Call - Cross-sectoral solutions for the climate transition

HORIZON-CL5-2021-D2-01

Conditions for the Call

Indicative budget(s)[[1]](#footnote-1)

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| Topics | Type of Action | Budgets (EUR million) | Expected EU contribution per project (EUR million)[[2]](#footnote-2) | Number of projects expected to be funded |
| 2021 | 2022 |
| Opening: 15 Apr 2021Deadline(s): 19 Oct 2021 |
| HORIZON-CL5-2021-D2-01-01 | RIA | 21.00 |  | 6.00 to 7.00 | 3 |
| HORIZON-CL5-2021-D2-01-02 | RIA | 24.00 |  | 6.00 to 8.00 | 3 |
| HORIZON-CL5-2021-D2-01-03 | RIA | 36.00 |  | 8.00 to 9.00 | 4 |
| HORIZON-CL5-2021-D2-01-04 | RIA | 20.00 |  | Around 5.00 | 4 |
| HORIZON-CL5-2021-D2-01-05 | RIA | 26.00 |  | 6.00 to 7.00 | 3 |
| HORIZON-CL5-2021-D2-01-06 | RIA | 30.00 |  | 9.00 to 10.00 | 3 |
| HORIZON-CL5-2021-D2-01-07 | CSA | 3.00 |  | Around 3.00 | 1 |
| HORIZON-CL5-2021-D2-01-08 | RIA | 20.00 |  | Around 2.50 | 8 |
| HORIZON-CL5-2021-D2-01-09 | RIA | 15.00 |  | 2.00 to 3.00 | 2 |
| HORIZON-CL5-2021-D2-01-10 | RIA | 2.00 to 3.00 | 2 |
| HORIZON-CL5-2021-D2-01-11 | RIA | 2.00 to 3.00 | 2 |
| HORIZON-CL5-2021-D2-01-12 | RIA | 10.00 |  | 3.00 to 4.00 | 3 |
| HORIZON-CL5-2021-D2-01-13 | CSA | 3.00 |  | 2.00 to 3.00 | 1 |
| HORIZON-CL5-2021-D2-01-14 | CSA | 2.00 |  | 2.00 to 3.00 | 1 |
| HORIZON-CL5-2021-D2-01-15 | CSA | 2.50 |  | Around 2.50 | 1 |
| HORIZON-CL5-2021-D2-01-16 | COFUND | 18.50 | 18.50 | N/A | 1 |
| Overall indicative budget |  | 231.00 | 18.50 |  |  |

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| **General conditions relating to this call** |
| *Admissibility conditions* | The conditions are described in General Annex A. |
| *Eligibility conditions* | The conditions are described in General Annex B. |
| *Financial and operational capacity and exclusion* | The criteria are described in General Annex C. |
| *Award criteria* | The criteria are described in General Annex D. |
| *Documents* | The documents are described in General Annex E. |
| *Procedure* | The procedure is described in General Annex F. |
| *Legal and financial set-up of the Grant Agreements* | The rules are described in General Annex G. |

A competitive and sustainable European battery value chain

Proposals are invited against the following topic(s):

HORIZON-CL5-2021-D2-01-01: Sustainable processing, refining and recycling of raw materials (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of between EUR 6.00 and 7.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 21.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 4-5 by the end of the project – see General Annex B. |

Expected Outcome: Raw materials need to be competitively processed and refined in Europe in a sustainable way, including reduced environmental footprint, and improved social aspects and competitiveness.

Project results will contribute to decreasing dependency of Europe on imported battery chemicals and raw materials. As a result new business opportunities and jobs will be created for the European industry.

Projects are expected to coordinate with projects funded under *Cluster 4 RESILIENCE Green and Sustainable Materials topics.* Projects are expected to contribute to European Raw Materials Alliance objectives.

Project results are expected to contribute to all of the following expected outcomes:

1. European low-grade deposits and secondary material sources such as tailings as source of nickel, cobalt and lithium are taken into use, reducing the European dependency on important materials by increasing refining capacity to battery grade materials in Europe. This requires innovative, cost-effective and safe extraction technologies;
2. Battery grade intermediates such as lithium hydroxide and precursor materials are competitively produced and refined in Europe in a sustainable and socially acceptable way, improving the competitiveness and value of European battery and mobility industries;
3. Reduced carbon emissions, increased energy efficiency, and more efficient resource use and yield, for example by increasing the capacity to re-process recycled lithium from spent batteries integrated in primary lithium processing;
4. New business opportunities and models for the European industry (e.g. joint processing, centralised Lithium refinery) creating additional jobs from increased processing and refining capacity.

Scope: In order to secure a competitive battery industry in Europe, innovations in chemical and metallurgical production are required. The focus is at improved yield, better process control, flowsheet flexibility, improved product purity and quality, improved impurity removal, and improved recovery from secondary streams. These innovations are in some cases complementary unit processes to existing process flow sheets, while in others, such as European lithium or precursor production, completely new flowsheets. These advancements are expected to bring the European battery metal and chemical production to a global leadership. The activities are expected to cover one or several bullets:

1. Solutions to a sustainable Lithium value chain, such as:
	1. Novel sorting technologies, new comminution method and alternative energy sources to improve energy efficiency, CO2 emissions and reduce water use in lithium processing and refining.
	2. Selective methods for lithium extraction from pegmatites and other Lithium bearing minerals and refining of lithium materials to battery grade chemicals or even to lithium metal. Improvement of stability of refined LiOH. Cross-connections to other relevant WP parts which cover raw materials issues (e.g. Cluster 4) will be established.
	3. Specification of physical-chemical properties for Lithium deposits, to foresee how the mineral mix could be better processed.
2. New refining processes to increase value and yield from European mines and sustainably sourced and imported (nickel and cobalt) raw materials, but also from process waste, side streams, recycled materials, mine tailings and other non-conventional sources.
3. Improvements in performance and efficiency of existing (nickel and cobalt) refining processes in Europe, e.g. by implementing new methodologies to reduce carbon emissions, increasing energy and resource efficiency, raw material flexibility and substitution of fossil fuels.
	1. Development of new recoverable reagents and processes and real-time composition analysis for battery metal leaching and extraction to reduce waste and improve material efficiency
	2. New smelting and slag engineering technologies to address Ni and Co losses in smelting
4. Development of continuous processes for precursor materials (pCAM) to replace the currently used batch processing, including:
	1. Process control solutions for different cathode active material recipes
	2. Complete process design concepts including filtration, gas supply, mixing ratios, flow control, fluidised process solutions, and process automation
	3. Process optimisation to minimise and/or recover off-specification battery metals and compounds.
5. Zero Liquid Discharge processing in battery chemical and precursor material processing, including energy cascading and waste valorisation
6. New business models for co-processing and process integration
7. Process modelling competence combined with environmental impact evaluation (incl. LCA) for individual primary processes, in collaboration with a project funded under HORIZON-CL5-2021-D5-01-04.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2021-D2-01-02: Advanced high-performance Generation 3b (high capacity / high voltage) Li-ion batteries supporting electro mobility and other applications (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of between EUR 6.00 and 8.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 24.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 6 and higher by the end of the project – see General Annex B. |

Expected Outcome: Projects are expected to contribute to the following outcomes:

1. Advanced Li-ion batteries delivering on cost, performance, safety, sustainability and recyclability, with clear prospects for cost-competitive large-scale manufacturing and uptake by the electro mobility as well as other application sectors.
2. Increase in energy density and hence increasing driving distance at reduced cost on module and pack level, inducing a broader customer’s acceptance.
3. Broader user acceptance leading to a significantly broader market penetration, helping to reduce GHG emissions of the transport and industry sectors to support EU’s efforts to become climate-neutral by 2050: demonstrated for recyclability.

