European Commission

BATTERIES EUROPE

EUROPEAN **TECHNOLOGY** AND **INNOVATION** PLATFORM

DELIVERABLE #.#: TF DIGITALIZATION POSITION PAPER

Deliverable number	position paper
Version Date	23 November 2021
Issued by	Batteries Europe
Status	Ver 1
Deliverable writers	Margherita Moreno (BE Secretariat) Maher Chebbo (TF chair) Cami Dodge-Lamm (TF member) Nicolas Vallin (TF member) Henning Lorrmann (TF member) Francesco Guaraldi (TF member) Max Hoffmann (TF member)
Deliverable contributors	Edoardo Gino Macchi, Alain Vassart, Pedro Ignacio Quesada Anguita-Bago, Juan Enríquez, Fouad El khaldi, Mikko Pihlatie, Victor Gimeno Granda , David Guerrero Astigarraga, Panteleimon Panagiotou, Alan Pastorelli.

Disclaimer

The content of this Position paper does not reflect the official opinion of the European Commission.

Contents

LIST OF ACRONYMS

AI	Artificial Intelligence	**LCA**	Life Cycle Assessment
BDA	Big Data Analytics	**ML**	Machine Learning
BESS	battery energy storage systems	**O&M**	Operation & Maintenance
BMS	Battery Management System	**P2P**	Peer-to-peer
C&I	Commercial & industrial	**PLM**	Product Lifecycle Management
CAE	Computer Aided Engineering	**QR**	Quick Response
DSO/TSO	Distribution System Operator/ Transmission System Operator	**R&D**	Research&Development
EIS	Electrochemical Impedance Spectroscopy	**R&I**	Research&Innovation
EV	Electric Vehicles	**RES**	Renewable Energy Sources
H&S	Health & Safety	**SME**	Small Medium Enterprises
ICT	Information & Communications Technology	**SoC, SoH, SoE**	State of Charge, State of Health, State of Energy
IT	Information Technology	**TF**	Task Force
KPI	Key Performance Indicator	**V2B, V2G**	Vehicle-to-building, vehicle-to-grid

EXECUTIVE SUMMARY

Digital technologies will optimize the value that battery storage systems can bring to the decarbonisation of EU economy. At the same time, innovative business models are created, thereby enabling opportunities for new energy stakeholders, creating new jobs for the circular economy, and bringing Europe to the forefront of leadership in the fight against climate change. The high level of competency in Digital, Engineering and Science are a key success factor for Europe.

The development of **digital technologies** is required to improve the industrialization of new batteries and shorten the time to market. The design of **machine learning algorithms** will accelerate the discovery of materials and the development of AI-orchestrated characterization of battery materials and battery cells. Combining **computer aided engineering** tools and experimental measurements will help to understand and predict the battery performance. The utilisation of such tools and methods will be essential for a competitive industry in Europe. **Digital twins** can be used during the discovery, R&D, production, and usage cycles to improve battery performance, lifetime, safety, manufacturability and recyclability. Big **data analytics** methods can be developed and feed the digital twins, while IoT-based data analytics improve the maintenance cycle. The **design of experiments methodologies** can benefit from digital twins to accelerate the industrialization of new batteries. Finally, the development of a **battery data infrastructure** will help each actor to access the needed information and facilitate safe battery recycling. Data gathered during the usage cycle, using wireless communication technologies can provide information on performance and aging (e.g. SoC, SoH) to the consumers.

The **automated materials discovery** aims to increase the pace of development of new battery chemistries. Others will leverage the flexibility and competitiveness of the European **battery cell production** by making use of advanced Industry 4.0 concepts**.**

All stakeholders in the supply chain will benefit from a transparent and fraud-proof traceability of the full life cycle, from the raw material to the end-of-life, in form of a **digital battery passport** as currently proposed in the Battery Regulation proposal (COM (2020) 798/3) [1] and **advanced SoC/SoH monitoring** based on sensors and the use of big-data analytics.

In addition, battery-based flexibility services will be considerably facilitated by **real-time access to information of battery management systems (BMS)** that is envisaged in proposed amendments to the Renewable Energy Directive COM(2021) 557, new Article 20a)[2].

Digital interconnection of centralized and decentralized storage systems by **hybridization and multiuse of battery energy storage systems (BESS) into flexible portfolios** will be an important step towards democratized energy systems.

In broad terms, digitalization of **Europe's battery assets** will:

- enable the **sharing economy** and increase **social participation** in the evolving ownership relation between people, processes and products;
- unlock **all layers** of a highly **dynamic energy system** for energy, industries, and their customer operations;

[1] https://ec.europa.eu/environment/pdf/waste/batteries/Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf

[2] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021PC0559; https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14_en

- support Europe's goal of a **battery industry** that is more **sustainable**, **safer** and less dependent on foreign-sourced **raw materials**;
- enhance the social impact for **jobs** and Europe's **competitive edge.**
- **Data intelligence** and **digital customer services** will increase exponentially with a predominant role of global IT companies. Data will have a major technical and commercial value, to create services for society and industry with added value.
- Digitalization covers the **entire value chain**, facilitates the interconnection of different **cycles** and involves complex data science models using heterogenous data from various sources and phases, while **big data** circulates across systems and processes.

Digitalization of Europe's battery assets requires **tailored digital technologies**, where we have identified 7 technologies with 180 M€ of R&I estimated private and public investment & KPIs required, that will enable 7 innovative "use cases" across the value chain estimated at 315 M€ of R&I private and public investment & KPIs. The **use cases** listed in this document are a preview of how digital technologies will make the difference for European battery industry and society (See APPENDIX).

An important aspect is integration of digital data for the benefit of consumers and businesses. One aspect is access to easy-to use information needed for carbon foot-print tracing, repurposing and recycling of batteries. The Battery Regulation proposal (COM(2020) 798/3) currently under discussion will lay the basis for the establishment of the needed data space.The other aspect of integration of digital data is to improve system flexibility and enable higher renewable energy penetration rates in Europe, by:

- Facilitating robust research, innovation, and deployment of software solutions that are required to monetize BESS by providing multi-services through the creation of flexibility pools, hybridization, and opening access to multiple energy markets.
- Ensuring interoperability through the alignment of existing standards from the utility and ICT domains, across devices/assets and systems to enable innovative BESS services.

