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PART 2/3

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

Accompanying the document

Proposal for a Regulation of the European Parliament and of the Council

concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) 2019/1020

{COM(2020) 798 final} - {SEC(2020) 420 final} - {SWD(2020) 334 final}

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1. ANNEX 1: PROCEDURAL INFORMATION

1.1. Lead DG, Decide planning / CWP references

The preparation of this file was co-led by two Directorates–General: DG Environment (ENV) and DG Internal Market, Industry, Entrepreneurship and SMEs (GROW). It was included as the following items in the DECIDE/Agenda Planning database: PLAN/2019/5391, Modernising the EU's batteries legislation, Proposal for a Regulation (or a Directive) of the European Parliament and of the Council on batteries and accumulators and waste batteries and accumulators and repealing Directive 2006/66/EC

The reference in the Commission Work Programme is in ANNEX I (New Initiatives) Point 9.

1.2. Organisation and timing

On 11 December 2019 the Commission announced that it would **propose legislation** in 2020 to ensure a safe, circular and sustainable battery value chain for all batteries, including to supply the growing market of electric vehicles in its Communication on the Green Deal. Earlier on, in May 2018, the Commission adopted the the third 'Europe on the Move' mobility package[1], to which a **Strategic Action Plan on Batteries** was annexed. This set out measures to support efforts to build a battery value chain in Europe, embracing raw materials extraction, sourcing and processing, battery materials, cell production, battery systems, as well as re-use and recycling.

As part of the evaluation exercise started in 2017, the Commission also published in April 2019 the **Report on the Implementation of the Batteries Directive** and the **Report on the Evaluation of the Batteries Directive**

Following a political decision from the relevant cabinets, it was decided in December 2019 that a single legal instrument would be replacing the Batteries Directive and incorporate the sustainability requirements for rechargeable batteries on which DG GROW had been working since mid 2018.

The **Inception Impact Assessment Roadmap** was published on 28 May 2020. At its closure, on 9 July.

[1] Annex to COM(2018) 293 final

To support the analysis of the different options, the Commission awarded several **support contracts** to external experts:

- Study assessing the feasibility of measures addressing shortcomings in the current EU batteries framework
- Study addressing particular topics on batteries (second life, restrictions, deposit and refund schemes, etc), legal statuses, restrictions, etc).
- Preparatory Study on Ecodesign and Energy Labelling of rechargeable electrochemical batteries with internal storage
- Follow-up feasibility study on sustainable batteries
- Impact assessment on Ecodesign and Energy Labelling of rechargeable electrochemical batteries with internal storage.

These experts worked in close cooperation with the Commission throughout the different phases of the study.

The Inter Service Steering Group (ISSG) for the Impact Assessment was set up by the Secretariat-General (SG). It included the following DGs and services: CLIMA (Climate Action), CNECT (Communications Networks, Content and Technology), COMP (Competition), ECFIN (Economic and Financial Affairs), EMPL (Employment, Social Affairs and Inclusion), ENER (Energy), ESTAT (Eurostat), JRC (Joint Research Centre), JUST (Justice and Consumers), MARE (Maritime Affairs and Fisheries), MOVE (Mobility and Transport), OLAF (European Anti-Fraud Office), REGIO (Regional and Urban policy), RTD (Research and Innovation), SJ (Legal Service), TAXUD (Taxation and Customs Union) TRADE (Trade). Meetings were organised between February and September 2020. Further consultations with the ISSG were carried out by e-mail.

The ISSG discussed the Inception Impact Assessment and the main milestones in the process, in particular the consultation strategy and main stakeholder consultation activities, key deliverables from the support study, and the draft Impact Assessment report before the submission to the Regulatory Scrutiny Board.

1.3. Consultation of the RSB

The Regulatory Scrutiny Board (RSB) delivered a positive opinion with reservation on a revised draft of the Impact Assessment on 18 September 2020.

The table below presents an overview of the RSB's comments and how these have been addressed.

RSB comments	How the comment has been addressed
The report does not sufficiently present recent and emerging developments in the batteries sector in the EU. The baseline is, therefore, not a good basis for comparison.	Section 5 on the baseline was complemented with data on the announced number of investments (see also further comment below).

RSB comments	How the comment has been addressed
The argumentation behind the composition of measures in the options is not clear and coherent.	The options table has been restructured. A new column has been added to group sub-measures with a "very high level of amibition", labelled as Option 4, and some sub-measures were moved from the "medium level of ambition" (Option 2) to the "high level of ambition" Option 3. This intervention ensures more transparency and coherence about the composition of the Options without fundamentaly changing the impact assessment. A table has been added in Section 6 to explain why certain sub-measures were not included in the Options (see also further comment below).
The report could strengthen the internal market dimension of the problem with additional evidence, especially on the extent to which competition is currently distorted in the EU. For this purpose, and to depict the global supply situation, the main report could integrate some information from annex 7. When referring to a 'lack of level playing field', the report should systematically specify who is affected and how. Furthermore, the report could also better present the current state of implementation of the existing legal framework and investigate to which degree the problem differs across Member States.	An additional figure from Annex 7 was added to Section 1.3.1. on future demand. Likewise in Section 1.3.2 on future production a figure was added depicting lithium-ion cell production capacities for industrial batteries within the EU in GWh per year by location of plants. A sentence was added in the introduction of Section 2 to clarify the definition of the term "level playing field". Sections 2.1.1.1 to 2.1.1.3 provide examples of who is affected by this problem and how. The use of the term "level playing field" was also reduced in Section 3. Information on the state of implementation of the Batteries Directive is included in various sub-sections of Section 2.1, including on collection, recycling efficiencies, removability, hazardous substances and labelling. The report on the implementation of the Directive (COM(2019)166) does not include any further information on differences between Member States.
The report should better cover recent rapid developments in the EU batteries market. It should better assess to what extent problems remain after the ongoing and announced investments in EU battery capacity. In particular, it should explain remaining risks to fair competition within the EU. The baseline should include these developments.	Section 5 on the baseline was complemented with data on the announced number of investments. Section 5 now also better explains which problems will remain and what the risk of unfair competition are. Furthermore two paragraphs were added in Section 2.1 on the problem definition to explain the example of the second life market for industrial batteries, which may result in market fragmentation if no regulatory action is undertaken.
The main report should explain the selection of 'most relevant sub-measures' in the options. It should clarify the reasons for discarding certain non-preferred sub-measures (as analysed in annex 9) and maintaining others.	A table has been added in Section 6 to explain why certain sub-measures were not included in the Options. This table sums up the key points of what is mentioned in the Annex 9.

RSB comments	How the comment has been addressed
The table on costs and benefits of the preferred option (annex 3) should use the standard template, distinguishing more clearly between costs and benefits. It should not include unnecessary information, such as stakeholders' views. It should contain all available quantification. In addition, the text of the annex should describe the practical implications of the preferred option for different stakeholder groups.	Annex 3 was revised using the template from the Better Regulation Toolbox, thus better distinguising between costs and benefits. All the available quantified data are included. Stakeholder views have been removed from the table and have been been clarified beneath the table where they concern practical implications.

In an earlier stage the Regulatory Scrutiny Board (RSB) delivered a negative opinion on a draft of the Impact Assessment on 24 July 2020 after the meeting on 22 July 2020.

The table below presents an overview of the RSB's comments and how these have been addressed.

RSB comments	How the comment has been addressed
The report does not explain clearly enough what the problem is with regard to the internal market and EU domestic production.	The explanation of the problem with regard to the internal market and EU domestic production has been improved in Section 2 of the report (see also more detailed comment below).
The report does not sufficiently justify the composition of the options. It does not explain what (part of the) measures it proposes to leave for future secondary legislation.	The composition of the options has been clarified in Section 6 of the report, by adding a table that includes all the sub-measures and another table with an overview of the policy options that makes a cross-reference to the table with the sub-measures (see also more detailed comment below).
The report does not sufficiently explain and assess the combination of measures included in the preferred option.	The explanation of the combination of the measures included in the preferred option has been improved in Section 8 (see also more detailed comment below). The simplification potential of the preferred option has also been added to the analysis.
The report should better explain the internal market dimension of the problem. It should be specific how the 'level playing field' is not guaranteed for the different stages of the battery value chain. It should clarify how competition is distorted in the EU. It should better justify that the internal market problems are more significant than the environmental problems. The report needs to strengthen the arguments in favour of EU domestic production of batteries. It should include an account of the recent changes in EU industry capacity expansion.	Section 2 on the problem definition has been significantly redrafted to address the points listed in this comment including clarifying the problem related to responsible sourcing. An account of recent changes in EU industry capacity could not be added because until now there have not been any significant changes. Regarding planned investments in future capacity expansion no comprehensive data are available.
The report should more clearly spell out the political and inter-institutional commitments that have been made in this area (e.g. in the context of the Strategic Action Plan on Batteries, the Green Deal and Industrial policy agenda) and to what extent these influence the starting point of this impact assessment.	Section 1.1 has been completed with a point on a resolution for the EP Committee on Industry, Research and Energy and with a point on an announcement of the EIB to increase its backing of battery-related projects to €1 billion. Section 6 has further clarified the starting point of the Impact Assessment.

RSB comments	How the comment has been addressed
The report should better explain and justify which measures it includes in each option. It should more clearly argue why it discards some measures at an early stage. It should explain what part of the measures will be included in the revision of the Directive and which will be developed in secondary legislation.	Section 6 has been redrafted to better explain the selection of the measures and the composition of the policy options. A new section explains the common measures and why they are not discussed in detail. An explanation has also been added on why some measures were discarded in an early stage, and also on which measures will be further developed through secondary legislation.
The report should strengthen the comparison of the medium and high-ambition options and document it transparently. It should better justify the composition of the preferred option.	Section 7 has been redrafted so as to present a clearer, self-standing summary of the detailed analysis that was carried out for all the measures. For every measure section 7 now includes a summary of the economic and environmental impacts and of the measure's feasibility and stakeholder acceptance (including minority views) Building on this summary, Section 8 has also been redrafted to provide a short explanation for every measure what the preferred option is. In addition Annex 9 has also been significantly redrafted in view of improving the clarity of the analysis including adding an introduction which further elaborates the logic of the Annex.
The report should include a clear synthetic overview of all costs and benefits of the preferred option. The required standard cost and benefit table in annex should contain all quantitative and qualitative cost and benefit data related to the preferred option.	Section 7 has been redrafted and now includes a concise discussion of the costs and benefits of all the measures. Annex 3 of the report has also been redrafted. It now includes an overview of all the quantitative and qualitatitve impacts of the preferred option.
The report should be a self-standing document. It should contain the main elements of the analysis, leaving more detail to the annexes.	Thanks to the redrafting of Sections 2, 6, 7 and 8 the main report is now a self-standing document that includes all the key elements for all the measures.

The RSB had previously given some indications of what was required through an upstream support meeting organised on 18 March 2020. The table below presents an overview of the RSB's suggestions and how these have been addressed.

RSB comments	How the comment has been addressed
ENV and GROW should continue to work closely together on the file given its industrial and environmental dimensions. To note that there have been two distinct processes until recently: the Batteries Alliance (GROW) and the revision of Batteries (ENV) Directive. These are now pulled together.	A Task Force was established consisting of officials from DG ENV and DG GROW. The Task Force functioned as a team and prepared the IA together.
In terms of objectives, industrial competitiveness and the need to meet Europe’s increasing demand for batteries should feature prominently in the objectives section of the Impact Assessment.	Industrial competitiveness and the need to meet Europe's demand for batteries have been included in section 4 on the objectives. It is also discussed in Section 2 on the problem definition

RSB comments	How the comment has been addressed
Addressing market failures and reinforcing the requirements in terms of efficiency and recycling is key. The evaluation showed the need for additional requirements for recycling but also for production (recyclability).	Market failures and inefficiencies in the use of resources have been highlighted in section 2 on the problem definition. Several measures included in the proposed options aim to address these issues.
The report should reflect on the relationship and any trade-offs, for instance between a possible increase in transport battery costs as a result of the initiative and the decarbonisation of transport.	The impacts of the measures are assessed against 5 criteria, one of which is economic impacts (including possible additional costs to producers or end-users). These are discussed in Section 7 on the assessment of the impacts and in more detail in Annex 9.
Board members noted that revisions of the battery Directive are likely to have a wide range of impacts on a wide range of stakeholders. Rather than comprehensiveness, they will be looking for clarity on what political decisions need to be taken. Informing these decisions should serve as the focal point for evidence gathering and presentation.	The key political decisions to be made are presented in section 6 on the policy options and in section 7 on the impacts of the policy options. The political aspects have been made the centre of the presentation.
Given the numerous challenges related to the environmental and industrial dimensions, it will be important to position the new legislation in the international dimension and to assess how the initiative would affect the EU's competitiveness with third countries.	The impacts of the proposed measures on the EU's competitiveness vis-à-vis third countries are discussed in Section on international competitiveness.
On stakeholder consultation, Board members stressed the need to gather information from different stakeholder groups on how they perceived likely impacts and consequences of the different policy options. Targeted activities aimed at NGOs and the civil society could supplement or fill gaps in the public consultation.	There have been several consultation processes on batteries. DG ENV carried out extensive stakeholder consultations as part of the Evaluation of the Batteries Directive. There was later a similar process with the preparation of sustainability criteria as a possible development under the eco-design directive. Stakeholders have been consulted through targeted interviews and sectoral meetings. NGOs participation in these processes has been noticeable.
Board members stressed the importance of specifying what success would look like. What benchmarks are relevant to determine that the policy will have had the intended effects? Clear objectives and transparency about the trade-offs is essential.	Relevant benchmarks on what success will look like are discussed in Section 9 on monitoring and evaluation.
Board members stressed that clarity and reader-friendliness is important, including plain language with minimal jargon. This applies especially to the executive summary.	The IA has been written such that it is accessible to non-experts. To this end it also includes an extensive "glossary" that explains the main terms". The executive summary is written in a clear and concise manner.
Board members and the SG mentioned the need to consider the one-in-one-out principle. Both administrative and compliance cost increases/savings should be quantified as far as possible.	The IA does it (see Annex 3) and there is a discussion in Section 8 of Regulatory Burden and Simplification

1.4. Technical changes made to the impact assessment after the RSB's approval

To reflect new data and insights, a number of technical changes were made to the impact assessment after approval by the RSB. These include:

- For Measure 3, an additional intermediate target of 70% by 2030 (Option 3) was included and assessed. This was done on the grounds that the cost benefit assessment showed that increasing the target (70%) while prolonging the timeline (2030) would be comparable to the costs and benefits of Option 2.
- For Measure 5: changes to the target levels for lead-acid batteries to take into account the inclusion of outer casings. This was done based on modelled data to reflect a change in the definition of the rates, which includes the outer casing in the proposed Regulation because this is important for Li-ion batteries (contrary to the Batteries Directive, which doesn't cover Li-ion batteries and excludes the outer casing for other battery types, notably lead-acid batteries).

2. ANNEX 2: RESULTS OF THE PUBLIC AND STAKEHOLDER CONSULTATIONS

The Impact Assessment accompanying the Batteries Regulation was subject to a thorough consultation of all stakeholders to ensure that view from different organisation were presented and considered.

As part of the preparation of the reports on the Implementation and the Evaluation of the 2006 Directive, the Commission carried out consultation activities consisting of a 12-week public consultation, consultations with Member States experts, stakeholders and relevant NGOs. In addition, expert-group meetings and targeted interviews provided for a more detailed and technical perspective[2].

The Eco-design preparatory Study for Batteries also included an 8-week public consultation[3] and targeted interviews.

The Commission has in addition carried out further targeted consultations with Member State experts, stakeholders, NGOs and consumers' associations, in addition to welcoming the feedback on the Inception Impact assessment.

This synopsis report presents a summary of these consultation activities and their results. It should be noted that Annex 9 shows in detail the views of the stakeholders on the measures under discussion.

2.1. Feedback to the Inception Impact Assessment.

The Inception Impact Assessment was published on 28 May 2020 and the period to provide feedback was closed on 9 July 2020.[4] A high level of response was received, largely supporting positions set out by stakeholders earlier in the process (for example, during the targeted stakeholder consultations).