Translating these outcomes into indicative KPIs to guide the R&I efforts, it is recommended to target the following for impact by 2025 and beyond:

1. Gravimetric, volume energy density at cell level of 350-400 Wh/kg, 750-1000 Wh/l respectively.
2. Power density at cell level of 700 W/kg, 1500+ W/L.
3. For high voltage application, operation at 4.7+ Volt.
4. 3000+ and 2000+ deep cycles for high capacity and high voltage applications respectively.
5. Cost at pack level < 100 euro/kWh.

Scope: The overarching R&I challenges lie in the development of advanced materials enabling higher energy / power density thanks to higher capacity (voltage range 4.3-4.5V) and/or operating at higher voltage (4.7+V). Focus is on adapting the cathode materials (high-nickel NMCs for capacity, spinels / Li-rich Mn NMCs for voltage), the anode materials (graphite-containing Si(Ox)), the electrolytes (stabilised formulations) and their interplay.

1. **For the higher capacity approach, focusing on maximising energy and power density should address topics such as**
	1. High-capacity cathode materials operating in 4.3-4.5 Volt range while delivering on cycle life, protective coatings for safety improvements;
	2. High-performance anodes with advanced graphite and silicon materials (increase Si content in Si/C anodes to achieve capacities ideally at 1000 mAh/g), - Other option is to, develop complete Si or other alloying anode solutions in nanostructured form;
	3. Suitable inactive materials (binders, conductive carbons, current collectors, separators);
	4. Electrolytes stable in 4.3-4.5 Volt (new additives and/or solvent systems), advanced processing routes for the novel materials and advanced electrode and cell/module designs.
2. **For the higher voltage approach, focusing on maximising energy and power density should address topics such as**
	1. High-voltage stable electrolyte systems (new electrolytes and/or new formulations);
	2. High-voltage stable cathode active materials (e.g. HV spinels, Li-rich Mn NMCs, phosphates, disordered materials etc. with lowered content in critical and high price elements, protective coatings);
	3. Tailoring and operando monitoring of the electrochemical interplay between the cathode active material and the electrolyte formation of stable SEI interfaces;
	4. Advanced high performance anodes matching these high-voltage cathodes and electrolytes;
	5. Structuring of the cathode and anode electrodes for among others their competition and electric conductivities.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2021-D2-01-03: Advanced high-performance Generation 4a, 4b (solid-state) Li-ion batteries supporting electro mobility and other applications (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of between EUR 8.00 and 9.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 36.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 5 by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Advanced Li-ion batteries delivering on cost, performance, safety, thermal stability, sustainability with clear prospects for cost-competitive large-scale manufacturing and uptake by electro mobility sector.
2. Increase in energy density and hence increasing driving distance at reduced costs on module and pack level, positively affecting the customer’s acceptance.
3. Broader user acceptance will help to reduce GHG emissions of the transport sector and support EU’s efforts to become climate-neutral by 2050.

Translating these outcomes into indicative KPIs to guide the R&I efforts, it is recommended to target the following for impact by 2030 and beyond:

1. Gravimetric energy density at cell level of 400+ Wh/kg volumetric energy density at cell level of 800+ Wh/l (Gen 4a) progressing to 1000+ Wh/l (Gen 4b).
2. Cycle life up to 3000 and beyond and ability to operate at charging rate of 3-5C (for aviation up to 10C).
3. Cost at pack level down to below 75 euro/kWh.
4. High-power variants for fast charging, airborne, heavy-duty, hybrid segments targeting >500W/kg and >700 W/l.

Scope: The overarching R&I challenges lie in the development of solid-state electrolytes, cathode materials and anode materials enabling higher thermal and electrochemical stability while targeting higher energy / power densities, fast charging, cyclability and improved safety. These new materials should contribute in the control of thermal runaway at early stage, and create non-propagation designs. Developments should range from using conventional materials to using Li metal-based anode materials. Projects should be aligned with ongoing H2020 projects on the subject, especially from H2020-LC-BAT-2020 call and their publicly-available results.

1. **For Generation 4a (solid state with conventional materials) projects are expected to cover all bullets:**
	1. Developing low direct current resistance active materials;
	2. Reducing thickness of the anode;
	3. Developing thin solid electrolyte with high ionic conductivity;
	4. Developing concepts/strategies for manufacturing new solid electrolyte interlayers;
	5. Improving interface design to ensure efficient charge-transfer and electrochemical stability and improved cell mechanical stability;
	6. Proposed approach is expected to have no negative impact on energy densities, safety, and cyclability;
	7. Development of coating strategies for current collectors.
2. **For Generation 4b (solid state with Li metal-based anode materials) projects are expected to cover one or several bullets:**
	1. New materials and/or chemistries to increase the energy densities beyond the state of the art of batteries used in electro mobility applications.
	2. At the anode side, lithium metal appears as the most appealing choice in terms of gravimetric energy density.
	3. Improved reversibility, homogeneity and density of electrodeposition process by doping or coating strategies.
	4. Solutions for manufacturing and handling Li metal sheet in dry atmosphere.
	5. Novel solutions for low cost manufacturing strategies such as solvent-free electrode manufacturing and solid electrolyte deposition.
	6. Another technology (anode-less), could also be developed by designing current collectors for reversible electrodeposition of lithium. Current collector coating strategies which regulate lithium deposition and improve cycling performance can also be developed.
	7. Solid-state electrolytes and lithium metal anodes open the way to new cathode chemistries reaching high energy density such as lithium-free cathode in combination with lithium metal or Li-excess cathode exhibiting high irreversible capacity in the anode-less configuration.
	8. Improving interface design to ensure efficient charge-transfer and electromechanical stability and improved cell mechanical stability.
	9. Bipolar cell design concepts and processing.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2021-D2-01-04: Environmentally sustainable processing techniques applied to large scale electrode and cell component manufacturing for Li ion batteries (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 20.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Provide European a leadership position in production of batteries with lower carbon footprint.
2. New sustainable electrode and cell manufacturing techniques are with reduced energy consumption, lower carbon footprint and no Volatile Organic Compounds (VOCs) emissions. Electrode and cell manufacturing processes are scalable, safer, cheaper, cleaner and less energy consuming compared to state-of-the-art technologies, ultimately reinforcing an internationally competitive European battery manufacturing industry.
3. Electrode coating production techniques completely eliminate organic solvents as slurry dispersing media leading to avoid the large capital costs associated to the solvent recovery system Implementation of dry manufacturing techniques such as 3D patterning of active electrode layers, and/or hydrophobic surface treatment of electrodes with next generation materials.
4. Industrialising closed loops and process design to return low-value chemicals from manufacturing processes to high-value and necessary inputs for the battery manufacturing industry.

Scope: Industrial scale fabrication of Li-ion battery (LIB) porous electrodes imply casting of a slurry over a thin metallic current collector according to conventional coating procedures. This is the technology used also for advanced LIBs with high energy electrode materials and liquid electrolyte (Gen3a/b). The slurry to be coated is prepared by mixing the active material, conductive agent and binder in a solvent, typically N-Methyl-2-pyrrolidone (NMP). Since NMP is toxic in nature, an expensive recovery system should be placed to collect the evaporated NMP in the drying process.

Less expensive and environmentally friendly solvents, such as water are already employed for anode manufacturing, which eliminates the large capital cost of the solvent recovery system. Wet coating technologies can still be further optimised and benefit from reducing the solvent fraction, thus, reducing the energy demand of the drying step. Moreover, completely dry processing techniques could completely remove the need for energy consuming drying, hence reducing the CO2 footprint of the electrode fabrication process.