This will be facilitated by real-time access to information of battery management systems envisaged in the proposed amendments to the Renewable Energy Directive (new Article 20a)[3].

Empowering the consumer will be a vital aspect of the new energy economy. By democratizing and expanding the battery storage sector new demands will be generated within the market and will give rise to a new generation of innovative services and start-up or SME companies.

The digital initiatives ranging from managing the performance of assets and real-time platforms, to integrating energy storage and customer solutions, will **impact** strongly our **Europe's future**. Main impacts are: **value creation**, disruption in the **energy market** and forging **new jobs**. The intensive focus of Europe on batteries, the increased customers' demand and the rapid development of renewables will help evolve the economy leading to impressive socio-economic benefits where the field of digitalization will count for up to 25% of the investments and jobs created will count for much more (according to our estimates).

To achieve these goals, the working group identified key recommendations, both for policy makers and stakeholders that are available in the conclusions section of this document.

[3] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021PC0559; https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14_en

1 INTRODUCTION

The Green Deal and the digitalization of the European economy are important new priorities of the European Union. Moreover, by 2050, renewables could reach as much as 87% of the electricity mix (65% in 2030), with wind and solar playing a dominant role. Cheap renewables, **flexible** demand and battery storage will be **digitally** combined to shift the European power system away from fossil fuels and nuclear power to a cleaner society around variable renewables and emissions-free energy. This energy transition will be **enabled by smart digital technologies**. Digital technologies will optimize the value that battery storage systems can bring to the energy markets, thereby enabling opportunities for new energy stakeholders, creating a new generation of jobs for the circular economy, and bring Europe to the forefront of leadership in the fight against climate change.

The **deployment of batteries** for mobility and stationary application will call for:

- the need for an **automated platform** for the discovery of the materials that integrate modeling tools and high-throughput synthesis and characterization and the importance of **AI** supported tools for **accelerating** the **discovery** process of the battery materials and the development of new batteries across the value chain;
- improving the productivity, efficiency and flexibility of the transport and energy systems by **optimizing the design and lifecycle of battery systems** (by using e.g. AI, data, digital twins)
- generating business opportunities along a transparent, digitized value chain where all relevant cell properties will be made accessible to relevant stakeholders, e. g. producers and customers, re-purposing operators and recyclers, stored and made accessible online (Battery Passport, see Battery Regulation proposal COM(2020) 798/3)
- an EU platform to support **an optimized selection and use of the battery technologies and the integration of batteries in the energy systems** (see Lighthouse Project in chapter 4). Real-time access to BMS information foreseen in the proposed amendments of the Renewable Energy Directive

Digitalization of **Europe's battery assets** will:

- support Europe's goal of a **battery industry** that is more **sustainable**, **safer** and less dependent on foreign-sourced **raw materials**.
- enable the **sharing economy** and increase **social participation** and transforming ownership relations between people, processes and products;
- unlock **all layers** of highly **dynamic energy and mobility systems** for energy, transportation & industries and their customer operations;

Moreover, **data intelligence** and **digital customer services** will exponentially increase. Data will have a major technical and commercial value, to create services for society and industry with added value.

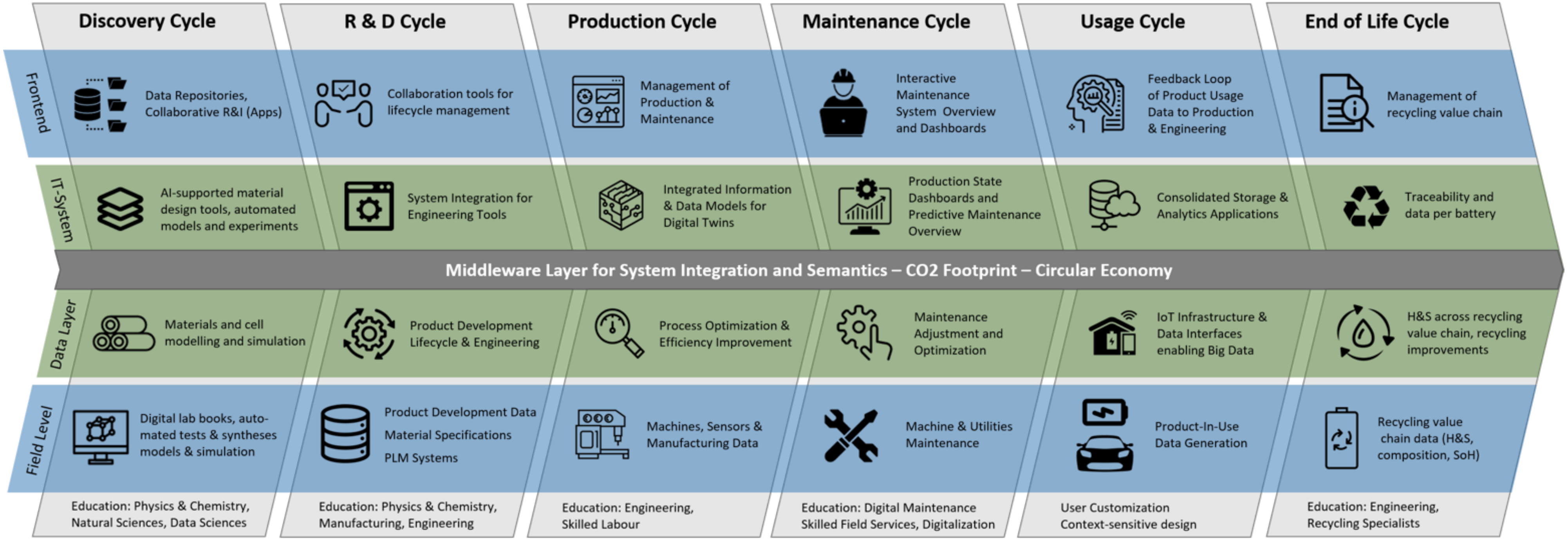

FIGURE 1: DIGITALIZATION ACROSS THE BATTERY VALUE CHAIN. *Please refer also to the zoom on the usage cycle in the next page (figure 2).*

FIGURE 2: USAGE CYCLE AND SERVICES OF THE BATTERIES INTEGRATED WITH THE REST OF THE ENERGY SYSTEM ILLUSTRATING THE ROLE OF ENERGY MARKET STAKEHOLDERS (LISTED IN THE "BUBBLES"). A DETAILED EXPLANATION OF THE LIGHTHOUSE PROJECT PROPOSED IN CHAPTER4.