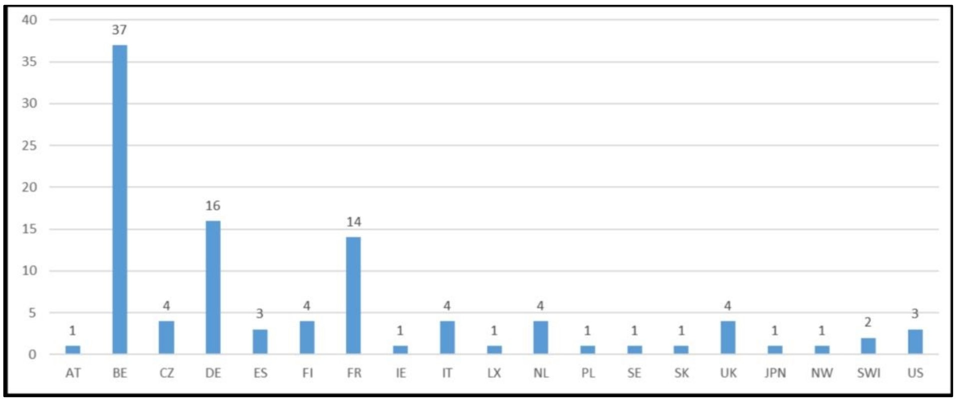

Figure 1: Origin of respondents to the consultation on the Inception Impact Assessment[5]

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2 See relevant annex to document SWD(2019)1300

3 See https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/1996-Sustainability-requirements-for-batteries

4 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12399-Modernising-the-EU-s-batteries-legislation

5 The relatively high number of respondents from Belgium is due to companies and business associations that have an office in Brussels for representational purposes.

One hundred and three valid contributions were received. In addition, more than 50 statements have been uploaded as attachments. The country origin of the respondents is presented in **Figure 1**.

The analysis of the stakeholders' input shows a general recognition of the need for this regulatory initiative. Respondents acknowledge that technological, economic and social changes would justify the establishment of a new regulatory framework for batteries.

In general, respondents think it is appropriate that a single instrument contains all (or the majority) of legal provisions concerning batteries, along its entire value chain and life cycle.

The ambition of the initiative is pointed out as a difficulty for the assessment, in particular as regards the scope of the changes considered. Several contributors underlined the difficulties to conciliate diverse and, sometimes, very different policy objectives like competitiveness and environmental sustainability.

In the majority of cases, the measures proposed by stakeholders were already considered by the Inception Impact Assessment. In some cases, however, very specific sub-measures were proposed that did not fit in with the scope of the initiative. Several contributions proposed criteria and feasibility conditions to be considered when assessing possible measures.

Some important topics received particular attention from the respondents and were considered during the Impact Assessment process.

- A Regulation, not a Directive. The large majority of contributors welcome a change of the type of legal instrument, to reach full harmonisation and assure a level playing field. Some point out the risks of having a single instrument with such a broad scope and indicate the need not to dismiss taking the route of product-specific legislation, e.g. on eco-design.

  The Impact Assessment process has kept the door open to such approach, in particular when dealing with product-design sub-measures, as, e.g. on interoperability.

- A new methodology for the calculation of collection rates, since the currently existing one, established by the 2006 Directive and based on the weight of batteries placed on the market is sharply criticised. Several stakeholders propose to use a new methodology based on the concept of waste batteries 'available for collection', even as a possibility for the calculation of collection rates for automotive and industrial batteries

  The Impact Assessment process has adopted a practical approach in this regard, keeping the current calculation methodology for the evaluation of the impacts and considered moving towards the proposed new methodology.

- Several recyclers insist on avoiding closed-loops approaches as in their view they would result in increased environmental impacts and losses of efficiency in the use of materials. Other stakeholders proposed to enlarge the closed-loop recycling possibilities and incorporate additional materials (as, e.g. battery casing) to the assessment.

  The approach taken in the Impact Assessment process is to assume closed-loop recycling in view of obtaining a conservative estimate, while making clear that the legal definition of recycling includes open-loop processes.

- A number of respondents underlined the importance of verification and certification processes to ensure the success of sustainability requirements namely as regards their compatibility with existing international initiatives. This would allow increasing the transparency and ensuring a level playing field for battery producers globally.

  The Impact Assessment process has considered this and in particular, the setting of a verification system as regards responsible sourcing, carbon intensity and recycled content. In the case of responsible sourcing, the link with international initiatives like for example the OECD Guidelines on Due Diligence is taken into account.

- Several respondents underlined the risks that some possible measures would trigger changes in the development and use of existing (or future) battery technologies. There was also the concern that some measures could entail important changes in the demand and supply of battery raw materials within the EU market, leading to results that could be contrary to the desired effects.

  The Impact Assessment has taken note of these opinions. Nevertheless, the spirit of the initiative is to ensure an adequately designed schedule for the entry into force of the measures that will allow avoiding or at least minimising the risk of adverse effects. This is why for some measures the Impact Analysis found that an incremental approach is the most appropriate and that revision clauses should be foreseen.

- Many respondents insisted on the fact that the Impact Assessment should consider the use of IT systems for most of the regular monitoring, reporting or information actions being considered.

  This concern has been taken into account and for the sub-measures that require monitoring or verification, the Impact Assessment has considered all options for digitalisation.

- Many stakeholders have emphasised the convenience of reducing the number of legal instruments on batteries as far as possible. Nonetheless, when the coexistence of different legal instruments is needed, stakeholders consider the coherence between the legal provisions concerned essential.

  The basic assumption of this initiative is that a single instrument should be prepared. Particular care has been taken to exclude from the assessment areas where existing EU legislation is sufficiently developed (as, e.g. chemicals). In other cases, for instance in relation to the end-of-life vehicles Directive, the existence of possible synergies has been taken into consideration.

2.2. 2019 Public consultation

In the context of the preparation of a regulatory initiative on sustainability requirements for batteries, a first consultation round was organised by DG GROW between June and November 2019. It consisted of an open public consultation for which 180 contributions were received, and three public stakeholder meetings on the findings of two feasibility studies.[6]

Figure 2 gives an overview of the respondents to the DG GROW open consultation.

[6] See the details at https://ec.europa.eu/eusurvey/runner/EcodesignBatteries2019

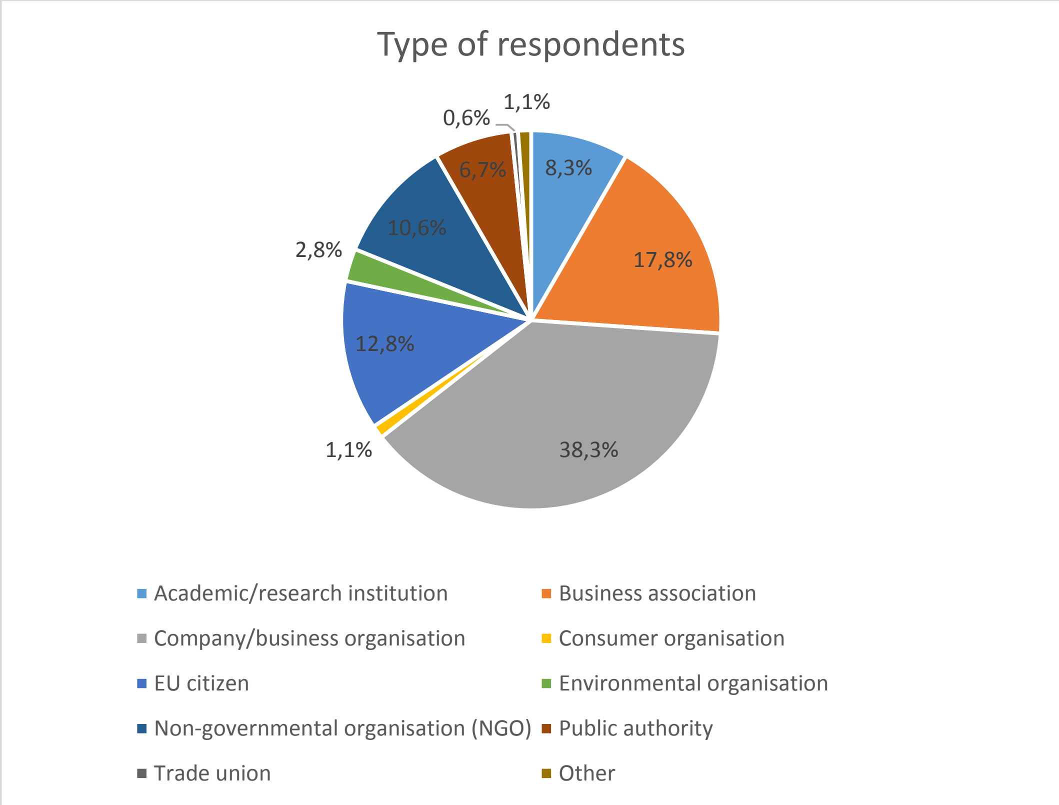


Figure 2: Type of respondent to the public consultation by category

The main results of this open consultation are presented below.

2.2.1. The importance of the batteries value chain

DG GROW's open consultation aimed at eliciting feedback on market trends and forecasts for the batteries market and the type of EU policy and regulatory interventions that would be most appropriate for the promotion of the European batteries ecosystem.

More than three quarters of respondents agreed with the idea that Europe will be an important player in the global market for batteries. Only 14% of respondents disagreed with this prospect. Amongst those disagreeing, the reasons put forward were very scattered, although almost 10% stated that European manufacturers will not be able to compete with Asian ones.

In terms of the drivers for Europe being an important player, 60% of respondents agreed that having a strong battery value chain in the EU is of strategic importance, and 55% considered that batteries are key to sustainable mobility and to the integration of renewable electricity generation in the grid.

2.2.2. Policy and regulatory interventions

When asked about the appropriate policy and regulatory interventions for the promotion of battery manufacturing in Europe, three categories came clearly on top: strict sustainability requirements (68%), R&D funding (67%) and financial instruments (63%). **Figure 3** below provides the complete breakdown of the replies to this question.

More than 40% of respondents believe there are barriers to the manufacturing and trading of new and used batteries in the EU. In terms of trading, the lack of harmonisation of rules on the transportation of hazardous waste (i.e. used batteries for re-use or recycling) was, by far, the most quoted barrier.

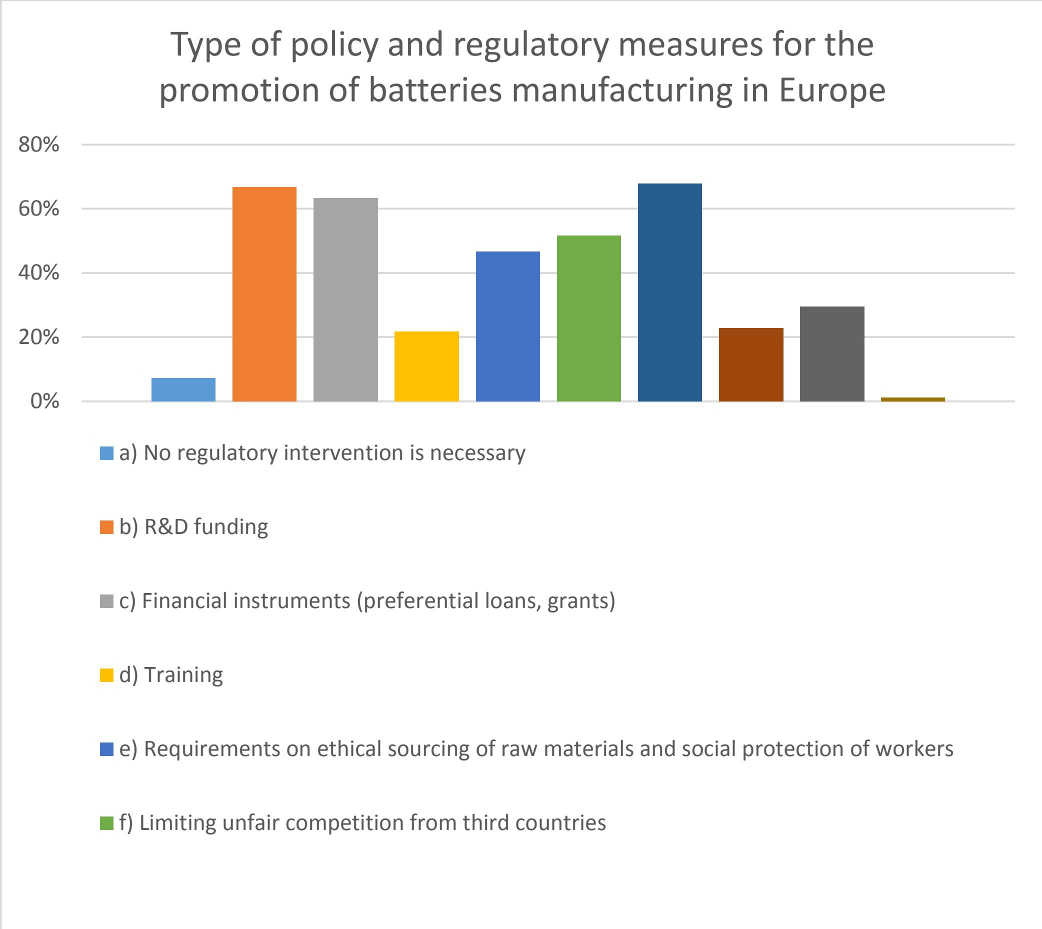


Figure 3: Type of policy and regulatory measures for the promotion of batteries manufacturing in Europe (multiple replies were possible)

2.2.3. Sustainable sourcing

When asked about the most relevant social and environmental impacts in battery production, almost 60% of respondents were in favour of setting reporting obligations on the responsible sourcing of raw materials. Furthermore, almost 54% of respondents supported a reporting obligation on all environmental impact categories, including climate change. Only 12% of respondents were in favour of not putting in place any reporting obligations or fixing minimum standards on the social and environmental impacts of battery manufacturing.

2.2.4. Performance requirements

In terms of the most relevant parameters to set minimum performance requirements for batteries placed on the EU market: almost 51% of respondents chose energy density as rather or very relevant and almost two thirds of respondents (63%) stated that round-trip efficiency would be a rather relevant or very relevant parameter to consider. 58% of respondents responded that access to relevant usage data history to facilitate the State of Health (SoH) determination would be rather or very relevant, and more than 74% of respondents claimed that durability would be a relevant parameter to set performance requirements.

2.2.5. Recycling

Almost 78% of respondents partially or totally agreed that design for recycling requirements could help increase the efficiency of battery recycling plants, while 13% partially disagreed or did not agree.

When asked about the possibility to set minimum weight based recyclability targets at product level to help increase recycling efficiency, slightly over 53% of respondents agreed partially or totally, while 22% partially disagreed or did not agree.

In regulatory discussions, some stakeholders put forward the claim that recycling technology and market-based solutions are more important than design requirements to achieve higher recycling efficiency rates. in. More than 53% of respondents either partially or completely agreed with this assertion, and a further 32% did not disagree. However, the fact that an overwhelming 78% agreed with the important role that design for recycling can play in achieving higher efficiency recycling rates would suggest that the recycling discussion may be trapped in a false dichotomy of either or.

Finally, more than 70% of respondents either partially or completely disagreed with the idea that no further action is needed to achieve higher recycling efficiency rates for batteries in the EU.

2.3. 2020 consultation activities

Following a political decision that a single legal instrument would replace the Batteries Directive and incorporate the sustainability requirements for rechargeable batteries on which DG GROW had been working since mid 2018, a second round of consultation activities was undertaken between February and May 2020, including

- Targeted interviews with representatives of the battery value chain, consumers and environmental associations;
- Survey for economic operators (manufacturers, waste managers and recyclers)
- Survey for research and innovation projects' representatives (funded under H2020 and LIFE programs);
- Sectoral meetings with stakeholders;
- Meeting with Member States Expert Group.

The main results of this new consultation round are presented below.

2.3.1. Collection rates of portable batteries

The main controversial aspect discussed by the stakeholders in relation to the collection rates of portable batteries is the method for its calculation – placed on the market (PoM) vs. available for collection (AfC). The majority of stakeholders defend the AfC approach because this would take into account losses such as batteries exported with equipment and the one retained/in use by the consumers. The retention effect (hoarding) was indicated as an important reason for the delay of the entrance of spent batteries in the waste chain – collection and recycling. Also, in some cases, batteries can last for several years resulting in a long lifetime before being discarded. However, the main problem of the AfC approach is the lack of an objective quantification method and hence the difficulty in achieving reliable data. Some stakeholders explained that in some cases targets based on PoM, might become unachievable because they might be higher than the amounts available for collection. The important role of consumers was also discussed, as implementation of collection targets is clearly dependent on consumer behaviours.