This may also apply for example to protective interface coatings for both advanced anode –e.g. lithium metal- and cathode – e.g. HV spinel materials. Also, there are other new concepts that can benefit from the implementation of dry manufacturing techniques such as 3D patterning of active electrode layers, or hydrophobic surface treatment of electrodes with next generation materials. The process should be scalable, safer, cheaper, cleaner and less energy consuming compared to state-of-the-art technologies. The proposed/developed processes are expected to address the notion of “Design to Manufacture”, which should reduce production cost and increase battery performance resulting in increased efficiency and better cycle life. As the manufacturing techniques may benefit from digitalization, and moreover be ready to be integrated in digitally-driven larger production lines, project proposals should address digitalization within their scope..It should also propose innovative technical solutions and/or standardized approaches to ensure workers and users safety, particularly in the field of handling new materials during processing – such as in the case of nano-materials. The challenge is proposed for Li-ion up to generation 3.

Focus is into manufacturing technology development, up to pilot-level proof of concept. Activities to be aligned/feeding into the specific machinery development topic – industrial machinery development is beyond the scope of this topic.

Projects are expected to be aligned with H2020 project LiPLANET initiative – The EU network of R&D Li cell manufacturing pilot lines.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2021-D2-01-05: Manufacturing technology development for solid-state batteries (SSB, Generations 4a - 4b batteries) (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of between EUR 6.00 and 7.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 26.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Position Europe at the industrial production lead in the international race for next generation, SSB technologies all through the value chain.
2. Generation of an indigenous technological knowledge portfolio of industrially scalable manufacturing solutions for the different approaches to SSB including all core components: electrolytes, anodes –either carbon or Li(m) based - and their ad hoc composites cathodes.
3. Contribute to climate neutral transport via the development of breakthrough technology in SSB batteries.
4. Enable cost effective, low carbon footprint and low-emission mass production of Gen4 technology in Europe.

Scope: Lithium ion battery cells with conventional active materials are reaching their limits in terms of energy densities. Also, safety issues arise with the utilisation of liquid organic electrolyte which are becoming even more critical with the nearly introduction of advanced materials made to increase cell voltage and fast-charging rates. Hence, there is an urgent need for the development of innovative scalable manufacturing technologies based on of new solid electrolytes that can be also combined with metallic lithium at the anode, leading to significantly enhanced energy density. In that context, solid-state electrolytes enable overcoming current battery cells limitations in terms of voltage and safety (reducing dendrites formation risk) leading to and increased intrinsic thermal and electrochemical stability.

As a consequence, in parallel to the progress in new materials developments, there is a growing need of Research and Innovation addressed to develop appropriate processing techniques for assemble cells based on solid type electrolytes including all current foreseen technological options: polymer-based, hybrid polymeric, inorganic and other alternatives such as gel-like semisolid electrolytes.

Also, processing, handling and integration of lithium metal anodes into cells, with special attention to solid-solid interfaces and protection layers need to be tackled (Generation 4b). As an alternative route, advanced Si/C composite-based anodes (Generation 3b) may come as a possible solution, and their specific manufacturing approach and interface requirements towards solid state electrolytes should be covered as well. Thus, appropriate processing techniques should be developed, optimised, adapted or reinvented for the preparation of dense electrode and electrolyte layers, to enable scale up of solid-state battery cells (Generation4a and Generation4b) towards industrial GWh mass production.

Cathodic electrodes making use of advanced materials – e.g. high Ni content oxides- combined with electrolyte material to enhance interfacial compatibility may pose specific manufacturing challenges involving innovative dry and/or extrusion coating techniques.

Projects funded under this topic should make provisions to establish adequate coordination schemes with related materials running projects, with special focus in HORIZON-CL5-2021-D2-01-03: Advanced high-performance Generation 4a, 4b (solid-state) Li-ion batteries.

The new manufacturing techniques for the SSB Gen 4a/4b batteries should focus on cost, performance, safety and sustainability with clear prospects for cost-competitive large-scale manufacturing and uptake by the electro mobility sector. Also, as the manufacturing techniques may benefit from digitalization, and moreover be ready to be integrated in digitally-driven larger production lines, project proposals should address digitalization within their scope. Manufacturing and cell assembly processes to be developed should be more sustainable compared to the current LIB manufacturing. In order to demonstrate cost reduction and improvement in other parameters projects are expected to provide comparison with baseline manufacturing techniques.

Focus is into manufacturing technology development, up to pilot-level proof of concept. Activities to be aligned/feeding into the specific machinery development topic –industrial machinery development is beyond the scope of this topic.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2021-D2-01-06: Sustainable, safe and efficient recycling processes (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of between EUR 9.00 and 10.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 30.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B. |

Expected Outcome: Projects are expected to contribute to the following outcomes:

1. Improved access to battery materials and strengthened European raw material independency by increased circularity of material flows and use of the secondary raw materials in new batteries produced in Europe.
2. Increased European competitiveness offering sustainable, safe, energy efficient and low carbon footprint battery recycling technologies and upscaleable solutions.
3. Reduced recycling cost and environmental impacts through new and disruptive concepts for very high efficiency recycling.
4. Improved health and safety aspects of recycling.
5. The industry is prepared to meet the new regulatory targets for the recycling.

Scope: In order to effectively exploit the vast amounts of EV and stationary battery waste emerging in the next decades, as well as the increasing amounts of production scrap resulting from larger manufacturing, it is important to create innovative feasible and holistic recycling processes in Europe.

Newly developed recycling processes are expected to be more flexible and adaptive, to be able to meet a wide variety of battery waste or production scrap resulting from cross different Li-battery chemistries (i.e. with and without transition metals). It is desirable to implement intelligent process design through integrating selected fractions into existing industrial infrastructure, or other innovative integration of fractions or processes. The recycling processes may partially utilise existing metallurgical infrastructure of the primary materials to support feasible processing and explore ways to support industrial transition towards green technologies.

Newly developed recycling processes are expected to aim at recovering the highest amount of resources (e.g. metals, graphite, fluorinated compounds and polymers, active materials) present within secondary raw materials which result from spent Li-batteries with and without transition metals and focus on the reuse of these materials in batteries.

Low-value chemicals from manufacturing processes should be returned to high-value and necessary inputs for the battery manufacturing industry. Focus should, however, be on developing materials recycling routes which as directly as possible target next-generation battery cathode and anode materials. Vertical integration to component/cell manufacturing should be improved.

Proposals are expected to aim at the outmost recovery rates and recovered material purity, meeting industrial requirements for their integration in the loop of cell manufacturing, in line with values reflected in Partnership Strategic Research Agenda (SRA).

Recovery/re-use/re-purposing/reconditioning of battery materials/electrodes/components should also be maximised and recycling discharge minimised.

Proposals are expected to develop new unit processes, or innovative combinations of optimised unit processes, including, but not limited to mechanical pre-processing, leaching, precipitation, solvent extraction, ion exchange, centrifuging, crystallisation, electrowinning, roasting, smelting, pyrolysis, shock wave disruption and direct reuse of materials and components.

Proposals are expected to identify and address health risks, environmental impacts, safety hazards and new safety practices related to developed processes.

The environmental impacts and benefits are to be quantified through life cycle thinking approach (e.g. LCA/SLCA), also in collaboration with the project funded under the joint topic HORIZON-CL5-2021-D5-01-04.

The co-operation with projects funded under topics HORIZON-CL5-2021-D2-01-01, HORIZON-CL5-2022-D2-01-01 should be established.