2 Digital Batteries – Technology

Digitalization covers the **entire value chain** and helps to **interconnect** different **cycles**, involves complex data science models using heterogenous data from various sources and phases, while **big data** is generated across systems and processes. (see Figure 1) Digitalization of Europe's battery assets requires tailored digital technologies that will enable several "use cases" across the value chain. The use cases listed in this document are a preview of how digital technologies will make the difference for European battery industry and society.

The development of **digital technologies** is required to improve the industrialization of new batteries and shorten the time to market. The design of **machine learning algorithms** will accelerate the discovery of materials and the development of AI orchestrated characterization of battery materials and battery cells. Combining **computer aided engineering** (CAE) tools and experimental measurements will help to understand and predict the battery performance. The democratization of such tools and methods will be essential for a competitive industry in Europe. **Digital Twins** can be used during the discovery, R&D, production and usage cycles to improve battery performance, lifetime, safety, manufacturability and recyclability. The digital twin concept spans across the complete lifecycle of the product or the process, from engineering to manufacturing to operations and recycling. Digital twins aim at describing, understanding, and optimizing any complex system by comparing the real physical product or process, with its virtual replica. The first step, during the engineering of the system, is to build its 3D representation, further augmented with realistic behavior modeling. Multiple CAE tools are used for that purpose. In this phase, the digital twin helps describe the physical system (Digital => Real). Later, as the system is used, data is collected to complete the digital twin, bringing accuracy on the system behavior (Real => Digital). Ultimately, the digital twin should help improve the design, manufacturing and use of the system, by closing the loop of innovation. Machine Learning algorithms can be used to automate the process of continuously improving the digital twin.

Applied to batteries, computer-aided engineering (CAE) tools and data collection methods already exist and need to be further improved. To create the digital twin of batteries and better predict the system behavior, it will also be required to integrate these various CAE tools and data collection methods together. This process of connecting / integrating multi-physics and multidisciplinary solutions is complex (multi-physics models coupling, data formats, bilateral Digital <=> Real data exchanges) and lots of work remains to be done. For instance, battery aging is a complex phenomenon, that needs to be better understood and managed. The Digital Twin concept can be applied to better describe, understand and optimize the battery life. Today, no such twin exists on the market. This critical step should therefore be promoted and a dedicated budget should be allocated for research and innovation in this area. Methods for big **data analytics** can be developed and feed the digital twins, while IoT-based data analytics improve the maintenance cycle. The **design of experiments methodologies** can benefit from digital twins to accelerate the industrialization of new batteries. Finally, the development of a **battery data infrastructure** will help each actor to access the needed information and facilitate safe battery recycling. Data gathered during the usage cycle, using wireless communication technologies can provide information on performance and aging (e.g. SoC, SoH) to the consumers.

TABLE 1: DIGITAL TECHNOLOGIES SUMMARY TABLE

Technology	Readiness	EU Competitive Advantage	R&I Investment required	Preliminary estimated Budget[4]	KPI example
CAE for Modelling & Simulation	++	++	++	40M€	% Model accuracy vs measurements, reduction in computational time and reduction in product time to market
Design of Experiments	++	++	+	15M€	#Relationships Established between parameters
ML Algorithms / AI	+	+++	++	40M€	% Level of prediction, reduction in time
Data Infrastructure	+	+++	++	25M€	#Test Data, #Organizations sharing information
(Big) Data Analytics	++	++	++	25M€	#Analytics programs, Amount of Data proceeded
Digital Twin[5]	+	+++	+++	60M€	% Accuracy of Digital Twins vs. real Batteries / Production Lines
Wireless Communication	++	+	+	15M€	#Data flow through wireless communication

READINESS DEFINITION: + ADJUSTMENT NEEDED FOR BATTERY APPLICATION; ++ IMPROVEMENT NEEDED; +++ RESEARCH NEEDED

[4] This estimation refers only to digital related research investment both from private resources and public funding agencies.
[5] combining all above technologies

3 Digital Batteries across the value chain and as part of the Energy System - Use Cases & benefits

3.1 Digital battery application background: some examples

Smart metering as the most prominent example of digitalized energy systems was first established in the 1990ies for industrial sites and beginning of the millennium for private households. With the rapid growth of electrochemical storage systems in the last years new requirements and possibilities in emerge. Digital interconnection of these centralized and decentralized storage systems by hybridization and multiuse of battery electric storage systems (BESS) into flexible portfolios will be an important step towards democratized energy systems.

Digitization can further advance future generations of EVs and EV charging infrastructure interfaces, thereby enhancing ease-of-use, whilst also broaden the scope of uses, e.g. back-up power for homes.

Electric storage systems for industrial vehicles have tighter application requirements rendering them ideal test cases for digital approaches. Long lifetime and a fast return on investment even under heavy duty operation context requires precise state estimation. Digital twins of the battery developed with large data sets of interconnected batteries will allow for statistical backed maintenance requests from the batteries (predictive maintenance, state-of-health, state-of-safety). Ultrafast charging for a high productivity will require very precise state-monitoring and exact digital models avoiding critical battery states (state-of-charge, state-of-safety).

Off road applications such as vessels, battery-electric locomotives, drones, airplanes require high customization, easy integration and higher safety level. Depending on the application customization, reliability, predictive maintenance and safety will be a factor of utmost importance. For very large batteries in vessels with only rare deep discharge cycles, hybrid AI and advanced sensors of interconnected batteries will help for precise estimation of the state of energy and the remaining useful lifetime. The long lifecycle and large capacities associated with vessels might offer clear incentives to promote standardized modular systems, easy to integrate.