Concerning the target, 65% was seen an easily achievable target in several countries but a high ambition for the ones that did not comply with the current 45% target. In addition, the cost associated with high collection targets was mentioned as an important constrain.

2.3.2. Critical Raw Materials

Some of the raw materials used in battery manufacturing (e.g. cobalt, manganese, nickel and natural graphite) have a high economic impact as well as high supply risks and are screened by the European Commission as Critical Raw Materials (CRMs).

More than 73% of respondents either partially or totally agreed with the proposal to establish specific criteria to facilitate the recovery of CRMs, while 74% agreed partially or totally with the idea to set minimum recyclability targets for CRMs at product level.

When asked about the possibility to set specific requirements to guarantee a minimum recovery rate of the CRMs contained in batteries, the replies were too scattered to be significant, although almost 32% did not agree with the idea.

2.3.3. Recycling efficiencies / material recovery

Concerning recycling efficiencies, one of the concerns raised by the stakeholders was the scope for certain batteries. For example, in the case of Li-ion batteries, as there are several types of Li-ion batteries the question was if one target would be used for all types. Recyclers of alkaline batteries explained that they have their own internal targets and do not see the need for an official/mandatory one so they suggest keeping alkaline batteries out of the scope.

Another point of discussion was related to the material recovery rates and particularly the advantages and disadvantages of establishing targets for individual elements or for groups of elements. For the latter, one suggestion was to introduce different weights to the different metals of the group. Some stakeholders suggested that if the target is set for each metal everybody will go in the same direction and flexibility will be lower. Stakeholders also raised the question of which metals should be considered as valuable materials to be recovered and hence have defined targets, particularly manganese and graphite. Moreover, recyclers supported by producers, advocate that the current situation in which manganese is recovered not as a substance but in the steel production should be taken into account.

Concerning the individual or group metals approach, a consensus was not reached. Some stakeholders support the flexibility of targets per group and others did not see any advantage of such an approach.

Finally, the fact that black mass should be considered an intermediate product and not a final recovered material, was agreed by all the stakeholders,

2.3.4. Second-life applications for EV Li-ion batteries

In the academic literature on the second life applications for rechargeable batteries, there is an ongoing debate and inconclusive evidence on their economic feasibility and net environmental impact. This sparked a debate on the economic and environmental impact that a generalisation of second life applications for batteries would have. Almost 53% of respondents stated that this should have a positive economic and environmental impact, while 15% stated that recycling batteries after their first use would be more efficient in economic and environmental terms. Access to the battery management system to make a battery suitable for a second use was seen as relevant but this could create some issues mainly related to safety and control. This aspect was clarified by some producers who said that this is not necessary. Another important aspect raised by some stakeholders was the need to clarify the nomenclature – repurpose, reuse, 2nd life and remanufacturing.

Also, the health state of the batteries, the quality grades, possible certification means and transfer of EPR were aspects raised by several stakeholders.

In relation to other measures, in the case of 2nd life, batteries will have an extended life time and will hence not be available for recycling in the short term. This impact the minimum recycled content measure.

2.3.5. Recycled content

Stakeholders most directly affected by provisions of recycled content – producers and recyclers –expressed a generally favourable opinion on the introduction of a provision on mandatory recycled content in the new regulation. However, they raised some questions concerning the types/chemistries of batteries and the materials to be included in the provision, dates of entry into force, the recycling routes and expected rates of recovered materials, the carbon footprint balance of recycled vs. virgin materials, the costs of the processes and their impact on the batteries' costs and the verification/certification processes. The main advantages highlighted were the job creation, the boosting of the market for secondary raw materials, the potential for urban mining and the expected effect on the promotion of batteries collection.

2.3.6. Portable primary batteries restrictions

The first aspect raised by several stakeholders was the use of the expression "single-use batteries" for primary or non-rechargeable batteries. They expressed that, in opposition to other single-use products, primary or non-rechargeable batteries are not single-use. They can be used several times, even in different appliances, until they are spent.

Several producers explained that primary batteries, particularly alkaline batteries, are the best choice in several situations for example for low/medium drain appliances in which they are much more energy-efficient and last longer than rechargeable batteries. Additionally, the convenience factor of having a battery ready to be used is sometimes overlooked when primary batteries are compared to rechargeable ones. Moreover, for some appliances, there are currently no rechargeable alternatives.

The quality/performance of the batteries was also a point of concern of the consulted stakeholders. They consider the low-quality batteries available in the European market as the main reason for the bad reputation of primary batteries and for their impact on the environment.

Recyclers mentioned that some materials that would be necessary to produce the additional rechargeable batteries needed to replace all the alkaline ones are very scarce, for example cobalt.

Both producers and recyclers anticipated a significant social impact if primary batteries were banned from the market, mainly for alkaline batteries, which currently dominate the market. There are European recyclers only targeting alkaline primary batteries, whose processes cannot be converted to recycle rechargeable batteries and producers for which this segment is their core business. According to them, the loss of jobs in Europe will be significant.

The main conclusion from this part of the consultation was that primary and rechargeable batteries should coexist because they are used in very different applications. However, quality/performance should be a factor to take into account if restrictions are considered.

2.3.7. Classification of batteries

The stakeholder consultation showed clear support for creating a sub-category of EV batteries in the current industrial batteries category or the creation of a separate category for EV batteries. They did however not see the need for a drastic change in the current classification.

Several stakeholders such as producers of batteries and equipment expressed a favourable opinion on the use of a weight threshold to distinguish between portable and industrial batteries. In practical terms, this means that some batteries considered industrial under the current classification, would be considered as portable. This is already common practice in some Member States.

There was no consensus on what the weight limit should be for a battery to be classified as portable or industrial. Advantages and disadvantages were put forward in both cases. The main discussion was about the most adequate category for e-bikes, e-scooters and other e-mobility equipment and that a low weight threshold might divide batteries with similar purposes such as the ones used for e-mobility and for power-tools between two different categories.

2.3.8. EPR for the collection of industrial batteries

The consulted stakeholders raised several questions related to the EPR particularly concerning the practical arrangements at the end of the life of a battery. The most commented issues were the expected business model, the batteries' labelling system, and to which entity the costs would be charged – manufacturer, retailer or consumer. Some examples were given such as the German system, which follows a voluntary scheme. Linkages to the ELV Directive were also mentioned.

3. ANNEX 3: WHO IS AFFECTED AND HOW? OVERVIEW OF COSTS AND BENEFITS

3.1. Direct and indirect benefits

The table below summarises the direct and indirect benefits that will arise from the provisions of the Batteries Regulation. The stakeholders' positions are provided as text under the table.

I. Overview of Benefits (total for all provisions) – Preferred Option(s)		
Description	Amount	Comments
Direct benefits		
More targeted requirements for EV batteries		Introducing a new sub-category for EV batteries allows for specific requirements for these batteries.
Increase of EPR contributions		Introducing a 5 kg threshold for portables means that more producers will contribute with fees covering emerging categories of batteries handled by consumers.
Second-life of industrial batteries	GWP savings of 400000 tonnes of CO2 per year by 2035 Lower administrative costs due to less cumbersome procedures for dangerous goods	At the end of first life, batteries are not waste, second-life batteries are considered new products, and the EPR and product compliance requirements restart. Reliable information needs to be provided to economic actors for them to evaluate second-life possibilities.
Higher collection rates of portable batteries	Additional 40 000 to 43 000 tons of portable batteries collected (2025) representing a value of € 90 million per year. GHG savings of around 50% compared to baseline.	Setting a collection rate target of 65 % for portable batteries in 2025 and a target of 70% in 2030
Higher collection rates of automotive and industrial batteries	A 3% increase in the collection rate of lithium industrial batteries would lead to the recovery of 300 t/a more secondary cobalt in 2035	Establish reporting mechanisms for industrial batteries
Improved recycling	Additional amounts	

efficiencies and recovery of materials	collected (cumulative 2025-2035): 11 500 t of Co, 5 300 t of Ni, 22 000 t of Li and 57 000 tons of Cu are recovered 2025-2035 For lithium batteries about 11000 t of Co, 30700 t of Ni, 21500 t of Li and 56000 tons of Cu are additionally recovered from 2025 to 2035 (cumulative) compared to the baseline. For lead batteries about 191 000 tonnes of lead would be recovered from 2020 to 2035 (cumulative). This represents: For lithium batteries, under very conservative assumptions, estimated revenues range from € 23 million per year at present to € 497 million per year in 2035. For lead batteries this would be around about 32 million € per year until 2035. Cobalt revenues from 9.5 million € in 2025 to 80 million € in 2035, Nickel revenues from 2,4 million € in 2025 to 90 million € in 2035, Lithium revenues from 8 million € in 2025to 255 million € in 2035, Copper revenues from 3.3 million € in 2025 to 72 million € in 2035. GHG savings: 9.8	Lithium-ion batteries and Co, Ni, Li, Cu: Recycling efficiency lithium-ion batteries: 60% by 2025, 65% by 2030 Material recovery rates for Co, Ni, Li, Cu: resp. 90%, 90%, 35% and 90% in 2025, 95%, 95%, 70% and 95% in 2030 Lead-acid batteries and lead: Recycling efficiency lead-acid batteries: 75% by 2025, 80% by 2030 Material recovery for lead: 90% in 2025, 95% by 2030

	million tonnes of CO 2-eq for lithium and 189 000 tonnes for lead between 2020 and 2035 15 % reduction of 'Human Toxicity'	
Transparency and comparability for consumers		Information made available on carbon intensity, and performance and durability.
Better quality batteries on the EU market	Reinforces the benefits of rechargeable batteries in high drain products and leads more users to shift to such batteries. For low drain products, consumers could use better quality batteries, which may be more costly at purchase but will have longer lives.	Restriction of primary batteries that do not fulfil certain criteria
More mature secondary materials market	Mandatory levels of recycled content will contribute to the development of cost-efficient recycling activities that can deliver battery-grade recycled materials. The market will have the legal certainty it requests to invest in technologies that would otherwise remain undeveloped.	Information requirements on mandatory levels of recycled content and mandatory levels of recycled content
Battery design to facilitate battery removal	Increase in material recovery and related revenues. Decrease in safety incidents.	Strengthened obligation on removability and additional requirements on repairability and replaceability/
Better informed purchase decisions		Basic information available on battery or packaging and complete information available online
Reduced environmental impact through due diligence obligations		Basic information available on battery or packaging and complete information available

		online
Indirect benefits		
Job creation	2000 FTEs by 2030 for second-life market linked to expected revenues of € 200 million by 2030. 3100 FTEs for additional collection and recovery of portable batteries as well as for automotive and EV batteries. 2168-3272 new jobs in 2030 and 5481-7302 in 2035 compared to the baseline in recycling and recovery of materials. Job creation in batteries removal and treatment facilities Expected positive impact in employment of high quality batteries' producers	
Higher quality data for EV batteries		Introducing a new sub-category for EV batteries allows linking the reporting system for EV batteries to the existing EU-wide reporting system for vehicles. The data will be more granular with transparent mass flows and will still be comparable to existing data.
Shift to greener electricity providers/contracts		Mandatory carbon footprint declaration may prompt manufacturers to choose greener electricity providers/contracts.
Increased secondary materials demand		Mandatory recycled content targets will increase secondary material demand, in turn driving increased collection of batteries and recycling.
Improved knowledge of		Due diligence obligations

supply chain, better risk management and capital allocation Increased transparency, credibility, reputation and public image		will improve transparency of information
Improved employment stability and reduced health issues for operators and communities in sourcing and manufacturing regions.		Due diligence obligations will improve transparency of information

There is clear support from stakeholders to create a sub-category for EV batteries so that specific requirements can be targets to this segment, which is estimated to represent such a large part of the batteries market in the future. There is also support for the 5 kg threshold for portable batteries as this measure puts similar batteries together in the same group. Some Member States have already introduced measures to distinguish purely industrial batteries from lighter ones typically used by consumers.

As regards the EPR obligations, producers are opposed to a mechanism where the operator placing the battery on the market for the first time would be responsible for its second-life. In terms of access to dynamic information stored in the Battery Management System, stakeholders have raised concerns in terms of the risk of intellectual property rights infringement, security issues and misuse.

Stakeholders recognise the need to increase the collection targets for portable batteries: both producers and recyclers support high collection targets. Some stakeholders consider that the PoM methodology is unsuitable due to the increased battery lifespan while collectors are reluctant unless the calculation methodology is changed. Member States suggested using 6 years in the calculation of PoM to address this issue.

Stakeholders recognise that the risks of losses on non-EV batteries is higher than for EVs and that, in practice, the obligation to collect and recycle the entirety of the batteries concerned is far from being achieved.

There is broad stakeholder support to boost recycling activities within the EU by establishing a separate recycling efficiency target for lithium-ion batteries and increasing current value for lead acid batteries. Some stakeholders pointed out possible problems to ensure a level playing field for all actors since a minority of industrial processes are not fit to deliver these type of targets.

There is also broad stakeholder support to establish mandatory carbon footprint declaration and information requirements on performance and durability if the rules are clear and widely accepted. Battery manufacturers prefer information requirements to mandatory thresholds in order to retain design freedom.

European producers support the idea of restricting primary batteries that do not fulfil certain criteria.

In terms of mandatory recycled content, stakeholders are concerned that market prices of secondary materials could increase due to the increase in demand and that targets could hence become harder to achieve. They propose that the targets are adopted with some delay to avoid market distortions.

Some stakeholders argue that specific and elaborated EPR obligations are not needed as there are currently voluntarily schemes while PROs request a guarantee of a level playing field.

3.2. Direct and indirect costs

The table below indicates the direct and indirect costs that will arise from the Batteries Regulation for different stakeholder groups: citizens/consumers, businesses and administrations. The table also specifies whether these costs are one-off or recurrent.

II. Overview of costs – Preferred option(s)							
		Citizens/consumers		Businesses		Administrations	
		One-off	Recurrent	One-off	Recurrent	One-off	Recurrent
New sub-category for EV batteries in industrial batteries	Direct costs					Amend the categories	
	Indirect costs				Reporting linked to existing EU-wide reporting system for vehicles		
Set 5 kg threshold for portables batteries category	Direct costs				EPR contributions	Amend the categories	
	Indirect costs						
Second-life	Direct costs	-					
	Indirect costs			Availability of secondary raw materials is postponed	EPR and product compliance requirements are split between the producer and the downstream economic operators		
Increase collection rate target portable batteries	Direct costs				EUR 1.24-1.43 per capita per year	Some costs to change the reporting methodology	Some costs for waste stream analysis
	Indirect costs						
Collection rate target for automotive and industrial batteries	Direct costs					PRO to establish monitoring system	Monitoring collection rates
	Indirect						

	costs						
Setting recycling efficiencies and material recovery targets	Direct costs				Recycling costs: €2290-3730/tonne in 2020 Going down to €860-1300 in 2035 due to economies of scales and technological progress	Existing reporting systems for recycling efficiencies to be modified New reporting system for compliance on material recovery rates	
	Indirect costs						Managing public access to information
Mandatory rules for the calculation of the carbon footprint	Direct costs			Data collection, calculation and third party verification: € 0.5 – 3 million		Commission: IT tool €60.000 2 FTEs	Member States: hiring/training costs for checking declarations and third party verification Commission: €125.000 for secondary data every four years IT tool €20.000 for periodic maintenance
	Indirect costs						
Performance and durability requirements	Direct costs				Admin cost to disclose available information		Member States: 1 FTE each
	Indirect costs			Supporting harmonised standards or technical		Supporting harmonised standards or technical	

				specifications		specifications	
Restriction of primary batteries that do not fulfil certain criteria	Direct costs						Costs of market surveillance
	Indirect costs						
Mandatory levels of recycled content	Direct costs			Reporting and auditing/controlling system for recycled content. € 1 180 000 and € 7 080 000	Reporting and auditing/controlling € 85 000 /yr		
	Indirect costs				Risk that high recycled content targets lead to increasing prices (Co, Ni, Li, Pb), if the increased demand cannot be met by existing (or future) sources of secondary materials.		
Design obligations	Direct costs			Cost for redesign	Reporting obligation		Surveillance cost
	Indirect costs						
Provision of reliable information to consumers	Direct costs			Set up site to provide static information	Update the static information		
	Indirect costs						
Provision of reliable information to economic actors	Direct costs				Update the dynamic information	Commission: develop dataspace and traceability management system Decentralised system 7.8 million € versus	Maintain dataspace: 2.7 million € per year for a decentralised system versus 1.3 million € per year for a centralised

						centralised system 5.6 million € for the period 2021-2026	system
	Indirect costs						
Due diligence obligations with third-party verification based on notified bodies	Direct costs			Set-up due diligence obligations € 2-15 million	Annual due diligence € 2-20 million	Commission: develop dataspace and traceability management system	Maintain dataspace
	Indirect costs						

4. ANNEX 4: ANALYTICAL METHODS

4.1. Oeko-Institut study model and analytical tool

The feasibility study is based on a model developed by the Oeko-Institut in the context of the study procured by the Commission. The model is based on mass flows on the end-of-life stages of the battery life cycle.

