypropylene/polyethylene (PP/PE) separator produced on an industrial scale. On the cathode side, polyvinylidene fluoride (PVDF) is used as a binder and *N*-methyl-2-pyrrolidone (NMP) as a processing solvent, while on the anode side, carboxymethyl cellulose/styrene-butadiene rubber (CMC/SBR) and water are used.

This reference cell has the following baseline values:

Specific energy: 0.25 kWh/kg

Cost: \$120 per kWh

Carbon footprint: 80 kg CO₂-eq per kWh

In the survey, each of these values is set at 100%, and you will be asked to estimate how different innovations compare to this baseline in terms several parameters. In this context, a **positive** impact is defined as an **increase** in specific energy, lifetime/cycling, and recycling capability, as well as a **decrease** in costs and carbon footprint. A **negative** impact is the opposite of this.

The survey is structured so that you answer the same questions for each innovation option, followed by some general questions about the innovations and about yourself to enable comparison.

Thank you for supporting our research!

The BIOSTORE-Team

* Erforderlich

Privacy Notice - GDPR Compliance

As part of our research project at the University of Münster, we are conducting a survey to gather data for academic purposes. This privacy notice is intended to inform you, in accordance with the General Data Protection Regulation (EU) 2016/679 (GDPR), about how your personal data will be processed.

Who is responsible for your data?

The data controller for this research project is the University of Münster, represented by the BIOSTORE Team. For any questions, you can contact us at biostore@uni-muenster.de.

Purpose of data collection

Your responses will be used solely for academic research purposes. The data collected will help us evaluate the opportunities and trade-offs of integrating new, nature-based components into established battery systems.

Legal basis for processing

Your participation is entirely voluntary. By agreeing to take part in this survey, you provide your informed consent for us to collect and process your data under Article 6(1)(a) GDPR.

What data we collect

The survey may collect the following:

- Anonymous responses to research questions
- Demographic data such as age, gender, or education level
- No personally identifiable data will be collected unless explicitly stated and consented to

Data storage and protection

All data will be securely stored on encrypted and password-protected systems. Only authorized members of the research team will have access to the data. No data will be shared with third parties or used for commercial purposes.

Data retention

Your data will be retained only as long as necessary to fulfill the research purpose and will be anonymized or deleted upon publication of the results.

Your rights

Under GDPR, you have the right to:

- Withdraw your consent at any time without consequences
- Access your data
- Request rectification or erasure
- Restrict or object to processing
- Lodge a complaint with a supervisory authority (e.g., the German Data Protection Authority)

Contact for data protection concerns

If you have questions about how your data is used, please contact Nina Meyer-Pachur, at nina.meyer-pachur@uni-muenster.de.

Innovation I: Bio-based Graphite

Bio-based graphite is an alternative to conventional graphite used in lithium-ion batteries. Unlike traditional graphite sourced from fossil resources, biobased graphite is derived from renewable biomass, such as vegetable carbon (biochar). This material aims to reduce environmental impact while offering comparable performance.

1. How do you think will this innovation impact the cell's... *

	Strong negative impact (> 15%)	Moderate negative impact (5- 15%)	Weak negative impact (<5%)	Weak positive impact (<5%)	Moderate positive impact (5- 15%)	Strong positive impact (> 15%)	I don't know
Specific Energy	☐	☐	☐	☐	☐	☐	☐
Lifetime/Cycling	☐	☐	☐	☐	☐	☐	☐
Material Cost	☐	☐	☐	☐	☐	☐	☐
Production Cost	☐	☐	☐	☐	☐	☐	☐
Carbon Footprint	☐	☐	☐	☐	☐	☐	☐
Recycling Capability	☐	☐	☐	☐	☐	☐	☐

2. How long do you think would it take for this innovation to be successfully introduced to the market (lab-research + scale-up)? *

- ☐ <5 years
- ☐ 5-10 years
- ☐ > 10 years
- ☐ Never
- ☐ I don't know

3. If possible, could you please elaborate on this?

Innovation II: Bio-based/Organic Cathode Active Material

Bio-based cathode active materials are innovative alternatives to conventional metal-based cathodes in lithium-ion batteries. Instead of relying on mined metals like cobalt or nickel, these materials utilize organic compounds derived from renewable biomass sources. They aim to reduce dependence on critical raw materials while providing stable electrochemical performance and improved environmental sustainability.