3.2 Digital battery use cases

Stationary storage, automotive, industrial and off-road vehicles, have specific requirements for the digitalization of the value chain from discovery to R&D, from production and maintenance, to usage and recycling. Each battery digitalization technology offers strong innovation potential and has a clear development opportunity, driven by market demand.

Table 2 summarises the use cases proposed by the task force. The **automated materials discovery** aims to increase the pace of development of new battery chemistries. Others will leverage the flexibility and competitiveness of the European **battery cell production** by making use of advanced Industry 4.0 concepts**.** All stakeholders in the supply chain will benefit from a transparent and fraud-proof traceability of the full life cycle, from the raw material to the end-of-life, in form of a **digital battery passport** and **advanced SoC/SoH monitoring** based on sensors and the use of big-data analytics.

Digital interconnection of centralized and decentralized storage systems by **hybridization and multiuse of battery energy storage systems (BESS) and EVs in flexible portfolios** will be an important step towards democratized energy systems.

A large integrated use case is the **Battery Marketplace Platform for Management, Services, and Supplies**, described in the next chapter as a lighthouse project.

TABLE 2: DIGITAL USE CASES SUMMARY TABLE

Use Case	Feasibility	Impact	R&I Investment required	Preliminary estimated Budget[6]	KPIs Example
Automated materials discovery	+	++	+++	100 M€	- Number of new battery chemistries discovered - Cost of Discovery and development of new battery materials - Number of materials developed in a time period - Lead time for material development
Green Battery Passport & digital referential	+++	+++	++	45M€	- % of batteries that go to the second life market -% Improvement of the recycling efficiency (more than one material) - % of Savings in the Design and Development cycles of battery-based products - % of cost avoided related to health and safety along the whole battery value chain
Advanced methods for SoX now- and forecasting (sensors & big-data)	++	++	++	20M€	- Number and models of batteries with initialization problems - % of batteries with maintenance needs above the normal maintenance range
Hybridization and multi-use of battery energy storage systems (BESS) and EVs in flexible portfolios	+++	+++	++	50M€	- % of use of renewable energy in BESS and EVs - % of battery users who monetize their energy storage
Accurate datasheet generator based on application specific Big Data Simulation Platform	++	++	++	30M€	- % of elements changed over original design in production phase - % of batteries with a lower life than the forecasted one
Digitalization of the battery cell production	+++	+++	++	50M€	- % savings in producing batteries with digital twin developed in the design and development phase vs without digital twin
Lighthouse project[7]: Battery Marketplace Platform for Management, Services, and Supplies	++	+++	+	20M€	• percentage of market participants using the platform to identify and purchase services and products, • sustained use of the platform by market participants, and • year-to-year growth of the number of active vendors on the platform.

FEASIBILITY DEFINITION: + RESEARCH NEEDED; ++ IMPROVEMENT NEEDED; +++ ADJUSTMENT NEEDED FOR BATTERY APPLICATION

[6] This estimation refers only to digital related research investment both from private resources and public funding agencies.
[7] See next chapter for description

4 LIGHTHOUSE PROJECT: A VISION FOR A COMMON EUROPEAN BATTERY MARKETPLACE

4.1 DESCRIPTION, SCOPE AND ARCHITECTURE

Empowering the consumer will be a vital aspect of the new energy economy. By democratizing and expanding the battery storage sector – EV and stationary – new demands will be generated within the market and will give rise to a new generation of innovative services and companies. However, easy accessibility to these resources via a common digital market platform will be the key to unlocking this potential. The TF considers it important to address consumers' needs for battery- related information, supplies, and services in a user-friendly manner. Figure 3 illustrates role of the information system and the services it could facilitate for different energy market stakeholders. Figure 4 describes how the platform accounts for the battery value chain to meet the needs of the customers with various supplies and services, and how the platform fits within a broader, economic ecosystem. This type of platform would address the needs of both EVs and stationary applications and inform consumers about how to optimize the use of their battery storage resource.

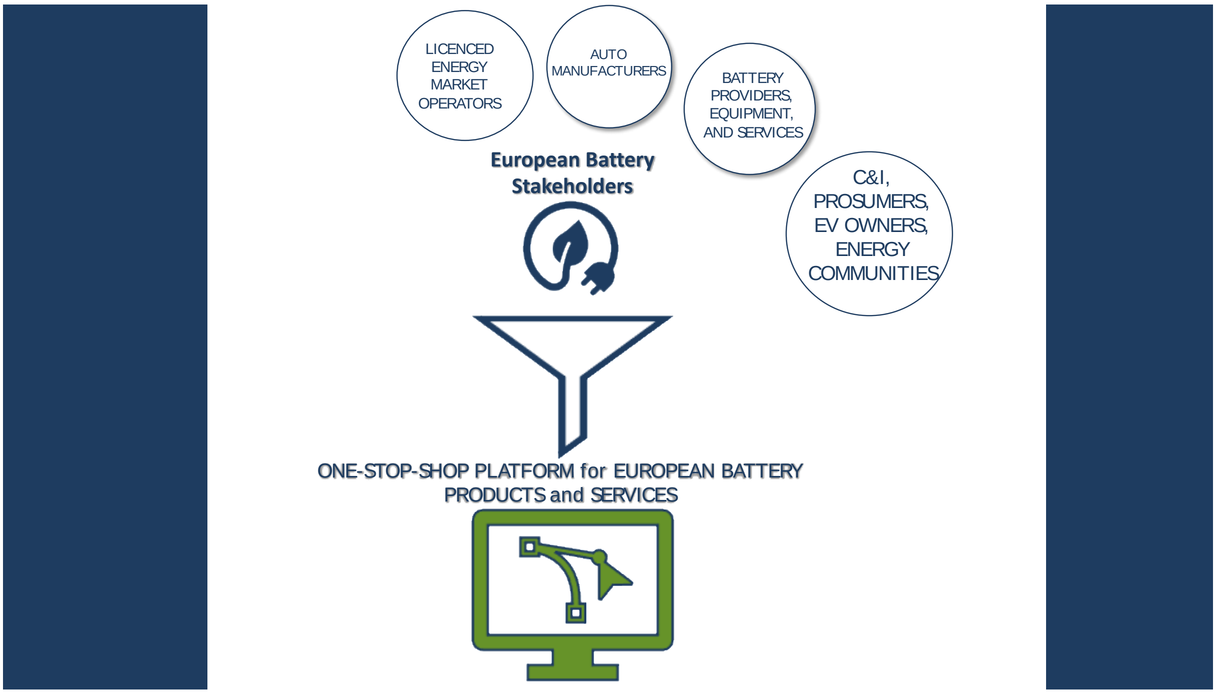

FIGURE 3: TAKING THE COMPLEXITY OF THE ENERGY MARKET AWAY FROM THE USER.