The model aims to assess the impacts of applying the different measures proposed. The impacts covered are the protection of the environment, the promotion of the circular economy and the smooth functioning of the internal market. The calculation model delivers quantitative results on some of the economic, environmental, and social issues and it also identifies the relationships, dependencies and linkages between different stakeholders or operators and along the entire lifecycle of batteries even when it was not possible to develop quantitative impacts.

4.1.1. Description of the model

The main task of the model is to determine the impacts of the proposed measures intended to address the shortcomings identified in the Batteries Directive. On the one hand, the model contains a baseline that represents the status quo and a projection describing the development if no changes occur. On the other hand, when the proposed measures are applied - all at once, separately or as a mix of both – the changes in impacts are assessed. Measures include e.g. collection rate, recycling rate etc.

The outcome of the model, however, will not be restricted to outputs of quantitative data. As an analytical tool, relationships, dependencies and linkages between different stakeholders or operators and also along the entire lifecycle of batteries will be identified, analysed and clarified. Particularly, the mass flows from placed on the market (PoM) until the end-of-life stages of the battery life cycle will play a key role in the model.

A full range of impacts and thus a relevant share of the results of the measure are directly linked and are proportional to the mass flows. This applies especially to environmental impacts. Some economic data is directly linked to mass flows too.

The model focuses on the battery life cycle from PoM to the end-of-life so the production of batteries is considered less important. Therefore, the consultant aggregated the initial life cycle stages of resource extraction, material processing, cell production and battery assembly to a common process ‘battery production’. Thus, the mass flows will start with the stage ‘placed on the market’, which comes along with the footprint of the battery production (e.g. carbon footprint, x kg CO2eq per tonne of battery; material footprint, x kg cobalt per tonne of battery). The battery life cycle ends with recycling and recovery of secondary battery materials.

The model covers the EU-27, thus excluding the United Kingdom. It covers the period up to 2035 because beyond this timeframe the technical possibilities and developments become largely unpredictable, especially in battery chemistry. In addition, considering the fast changing nature of this market, the Batteries Directive could be subject to a review again before 2035. To develop, check and adapt the modelled battery mass flows, the study uses a time series starting in 2009. The most recent data from Eurostat is available for the reference year 2018. The future perspective is based on other data sources.

Annex 4 could be accompanied by a section that spells out the strengths and limitations of this model for assessing the initiative concerned. For example, the model seems to focus more on the end-of-life and less on the upstream design and production phase. In addition, it would be useful to spell out the main assumptions adopted when working with the model.

4.1.2. Chemical types of batteries

For each individual life cycle stage, the mass flows are differentiated for the following battery chemistries:

- Pb-acid,
- Li-ion,
- NiMH
- NiCd,
- Alkaline (and ZnC).

This means that the study takes a simplifying assumption: primary portable batteries are represented by alkaline and zinc carbon batteries while button cells, Li primary batteries, etc. are not modelled separately. On the other hand, up to six different chemical types of Li-ion batteries are in use, depending on the respective application and the technological developments over time. A differentiation according to chemical type and category or application of batteries is presented in the section below.

4.1.3. Modelling of categories and applications

A general distinction is made in the model according to the Batteries Directive's three categories: portable, industrial and automotive batteries. Among these, again there are possibilities to differentiate according to applications of the batteries.

The main applications and the relevant battery chemistries of each category are listed below. For each of the listed applications, separate mass flows and results can be calculated.

Portable (alkaline, ZnC, Li-ion, Pb-acid, NiCd, NiMH): electronic equipment, power tools, new applications, other applications.

Industrial:

- e-vehicles (Li-ion, NiMH) and second life;
- e-bikes (Li-ion, Pb-acid, NiCd, NiMH);
- other industrial batteries incl. stationary electricity storage systems (Pb-acid, Li-ion, NiCd, NiMH).

Automotive (Pb-acid): automotive SLI.

4.1.4. Impact categories

A full range of impacts and thus a relevant share of the results of the measure are directly linked and are proportional to the mass flows. This applies especially to environmental impacts. Some economic data are directly linked to mass flows too, depending on the measures and options that are selected for assessment.

There are three main categories of impacts that were evaluated through the model and described in the report:

- Climate change (GWP in t CO2 eq),
- Human toxicity potential (HTP in t 1,4-DB eq),
- Depletion of abiotic resources (in t Sb eq).

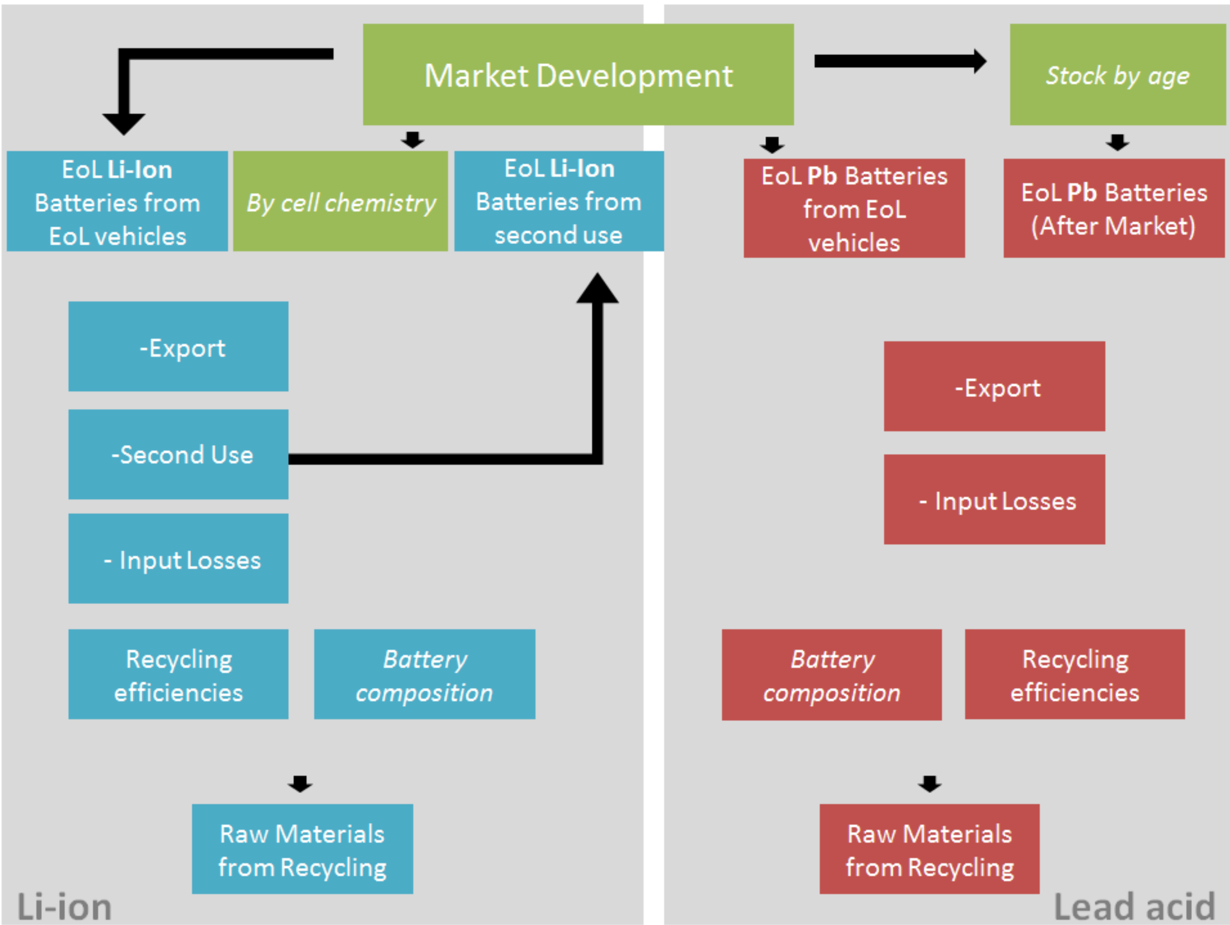
A further 13 environmental impact categories are included in the model, including e.g. acidification potential, ozone layer depletion, photochemical oxidation or eutrophication and can be assessed according to the specific measure considered.

The impacts are linked to individual life cycle stages of the mass flows as described above for the example of the production footprint linked to 'placed on the market'. Other life cycle stages with relevant environmental impacts are 'recycling' and a comparison of the raw materials needed for the production of primary and secondary battery materials (e.g. lithium, cobalt, nickel and lead). LCA studies and LCA databases are the source for the calculation of the environmental impacts.

4.1.5. Vehicle batteries example

For a better understanding of how the model functions, the example of automotive batteries is described in more detail below using the example and illustrated in the figure below.

Schematic causal loop diagram for batteries from vehicles



The model delivers mass flows based on the development of different types of vehicles. It includes passenger cars, light commercial vehicles and heavy commercial vehicles with a variety of different propulsion types (Internal combustion engine, hybrid, plug-in hybrid electric vehicle and battery electric vehicle). Moreover, the model differentiates between different cell chemistries of Li-ion batteries as well as different sizes. Each type of vehicle also contains information regarding a lead-acid battery. Since the average lifetime of lead-acid batteries is a lot shorter than that of a vehicle, the model also calculates the volumes of exchange batteries.

The model determines both the mass flow of batteries placed on the market (PoM) and the amounts that are generated at the end of life (EoL) based on different average lifetimes and end-of-life distributions for each vehicle type and each year. Since the model includes detailed information related to battery compositions it allows for the estimation of recycling potentials. For example, the estimation of realistic recycling content figures is based on the comparison of material that comes from recycling operations and the demand resulting from the market development.

The most important input to the model in this case is the evolution of the EV market. The share of EVs in the EU passenger car segment is calculated individually for each MS based on the registration statistics starting from 2009 and the specific growth rates for the different EV propulsions types in each country. Moreover, each EV propulsion type (ICEV, HEV, PHEV and BEV) is accompanied by information concerning battery chemistry and size including changes in the course of the projection. Therefore, the current trend towards Li-ion battery cell chemistries with less cobalt and more nickel is also reflected in the model. Accordingly, the first BEVs reaching their end-of-life are modelled to contain more cobalt. This kind of differentiation allows for a very detailed economic assessment regarding the revenues of recycling. Moreover, the model includes material recovery rates that change over time. For example, the share of lithium recovery is likely to increase (in measure 7). Therefore, the tool can also reflect effects of changing raw material specific recovery rates (in the baseline the rates do not change).

Overall, the output of the mass flows can be controlled via different measures and variables, such as adjusting the export quotas of EoL batteries, adjusting the share of second life batteries, changing recovery rates for certain raw materials or increasing collection rates etc.

Therefore, the model works as a helpful tool that contains the most recent information on the market development of EVs and cell chemistries allowing for the estimation of effects resulting from measures envisaged for the revision of the Batteries Directive.

5. ANNEX 5: THE BATTERIES DIRECTIVE

The Batteries Directive (2006/EC/66) is the only piece of EU legislation that is entirely dedicated to batteries. Its provisions address the lifecycle of batteries, i.e. design, placing on the market, end-of-life, collection, treatment and the recycling of spent batteries. It defines objectives, sets targets[7] and outputs, identifies measures to meet them and establishes additional provisions to enable and complete these key requirements.

The Directive applies to all batteries and classifies them according to their use. Classes of battery include:

- portable batteries (e.g. for laptops, or smartphones or typical cylindrical AAA or AA-size batteries);
- automotive batteries (e.g. for starting a car's engine or powering its lighting system) excluding traction batteries for electric cars; and
- industrial batteries (e.g. for energy storage or for mobilising vehicles such as fully electric vehicles or electric bikes)[8].

The Directive's primary objective is to minimise the negative impact of batteries and waste batteries on the environment to help protect, preserve and improve the quality of the environment. It also aims to ensure the smooth functioning of the internal market and avoid the distortion of competition within the EU.

The Directive links the environmental impacts of batteries to the materials they contain[9]. Due to the presence of hazardous components, in particular mercury, cadmium and lead, the mismanagement of batteries at the end of their life is the key concern. Batteries are not a particular environmental risk when they are safely used or stored, but if spent batteries are landfilled, incinerated or improperly disposed of at the end of their life, the substances they contain risk entering the environment, affecting its quality and affecting human health.

The Directive does not address negative externalities affecting the environment, for example, resulting from the massive extraction of raw materials, or from energy and water extensive recycling processes.

The Directive addresses the risks in two ways:

1) by reducing the presence of hazardous components in batteries; and
2) by establishing measures to ensure the proper management of waste batteries.

The total prohibition of batteries containing mercury[10] and, partially, of those containing cadmium, is the most effective way of reducing hazardous components. As such, this measure for regulating the placing of batteries on the market is in line with the Directive's objectives to ensure the smooth functioning of the internal market and to avoid the distortion of competition within the EU.

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7 In this document, 'objective' means general or aspirational goals to be achieved in the medium or long term; 'target' means concrete goals that will considered met when parameters defined in the Directive reach pre-established values.

8 Directive 2006/66/EC, Article 3.

9 See page 7 of the Impact Assessment, CSWD SEC(2003) 1343.

10 Article 4.

The Directive's labelling requirements[11] also intend to harmonise market requirements for batteries.

The Directive requires Member States to ensure that appropriate collection schemes are in place for waste portable batteries[12] and sets targets for the collection rates[13] (25 % in weight of the amount placed on the market by September 2012 and 45 % by September 2016). It also requires Member States to set up collection schemes for waste automotive batteries[14] and to ensure that producers of industrial batteries do not refuse to take back waste industrial batteries from end-users[15].

All spent batteries collected must undergo treatment and recycling[16]. In this regard, the Directive establishes minimum levels of recycling efficiency[17] and the general obligation to recycle lead and cadmium to the highest degree[18], and requests that all processes concerned comply with relevant EU legislation[19].

Member States have to monitor collection rates and recycling efficiencies and submit relevant data to the Commission.

The Directive's overarching objective[20] is that Member States take the necessary measures to maximise the separate collection of waste batteries and to minimise the disposal of batteries as mixed municipal waste. However, there is no target or monitoring obligation linked to this objective.

The Directive also seeks to improve the environmental performance of batteries and the activities of everyone involved in their lifecycle[21], e.g. producers, distributors and end-users, particularly those directly involved in treating and recycling waste batteries. The Directive does not establish any concrete targets for this but it mentions promoting research.

Provisions on extended responsibility[22] give producers of batteries and producers of other products that incorporate batteries the responsibility for the end-of-life management of the batteries they place on the market. The Directive specifies the national schemes'[23] tasks and objectives, including financial aspects[24].

Producers must therefore fund the net costs of collecting, treating and recycling all waste portable batteries and all waste industrial and automotive batteries as well as any public information campaigns on the topic.

11 Articles 20 and 21.
12 Article 8.1.
13 Article 10.
14 Article 8.4.
15 Article 8.3.
16 Article 12.1.b.
17 Annex III, part B.
18 Directive 2006/66/EC, Annex III.
19 Article 12.1.b.
20 Article 7.
21 Article 1.
22 Recital 19.
23 Article 8.
24 Article 16.

6. ANNEX 6: THE BATTERIES DIRECTIVE EVALUATION

Article 23 of the Batteries Directive tasked the Commission with reviewing the implementation of the Directive and its impact on the environment and on the functioning of the internal market. This Article specified that the Commission should evaluate:

- the appropriateness of further risk management measures for batteries containing heavy metals;
- the appropriateness of the minimum collection targets for all waste portable batteries;
- the possible introduction of further targets; and
- the appropriateness of recycling efficiency levels set by the Directive.