International collaboration is strongly encouraged.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2021-D2-01-07: Support for establishment of R&I ecosystem, developing strategic forward-looking orientations to ensure future skills development, knowledge and technological leadership for accelerated disruptive technology exploration and uptake (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 3.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 3.00 million. |
| *Type of Action* | Coordination and Support Actions |

Expected Outcome: In order to succeed in the development of a thriving innovative battery industry, pan-European cooperation on research and innovation is essential. It is not only essential to work across geographical boarders and institutional levels but it is also crucial that stakeholders from all parts of the battery value chain pull together in a strategic coordinated manner to ensure our collective research efforts are efficiently translated into sustainable technologies and products economically, environmentally and socially.

Europe has an extensive landscape of battery R&I stakeholders. Thus there is a need to continuously consolidate the Battery R&I community across the EU and associated countries and across Battery-related networks, projects and initiatives (including European, national, regional – HEU Partnerships, IPCEIs, Interregional partnership on advanced battery materials, European Battery Alliance and coordination actions including BATTERY 2030+, LiPLANET).

Project results are expected to contribute to all/ of the following expected outcomes:

1. Consolidated Battery R&I community across the EU and associated countries and across Battery-related networks, projects and initiatives (including European, national, regional – HEU Partnerships, IPCEIs, Interregional partnership on advanced battery materials, European Battery Alliance and coordination actions including BATTERY 2030+, LiPLANET, and other initiatives established until the project end). Exceptional participation of third country participants is therefore not foreseen.
2. Facilitated access to information for all – enabled European "one-stop shop" on Battery R&I information, including information on national programmes, events, battery projects and national battery networks (via website and other communication channels) reaching as many as possible battery stakeholders.
3. Reduced time to market of technologies and improved European competitiveness through established research-industry collaborations, information sharing and expert group work.
4. Synergies and research results efficiently shared along the whole value chain, thus mobilizing R&I efforts.
5. Attracted talent and competences necessary to achieve the technical goals and to support European industry.
6. Provided scientific evidence for policymakers.
7. Increase and reinforce international collaboration within the geographical scope outlined above..

Scope: Proposals are expected to:

1. Develop, consolidate and communicate a strategic research approach for all stakeholders throughout the entire European Battery Value Chain.
2. Develop and/or update coherent Strategic Research and Innovation agenda (SRIA) and corresponding detailed roadmaps covering all aspects of the battery value chain through expert group work.
3. Facilitate and support work of experts from a different field in a cross-collaboration manner, identify the challenges and opportunities and so create guidelines and recommendations on how best to develop synergies.
4. Establish and continuously update Key performance indicator (KPI's) values for current state-of-art battery technology, as collected from stakeholders across the battery value chain correlated and communicated via SET Plan progress monitoring.
5. Establish Target Key performance indicators (Target KPI's) values for future battery R&I as collected from all relevant forums, correlated and communicated via SET Plan progress monitoring and the Strategic Research and Innovation agenda (SRIA) to the entire R&I community in general.
6. Implement and foster the adoption of uniform standards and methodologies for the reporting of battery research developments across EU and national projects building on existing European and national work/efforts.
7. Execute a clear communication plan describing the hosting and updating website, organising events and facilitating networking. Communicate results and progress in Battery R&I on both a European and International level.
8. Cooperate with ETIPs and similar stakeholders fora, provide support to existing SET Plan Implementation Plans and advancement towards more interconnected activities, both in terms of contents and implementation mechanisms (see topic HORIZON-CL5-2021-D3-01-17)
9. Promote and facilitate international collaborative actions, where necessary.
10. Perform additional activities which are relevant to reach the expected outcomes.
11. In order to ensure high quality coordination and technical outputs from the proposals should possess both technical and operative expertise.

The overarching European R&I platform should build on previous efforts and continue to foster pan-European active cooperation and maintain up-to-date clear realistic strategic research and innovation agenda for Europe.

The project’s main governance (e.g. Steering Group, Advisory Board) is expected to provide for direct involvement of European Commission services for collaboration on relevant policy activities, incl. further supporting SET plan.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

Call - Cross-sectoral solutions for the climate transition

HORIZON-CL5-2022-D2-01

Conditions for the Call

Indicative budget(s)[[3]](#footnote-3)

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| Topics | Type of Action | Budgets (EUR million) | Expected EU contribution per project (EUR million)[[4]](#footnote-4) | Number of projects expected to be funded |
| 2022 |
| Opening: 28 Apr 2022Deadline(s): 06 Sep 2022 |
| HORIZON-CL5-2022-D2-01-01 | IA | 10.00 | Around 5.00 | 2 |
| HORIZON-CL5-2022-D2-01-02 | RIA | 10.00 | Around 5.00 | 2 |
| HORIZON-CL5-2022-D2-01-03 | RIA | 20.00 | Around 20.00 | 1 |
| HORIZON-CL5-2022-D2-01-04 | IA | 15.00 | 7.00 to 8.00 | 2 |
| HORIZON-CL5-2022-D2-01-05 | RIA | 15.00 | Around 5.00 | 2 |
| HORIZON-CL5-2022-D2-01-06 | RIA | 15.00 | Around 5.00 | 3 |
| HORIZON-CL5-2022-D2-01-07 | RIA | 15.00 | Around 5.00 | 3 |
| HORIZON-CL5-2022-D2-01-08 | CSA | 3.00 | Around 3.00 | 1 |
| HORIZON-CL5-2022-D2-01-09 | RIA | 15.00 | Around 5.00 | 3 |
| HORIZON-CL5-2022-D2-01-10 | RIA | 15.00 | Around 5.00 | 3 |
| HORIZON-CL5-2022-D2-01-11 | CSA | 5.00 | 4.00 to 5.00 | 1 |
| Overall indicative budget |  | 138.00 |  |  |

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| **General conditions relating to this call** |
| *Admissibility conditions* | The conditions are described in General Annex A. |
| *Eligibility conditions* | The conditions are described in General Annex B. |
| *Financial and operational capacity and exclusion* | The criteria are described in General Annex C. |
| *Award criteria* | The criteria are described in General Annex D. |
| *Documents* | The documents are described in General Annex E. |
| *Procedure* | The procedure is described in General Annex F. |
| *Legal and financial set-up of the Grant Agreements* | The rules are described in General Annex G. |

A competitive and sustainable European battery value chain

Proposals are invited against the following topic(s):

HORIZON-CL5-2022-D2-01-01: Sustainable processing and refining of battery grade graphite (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 10.00 million. |
| *Type of Action* | Innovation Actions |
| *Legal and financial set-up of the Grant Agreements* | The rules are described in General Annex G. The following exceptions apply:The funding rate is up to 60% of the eligible costs. This funding rate applies both to members and non-members of the partnership, except for non-profit legal entities, where the funding rate is up to 100% of the total eligible costs. |
| *Technology Readiness Level* | Activities are expected to achieve TRL 6-7 by the end of the project – see General Annex B. |

Expected Outcome: For graphite, both natural and synthetic graphite production for the EV market take place almost exclusively in China. Although there is some existing mining of Natural graphite in Europe, scaling these sources for the active anode material needs within Europe will be very challenging as (i) extensive graphite exploration and mining would be needed, and (ii) almost all of the refining capacity is based in China. The main challenges in refining are low yield in the spheronisation and the use of large amounts of hydrofluoric acid in the refining step.

For synthetic graphite, by-products of oil distillation are used as the starting point, followed by calcining, milling, shaping and graphitisation. This process produces high quality anode graphite (enabling long lifetimes and fast charging) but is energy intensive and causes environmental emissions (CO2, PAH). Opportunities to overcome all these problems exist already in Europe but need further development and investment to reach the required scale.