Growing demand in all battery sectors underscores the need and economic potential for this type of platform.

By making it easy for consumers – e.g. a homeowner, EV owner, a large industrial customer, power generator or a DSO/TSO – to engage in the battery use and services will likely increase demand, and, therefore, growth in the sector. This type of information system would facilitate and speed-up current interactions between battery market players and would aim to create a host of new digitally based jobs. It would enable new services to all stakeholders and lay the foundation for innovative resilience approaches, i.e. cross-sectoral integration. Furthermore, the commercial provision of services and technology solutions would favour access to sustainable energy and improve the use of energy flexibility.

Such a platform where end users can shop for and compare prices in one place would raise the level of competition amongst manufacturers and service providers. This would generate a cost-competitive environment favourable for European consumers. More people would be empowered to participate in the battery storage market by way of lower costs and the ease of the platform itself. This would also serve to strengthen the EU battery market and overall circular economy: products in this battery market will, of course, comply with the European Battery Regulation (Battery Regulation proposal COM(2020) 798/3).

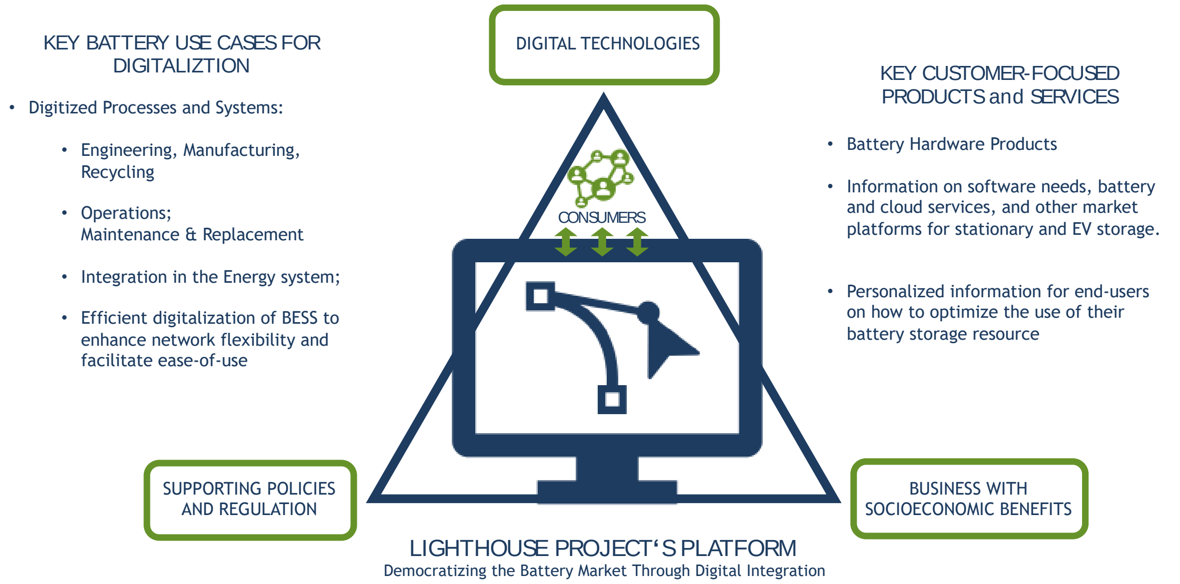

FIGURE 4: DEMOCRATIZING THE NEEDS OF THE CUSTOMERS WITHIN THE DIGITAL, ECONOMIC AND POLICY ECOSYSTEMS

The Lighthouse Project is a use case for a European battery marketplace and will facilitate the integration between many stakeholders. It will be complex in nature due to the various aspects of the battery market, but will ultimately make things simpler for the end user. The vision for such a digital marketplace would be underpinned with European-based products and services, thereby raising the prominence and increasing the competitiveness of the European battery sector. This process for translating a complex market into a simple, one-stop-shop will need to be supported by current legislative and accompanying initiatives from the EU to ensure regulatory compliance at every step of the way for the end user. Therefore, one should consider battery regulations that are currently under discussion. This notably concerns the Commission proposal for a new Regulation on batteries and waste batteries of 10/12/2020[8]. Chapter 8, the electronic exchange of information and, more specifically, Article 64, concerning the electronic exchange system for rechargeable industrial and electric vehicle batteries (i.e. battery data space), and Article 65 for battery passports is relevant.

Building on the new legal provisions, the Lighthouse Project will help buyers making informed choices with respect to carbon footprint and performance characteristics of batteries and facilitate

[8] https://ec.europa.eu/environment/topics/waste-and-recycling/batteries-and-accumulators_en

transactions related to repurposing and recycling of batteries. Similarly, it should help to maximise revenues from battery assets.

The idea of the Lighthouse project can feed into the upcoming Digitalisation of Energy Action plan[9]. The latter will likely cover developing a European data-sharing infrastructure to create a competitive market for energy services that value demand-side flexibility. It may include the creation of a common European energy data space that is compatible with other data spaces, that fosters the development of an interoperability framework, and addresses the governance of the data spaces. Digitalisation TF will contribute to the currently ongoing public consultation on the Digitalisation of Energy Action Plan.