In April 2019 the Commission published an evaluation of the Batteries Directive[25], in line with the Commission's Better Regulation guidelines. Independent consultants supported the assessment of the information collected. The public, industry stakeholders and representatives of national administrations participated in the process. The evaluation addressed the usual evaluation criteria of relevance, effectiveness, efficiency, consistency and EU added value, along with the topics requested by Article 23, mentioned above.

This Annex presents the key conclusions from the evaluation.

6.1. Lessons learnt

Although the Directive has provided a broad EU framework, it is too general on the nature and extent of the objectives to be achieved and on important measures that the Member States have to implement. The Directive has problems with definitions, which hinders the achievement of its objectives.

For example, the links between long-term goals, quantified targets and the measures to reach them are not always suitably or clearly formulated. Nor is the expected outcome of the Directive detailed in depth. Key objectives, such as achieving a high level of material recovery — and obligations, such as ensuring that all collected waste batteries are recycled — are not sufficiently highlighted. Considerable time and effort has been devoted to discussing basic concepts with the Member States and the results were not always convincing. A clearer description of the Directive's internal logic and links would have improved its transposition and implementation.

The evaluation process has pinpointed some concepts in the Directive that are understood differently by different Member States — the role of producers' organisations (PROs) for example. Our assessment shows that the overall organisation and requirements imposed on PROs vary widely between Member States. This helps explain the differences in Member States' performance and the internal market's current imbalance and distortion risks. The recently adopted provisions on extended producer responsibility in the WFD will help to address these risks.

Some Member States and businesses have a different understanding of whether slags should be considered as recycled products. The situation is similar for the obligations on collecting waste industrial batteries or for classifying spent batteries (as wastes). These differences contribute to the distortion of the internal market, cause misreporting and lessen the Directive's impact. The Commission issued guidance to address these and comparable issues,

25 SWD(2019) 1300

but it does not seem to have been enough. A more detailed definition of the concepts concerned would have helped to avoid these problems.

Experience with the Directive shows that producing information depends on establishing precise targets and metrics, and clear and meaningful reporting obligations. The Directive's relatively small number of measurable targets makes assessing its implementation and impacts challenging. Directive's overarching objectives such as reducing the amount of waste portable batteries that are disposed of in municipal waste streams, are not quantified and there are no reporting obligations associated. Additional and more detailed reporting obligations could have ensured better information on the EU batteries sector including on the Directive's impact on the sector.

While the Directive has been effective in ensuring that portable and automotive batteries are labelled, ensuring that information reaches end-users could be improved. Labelling alone is not enough. Other activities, like public information campaigns would increase effectiveness. A clear definition of producers' obligation for financing these activities would have helped to inform end-users better on their expected role on ensuring spent batteries are collected.

6.2. Relevance

The environmental concerns addressed by the Directive are still relevant today: batteries contain hazardous substances and present a risk to the environment when improperly disposed of. While mercury-containing batteries are being phased-out, old and 'new' batteries still contain other hazardous substances.

The two main approaches to facing these risks (i.e. the reduction of hazardous components and the management of waste batteries) **are suitable,** even if new and stronger complementary measures are needed to deal with the huge amount of waste batteries that is expected to be generated in the coming years.

Several important elements of the Directive's circular economy-related approaches correspond to the **main elements of the circular economy policy,** to address material recovery, set conditions for recycling processes or establish supportive regulatory mechanisms, for example. However, not all stages are included in the Directive and provisions on sorting or other pre-recycling stages of waste batteries, for example, are lacking.

The evaluation also shows that **the Directive cannot sufficiently incorporate easily technical novelties**. For instance, lithium-based batteries are included in the scope of the Directive but not specifically considered. Likewise, the Directive does not address the possibility of giving advanced batteries a second life, making developing re-use approaches more difficult.

6.3. Effectiveness

The Directive contributed to reducing the use of hazardous substances in batteries and to preventing waste portable batteries from being landfilled or incinerated, but this was not achieved up to the level expected.

Only half of Member States have met the Directive's target on collection of waste portable batteries. An estimated 56.7 % of all waste portable batteries are not collected, of which around 35 000 tonnes enter municipal waste streams annually, resulting in environmental harm and loss of resources.

The problems to meet the collection rate target reveal **deficiencies in the Directive**. The c**urrent targets for collecting waste portable batteries do not promote a high level of collection**. Furthermore, the Directive has different approaches for managing end-of-life batteries. The fact that collection rate targets only exist for spent portable batteries could be confusing and prevent the achievement of the Directive's objectives.

The **Directive's methodology for compiling, assessing and reporting information on waste portable battery collection rates** creates some practical difficulties. As reporting obligations only apply to portable batteries, it is even more difficult for public authorities and industrial operators to access reliable information on the collection of waste batteries.

On the other hand, **the Directive has ensured the highly efficient recycling of collected waste batteries**. Current targets of recycling efficiencies appear to be easily achievable by the EU industry.

However, the general objective of achieving a high level of material recovery has not been achieved. Recycling efficiencies are defined for only two substances: lead and cadmium, ignoring other valuable components such as cobalt and lithium. In addition, these definitions are not oriented towards increasing material recovery. Therefore, **current recycling requirements are not considered appropriate to promote a high level of recycling and recovery from waste batteries and accumulators.**

The **implementation of extended producer responsibility** has taken place through collective producer schemes in many Member States. This is a success of the Directive. The positive role of these organisations could be strengthened if the Directive provided incentives to increase collection rates above established minimum values.

Problems to reach the Directive's targets indicate that **end-users do not always receive adequate information** about their expected contribution. Defining in detail Member States' awareness-raising obligations, establishing clear objectives and making use of more up-to-date means of communication, notably social media, could help increase the end-users' involvement and hence collection rates.

The Directive also lacks a proper system to inform end-users of the quality of the batteries placed on the market.

6.4. Efficiency

The efficiency analysis shows that the Directive has had an impact on the economy of batteries' manufacturing and recycling sectors. Businesses consider that implementing the Directive has entailed significant costs but they and other stakeholders broadly agree that these are outweighed by present or future benefits.

Implementing the Directive involves necessarily complex procedures that could sometimes entail significant costs for local authorities. However, **national administrations do not perceive** that implementing the Directive **results in unnecessary regulatory burdens**.

The Directive's provision on recycling all collected batteries is key to ensuring the viability of recycling activities. This obligation actively contributes to ensuring the supply to recyclers and its absence could cause investment risks. If higher levels of supply, i.e. higher collection rates of all types of batteries were achieved, better results for recycling activities would have been expected.

In addition to lowering the reliance on imports of particularly important raw materials, including critical ones, recycling may have economic benefits. However, the Directive unnecessarily limits these benefits, as it only establishes efficiency targets for lead and cadmium. The recovery of other valuable materials, such as cobalt, lithium or critical raw materials is not specifically promoted.

Extended producer responsibility obligations for industrial batteries are not well-defined. **There are no detailed provisions for collection, setting up national schemes and financing aspects for industrial batteries, which will be increasingly relevant in future as using these batteries is considered vital for low carbon policies in the EU.**

This absence of a specific provision in the Directive makes it difficult to ensure that all industrial waste batteries will be properly collected and recycled (or reused) in the future and affects regulatory framework's ability to appropriately deal with the expected growth of the industrial batteries sector.

6.5. Coherence With other Legislation

Stakeholders generally want the provisions on batteries to be concentrated in fewer legislative acts, particularly for chemicals and end-of-life issues, and that the relationships between these acts are clearly outlined.

While the Directive encourages developing batteries with smaller quantities of dangerous substances, it does not specify any criteria for identifying the substances concerned or the type of management measures that could be adopted. **It should therefore be considered whether REACH is more adequate for managing chemicals in batteries.**

Guidance documents have been prepared to ensure consistency and avoid contradictions between the Directive and other legal instruments. However, this may not be sufficient to guarantee that the requirements of the instruments concerned are fully implemented and that possible synergies are effective.

The development of new batteries, cars and electric and electronic equipment technologies requires clear demarcation lines for the obligations that apply to the products concerned, independently of the legal instrument concerned (i.e. the directives on Batteries, WEEE and ELV).

6.6. Internal consistency

The Batteries Directive has no obvious contradictions or duplications. However, **some of its basic concepts are not well-defined and some objectives remain vague, particularly when there are no specific measures to be implemented or targets to be met.**

The Directive only sets targets for the separate collection of portable waste batteries and the recycling efficiencies of certain types of collected waste batteries. In particular:

- there is no target for reducing the disposal of batteries as municipal waste;
- there are no quantitative targets for the separate collection of automotive and industrial batteries; and
- the obligation to ensure the treatment and recycling of ‘all’ collected waste batteries is not explicitly spelled out.

Reporting obligations are only established when targets are set. The absence of quantified targets makes it very difficult to assess Member States' performance on these particular aspects.

There are cases where the **lack of detail in the definition of the obligations may distort the internal market** such as the classification of batteries, exemptions to obligations on removability or labelling, and the consideration of slag as a recycled product.

6.7. EU Added Value

There is significant support for **the conditions for the sale, collection and recycling of batteries to continue being set at EU level.** Stakeholders consider that the Directive has been the major contributor to ensuring the harmonisation of the batteries market. Most stakeholders also consider that the Directive has contributed to the well-functioning of the single market for batteries and that **trade barriers are lower compared with what national regulations could have achieved**.

7. ANNEX 7: FACTS AND FIGURES

7.1. Mass flows, demand and production

7.1.1. Mass flows

In 2015, the total amount of batteries placed on the EU market in 2015 was about 1.8 million tonnes. Automotive batteries represented by far the largest share in weight in 2015, amounting up to 1.10 million tonnes, which correspond to 61 % of the weight of all batteries placed on the market (see figure 6 below). In 2018, more than 70 % of world rechargeable energy charging capacity was provided by lead-acid batteries.[26]

The second largest share, 27 % or about 0.49 million tonnes, corresponded to industrial batteries and accounted for nearly half the weight compared to automotive batteries. The remaining 12 %, 212 000 tonnes, were 'portable batteries'.[27]

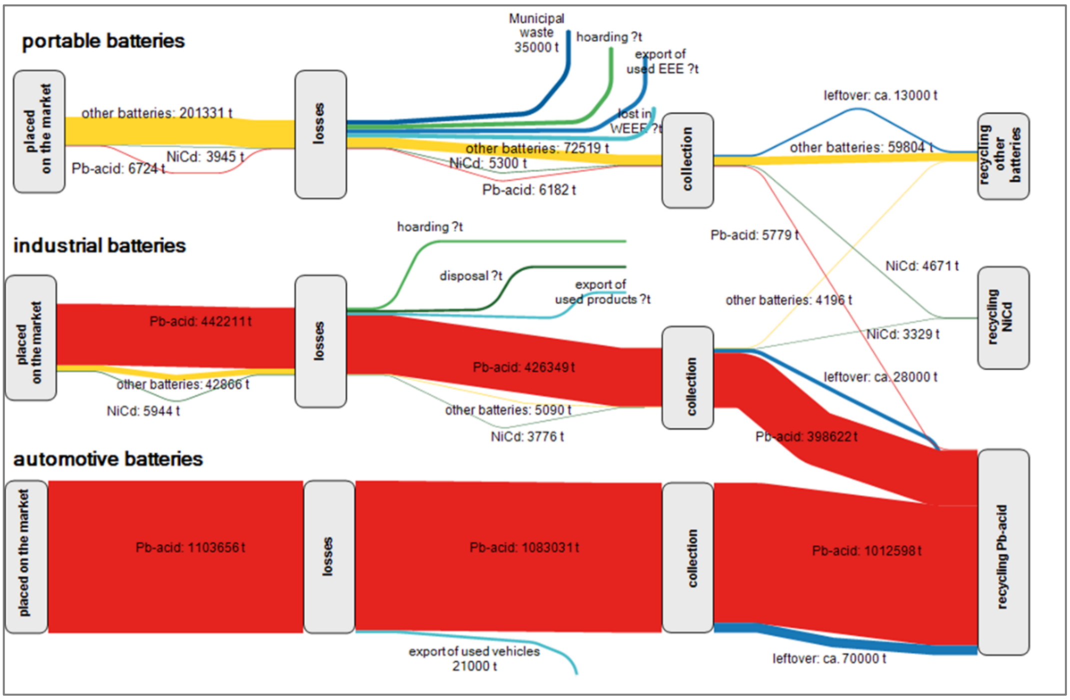

Figure 4: Mass flow of the different types of batteries (and their chemistries), in 2015.[28]

Although significant changes in mass flows take time to materialise, it is expected that the prevailing position of lead-acid batteries (mostly automotive ones) disappears in the near future as regards energy stored by batteries.[29] In terms of weight placed on the EU market, however, the situation described in **Figure 4** above could still exist.

7.1.2. Demand

Different sources diverge as regards the exact growth in demand of batteries in the near future within the EU, but not in the main driver.

[26] Avicenne (2018)

[27] H. Stahl *et al.* (2018) 'Study report in support of evaluation of the Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators'

[28] Study in support of the evaluation

[29] Avicenne (2018)

In the medium and long term, the increases in the demand will be triggered by mainly by EVs and also by Energy Storage Systems (ESS) sectors (see **Figure 5** below).

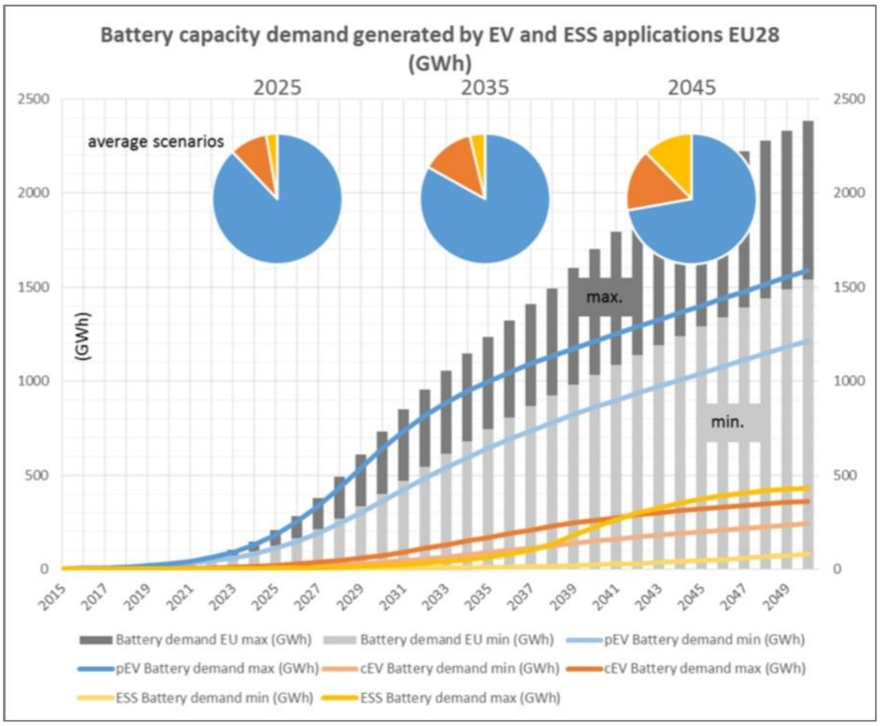

Figure 5: Battery capacity demand generated by Electric Vehicles and Energy Storage Systems applications in the EU28 in minimum and maximum scenarios from 2015 to 2050 and average scenario shares for each battery application[30]

Despite the small number of electric vehicles within the EU fleet and their small market share - about 321 000 in 2017, 1.5 % of new passenger vehicles - their registration numbers have increased steadily over the last few years (see **Figure 6** below).[31] Even if the combined share of PHEVs and BEVs in all car sales remained low in 2018 - 2 % - ACEA reports an exponential growth in the registration of electric cars already in 2019.[32] The Covid-19 crisis has had an impact on the uptake of e-mobility for both cars and light means of transport as e-bikes.