4. How do you think will this innovation impact the cell's... *

	Strong negative impact (> 15%)	Moderate negative impact (5- 15%)	Weak negative impact (<5%)	Weak positive impact (<5%)	Moderate positive impact (5- 15%)	Strong positive impact (> 15%)	I don't know
Specific Energy	☐	☐	☐	☐	☐	☐	☐
Lifetime/Cycling	☐	☐	☐	☐	☐	☐	☐
Material Cost	☐	☐	☐	☐	☐	☐	☐
Production Cost	☐	☐	☐	☐	☐	☐	☐
Carbon Footprint	☐	☐	☐	☐	☐	☐	☐
Recycling Capability	☐	☐	☐	☐	☐	☐	☐

5. How long do you think would it take for this innovation to be successfully introduced to the market (lab-research + scale-up)? *

- ☐ <5 years
- ☐ 5-10 years
- ☐ >10 years
- ☐ Never
- ☐ I don't know

6. If possible, could you please elaborate on this?

Innovation III: Bio-based Separators

Bio-based separators are a novel alternative to conventional battery separators made from fossil-derived polymers such as polyethylene (PE). These innovative materials are produced from renewable sources such as polysaccharides (e.g., cellulose or chitosan). They aim to maintain or improve battery safety and performance while reducing environmental impact and dependence on fossil resources.

7. How do you think will this innovation impact the cell's... *

	Strong negative impact (> 15%)	Moderate negative impact (5- 15%)	Weak negative impact (<5%)	Weak positive impact (<5%)	Moderate positive impact (5- 15%)	Strong positive impact (> 15%)	I don't know
Specific Energy	☐	☐	☐	☐	☐	☐	☐
Lifetime/Cycling	☐	☐	☐	☐	☐	☐	☐
Material Cost	☐	☐	☐	☐	☐	☐	☐
Production Cost	☐	☐	☐	☐	☐	☐	☐
Carbon Footprint	☐	☐	☐	☐	☐	☐	☐
Recycling Capability	☐	☐	☐	☐	☐	☐	☐

8. How long do you think would it take for this innovation to be successfully introduced to the market (lab-research + scale-up)? *

- ☐ <5 years
- ☐ 5-10 years
- ☐ >10 years
- ☐ Never
- ☐ I don't know

9. If possible, could you please elaborate on this?

Innovation IV: Bio-based Electrolytes

Bio-based electrolytes represent an emerging class of electrolyte solvents designed to replace conventional fossil-derived mixtures such as ethylene carbonate (EC) and ethyl methyl carbonate (EMC) in lithium-ion batteries. These alternatives are derived from renewable feedstocks and aim to match or exceed the electrochemical stability, ionic conductivity, and safety performance of standard solvents. The substitution may influence overall system performance, cost structures, and environmental impact.

10. How do you think will this innovation impact the cell's... *

	Strong negative impact (> 15%)	Moderate negative impact (5- 15%)	Weak negative impact (<5%)	Weak positive impact (<5%)	Moderate positive impact (5- 15%)	Strong positive impact (> 15%)	I don't know
Specific Energy	☐	☐	☐	☐	☐	☐	☐
Lifetime/Cycling	☐	☐	☐	☐	☐	☐	☐
Material Cost	☐	☐	☐	☐	☐	☐	☐
Production Cost	☐	☐	☐	☐	☐	☐	☐
Carbon Footprint	☐	☐	☐	☐	☐	☐	☐
Recycling Capability	☐	☐	☐	☐	☐	☐	☐

11. How long do you think would it take for this innovation to be successfully introduced to the market (lab-research + scale-up)? *

- ☐ <5 years
- ☐ 5-10 years
- ☐ >10 years
- ☐ Never
- ☐ I don't know

12. If possible, could you please elaborate on this?

Innovation V: Bio-based Binders

Bio-based binders serve as renewable alternatives to traditional polymer binders in lithium-ion batteries. Sourced from natural materials such as polysaccharides (starch, alginate) or lignin, these binders aim for strong adhesion of active materials to current collectors while maintaining flexibility and conductivity. By replacing petroleum-derived binders, they contribute to greener and more sustainable battery manufacturing.