Within this broad context, the Lighthouse project can be seen as an open platform that could be interconnected with other platform(s) which may be offering flexibility services within other assets.

9 https://ec.europa.eu/info/news/commission-launches-public-consultation-feed-action-plan-digitalise-energy-system-2021-oct-05_en

5 CYBERSECURITY AND DATA PRIVACY

When analysing cybersecurity and data privacy for the digitization of the battery sector there are overlapping considerations for the wider power sector too. Therefore, the comments in this section intertwine with both. The Digitalization Task Force recognizes the need for an accurate, testable, and affordable cybersecurity approach against malicious attacks and avoiding threats and vulnerabilities to the electricity supply chain, including battery assets and their complimenting digitized technologies and market platforms. Furthermore, it is equally important to protect personal data and business information by fostering the early detection, mitigation, and reaction to attacks, and the restoring of the services if a cyberattack occurs within any given aspect of the battery supply chain. These protections must be balanced with the future needs of a digitized battery sector, in addition to the multitude of other emerging technologies, and thereby supporting new business models within the battery sector.

Digital solutions to addressing cybersecurity should consider the specificities of real-time requirements, cascading effects and combination of legacy and state of-the-art technology. Solutions should provide functionalities focused on avoiding, detecting, mitigating, reacting and rebooting or restoring assets, digital technologies, and ICT infrastructure. Continuing research, development, and deployment of these solutions will be a key defence against future cyberattacks on critical infrastructure. EU-supported assistance and guidance to stakeholders within the battery sector, e.g DSOs, energy communities, vendors, platform providers, to developing cybersecurity plans would also be an effective tool for developing a more robust, secure digitized battery value chain.

The EU has implemented a number of cybersecurity and data privacy frameworks that have shaped the cybersecurity landscape throughout the European economy since energy assets are considered critical infrastructure. Energy companies and related services are subject to numerous regulations for cybersecurity and the protection of citizens' data. Regulations that may impact the digitization of the battery sector include, but are not limited to:

- The Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC more commonly known as the **General Data Protection Regulation** and the national regulatory frameworks.

- Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union (The NIS Directive)
- The Regulation (EU) 2019/881 of the European Parliament and of the Council of 17 April 2019 on ENISA (the European Union Agency for Cybersecurity) and on information and communications technology cybersecurity certification and repealing Regulation (EU) No 526/2013 (Cybersecurity Act) is focused on ensuring the proper functioning of the internal market while aiming to achieve a high level of cybersecurity, cyber resilience and trust within the Union.
    - This regulation includes a framework for the establishment of European cybersecurity certification schemes for the purpose of ensuring an adequate level of cybersecurity for ICT products, ICT services and ICT processes in the Union, as well as for the purpose

of avoiding the fragmentation of the internal market regarding cybersecurity certification schemes in the Union.

EU cybersecurity frameworks and regulations will need to continue to evolve as cybersecurity attacks are expected to become more sophisticated. This continuing evolution of regulations within the EU must protect its citizens' and business' privacy and data, but strike a balance with the need for digitization within the battery sector. Existing frameworks, R&D efforts, and cybersecurity regulations need to continue to be improve upon. However, the EU is strongly recommended to consider the digital communication needs for carrying out sector-specific services, such as battery storage. Secondly, e-privacy and digitization of the battery sector, and overall power sector, should be advanced in parallel. One should not hinder or hurt the other. Finally, broad stakeholder engagement on these issues will continue to be a key to the overall success of achieving a secure, digitized battery sector.

6 CONCLUSIONS

The digital initiatives ranging from managing the performance of assets and real-time platforms, to integrating energy storage and customer solutions, will **impact** strongly on **Europe's future**. Main impacts are: speed up innovation paths and time to market, **value creation**, disruption in the **energy market** and forging **new jobs**.

Data will be one of the critical pillars within the energy storage sector. This extends all along the battery value chain, from creating new business models to enhancing storage operation and increasing batteries life while ensuring it as a sustainable industry. This will require the deployment of data analytics capabilities at all levels: descriptive, predictive and prescriptive.

The electricity sector is ripe for realizing value from **rapid digital transformation**. By leveraging the building blocks of digitization, such as product and service platforms, smart devices, the 'cloud' and advanced analytics. Companies in the industry have the opportunity to increase the asset life cycle of infrastructure, including batteries, optimize electricity network flows, where storage has an increasing role, and innovate with customer-centric products and flexible energy systems.

Specific recommendations of Batteries Europe Digitalisation Task Force:

- Digitalization, decarbonization, decentralization and democratization tasks are paving the way for the "*platformization"* of the energy sector. Batteries Europe Digitalisation TF proposes building a battery- and customer-centric digital leading platform, which will inter alia benefit from proposed amendments to the Renewable Electricity Directive (new provisions on real-time access to information of battery management systems).
- Definition of policies and requirements to ensure quality and sustainability (i.e. processes, materials, stakeholders involved) along the battery life cycle and value chain (i.e. design and development to production, set up, O&M, usage, decommissioning and recycling), in alignment with the quality and sustainability policies in the EU. Procedures and sources of information and enforced measuring and monitoring through indicators should also be considered. Recent proposal for the new Batteries Regulation lays down the necessary basis for these developments.
- Enhanced cross-sector partnerships along the battery value chain, customers, new disruptive players, and policy-makers will be the key element to the digitalization of the battery and energy sector.
- Co-innovation pilots and prototypes should drive decisions and actions for a massive deployment while still benefitting from continuous learning and sharing best practices.
- Technology innovation must be open to everyone and specially incentivize consumers' engagement and empowerment (possibly by policy makers as well).

7 Appendix

7.1 Digital technologies

Digital Technology 1	
Tech name	Computer Aided Engineering (CAE)
Tech description	Computer Aided Engineering tools such as Finite Element Analysis (FEA) and Computational Fluid Dynamic (CFD) allows a detail analysis of processes.
Market figures	Many different CAE vendors
What can this Technology enable?	This technology allows to find bottle-necks and potential optimization before the actual tests are performed, improving time to market.
Readiness/Gaps (+, ++, +++)	Commercially available
R&I investment required if relevant for batteries	Adaptation of CAE models to replicate the different types of chemistry batteries including electrodes, Battery Management System and whole Battery. It is applied research.