While European passenger cars sales have gone down by about 50%, sales of electric vehicles have increased and in March 2020, they reached an all-time high market share of 10% of passenger cars sales[33]. The upward trend in the sales of EVs is likely to continue in the future as all but one Member States have put in place some form of incentive for EV purchases including acquisition tax or VAT exemptions, car ownership tax reductions, company car deductibility and purchase incentives[34]. Additional public measures include increasing availability charging facilities, access to restricted traffic, free parking, etc. Similarly, after an initial stall due to lockdown and retail store closures, the sales of e-bikes

30 VITO, Fraunhofer and Viegand Maagøe (2019) "Study on eco-design and energy labelling of batteries"
31 European Environment Agency (2019) 'Electric vehicles as a proportion of the total fleet' at https://www.eea.europa.eu/data-and-maps/indicators/proportion-of-vehicle-fleet-meeting-4/assessment-4 (accessed on the 11 March 2020)
32 See https://www.acea.be/statistics/tag/category/electric-vehicles
33 ICCT, Market Monitor, 2020
34 ACEA, Electric vehicles: tax benefits & purchase incentives, 2020

are now booming. Stakeholders have reported increased sales that have already compensated for the losses during the lockdown weeks.

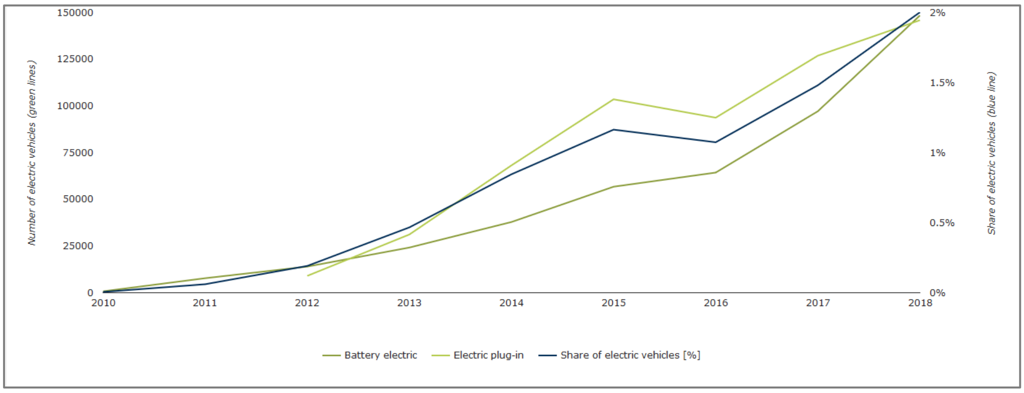

Figure 6: Electric vehicles registered within the EU (2010-2018)

In very broad terms, and keeping in mind the large margin of variation in the figures estimated by different sources, the most conservative estimations result in a range of 450 GWh and 500 GWh[35] [36] for the demand for batteries within the EU in 2030, compared to less than 50 GWh in 2020. These forecasts are in line with the conclusions of a recent JRC report.[37]

In 2015, consumer electronics was the biggest sector with 50 % of the lithium batteries global market[38]. This situation is expected to change, 3-C batteries which in 2019 accounted for more than 20 % globally, would only represent the 2.5 % in 2030. Within the EU, this sector would continue to grow in the period considered, but at a much lower rate than the others. Based on mass-flows assessments, it can be estimated that, for alkaline batteries, the total EU demand in 2030 will be about 13 GWh (assumption: ca. 85 kWh/tonne of battery).[39]

Portable rechargeable lead-acid and NiCd batteries together accounted for about 4 % of all portable batteries placed on the market. Primary batteries account for about three-quarters of all portable batteries, of which alkaline batteries were the most important type (covering e.g. 61 % in Germany or 64 % in France). Amongst portable rechargeable batteries, Li-ion batteries were the most relevant ones.

As regards lead-acid batteries (including automotive and industrial batteries) the global demand in 2018 was 450 GWh.[40] In that year, lead-acid batteries provided approximately 72% of the world rechargeable battery capacity (in GWh).[41] Within the EU market, it is estimated that the current demand for this type of batteries, 100 GWh, will be reduced to about 80 GWh in 2030.

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35 Ecodesign preparatory study for batteries, at https://ecodesignbatteries.eu/documents

36 New ENV Study

37 Tsiropoulos, I., Tarvydas, D., Lebedeva, N., Li-ion batteries for mobility and stationary storage applications – Scenarios for costs and market growth, EUR 29440 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-97254-6, doi:10.2760/87175, JRC113360

38 Avicenne (2017).

39 ENV Study 2020

40 Global Battery Alliance & World Economic Forum (2019) 'A Vision for a Sustainable Battery Value Chain in 2030'

41 Avicenne 2019

7.1.3. Production

If the expected demand presented above materialises, annual global battery production revenues in 2030 could amount up to $300 billion, of which more than 30 would correspond to the EU.[42]

If these forecast materialise the EU would nevertheless continue to be in deficit as regards the production of lithium – ion batteries.

As shown in **Table 1** below, in 2016, the EU industry manufactured 15 % of the global production of lead-acid batteries, and the EU was a net exporter of this type of battery. Concerning primary cells and batteries, the EU was also a net exporter, although to a lower extent. The volume of NiCd (nickel-cadmium), NiMH (nickel metal hydride) and lithium-based batteries manufactured in the EU was around 5 % of the global output. The EU is a net importer of Ni - based batteries.

Table 1: Battery production (EU-28), import and export values by 2016, million € [43]

	Production	**Import million €**	**Export million €**
Lead-acid batteries	5 141	1 346	1 452
Primary cells and primary batteries	812	763	354
Nickel cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel iron and other batteries	1 083	3 418	738
Total	**7 037**	**5 526**	**2 545**

Table 2: Battery Production (EU-27), import and export values in 2018, million €, source Prodcom data, ESTAT

Prodcom Code	Exports	Imports	Production	Placed on the market
27201100 - Primary cells and primary batteries	520	771	1.039	1.290
27201200 - Parts of primary cells and primary batteries (excluding battery carbons, for rechargeable batteries)	15	29	8	21
27202100 - Lead-acid accumulators for starting piston engines	1 169	530	3 815	3 176
27202200 - Lead-acid accumulators, excluding for starting piston engines	800	881	1.666	1 747
27202300 - Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators	1 186	4 831	1 559	5 204

42 Global Battery Alliance & World Economic Forum (2019) 'A Vision for a Sustainable Battery Value Chain in 2030'

43 H. Stahl et al. (2018) 'Study report in support of evaluation of the Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators'

27202400 - Parts of electric accumulators including separators	260	503	337	580
Total	**3 951**	**7 543**	**8 424**	**12 017**

In broad terms, the EU's share of global lithium – ion battery production was only 3% in 2018, of a total of 147GWh.

Pack manufacturing and system integration and assembling for industrial lithium-ion batteries is taking place on large scale in Europe, due to the importance of the car manufacturer sector within the EU. The lack of large-scale cell production constitutes a significant gap in the value chain of this industry.

This situation is likely to change in the future, if the industrial plans brought forward by the members of the European Batteries Alliance finally materialise. They state that they plan investments intended to establish cell manufacturing facilities within the EU in coming years. The production of lithium base batteries could amount up to around 340 GWh per year in 2030.

According to the information provided by members of the European Batteries Alliance on the industrial plans of its members and the information of publically announced investments in the EU **production of lithium-based cells within the EU (by EU and non-European manufacturers) could reach up to around 370 GWh per year in 2025**. **If these levels of production materialise**, this could serve the demand in Europe.[44] This would also make the EU the second highest region of production worldwide, after China (see **Figure 7**).[45].

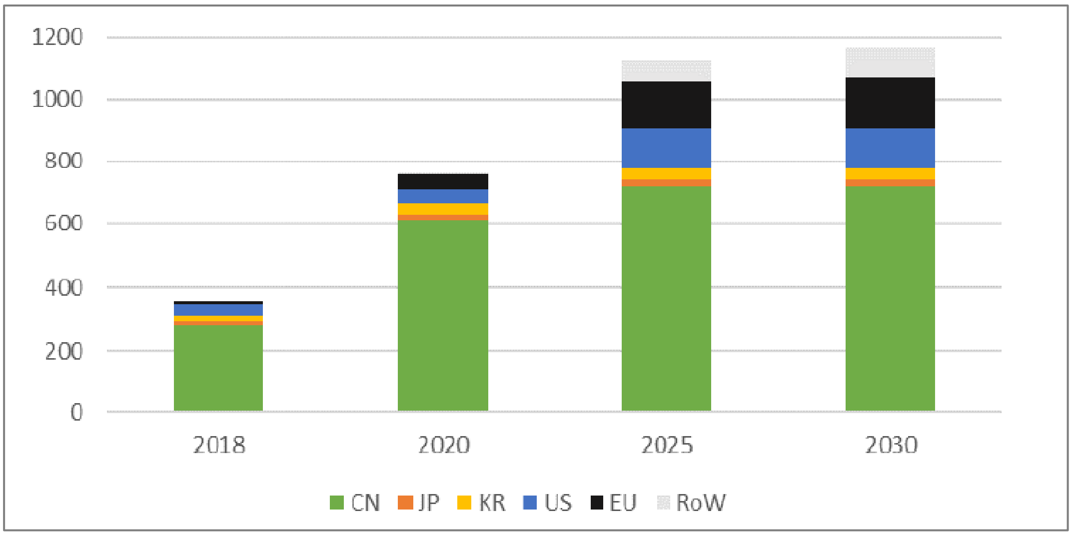

Figure 7: Lithium-ion cell production capacities for industrial batteries within the EU in GWh per year by location of plants

Efforts for establishing manufacturing capacity in Europe will primarily target lithium-ion cells with cathodes employing nickel, manganese and cobalt (NMC) at different proportions, and anode mainly graphite.[46 47] An increasing number of carmakers are choosing full NMC

44 Based on announced investments at the time of writing.

45 VITO, Fraunhofer and Viegand Maagøe, *Study on eco-design and energy labelling of batteries*, 2019.

46 M.Steen et al (2017) 'EU Competitiveness in Advanced Li-ion Batteries for E-Mobility and Stationary Storage Applications – Opportunities and Actions' JRC Science for Policy report

chemistry to achieve higher energy density and thus longer autonomy of the vehicles concerned.[48]

7.2. Raw materials

While the number of components and raw materials of alkaline and lead-acid batteries is low, lithium-ion batteries are composed of many substances, in different rates, and require more numerous raw materials for their manufacturing.

The demand of particular substances strongly depends on the technical evolution that batteries undergo. Thus, for instance, NMC 910 batteries, i.e. without cobalt, could be the prevailing technology in lithium-ion batteries in 2035, with the logical consequences in the whole sector.[49]

Batteries manufacturing is becoming one of the main drivers for the extraction of raw materials. The development of the battery market in recent years is linked to the increasing amount of cobalt in this sector, the use of cobalt in lithium ion batteries went from 25 % in 2005 to 44 % in 2015.[50] In the case of nickel the rate of variation for lithium is estimated at 35 % and more than 50 % for nickel.

The actual demand will be determined by the type of battery which is produced and placed on the market. Even inside the same technological/chemical group (lithium-ion) variations in the composition of cathodes (nickel-manganese-cobalt in this case) entail differences in the demand of components, as shown in **Table 3** below.

Table 3: Elements required for the preparation of three NMC types of cathodes (kg/kWh)

Cathode	Cobalt	Lithium	Nickel	Manganese
NMC 111	0,394	0,139	0,392	0,367
NMC 622	0,214	0,126	0,641	0,200
NMC 811	0,094	0,111	0,750	0,088

Very little extraction of non-energy raw materials occurs within EU Member States. Even if different minerals that after treatment and transformation yield usual components are exploited within the EU (see **Table 4** below), the domestic supply of battery raw materials from mining activities is currently limited.

Of the six substances mentioned in the **Table 4** below, cobalt, lithium and natural graphite display a particularly high risk of supply shortage in the next years and are particularly important for the value chain and are considered critical raw materials.[51] [52]

47 D. T. Blagoeva et al., (2017) 'Assessment of potential bottlenecks along the materials supply chain for the future deployment of low-carbon energy and transport technologies in the EU.'

48 EC Report on Raw Materials for Battery Applications, CSWD(2018)245/2 final

49 From CLIMA study

50 JRC, 2017, Critical raw materials and the circular economy

51 Communication from the Commission 'Tackling the challenges in commodity markets and on raw materials' COM(2011)0025 final

52 New Communication/Report on Raw Materials, 2020

Table 4: EU Member States where minerals used for the manufacturing of batteries are extracted (situation at 2017)[53]

	Cobalt	Lithium	Nickel	Manganese	Lead	Graphite
Austria						✓
Belgium						✓
Bulgaria				✓	✓	✓
Czech R.						✓
Finland	✓		✓			
France	✓		✓			
Germany						✓
Greece			✓		✓	
Hungary				✓		
Ireland						
Italy				✓	✓	
Poland			✓		✓	
Portugal		✓			✓	
Romania				✓	✓	✓
Slovakia					✓	
Spain		✓	✓		✓	
Sweden					✓	✓

Moreover, the sourcing of some particularly important raw materials is concentrated in a few countries. The 69 % of the global supply of natural graphite comes from China, the 64 % of global cobalt supply comes from the Democratic Republic of Congo, and the 83 % of the actual global supply of lithium comes from brines and mine sites located in Chile, Australia, Argentina and China (see **Figure 8** below).

While the supply of these materials is potentially vulnerable to disruption, there is a general recognition that the sources of most materials contained in lithium-ion batteries should be able to meet the demand for the near future.[54] A number of conditions should however be taken into consideration for this equilibrium to materialise. If national or international policies incentivize the uptake of electric vehicles, including for instance taxes on fossil fuels, demand could outpace supply for some battery-grade materials (even for lithium in the very near term).[55] However, there is consensus on that there is enough reserves of lithium

53 Minerals 4EU project, 'EUROPEAN MINERALS YEARBOOK – DATA', http://minerals4eu.brgm-rec.fr/m4eu-yearbook/ (accessed on 21.3.2020)

54 EC Raw Materials on Batteries Report

55 E.A Olivetti et al., (2017) Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals

minerals, but there will be difficulties to adapt its production levels and develop new projects if the demand grows too fast..

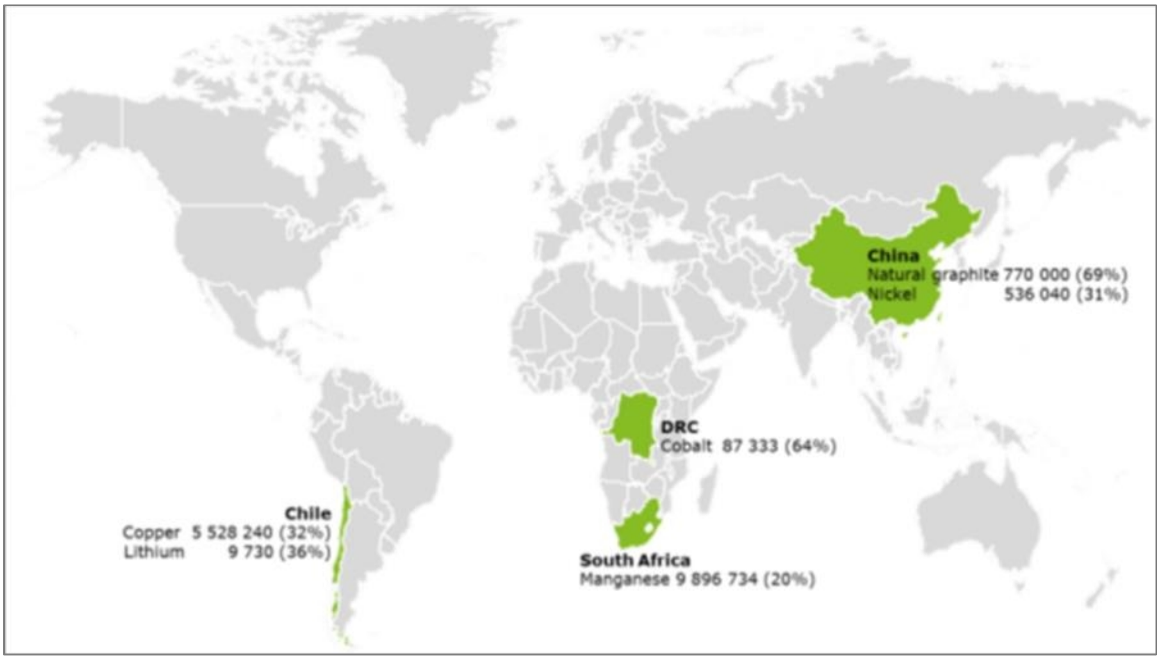

Figure 8: Countries accounting for largest share of EU supply of battery materials[56]

The case of lead is different. Disruption of supply seems very unlikely. Moreover, the provision of secondary lead covers around 80 % of the demand (see **Figure 9** below).