Project results are expected to contribute to all of the following expected outcomes on either natural or synthetic graphite production respectively:

1. Decreased dependency of Europe on imported battery grade graphite and decreased risk in European Battery supply chains.
2. Graphite (both natural and synthetic) competitively produced and refined in Europe in a sustainable and socially acceptable way improving the competitiveness of European batteries.
3. Graphite leveraging the potential for fast charging of batteries, one of the key factors for the user acceptance of electric vehicles.
4. Reduced carbon and environmental emissions from the anode material supply chain.
5. Projects should contribute to European Raw Materials Alliance objectives.

The Synthetic graphite projects are expected to focus additionally on:

1. System prototype demonstration of battery grade anode graphite material with high energy density, long lifetime and quality enabling fast charging, produced with increased yield and lower environmental footprint.
2. As a longer-term option, biocarbon alternatives to petroleum coke are expected to be developed to ensure long term sustainable supply.

The Natural graphite projects are expected to focus additionally on:

1. Advanced refining of Natural graphite to improve the yield of battery grade products and lower the environmental footprint.

Scope:

1. Enabling European graphite production – with vertical integration into the European battery production. Resource efficient sustainable production of both synthetic and natural graphite emphasising reduction of energy consumption, CO2 emissions, chemical use and the optimisation of recovery yield and raw material consumption. Enhance versatility regarding products and usable primary/secondary raw materials.
2. Development of solutions for combined use of natural and synthetic graphite.
3. For natural graphite: improving purification, milling, shaping and coating technologies that improve the performance characteristics of natural graphite.
4. Improving the yield of spheronised products from natural graphite concentrate.
5. Development of a non-HF purification technology to produce battery-grade anode material from spheronised natural graphite.
6. Developing improved coating technologies for natural graphite that will increase the performance characteristics of natural compared to synthetic.
7. For synthetic graphite: Improving graphitisation, calcining, milling, shaping and coating that improve the performance characteristics of synthetic graphite.
8. The use of other available European carbon options like biobased anode carbon and by-products from anode material production as raw materials for synthetic graphite are expected to be developed.
9. Development of new processes for synthetic graphite production from natural gas pyrolysis.
10. Reduction of process discharge and emissions in synthetic graphite production.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-02: Interface and electron monitoring for the engineering of new and emerging battery technologies (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 10.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 3-4 by the end of the project – see General Annex B. |

Expected Outcome: State-of-the-art in experimental and computational techniques for characterisation of battery materials and interfaces are targeting the scale of the atoms and ions. There is still a lack of understanding hampering the engineering of new and emerging battery technologies,, due to the complexity of interface formation and evolution as a function of time, temperature, battery cycling conditions and chemical composition of the electrolytes consisting of different salts, additives and liquid solvents and/or solid components,. Going into more depth, at process level, the time and the length scale of the electron transfer reactions remain almost completely underexplored.

Pushing the frontiers of present in situ analytical techniques is a must to more efficiently pursue research on sustainable materials and to develop greener Li-ion as well as future battery chemistries. Improvements in analytical techniques that would allow to follow the movement of interfacial reactions at the molecular scale all the way to the role of electrons at the nanoscale and sub-nanoscale, at relevant timescales and on relevant systems and interfaces, will have great impact beyond the sole battery field and would benefit to the electrochemistry field as a whole, including electrocatalysis and others. It will contribute to open up a new era for the study of transport at interfaces, which remains one of the greatest challenges of research for any electrochemist. For researchers exploring new storage concepts and engineering new interfaces, it will also provide insight into how to control the movement and redox processes of atoms. It can lead to an increased control of the electronic wiring of electrodes and a deeper understanding of the redistribution of electronic charge during redox processes.

Project results are expected to contribute to all of the following expected outcomes:

1. New methods for studying electrode/electrolyte interfaces for liquid-based electrolytes and batteries and for studying solid-state and buried interfaces.
2. Models for explaining the degradation of battery interfaces.
3. Deeper understanding of the formation and evolution of battery interfaces, leading to new insights on how to increase the lifetime and safety of new and emerging battery technologies, and therefore contributing to the long-term competitiveness of the European battery industry.

Scope: This topic should support the development of novel experimental and computational techniques targeting the time and length scales of interface reactions in a battery cell including electron and ion localisation, mobility and transfer reactions.

This targets the development of novel analytical techniques, supported by modelling and simulation, able to follow interface, electron and ion dynamics in battery materials and battery cells, and carefully selecting controlled model systems to implement those novel techniques.

Examples of experimental tools include operando Transmission Electron Microscope (TEM), Electron Paramagnetic Resonance (EPR), operando ambient pressure photoelectron spectroscopy techniques, operando X-ray scattering techniques, NMR, soft X-ray spectroscopy with RIXS, neutron spectroscopy, ultra-fast spectroscopic methods as well as Free Electron Laser (FEL) facilities. Other synchrotron and neutron scattering and ion-beam techniques leading to development of new understanding of interfaces can also to be suggested and implemented. The goal is to give advice and new insights on how to increase the life time and safety of new emerging technologies.

Building upon the BATTERY 2030+: this call topic addresses the need of increasing the fundamental understanding of processes in batteries at a level that will accelerate the development of more stable chemistries adapted for their specific purpose. The proposal should also cover the contribution and collaboration to the BATTERY 2030+ large scale initiative.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-03: Furthering the development of a materials acceleration platform for sustainable batteries (combining AI, big data, autonomous synthesis robotics, high throughput testing) (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 20.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 20.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 3-4 by the end of the project – see General Annex B. |

Expected Outcome: Batteries have complex and dynamic processes taking place in and between materials and at the interfaces/interphases within a battery cell. For each new battery chemistry explored, new challenges in understanding these processes are revealed. To accelerate the finding of new material’s and their combinations for both existing and future battery chemistries the iterative and fragmented trial and error approach used today needs to be replaced since it is slow and insufficient.

To accelerate the discovery of battery interfaces, materials and new sustainable concepts with high energy and/or power performance there is a need to develop a fully autonomous and chemistry neutral Materials Acceleration Platform (MAP) for battery materials and interfaces. This is a key and long-term challenge for European battery community. The aim is to integrate advanced multi-scale computational modelling, materials synthesis, characterisation and testing to perform closed-loop autonomous materials findings and interphase engineering that would accelerate by at least a factor of five the discovery of new battery chemistries with ultra-high performances.

Building upon the shared data infrastructure, standards and protocols developed in the BATTERY 2030+ initiative, this call topic addresses the need of increasing the level of autonomy in the MAP-based discovery and development process. The proposal should also cover the contribution and collaboration to the BATTERY 2030+ large scale initiative.

Project results are expected to contribute to all of the following expected outcomes

1. Develop new tools and methods for significantly accelerating the development and optimisation of battery materials and interfaces, in order to increase the competitiveness of the battery material and cell industry in Europe.
2. Demonstrate a fully autonomous battery-MAP capable of integrating computational modelling, materials synthesis and characterisation of both Li-ion and beyond Li-ion chemistries.
3. Scale-bridging, multi-scale battery interface models capable of integrating data from embedded sensors in the discovery and prediction process, e.g. to orchestrate proactive self-healing.
4. Community wide state-of-the-art collaborative environment to access data and utilise automated workflows for integrated simulations and experiments on heterogeneous sites, e.g., exploiting European HPC architectures and Large-scale facilities in collaboration with LENS and LEAPS.
5. Demonstrate a robotic system that is capable of material synthesis for inorganic, organic or hybrid compounds following standard synthesis routes via automated characterisation of intermediate and final products and autonomous decision-making.
6. Deploy predictive hybrid physics- and data-driven models for the spatio-temporal evolution of battery interfaces and demonstrate inverse design of a battery material/interface.