Digital Technology 2	
Tech name	Design of Experiment Methodology
Tech description	Usage of Design of Experiment Methodology to reduce the number of experiments to characterize a process.
Market figures	Methodologies are currently available
What can this Technology enable?	Reduce the number of experiments to be performed with the CAE model to develop a Digital Twin of the batteries and their components. Similarly, the methodology can be applied to the production processes.
Readiness/Gaps (+, ++, +++)	Commercially available
R&I investment required if relevant for batteries	Currently available, it needs to be adapted for the specific characteristics of the types of batteries and different proposed manufacturing processes. It is applied research.

Digital Technology 3	
Tech name	Big Data Analytics (BDA)
Tech description	In the context of strategical optimization in battery production, the generation of knowledge based on an overall understanding of the underlying processes becomes more vital. Both in manufacturing as well as in planning Big Data Analytics tries to recombine different data sets from different production facilities and aims at gaining a general understanding of processes and key figures.
Market figures	Analytics Platform of successful enterprises with digital value chain and business models
What can this Technology enable?	This technology can enable a broader understanding of common challenges in battery manufacturing. BDA is able to forecast production quality along with machine health, enabling e.g. use-cases such as predictive maintenance.
Readiness/Gaps (+, ++, +++)	Huge open-source community, complex ecosystems ready to use and to implement
R&I investment required if relevant for batteries	Combination of tools for the generation of an ecosystem that fits well to the scale and availability of information in battery manufacturing.

Digital Technology 4	
Tech name	Digital Twin and AI for manufacturability & for battery operation optimisation
Tech description	Establish a proper digital twin of the battery that encompasses the realistic behaviour of the battery (mix of experimental and simulation data), in order to assess the battery/electrodes

	behaviour during the manufacturing process (mixing/coating/calendaring/winding/filling…). There is a need to model the manufacturing process as well as the battery itself. Different views on the product/process offer insights about process quality and optimization potentials. It takes advantage of the CAE technologies (Tech 2b) and Design of Experiment (Tech 2c) methodologies to create a virtual model. Battery cell-module-pack-system digital twin with accurate description of dynamics, included with learning AI to parametrise with operational data
What can this Technology enable?	Creation of a virtual model that allows to have online analysis for maintenance, include sensors into batteries, performance prediction, Life Cycle analysis, forecast safety analysis for workers and end-users. Coupling of these technologies under one single Graphical User Interface. The Digital Twin enables context-sensitive analytics of information from the production process and allows to reduce production scrap. In addition, digital twin(s) support: - battery lifetime optimisation - improved safety management - assessment of end of life point and possibility for 2nd life - operation optimisation of vehicle/application
Readiness/Gaps (+, ++, +++)	Improvement needed Most of these technologies are currently available, it is mostly applied research. Interconnectivity of hardware devices and software platforms required, technology readiness level already high
R&I investment required if relevant for batteries	Mostly applied research of previously developed technologies and methodologies of other sectors. Huge research potential in combination with Big Data Analytics and AI methods, e.g. Machine Learning. Application of digital twin/AI technology for end of life determination, advanced modelling, real time data availability,
EU Competitive advantage	Manufacturing performance

Digital Technology 5	
Tech name	Cells/Modules wireless communication within battery pack
Tech description	Using wireless communication to communicate with cell/modules sensors and assure a new safety level avoiding wiring cables that might generate hazards and fault risks. This will exploit present and future available networking systems (Bluetooth,5G, MEC, …) that will be available in the industry or around the city.
Market figures	Investment in 5G and fast and cheap networking system are one of the main driver of worldwide economics
What can this Technology enable?	Transition to a seamless integration of battery pack assembly and cloud/edge stack monitoring.
Readiness/Gaps (+, ++, +++)	+++
R&I investment required if relevant for batteries	Cost effective analysis should be implemented and case studies identified
EU Competitive advantage	Very few studies have been implemented so far

7.2 Digital use cases

-WHAT DIFFERENCE WILL MAKE BRINGING DIGITAL BATTERIES PART OF THE ENERGY SYSTEM-

Digital Use Case 1	
Name	Automated materials discovery
Description 	Autonomous synthesis of advanced materials driven by databased models and high-throughput characterization for new battery technologies will fundamentally change the way new materials will be discovered. For the full utilization of digital discovery the link to holistic cell models (materials interface genome), high-throughput and –fidelity characterization and feedback loop from cell production and testing is required. Materials and interface data will be input parameters for the development of cell-specific digital twins.
Innovation level (+, ++, +++)	+++
Feasibility (+, ++, +++) (time to market)	+ (Time to market 2030)
R&I investment required – private and public	100 M€
Value and impact (qualitative /quantitative)	Automated discovery will drastically reduce development times for new battery generations and allow for fundamentally new cell concepts. New technologies with performance parameters way beyond the existing will open new markets and leverage decarbonisation of existing markets.
Link to Market	R&D
Link to Supply chain	Discovery and Development, Maintenance, Usage (digital twin)

Digital Use Case 2	
UC name	Green Battery Passport & digital referential
Short Description	Battery supply/value chain information system
UC description 	Actors in the battery supply chain, from manufacture to end-of-life management do not have the necessary information or data to manage their tasks in an efficient and safe way. The battery information system, fed by data from traceability of battery materials, importers or companies placing batteries on the EU market, should help each actor to access and produce the documentation of the sources/trace information needed. Batteries could have a kind of QR code labelling allowing the access to a decentralised database. The proposed use case shall be in line with the concepts as described in Article 65 of the proposal for Battery regulation. Additional measures can include a battery passport's integration into a Product Lifecycle Management framework which would evaluate the LCA and recyclability of the battery. The battery passport could be connected to a new Smart BMS which would: track the degradation of each single cell over time; publish and update this information on an accessible and fraud-proof online database for second life usage. This is without prejudice to ongoing negotiations on the Battery Regulation. Relevant R&I will be facilitated by Digital Europe programme's CSA call for Digital Product passport. In addition, there may be EU support to a proper tracking and block-chain or