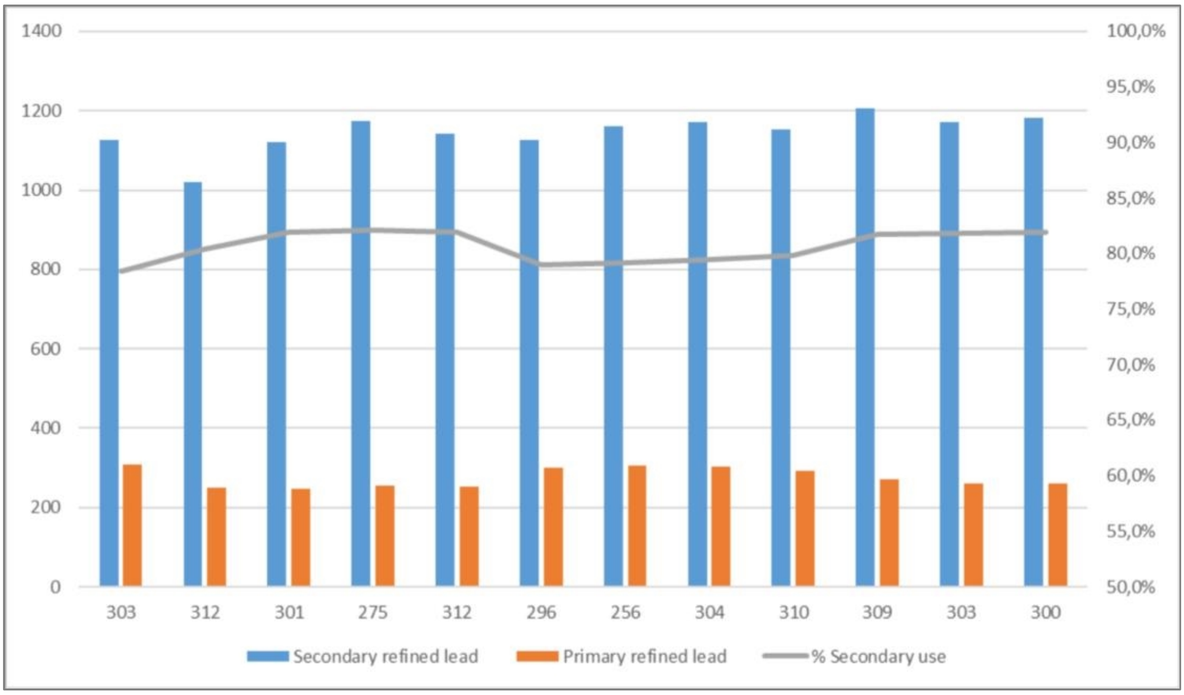

Figure 9: Amounts (in thousands of tons) of secondary and primary refined lead produced within the EU, and level of coverage of needs by secondary material (%)[57]

56 Criticality study 2017

GHG emissions from batteries manufacturing

In the EU, transport causes roughly a quarter of Green House Gas (GHG) emissions and is the main cause of air pollution in cities,[58] Road transport in particular is the main contributor to transport-related GHG emissions.[59]

A broader uptake of electric vehicles will help to reduce GHG and other noxious emissions from road transport. In the EU, a strong increase in the electrification of passenger cars, vans, buses and, to a lesser extent, trucks is expected to take place between 2020 and 2030, mainly driven by the EU legislation setting CO_2 emission standards for new vehicles. The electrification of some housing services, like energy storage or heating, will follow and contribute to further reducing the emissions concerned.[60]

A recent study for the European Commission has elaborated and applied a methodology for assessing and comparing the environmental impact of vehicle types equipped with different powertrains and running on different fuels using a Life Cycle Assessment approach. [61]

The study shows the better environmental performance of electric vehicles compared to conventional vehicles across all assessed indicators. It is also concluded that environmental benefits from the use of battery electric vehicles will increase in the future, in particular in view of the steadily decarbonised electricity mix. Results on human toxicity or abiotic depletion are less outspoken as they are influenced by the use of specific materials in the electronic systems or wiring of the vehicles.

Technological developments have made lithium-ion batteries the preferred choice for batteries used in electric vehicles and for stationary energy storage, even if other technologies are also used.

The manufacturing of all type of batteries entail GHG emissions, in addition to other environmental impacts. According to the PEFCR, in LCA terms, Global Warming Potential accounts for about one fourth to one third of the total environmental impact of Li-ion batteries over their entire life cycle.[62] The most important GHG emissions across the lifetime of such batteries take place during the production phase,[63] i.e. extraction, processing and production of materials, cell production and battery assembly altogether. This is due to mining, extraction, processing and refining activities needed to transform minerals into components of the battery, as well as to energy-intensive chemical processes needed to build the cell (e.g. coating and drying).

To maximise the environmental benefits of electric vehicles, the batteries used in them and the industrial processes to manufacture them have to be highly resource, energy and carbon efficient. This will allow the placing on the market of batteries that require lower amounts of energy or materials in their production or that have longer lifetime or better roundtrip efficiency.

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57 Data from the International Lead and Zinc Study Group data base, http://stats-database.ilzsg.org/ (accessed on 21.3.2020)

58 Gabriel et al 2014

59 European Parliament study

60 Knobloch et al (2020) 'Net emission reductions from electric cars and heat pumps in 59 world regions over time'

61 CIMA Ricardo study

62 http://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_Batteries.pdf (page 42)

63 M.A. Cosenza et al.,2019. Energy and environmental assessment of a traction lithium-ion battery pack for plug-in hybrid electric vehicles. https://doi.org/10.1016/j.jclepro.2019.01.056

Although the recycling of waste batteries contributes to mitigate the environmental impacts, it also produces emissions, even if its impact is relatively low. [64] Recycling systems that rely on intensive energy use (as e.g. pyro metallurgical treatments) are likely to produce higher emissions, while hydrometallurgical process, which make use of selective dissolution by specific solvents are likely to have higher impact in environmental quality terms.[65]

The use and recycling of rechargeable batteries (including portable ones) is in principle less energy-intensive. The total balance, however, depends strongly on the number of charging cycles they are able to undergo, and on the recovery of the materials that these batteries contain. [66]

In any case, recycling is key aspect to maximize the benefits of using battery technologies for decarbonisation. Increased levels of recycling will feed into the raw materials supply and ease the pressure on raw materials and reduce the GHG emissions associated with the production of substances needed for the cells and other components of the batteries.

7.3. Hazardousness of components

The hazardousness[67] of the most relevant chemical components of the batteries mentioned above is presented in this annex.

Lead - acid batteries

The lead-acid battery is based on lead dioxide as the active material of the positive electrode, metallic lead, in a high surface area porous structure, as the negative active material and sulphuric acid solution.

- Lead itself (Pb) is a toxic heavy metal. This substance may damage fertility or the unborn child, causes damage to organs through prolonged or repeated exposure, is very toxic to aquatic life with long lasting effects, may cause cancer, is very toxic to aquatic life and may cause harm to breast-fed children.
- Lead oxide (PbO) and dioxide (PbO_2) may damage fertility or the unborn child, are very toxic to aquatic life with long lasting effects, may intensify fire (oxidiser), are harmful if swallowed or if inhaled and may cause damage to organs through prolonged or repeated exposure. Lead dioxide is believed to be carcinogenic.
- Sulphuric acid (H_2SO_4) causes severe skin burns, eye damage, and is toxic if inhaled.

7.3.1. Alkaline batteries

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64 Ellingsen et al 2016

65 M. Thomas, L. Ellingsen, C. Hung, 2019. Battery-powered electric vehicles: market development and lifecycle emissions. Available at: http://bit.ly/2HDKk0y

66 G. Dolci et al. (2016) 'Life cycle assessment of consumption choices: a comparison between disposable and rechargeable household batteries' Int J Life Cycle Assess (2016) 21: 1691. https://doi.org/10.1007/s11367-016-1134-5

67 Unless indicated otherwise, information on the hazardousness of the substances concerned is taken from the ECHA database at: https://echa.europa.eu/advanced-search-for-chemicals?p_p_id=dissadvancedsearch_WAR_disssearchportlet&p_p_lifecycle=0&p_p_col_id=column-1&p_p_col_count=2
ECHA makes use of information provided within the EU harmonised classification and labelling system, established by the CLP Regulation, and as a result of REACH registration procedures.

Alkaline cells contain Zinc, Zinc oxide, Manganese dioxide and potassium hydroxide, as the main components.[68]

- Manganese dioxide (MnO_2) is harmful if swallowed and is harmful if inhaled. Additionally, the classification provided by companies in REACH registrations identifies that this substance causes damage to organs through prolonged or repeated exposure.
- Zinc oxide (ZnO) is very toxic to aquatic life with long lasting effects. This substance may damage fertility or the unborn child, is harmful if swallowed, is harmful if inhaled and may cause damage to organs through prolonged or repeated exposure.
- Zinc (Zn) is very toxic to aquatic life and is very toxic to aquatic life with long lasting effects.
- Potassium hydroxide (KOH) causes severe skin burns and eye damage and is harmful if swallowed.

As an improvement seeking longer life or higher power for this type of batteries, the compound nickel oxide-hydroxide is used as additive.

- Nickel oxide-hydroxide (NiO) may cause cancer by inhalation, causes damage to organs through prolonged or repeated exposure, may cause long lasting harmful effects to aquatic life and may cause an allergic skin reaction.

7.3.2. Nickel-cadmium batteries

The active materials of this type of batteries contain cadmium, nickel oxyhydroxide and a solution of potassium hydroxide.[69]

- Cadmium (Cd) is fatal if inhaled, very toxic to aquatic life, also with long lasting effects, may cause cancer, causes damage to organs through prolonged or repeated exposure, is suspected of causing genetic defects, is suspected of damaging fertility or the unborn child and catches fire spontaneously if exposed to air.

7.3.3. Lithium – ion batteries

Electrochemically active materials in these batteries are a lithium metal oxide or a lithium metal phosphate and a lithiated graphite. Current lithium-ion batteries contain cobalt, nickel or manganese. Electrolytes are usually constituted of fluorinated lithium salts.

- Cobalt oxide (CoO) is very toxic to aquatic life with long lasting effects, is harmful or even fatal if swallowed and may cause an allergic skin reaction. It may cause cancer, may damage fertility or the unborn child and may cause allergy or asthma symptoms or breathing difficulties if inhaled.
- Lithium hexafluorophosphate (LiPF6), is toxic if swallowed, causes severe skin burns and eye damage, causes damage to organs through prolonged or repeated exposure and causes serious eye damage.

Electrochemically active materials in these batteries are a lithium metal oxide or a lithium metal phosphate and graphite. Current cathode materials in lithium-ion batteries may contain cobalt, nickel or manganese. Electrolytes are usually constituted of fluorinated lithium salts dissolved in highly volatile and flammable organic solvents.

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68 Linden's handbook of batteries
69 Linden's handbook of batteries

- Cobalt oxide (CoO) is very toxic to aquatic life with long lasting effects, is harmful or even fatal if swallowed and may cause an allergic skin reaction. It may cause cancer, may damage fertility or the unborn child and may cause allergy or asthma symptoms or breathing difficulties if inhaled.
- Lithium hexafluorophosphate (LiPF6), is toxic if swallowed, causes severe skin burns and eye damage, causes damage to organs through prolonged or repeated exposure and causes serious eye damage. LiPF6 can react with water, releasing HF and further potentially harmful species, becoming an additional health hazard.
- Organic volatile compounds in electrolytes (e.g. ethylene carbonate, diethyl carbonate, dimethyl carbonate) are highly volatile, flammable and toxic if inhaled.

7.3.4. Mercury-containing batteries

Mercury oxide chemistries have been used for button cells containing mercury oxide, cadmium components and zinc components. In addition, amalgamating zinc and mercury has been in the past the approach to counteract the tendency for corrosion in zinc-air batteries.

Mercury (Hg) is fatal if inhaled, may damage fertility or the unborn child, causes damage to organs through prolonged or repeated exposure, is very toxic to aquatic life, also with long lasting effects.

7.4. Analysis of the sector

Data is available for manufacturers of batteries and accumulators in Europe, using data from Eurostat. The **Table 5** below shows the number of companies, their turnover, number of employees and cost structure. This uses NACE classification code 27.20 (section C Manufacturing)[70].

In summary, there are almost 500 such firms in Europe (data below does not include a firm count for Italy) with a turnover of around 9 billion Euros per annum for the sample covered, and perhaps 13 billion Euros per annum overall. This suggests an average turnover of around 26 million per firm. Around 30,000 people are employed, or around 60 per firm.

Table 5: Eurostat data for batteries and accumulators

Country	Enterprises Number **2018**	Turnover or Gross Premiums (millions EUR) **2018**	Turnover from the principal activity at 3-digit level NACE Rev. 2 - (million euro) **2017**	Gross Operating Surplus (millions EUR) **2017**	Employees number **2017**	Persons employed number **2018**	Turnover per Person Employed (thousand EUR) **2017**	Cost Structure		
								Total Purchases of Goods and Services (million EUR) **2018**	Wages and salaries (million EUR) **2018**	Personnel costs (million EUR) **2017**
European Union - 27 countries (from 2020)	450	:	:	:	:	29,900	:	9,000.0	1,000.0	:
European Union - 28 countries (2013-2020)	:	:	:	:	31,909.0	31,699	:	:	:	:
European Union - 27	:	:	:	:	:	:	:	:	:	:

70 Source: http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

countries (2007-2013)										
Belgium	7	189.4	181.6	30.5	945	913	196.7	99.6	44.7	59.8
Bulgaria	12	249.7	211.6	12.2	1,053	1,114	221.7	220.1	11.6	12.0
Czechia	42	597.7	572.8	33.9	1,350	1,390	427.9	542.1	26.9	34.4
Denmark	5	:	:	:	:	:	:	:	:	:
Germany	76	3,365.8	3,151.1	87.7	9,923	8,843	391.3	2,987.9	403.2	555.7
Estonia	:	:	:	:	:	:	:	:	:	:
Ireland	:	:	:	:	:	:	:	:	:	:
Greece	13	211.7	227.9	22.9	807	780	284.3	176.0	15.9	20.4
Spain	23	1,105.7	1,048.8	77.4	2,211	2,239	475.2	954.6	74.1	100.1
France	27	1,128.2	538.9	71.3	2,207	:	430.9	902.4	142.6	133.9
Croatia	5	0.7	0.6	-0.3	40	32	33.8	0.6	0.2	0.3
Italy	:	1,465.7	1,380.9	86.8	2,869	2,926	472.9	1,259.4	96.1	138.4
Cyprus	0	0.0	0.0	0.0	0	0	:	0.0	0.0	0.0
Latvia	2	:	:	:	2	2	:	:	:	:
Lithuania	0	0.0	0.0	0.0	0	0	:	0.0	0.0	0.0
Luxembourg	3	:	:	:	:	:	:	:	:	:
Hungary	12	6.7	25.0	2.3	115	40	258.4	6.8	1.3	1.5
Malta	:	:	:	:	:	:	:	:	:	:
Netherlands	31	:	:	:	89	124	:	:	:	:
Austria	9	625.2	503.8	19.7	954	991	593.1	516.5	55.1	66.8
Poland	61	1,056.3	841.7	54.1	4,038	5,143	226.2	953.0	69.0	70.9
Portugal	3	132.6	127.8	1.4	445	446	297.2	117.6	11.6	15.7
Romania	5	104.4	:	:	817	822	120.1	:	:	:
Slovenia	3	:	:	:	:	:	:	:	:	:
Slovakia	6	6.4	:	:	:	25	:	5.7	0.2	:
Finland	10	2.5	2.3	0.4	30	33	69.6	3.0	1.1	1.4
Sweden	19	:	:	:	:	:	:	:	:	:

*the indicator for the employees number is expressed in number of people (not thousands or millions)

*Reported data missing for some countries because it is confidential or not reported

7.4.1. Analysis of the companies using the ORBIS database

The Joint Research Centre (JRC) undertook an analysis of firms using information extracted from the Orbis commercial database, provided by Bureau van Dijk, a Moody's Analytics Company. The database contains information on private corporations across the world, presenting it in comparable formats. The information in the Orbis dataset is collected from the firms' balance sheets reporting duties. Since the balance sheet reporting requirements vary according to different country legal frameworks and firms' listing status, the data collected is affected by limitations in terms of missing information. This has implications on the type (size) of firms sampled, and on the obligation of reporting certain variables. In many cases, this leads to the absence of financial and other information for a number of firms. For these reasons, the Orbis database is known to under-represent SMEs, which typically have fewer reporting obligations. As such, the result of any analysis conducted with this dataset must be interpreted with caution as the samples derived by it are not necessarily representative of the industry.