The type of binder also affects the processing of electrodes. As this can differ for anodes and cathodes, the answers to the questions below are separated in anode and cathode side. Please answer the questions for both electrodes.

13. In terms of the **anode**, how do you think will this innovation impact the cell's... *

	Strong negative impact (> 15%)	Moderate negative impact (5- 15%)	Weak negative impact (<5%)	Weak positive impact (<5%)	Moderate positive impact (5- 15%)	Strong positive impact (> 15%)	I don't know
Specific Energy	☐	☐	☐	☐	☐	☐	☐
Lifetime/Cycling	☐	☐	☐	☐	☐	☐	☐
Material Cost	☐	☐	☐	☐	☐	☐	☐
Production Cost	☐	☐	☐	☐	☐	☐	☐
Carbon Footprint	☐	☐	☐	☐	☐	☐	☐
Recycling Capability	☐	☐	☐	☐	☐	☐	☐

14. How long do you think would it take for this innovation to be successfully introduced to the market (lab-research + scale-up)? *

- ☐ <5 years
- ☐ 5-10 years
- ☐ > 10 years
- ☐ Never
- ☐ I don't know

15. In terms of the **cathode**, how do you think will this innovation impact the cell's... *

	Strong negative impact (> 15%)	Moderate negative impact (5- 15%)	Weak negative impact (<5%)	Weak positive impact (<5%)	Moderate positive impact (5- 15%)	Strong positive impact (> 15%)	I don't know
Specific Energy	☐	☐	☐	☐	☐	☐	☐
Lifetime/Cycling	☐	☐	☐	☐	☐	☐	☐
Material Cost	☐	☐	☐	☐	☐	☐	☐
Production Cost	☐	☐	☐	☐	☐	☐	☐
Carbon Footprint	☐	☐	☐	☐	☐	☐	☐
Recycling Capability	☐	☐	☐	☐	☐	☐	☐

16. How long do you think would it take for this innovation to be successfully introduced to the market (lab-research + scale-up)? *

- ☐ <5 years
- ☐ 5-10 years
- ☐ > 10 years
- ☐ Never
- ☐ I don't know

17. If possible, could you please elaborate on this?

General questions about these innovations

18. How likely are you to be willing to pay up to 20% more for a bio-based LIB? *

0	1	2	3	4	5	6	7	8	9	10
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Not at all likely

Extremely likely

19. Can you give reasons for your choice above? *

20. Among the innovations described, which two have the greatest potential for industry? *

Wählen Sie 2 Optionen aus.

- ☐ Innovation I: Bio-based Graphite
- ☐ Innovation II: Bio-based/Organic Cathode Active Material
- ☐ Innovation III: Bio-based Separators
- ☐ Innovation IV: Bio-based Electrolytes
- ☐ Innovation V: Bio-based Binders

21. Can you explain your choice above in one sentence? *

22. How will the above innovations impact recycling? *

23. What is the most promising innovation for the next five years? Did we overlook any potential innovations in this field? *

About you

Finally, here are some last questions about yourself

24. What is your highest degree? *

- ☐ Apprenticeship
- ☐ Bachelor
- ☐ Master/Diploma
- ☐ PhD
- ☐ Sonstiges

25. What is your scientific background? *

- ☐ Natural Sciences
- ☐ Engineering
- ☐ Social Sciences
- ☐ Humanities
- ☐ Sonstiges

26. In which sector are you currently working? *

- ☐ Academia
- ☐ Industry
- ☐ Sonstiges

27. Based on your answer above, which sub-sector would you classify yourself in? *

28. How many years of experience do you have in your field? *

- ☐ <5 years
- ☐ 5 - 10 years
- ☐ 10 - 15 years
- ☐ 15 - 20 years
- ☐ >20 years

29. What age group do you belong to? *

- ☐ 18 - 25
- ☐ 26 - 35
- ☐ 36 - 45
- ☐ 46 - 55
- ☐ >55

30. Which gender do you identify with? *

- ☐ Male
- ☐ Female
- ☐ Non-Binary
- ☐ Prefer not to say
- ☐ Sonstiges

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 Microsoft Forms