	DLT (Distributed Ledger Technology) based solution, along the value chain, with no data duplication, avoiding data manipulation and promoting data interoperability.
Innovation level (+, ++, +++)	+++
Feasibility (+, ++, +++) (time to market)	+++ (but there are regulatory/IP issues)
R&I investment required (up to 2030) –private and public	Investments: 30-45 M€
Value and impact (qualitative /quantitative)	• Transparent and fraud-proof value chain of battery materials Enabler for direct recycling concepts with respect to battery cells from unclear origin • first and foremost: managing **safely** the battery supply chain and more particularly the end-of-life management • Secondly: allowing a more efficient achievement of the collection and recycling targets foreseen in the Battery directive/upcoming Batteries Regulation • Digital referential will allow to compare product sustainability performance during engineering phase
Link to Market	All. New regulation will impact cell producers, battery system assemblers, re-purposers, recyclers, etc
Link to Supply/Value chain	Manufacturing, Maintenance, Usage, End of Life

Digital Use Case 3	
Name	Advanced methods for SoX now- and forecasting (sensors & big-data)
Description	At present, BMS determining the SoC and SoH on single cell level are rarely utilized in a battery module, statistical variation of characteristics of the cells in series will lead to premature aging and potential safety issues. Advanced sensing at cell level, e. g. by Electrochemical Impedance Spectroscopy (EIS) or acoustic characterization to analyse individual wear and critical failure states will allow for mitigation measures (active balancing, self-healing) on cell or pack level. Complementary to advanced sensing are Machine learning (ML) algorithms for a nowcast State of Energy (SoE) and forecast (remaining useful lifetime) of interconnected batteries (battery in the cloud / Big-data). Interface/data transfer to logistic
Innovation level (+, ++, +++)	+++
Feasibility (+, ++, +++) (Time to Market)	++
R&I investment required – private and public	20M
Value and impact (qualitative /quantitative)	Despite the fact that the technology is still under development, the potential market is enormous. In fact, the player who will set this system will open a new BMS frontier and open the space for new market focusing on second life of batteries and recycling.
Link to Market	All, especially BESS
Link to Supply chain	Development, Usage, Maintenance

Digital Use Case 4	
Name	Hybridization and multiuse of battery electric storage systems (BESS) into flexible portfolios.

Description	Utilise full content of ISO 15118 in smart charging of EVs and fleets to add availability of state of charge for full exploitation of the concept of virtual power plants of EV batteries in demand side management and V2B, V2G. Integration of the energy & charging management with local production and spot tariffs. Examples can range from car batteries to district storage and commercial/industrial (C&I) batteries.
Innovation level (+, ++, +++)	++
Feasibility/Complexity (+, ++, +++)	+++
R&I investment required – private and public	50M
Value and impact (qualitative /quantitative)	Multi-services in the form of coupling will elevate energy storage technologies as a means to improve system flexibility and enable higher renewable energy penetration rates in Europe.
Link to Market	BESS + EVs; Prosumer, Suppliers, Traders, C&I
Link to Supply chain	Development, Usage, Maintenance

Digital Use Case 5	
Name	Accurate datasheet generator based on application specific big data simulation platform
Description	New generation lithium cells are reaching the market, however there is always the big problem of the reliability of datasheet with respect to different application contexts. Exploitation of large data sets from the lab, the field and from simulations both for established and new chemistries via AI training tools in a multi-parameter space will allow for the automated generation of application-specific data sheets and a-priori estimation of SoH to be expected.
Innovation level (+, ++, +++)	++
Feasibility/Complexity (+, ++, +++)	++
R&I investment required – private and public	30 M
Value and impact (qualitative /quantitative)	The value proposition of this case is a reliable decision basis prior large investments and therefor a faster adoption of new chemistries into the market and for new markets utilizing batteries.
Link to Market	All, especially for customized BESS
Link to Supply chain	Development, Usage

Digital Use Case 6	
Name	Digitalization of the battery cell production
Description	Data driven process monitoring and control based on a generic system architecture of production hardware, interconnected actors and sensors, semantic databases and AI-toolboxes monitoring and controlling the production processes. The use case can also be used as for the setup of a holistic digital twin utilizing relevant production data.
Innovation level (+, ++, +++)	++
Feasibility/Complexity (+, ++, +++)	+++
R&I investment required – private and public	50

Value and impact (qualitative /quantitative)	Digitalization of the production processes will lead to a paradigm shift from linear production chains to format and demand flexible modular production of battery cells and increasing competitiveness of European cell manufacturers.
Link to Market	All
Link to Supply chain	Production, Usage, Maintenance

7. Digital integration	
UC name	Battery Ecosystem Marketplace Platform (s) for Management, Services, and Supplies
UC description	A platform to provide different market players with well-catalogued access to information on battery systems and complimenting services. Ideally it should be connected to battery passport and aligned with data space specified in the upcoming Batteries Regulation and contribute to the upcoming Digitalisation of Energy Action Plan[10] .
Innovation level (+, ++, +++)	+++
Feasibility (+, ++, +++) (time to market)	++ (Time to Market, 5-7 years, 2027)
R&I investment required – private and public	Investments: 20 M€ R&I is required to identify specific needs and characteristics of such a marketplace. To provide a catalogue for customers would require: business model development, technical requirements, and identifying inputs for comprehensive battery ecosystem development.
Value and impact (qualitative /quantitative)	Democratizes the value chain by providing easy, centralized access to battery supplies and services covering the whole life cycle of batteries. This includes (but is not limited to) detailed information about specific batteries, management services/battery as a service (BaaS), peer-to-peer market opportunities, and recycling services.
Link to Market	All consumers on the "usage" side of the battery value chain: TSOs, DSOs, C&I, Prosumers, Energy Communities, Suppliers, Traders, BRPs, Power Generators, Equipment and Battery Providers/Vendors.
Link to Supply/Value chain	Usage cycle

10 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13141-Digitalising-the-energy-sector-EU-action-plan_en