Scope:

1. Infrastructure tools for secure remote data access, data analysis and predictive modelling: Develop a FAIR[[5]](#footnote-5) data infrastructure for raw and curated experimental and modelling data, which can be accessed remotely and securely by relevant stakeholders, including industry. Develop the software infrastructure required to operate this platform, also with regard to future reproducibility and further exploitation of the results of the research activities. The software should provide specific access right and allow remote data access, complemented by distributed workflows using software-agnostic workflow engines that provide rapid-prototyping. Inverse materials design using hybrid physics- and data-driven battery interface genome models should also be demonstrated.
2. Automated high throughput characterisation and integrated experimental and computational workflows: High throughput, multimodal operando experimental techniques using standardised battery cells and established protocols should be optimised to perform effective screening of new materials and on-line diagnosis of realistic devices. A central objective is to establish, structure, operate and dynamically refine such facility platform to harmonise, mutualise and optimise the global demand for battery characterisation. This includes automated experimental and computational workflows and modules for data acquisition and multimodal/multiscale analysis. Particular attention should be paid to battery interfaces and direct observation of interfaces under dynamic conditions, which are key to improve the performances and the lifetime of batteries.
3. Autonomous synthesis robotics and orchestration software: The transition from low/no automated robotics for the synthesis of battery materials requires several R&I steps towards fully autonomous systems. Within the scope of this proposed call are partially autonomous systems following standard synthesis routes for inorganic and organic battery materials, especially also multi-step and high-temperature synthesis, that so far are challenging to automate for high throughput. AI-based orchestration and optimisation software modules and packages specifically targeting battery materials and interfaces are also central to the scope.
4. Inverse design and AI-assisted scale-bridging models for multiple time- and length-scale processes: To develop scale-bridging models correctly describing the multiple mechanisms occurring at atomistic scale and the mesoscopic scale on the cell level. The new model approaches should be able to incorporate data from the advanced sensing in virtual design optimisation and battery control algorithms for SoX estimation. Sensitivity analysis and uncertainty quantification of the developed SoX models is also a requirement to assess the robustness of the developed models. These models should achieve a challenge based rational balance of accuracy and computational effort. They should accurately describe the actual state of the system, but also enable diagnosis and prediction, e.g., when self-healing procedures should be initiated. Multiscale Modelling approaches should be developed for the control of safety between BOL (Beginning Of Life) and EOL (End of Life) of a battery system by different uses and diagnosing the safety state of a battery system by innovative methods.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-04: Towards creating an integrated manufacturing value chain in Europe: from machinery development to plant and site integrated design (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of between EUR 7.00 and 8.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 15.00 million. |
| *Type of Action* | Innovation Actions |
| *Legal and financial set-up of the Grant Agreements* | The rules are described in General Annex G. The following exceptions apply:The funding rate is up to 60% of the eligible costs. This funding rate applies both to members and non-members of the partnership, except for non-profit legal entities, where the funding rate is up to 100% of the total eligible costs. |
| *Technology Readiness Level* | Activities are expected to achieve TRL 6 (for machinery development) and TRL 7 (integration of manufacturing plant supply chain) by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Strengthening Europe’s battery cell industrial manufacturing value chain by building-up its Giga scale manufacturing capabilities distributed in the member states territories.
2. Development of new battery cell manufacturing machinery, with priority on minimising energy needed for cells production, enhancement of plant efficiency rates and integration of intelligent control processes to minimise scrap.
3. Enabling deeper collaboration between (i) battery process equipment companies (ii) industrial-scale cell manufacturing, (iii) material, energy and other supply chain sectors benefitting from sector coupling.
4. To stimulate and intensify the collaboration between pilot line operators, industrial-scale academia, cell manufacturing companies and European equipment companies to push innovations with regard to an economically and ecologically sustainable cell production in Europe.

Scope: In order to build globally competitive Li ion battery (LIB) cell production plants in Europe, all the production value chain from machinery to plant and site development and optimisation is expected to be considered holistically, from machinery development to plant and site integration and optimisation. This topic intents to cover both areas.

In recent years Europe has developed strong competences in Li ion battery technology with regard to academic research, material development and Battery system design. However, there is still a lack of knowledge and competence regarding the economically and ecologically production of LIB cells in both high volumes in Giga-factories or in much smaller batches for specialised applications as developed in Mega-factories. From this perspective, the scope of this topic is two-fold:

1. From one side, to be able to supply machinery which is developed and built locally, Europe has to develop a leading position in the production of resource efficient, intelligent electrode and cell manufacturing machinery.

In the development of such battery manufacturing machinery, important aspects for success include: minimising energy consumption, eliminating air and water pollution and integration of intelligent control processes to minimise scrap thus reducing costs and environmental impact of the production process. In addition, such machinery is expected to operate at very high productivity levels with incorporate intelligent quality control systems. Moreover, strategies of industry 4.0 should be intensively integrated in new European cell production plants to yield economic success.

Activities under this topics would cover from TRL 3 (start) to TRL 6 (target).

1. From the other side, battery cell production as a whole is currently confronted with enormous cost pressure. One major factor in the cost structure of European Giga-scale battery cell production is related to highly energy consuming manufacturing processes. A significant reduction and/or utilisation of low-carbon and low-emission energies would not only bring economic benefits, but would also provide clear advantages in terms of the ecological footprint. For sustainable success, the horizontal integration of the European supply chain for battery process equipment into the growing production of giga-scale battery cells is a major challenge.

Activities under this topic would cover from TRL 6 (today) to TRL 7 (target).

Hence, this topic aims at closing a gap and enabling deeper collaboration between industrial-scale cell manufacturing, battery process equipment companies, and material and other industrial sectors potentially benefitting from sector coupling with cell manufacturing (e.g. grid power or material suppliers)**.**

Therefore, existing cell production lines and their material and energy flow internally and externally interaction with other companies at the site should be investigated and evaluated. Based on this, the network should investigate the ecological impact of different machinery, production line configurations and factory designs to come to best practice proposals. Another challenge is to implement ecological standards along the production chain together with material suppliers and factory operators.

One additional target to achieve these goals is to stimulate and intensify the collaboration between pilot line operators (e.g. which should be organised within the LiPLANET network), industrial-scale academia, cell manufacturing companies and European equipment companies to push innovations with regard to an economically and ecologically sustainable cell production in Europe. This includes the support from running activities including for example IPCEI's on batteries.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-05: Next generation technologies for High-performance and safe-by-design battery systems for transport and mobile applications (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 15.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 5 by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Next-generation battery system technologies for electrification of a broad range of transport and mobile applications (including road, waterborne, airborne, and rail transport, as well as non-road mobile machinery).
2. Demonstrating increased performances (energy density, power density, lifetime) and safety of battery systems, to improve the competitiveness of the European battery industry in the transport market.
3. Novel design and process to reduce manufacturing, refurbishment, dismantling and recycling costs of battery systems.

Scope: Batteries are key for a climate neutral transport sector, which represents around 25% of the total CO2 emissions in the EU. The electrification of transport and mobile applications require high-performance and safe battery systems. In particular, fire is a critical safety risk for several transport modes.

Projects are expected to develop innovative battery systems technologies that will benefit several transport and mobile applications, by significantly improving performances and safety, as well as environmental sustainability and cost.

In order to leverage the full potential of the research ongoing in Europe at the battery material and cell levels, projects should consider the adaptation of battery system design to novel cell chemistries that will reach the market in the short-to-medium term (e.g., advanced lithium-ion or solid-state cells). Enhancing the cell-on-system volume ratio and/or weight ratio will increase the energy density and/or power density at the battery system level. More generally, projects should consider new technologies (battery system materials, mechanical design, electrical architectures, thermal management strategies, etc.) for enhancing performances and safety (for example, novel lightweight materials with optimum thermal characteristics to decrease battery module and pack weight and simultaneously enhancing safety; new dielectric cooling liquids with enhanced fire-retardant properties; etc.).

Manufacturability and recyclability should be explicitly addressed, in order to reduce the manufacturing, refurbishment, dismantling and recycling costs as well as the carbon footprint of the new battery systems.

Furthermore, the projects are expected to develop and assess methodologies to ensure the safety.

The projects should focus on the battery system level, i.e., on the integration of battery cells into a battery system (e.g., a battery pack), considering mechanical, electrical and thermal aspects.

The integration of battery systems into larger systems of application (e.g., into vehicles) is out of scope for this topic, but obviously projects are expected to provide for requirements of the chosen use cases.

Project outcomes should be applicable to one or several use cases among the main transport or mobiles applications (such as road, waterborne, airborne and rail transport, as well as non-road mobile machinery and industrial applications), with the aim to maximise the impact on the European industry and on CO2 emission reduction. Projects may consider the key performance indicators proposed by Batteries Europe or by the dedicated Partnerships, reflected in the Partnership Strategic Research Agenda (SRA), to guide the technology developments on the application segments and use cases that will be selected. Some of the project results can also be relevant for stationary energy storage applications.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-06: Embedding smart functionalities into battery cells (embedding sensing and self-healing functionalities to monitor and self-repair battery cells) (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 15.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 2-4 by the end of the project – see General Annex B. |

Expected Outcome: Batteries are operating in different conditions and although preventive approach during battery operation is a must, we need to develop curative functionalities which would enable battery operation in different non-ideal conditions while being transparent through the nasty chemical environment of the cell. Smart functionalities with sensing developed to detect irreversible reactions and self-healing functionalities designed to repair damage occurred within the cell, Europe can develop cells with much higher quality, better reliability and longer cycle life. This call is building on the long-term research roadmap of BATTERY 2030+. The proposal should also cover the contribution and collaboration to the BATTERY 2030+ large scale initiative.

Project results are expected to contribute to all of the following expected outcomes:

1. Increased quality, reliability and life (QRL) of the battery system by integrating both sensing and self-healing functionalities at the battery cell level.
2. Disruptive battery cell and battery management system technologies, to support a competitive and sustainable battery manufacturing industry in Europe.

Scope: The target of this call is to embed sensors and self-healing functionalities into single battery cell, with sensors being capable to detect defective operation and trigger self-repairing functionalities via the Battery Management System (BMS).

Proposal should aim at a combined approach with the development of sensors capable of continuous, long term operation within the cell and on the development of self-healing functionalities which can be triggered by external stimulus. Sensors and self-healing functionalities need to be adapted to detection of the critical degradation processes during cell electrochemical or chemical ageing. Different battery chemistries can be addressed with a focus on most critical degradation processes.

Proof of concept of coupling sensors and self-healing agents via BMS should be demonstrated. Clear benefit of embedding smart functionalities into battery cells should be demonstrated and approach needs to be adaptable to battery cells mass production processes and not hinder subsequent recycling process. Estimation of QRL over the life span should be assessed and the competitive advantage over alternative approaches like replacement or recycling or second-use should be demonstrated.

Building upon the BATTERY 2030+ roadmap, this call topic addresses the need to develop new sensors and self-healing functionalities which can give the batteries of the future increased life-time, efficient re-use and better commercial success. The benefit of these innovation on the global battery safety should be demonstrated. The proposal should also cover the contribution and collaboration to the BATTERY 2030+ large scale initiative.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-07: Digitalisation of battery testing, from cell to system level, including lifetime assessment (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 15.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 5-6 by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Competitiveness of the European battery industry across the value chain (from cell manufacturers to cell integrators);
2. Shorter time-to-market;
3. Reduced time and/or cost of battery development by at least 20% to 30%;
4. Improved battery design, for longer lifetime, and better reliability and safety;
5. Reduced investment and operational costs of battery systems.

Scope: The current way of developing batteries is mainly based on trial-and-error processes, which are time consuming, costly, and do not always lead to the best product design. It is particularly the case when it comes to testing batteries to assess their performance, lifetime, reliability and safety. Existing methods and tools lead to high costs, because of long test durations, and/or the high number of required test samples, and/or the use of costly test infrastructures. There is a significant room for improvement, by relying on digital methods and tools to minimise the use of standard trial-and-error processes. Digitalisation of battery testing will lead to an acceleration of the battery development time, a higher quality of the battery assessment (better evaluation of battery performances, lifetime, reliability and safety), and an improvement of the battery design itself (by better adapting the design to the application requirements and production capabilities) and a better estimation lifetime (by better modelling of battery ageing). Improvement in battery testing will result in major cost savings, in particular in the development phase (test before invest).

Projects are expected to provide novel methods and tools to accelerate and improve the battery testing process. A multi-scale approach should be used, by covering the value chain from battery cells to battery systems (here, a battery system refers to an energy storage unit integrating battery cells, excluding power converters). Projects should propose and validate a new paradigm based on intelligent design of experiment (to avoid duplicated experiments, or experiments that give low-quality information), the smart combination of physical and virtual testing, hardware in the loop solutions, and the development and use of advanced models describing battery cells and systems (physics-based models, data-driven models, or hybrid models) and the relevant expected evolution in multiple different conditions of usage. In turn, this requires full documentation of new modules, models or tools developed from scratch or substantially improved. Particular attention should be paid to the assessment of battery lifetime, reliability and safety, including the development of innovative methods for testing of safety in transport and safety in usage, based on representativeness of the method for the various potential failures (failure initiation, propagation control, mitigation means, etc…).Projects should have an ambition for cross-sectorial applications, and should focus on battery chemistries currently on the market or that will reach the market in the short term (i.e., advanced lithium-ion chemistries), with the potential to quickly adapt to next-generation battery chemistries (i.e., solid-state lithium-based chemistries).

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-08: Coordination of large-scale initiative on future battery technologies (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 3.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 3.00 million. |
| *Type of Action* | Coordination and Support Actions |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Fostering the scientific, technological, economic and societal impact of the initiative and paving the way to industrial exploitation of future battery technologies in key energy and transport application domains.
2. Well-coordinated European research initiative on future battery technologies gathering excellent scientists and innovators as well as involving other relevant stakeholders and linked with relevant international, national and regional programmes.
3. Spreading of excellence in future battery technologies across Europe, increased awareness of European activities and availability of European curricula in the field.
4. Increased synergies and collaboration between the relevant research and innovation stakeholders in Europe as well as with major initiatives that already exist or are under preparation.

Scope: This call topic aim to network and coordinate the BATTERY 2030+ large scale research initiative on Future Battery Technologies and its contribution to the broader efforts of the European research and innovation stakeholders in battery technologies foreseen at European level and in the Strategic Energy Technology (SET) Plan and to tackle long-term research challenges expected to result in 'game changing' impacts on future battery technologies paving the way for providing a technological competitive advantage to the European battery industry. Because of their ambition, their scale and their interdisciplinary nature, these challenges can only be realised through a long-term, coordinated and sustained effort at European level, by building on large scale research cooperation across academia and industry and with other research initiatives at regional, national and European level, and by mobilising Europe's best researchers around an ambitious long-term research agenda.

Proposals are expected to coordinate the research activities and the stakeholders participating in the initiative; to facilitate communication, dialogue and cooperation on crosscutting topics; to monitor the initiative's progress and maintain its roadmap; to provide support for its governance; to establish a robust and reliable knowledge base including key methodologies and established results; to promote and communicate the objectives of the initiative and its achievements, including by ensuring media presence and public visibility, by engaging with industry and society and by participating or organising outreach events; to identify training and education needs and promote European curricula in future battery technologies. In particular, proposals should identify and coordinate relevant efforts for modelling and data sharing, standardisation, intellectual property rights in cooperation with other relevant initiatives at European level. They should also help networking and collaboration with other relevant national and international activities in the field. They should cooperate with Batteries Europe, the ETIP on battery announced in the EU Strategic Action Plan on Batteries.

It is expected that such an activity is driven by representatives of the relevant actors of the field (e.g., from academia, RTOs and industry).

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-09: Physics and data-based battery management for optimised battery utilisation (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 15.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 4 by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. New physics and data-based approaches for battery management, with the potential to enhance performances, lifetime, reliability and safety of battery systems for transport and stationary applications.
2. New physics and data-based approaches for battery management facilitating predictive maintenance, and/or knowledge-driven end-of-life management of battery systems, and/or the development of more accurate degradation models.

Scope: Battery management plays an essential role by ensuring an efficient and safe battery operation. However, current battery management systems (BMS) typically rely on semi-empirical battery models (such as equivalent-circuit models) and on a limited amount of measured data. Consequently, there is currently a lack of knowledge about the overall state of the battery in operation, resulting in suboptimal utilisation.

Projects are expected to substantially advance the state of the art in the field of battery management, by developing innovative physics and data-based approaches, both at the software and hardware levels to ensure an optimised and safe utilisation of the battery system during all modes of operation.

Projects should pave the way towards next-generation BMS, which will leverage on an increased computational capability enabling the execution of advanced software, and on the ability to acquire, communicate and analyse large amount of data. Those next-generation BMS will lead to significantly enhanced performances, lifetime, reliability and safety of the battery system, by a dynamic update of battery usage limitations and the possibility to widen the battery operating range in a controlled manner. Moreover, they will provide open access to an increased amount of FAIR[[6]](#footnote-6) data (which can possibly be processed offline), enabling the development of effective degradation models (thus reducing the investments costs of storage systems by mean of improved sizing during the design phase), and facilitating predictive maintenance and end-of-life management.

Projects are expected to develop technologies at both the software and hardware levels, with a validation through a lab-scale prototype at TRL 4. Several of the following items should be addressed: the development and implementation of physics-based battery models (e.g., ageing phenomena models); adaptable battery models (e.g., based on operation data); sensor-based solutions at the battery system level (e.g., with respect to sensor integration, communication with the battery management, data fusion, data analysis); advanced state estimators (e.g., state of health, state of function, state of energy, state of power, state of safety); methods for the prognosis of remaining useful lifetime and ageing; methods for the early detection or prediction of failures; solutions for the management of special situations (e.g., unbalanced or dysfunctional cells). Project results should be applicable to a broad range of transport or stationary applications.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

HORIZON-CL5-2022-D2-01-10: Streamlined collection and reversed logistics, fully automated, safe and cost-efficient sorting, dismantling and second use before recycling (Batteries Partnership)

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| **Specific conditions** |
| *Expected EU contribution per project* | The EU estimates that an EU contribution of around EUR 5.00 million would allow these outcomes to be addressed appropriately. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. |
| *Indicative budget* | The total indicative budget for the topic is EUR 15.00 million. |
| *Type of Action* | Research and Innovation Actions |
| *Technology Readiness Level* | Activities are expected to achieve TRL 5-7 by the end of the project – see General Annex B. |

Expected Outcome: Project results are expected to contribute to all of the following expected outcomes:

1. Achieving the objectives of the Circular Economy Action Plan by enabling second life of batteries and increasing rates for recycling and recovery, in line with upcoming regulatory requirements.
2. Revolutionize and re-freshen recycling industry, by applying best-in-world innovations based on automatisation, efficiency and sustainability.
3. Create new circular business models, such as second life, to reduce the need for primary raw materials, and to maximize the use of battery cells reducing the cost per cycle.
4. Develop a community for actors involved in the management of the recycling value chain for batteries (including second life) for sharing best practices (health and safety, transport, dismantling, refurbishing, recycling).
5. Improve safety, through automatisation and reducing accidents.

Scope: Today the amount of end-of-life (EoL) batteries from e-mobility and stationary applications is still limited. Moreover, EoL batteries are not standardised (form, chemical composition, etc.) and consequently, their management and recycling are mainly based on manual process. This increases risk of accidents as the integrity of the batteries / cells is no longer guaranteed.

Within next several years, the amount of EoL batteries will surge, transforming the recycling and battery value chain in general. It is important to develop efficient recycling chain and processes able to meet these upcoming amounts of diversified waste streams. A general approach to recycling should thus be reconsidered and new sustainable recycling chain for batteries should be established, in terms of introducing novel approaches to products, processes and keeping in mind their socio-economic viability and environmental impact.

It will require new upscaleable techniques and concepts for collection, logistics, and automatisation in sorting, dismantling and second use before recycling.

Proposals are expected to cover all aspects below:

1. Development of standardized common diagnostics protocols and cut-off criteria between product (2nd life application) and waste (recycling).
2. Elaborate critical stage of diagnosis of batteries as a waste-prevention measure in order to define which batteries or components of batteries are still considered fit for a second life application.
3. Automate the dismantling of E-mobility and stationary batteries, reducing costs by avoiding manual work and improving sorting of parts for their replacement or preparation for recycling allowing the selective extraction of materials including the cathode and anode materials which for certain Li-chemistries lead to a higher value creation for the downstream recyclers.
4. Development of novel safe dismantling processes and safety procedures along all steps of EoL management chain with focus on battery burning process (thermal runaway), identification of Limiting Oxygen Index (LOI) and Lower Explosive Limits (LEL).
5. Development of technologies preventing or reducing thermal runaway during transportation, storage and dismantling of batteries.
6. Design and demonstration of standardized and cost-efficient storage and transportation containers with visual and thermal load monitoring systems and, if necessary, inert atmosphere or other measures reducing risk of fire or thermal runaway.
7. Development of technologies for fast and efficient discharge of used batteries, connected with energy recovery, possibly integrated with SoH diagnostic equipment, with flexible connectivity and adjustable to various kinds of batteries.
8. Development of standardized battery labelling system enabling all interested parties to automatically obtain necessary data on each battery. Potential integration of labelling system with battery passport database project and with labelling systems from other regions of the world (e.g. China). Identification of necessary data that should be included into labelling and battery passport projects.
9. Research on batteries sorting and dismantling technologies, particularly automated sorting including machine learning applicable to small and EV batteries.
10. Identify all potential risks and develop safe processes and safety procedures to reduce accidents.

This topic implements the co-programmed European Partnership on ‘Towards a competitive European industrial battery value chain for stationary applications and e-mobility’.

1. The Director-General responsible for the call may decide to open the call up to one month prior to or after the envisaged date(s) of opening.

The Director-General responsible may delay the deadline(s) by up to two months.

All deadlines are at 17.00.00 Brussels local time.

The budget amounts are subject to the availability of the appropriations provided for in the general budget of the Union for years 2021 and 2022. [↑](#footnote-ref-1)
2. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. [↑](#footnote-ref-2)
3. The Director-General responsible for the call may decide to open the call up to one month prior to or after the envisaged date(s) of opening.

The Director-General responsible may delay the deadline(s) by up to two months.

All deadlines are at 17.00.00 Brussels local time.

The budget amounts are subject to the availability of the appropriations provided for in the general budget of the Union for years 2021 and 2022. [↑](#footnote-ref-3)
4. Nonetheless, this does not preclude submission and selection of a proposal requesting different amounts. [↑](#footnote-ref-4)
5. FAIR (Findable, Accessible, Interoperable, Reusable) [↑](#footnote-ref-5)
6. FAIR (Findable, Accessible, Interoperable, Reusable) [↑](#footnote-ref-6)