The sample covers EU28 companies whose "primary" economic activity is registered under the NACE code 2720 - manufacture of batteries and accumulators. Note that a given firm's activity can be registered in several primary NACE economic classifications. In these cases it is relevant to consider the firm's "core" activity. These may also include firms whose main activity is under the NACE code 2711 - manufacture of electric motors, generators and transformer. The sample used in this analysis refers to the period 2015-2019.

The financial variables selected from the Orbis dataset and used to characterize the firms in the market are:

- Total assets (in millions), equal to the sum of fixed and current assets;
- Turnover (in millions);

ˆ Sales (in millions);

ˆ Number of employees;

ˆ Cost of labour force (in millions);

ˆ Cost of materials (in millions);

Due to missing information, other variables initially considered are not available (i.e. gross profit, investments in R&D, and partially also the number of patents). Keeping in mind that we cannot claim a perfect representativeness of the universe of relevant firms (neither at the European nor at the country level), the largest companies are present in Austria, Germany, Portugal, France, Spain, Slovenia, and Czech Republic.

The ORBIS database also provides a static analysis as if all balance sheets referred to the same period. This simplification entails keeping only the most recent observation for each company and for each variable. This is intended to maximize the sample size at the expense of time consistency across variables. It shows that materials make up a significant part of the cost base for the sector, which is not a labour intensive sector (rather it is capital intensive).

Table 6: ORBIS Analysis of Battery manufacturers

	count	mean	sd	min	25th	75th	max
Total assets	480	24.51	100.95	0	0.1	6.87	1230.26
Turnover	313	38.66	122.65	-0.26	0.11	11.58	1467.62
Sales	281	39.32	124.64	0	0.09	11.52	1430.74
Employees	352	89.45	207.89	0.00	3	47	1456
Cost of labour force	236	5.39	12.86	0.00	0.08	3.55	100.24
Cost of materials	205	38.16	116.08	-0.01	0.08	16.03	1194.97

All variables are measured in millions of euros, with the exception of number of employees. This sample contains the latest available information for each company and for each variable. This is intended to maximize the sample size at the expense of time consistency across variables. In other words, the table neglects the fact that observations may refer to 2015, 2016, 2017, 2018, or 2019.

The variable "number of patents" has non-missing values in 132 out of 778 distinct companies. No time trend is observable since this measure is constant over time. Moreover, non-reported information could be considered non disclosed or equal to zero. The cumulative number of patents held by the firms by country of registration. This number is obtained by summing up all the patents in the countries. Patents' ownership is extremely skewed, with some countries declaring no patents and three countries (Germany, Spain, and France) with more than 100 patents on average per firm.

Examples of Battery Companies in Europe

The following is list of example companies[71]. The companies highlighted in bold have as single/main activity battery manufacturing, whereas others have other activities sometimes to a much more significant degree than manufacturing.

71 The main sources are https://uenergyhub.com/world-battery-companies/ and for the Number of Employees and the Annual Revenue are: www.owler.com; www.growjo.com, https://rocketreach.co/

Company	Location	Specialty	Number of Employees	Annual Revenue in EUR	Company activity
Akasol	Germany	High performance battery systems	72	For the financial year 2019, AKASOL expects an increase in revenue to at least EUR 60 million	leading manufacturer of high performance battery systems for different applications - buses, commercial vehicles, rail vehicles, marine
ARTS Energy	France	Lithium-ion, Ni-MH and Ni-Cd chemistries	270	53 Million	High performance batteries specialist for industrial businesses.
Blue Solutions	France	Lithium polymer batteries	413	38.2 Million	
Bosch	Germany	Pb-acid and Lithium-ion batteries	400,000	78.5 Billion	
BroadBit	Finland	sodium-based chemistries			BroadBit is a technology company developing revolutionary new batteries using novel sodium-based chemistries to power the future green economy.
Continental AG	Germany	Lithium-ion (incl. all-solid-state) batteries for electric vehicles	243	44.4 Billion	
EAS Batteries	Germany	Cylindrical Lithium-ion cells with stainless steel containers via extrusion	28	4.5 Million	Solutions for hybrid electric and electric applications for ships, underwater vehicles and on shore harbor equipment
E4V	France	Lithium-ion batteries based on LiFePO4	21	15.4 Million	Battery solutions to electric vehicles
European Battery Technologies	Finland	Lithium-ion based prismatic cells			Industrial batteries
Johnson Matthey Battery Systems	England/ Poland	Lithium-ion batteries for electric vehicles	520	100 Million	Part of the Johnson Matthey group. Europe's largest independent designer and manufacturer of lithium-ion battery systems.
Leclanché	Switzerland	Lithium-ion batteries	163	45 Million	World provider of energy storage solutions, based on lithium-ion cell technology.
NorthStar	Sweden	Pb-acid batteries	500	144 Million	
Northvolt	Sweden	Greenest Lithium-ion batteries	250	18 Million	Northvolt is a supplier of sustainable battery cells and systems.
Saft	France	Lithium-ion batteries	4,500	827 Million	advanced-technology *battery* solutions

					for industry,
SK battery Hungary	Hungary	Lithium-ion batteries	979	4.5 Million	manufacture lithium-ion batteries for electric vehicles
Super B	Holland	Lithium-ion batteries based on LiFePO4	59	12.7 Million	*Super B* develops and produces advanced Lithium *Batteries* for Marine, Automotive, Motorcycle, UPS, Recreational and Industrial applications
Tiamat Energy	France	Na-ion batteries	31	5.5 Million	Tiamat designs, develops and manufactures sodium-ion batteries for mobility and stationary energy storage
Triathlon Batteries Solutions, Inc.	Germany	Pb-acid and Lithium-ion batteries	7	5.6 Million	assembly manufacturer and developer of Lead-Acid batteries and Lithium-Ion batteries,
Varta	Germany	Pb-acid and Lithium-ion batteries	130	362 Million	
Wyon	France	Miniaturized Lithium-ion batteries			

List of top Global Batteries Manufacturers

The following is a list of some of the largest global manufacturers. The companies highlighted in bold have as single/main activity battery manufacturing, whereas others have other activities sometimes to a much more significant degree than manufacturing.

Company	**Location**	**Specialty**	**Number of Employees**	**Annual Revenue in USD**	**Company activity**
SAMSUNG SDI	South Korea	Lithium-ion batteries	10,650	8 Billion	A subsidiary of Samsung electronics, Samsung SDI is dedicated to fuel research and innovation in lithium ion technology, both for in-house use and for potential clients elsewhere. Currently, the firm is engaged in the production of lithium ion batteries, solar energy panels, and energy storage systems among other things
Panasonic Corporation	Japan	Lithium-ion batteries and others		71.8 Billion	worldwide leader in the development of diverse electronics technologies and solutions
Toshiba	Japan	Lithium-ion			business conglomerate

		batteries			that focuses on Information Technology, electronics, energy, social infrastructure and communications sectors.
LG Chem	South Korea	Lithium-ion batteries	. 14,974	. 24.7 Billion	LG Chem is a manufacturer and supplier of petrochemicals, polyvinyl chloride resins and engineering plastics for industrial applications.
Contemporary Amperex Technology Co. Limited	China	Lithium-ion battery power solutions	24,875	6.6 Billion	battery manufacturer and technology company
BYD	China	Lithium-ion battery power solutions	229,000	. 18.2 Billion	The firm makes both lithium ion batteries along with electric cars
TESLA	USA	Lithium-ion batteries for automotives and solar power storage	.	.	
A123 Systems Inc.	USA	Automotive Lithium-ion Solutions	. 3,000	. 500 Million	A123 Systems develops, manufactures and supplies nanophosphate lithium iron phosphate batteries and energy storage systems.
Aquion Energy	USA	Aqueous hybrid-ion (AHI) chemistry	87	17 Million	Aquion Energy is the manufacturer of proprietary Aqueous Hybrid Ion (AHI™) batteries and battery systems for long-duration stationary energy storage application
Battery Streak	USA	Ultra Fast Charging lithium-ion cells	38	7 Million	
Electrovaya	Canada	Lithium-ion battery power solutions	123	5.6 Million	for automotive, power grid and medical industries.
ENOVIX	USA	3D Silicon Lithium-ion battery	120	28 Million	
Exide	USA	Pb-acid batteries	8,986	2.9 Billion	Exide Technologies is an American multinational lead-acid batteries manufacturing company. It manufactures automotive batteries and industrial batteries.

The following two tables show the top Battery Manufacturers[72]

Table 7: Top 12 Global Li-ion Battery Manufacturers

Rank*	Company	2017 Installed Manufacturing Capacity	Country	Revenue***	Market Cap****
1	LG Chem	17 GWh	Korea	$23.1 Billion	$23.9 Billion
2	BYD	16 GWh	China	$15.5 Billion	$15.4 Billion
3	Panasonic	8.5 GWh	Japan	$71.8 Billion	$31.8 Billion
4	AESC	8.4 GWh	Japan	NA	NA
5	CATL	7.5 GWh	China	$3.0 Billion	$23.3 Billion
6	Guoxuan High-Tech	6 GWh	China	$718 Million	$2.3 Billion
7	Samsung SDI	6 GWh	Korea	$5.7 Billion	$14.0 Million
8	Lishen	3 GWh	China	NA	NA
9	CBAK	2.5 GWh	China	$58.4 Million	$19.2 Million
10	CALB	2.4 GWh	China	NA	NA
11	LEJ	2.3 GWh	Japan	NA	NA
12	Wanxiang	2.1 GWh	China	$1.7 Billion	$2.6 Billion

[72] Source: https://www.thomasnet.com/articles/top-suppliers/battery-manufacturers-suppliers/

Table 8: Key Global Non-Li-ion Battery Manufacturers

Rank	**Company**	**Non-Li-ion Battery Technology**	**Country**	**Founded**	**Revenue** (Billions)**
1	Gridtential	Lead Acid	USA	2010	NA
2	Sumitomo Electric	Vanadium Redox	Japan	1897	$43.5
3	Enerox	Vanadium Redox	Germany	2018	NA
4	UniEnergy	Vanadium Redox	USA	2012	NA
5	Vionx Energy Inc.	Vanadium Redox	USA	2002	NA
6	Primus Power	Zinc Bromide Flow	USA	2009	NA
7	NGK Insulators	Sodium Sulfur	Japan	1919	$3.7
8	FIAMM	Lead Acid	Italy	1942	NA

8. Annex 8: EU research and innovation support for batteries

8.1. Context

This section presents the current policy context at EU level as well as the related research and innovation activities linked to the batteries ecosystem. An overview of the different EU-funded projects is provided to illustrate the extent of the funding and the variety of topics investigated. Details of the funded projects, their funding topics and the subject of their research are detailed for reference.

In its long-term vision for a climate-neutral economy by 2050 – "A Clean Planet for All"[73], the Commission shows how Europe can lead the way to climate neutrality, providing a solid basis for work towards a modern and prosperous climate-neutral economy by 2050. This vision makes clear that electrification is set to be one of the main technological pathways to reach carbon neutrality.

Batteries will be one of the key enablers for this transition given the important role they play in stabilising the power grid and in the roll-out of clean mobility. Driven by the ongoing clean energy transition, demand for batteries is expected to grow rapidly in the coming years (more detail in Annex 9), making this an increasingly strategic market at global level. Batteries development and production is a strategic imperative for Europe and is a key component of the competitiveness of its automotive sector as detailed in EUROPE ON THE MOVE [74].

Therefore, batteries have been identified by the Commission as a strategic ecosystem, where the EU must step up investment and innovation in the context of a strengthened industrial policy strategy aimed at building a globally integrated, sustainable and competitive industrial base.

Batteries offer a very tangible opportunity to use this deep transformation to create high value jobs and increase economic output. They can become a key driver for the EU's industrial competitiveness and leadership, notably for Europe's automotive industry.

To prevent a technological dependence on our competitors and capitalise on the job, growth and investment potential of batteries, Europe has to move fast in the global race to consolidate technological and industrial leadership along the entire value chain. The Commission is working together with many Member States and key industry stakeholders to build a competitive, sustainable and innovative battery ecosystem in Europe, covering the entire value chain.

This is the main objective behind the **European Battery Alliance (EBA)**, an industry-led initiative, which the Commission launched in October 2017, to support the scaling up of innovative solutions and manufacturing capacity in Europe. The EBA is helping to foster cooperation between industries and across the value chain, with support at both the EU-level and from EU Member States.

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73 COM/2018/773

74 COM(2018) 293, "EUROPE ON THE MOVE Sustainable Mobility for Europe: safe, connected, and clean

In this context, in May 2018, the Commission adopted the **Strategic Action Plan on Batteries**[75] which brought together a set of measures to support national, regional and industrial efforts to build a battery value chain in Europe, embracing raw materials extraction, sourcing and processing, battery materials, cell production, battery systems, as well as re-use and recycling. The measures include securing the supply of primary raw materials for batteries from EU and external sources, increasing the contribution of secondary raw materials, **supporting research and innovation**, working with investors to promote scalability and manufacturing capacity of innovative solutions, and **investing in specialised skills**.

Europe needs sustained and coordinated efforts to support **investments in research and innovation** in battery advanced materials and chemistries to enhance its performance on lithium-ion (Li-ion) battery cell technologies, and to pursue leadership in the next generation of battery technologies. Current state-of-the-art batteries are largely based on lithium-ion chemistry, but the demand for higher energy density and performance requires short- to medium-term improvements, together with more radical changes towards a new generation of post-Li-ion batteries based on new advanced materials. EU companies are well placed to take advantage of these technological developments.

In the area of batteries, the EU is mobilising all its support instruments covering the **entire innovation cycle**, from fundamental and applied research to demonstration, first deployment and commercialisation.

Coordinating battery-related research activities is key to harnessing the potential of this sector. Building on the collaborative efforts of the Strategic Energy Technology (SET) Plan and the Strategic Research and Innovation Agenda (STRIA), the Commission has launched a **European Technology and Innovation Platform (ETIP) "Batteries Europe"** to advance battery research priorities bringing together industrial stakeholders, the research community and EU Member States to foster cooperation and synergies between relevant battery research programmes. This platform enables co-operation between the numerous battery-related research programmes launched at EU and national levels, as well as private sector initiatives.

The Strategic Action Plan on Batteries also foresees the launch of **a large scale and long term research initiative on future battery technologies called Battery 2030+**. Battery 2030+ aims at 'inventing the batteries of the future' by developing the next generation of ultra-performing, sustainable and safe batteries. The objective is to provide European industry with high-performing and competitive battery technologies to regain technology leadership in the next decade.

The Commission, together with private partners is proposing a **co-programmed partnership on batteries** in the future Research and Innovation Framework Programme, "Horizon Europe", starting in 2021. This vision and objective-oriented policy activity will gather concrete commitments from the industry in order to accelerate research on European level through Horizon Europe activities together with a set underlying actions undertaken by industry, research organizations, associations and Member States. This coherent framework will allow moving towards a competitive European industrial battery value chain for stationary applications and e-mobility

[75] COM(2019) 176, Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe

The EU budget is already providing important funding opportunities to support research and innovation in batteries. The EU's Framework Programme for Research and Innovation for 2014-2020, **Horizon 2020**, has granted EUR 1.34 billion to projects for energy storage on the grid and for low-carbon mobility. In 2019, Horizon 2020 added a call to fund, under the European Battery Alliance, battery projects worth EUR 114 million. This was followed by a call in 2020 amounting to EUR 132 million, covering batteries for transport and energy. The European Regional Development Fund is also providing support for research and innovation to promote an energy-efficient and decarbonised transport sector.

8.2. The projects on batteries funded under H2020 programme

In this section, projects on batteries funded by the EC under H2020 programme are presented. They were selected for funding from calls/topics of different parts of H2020, some calls specifically addressing batteries and others more generalist. In terms of structure, the range of funding schemes, the expected Technology Readiness Level (TRL) of the proposed solutions, the number of participants and the budget/EC contribution, is very wide. In relation to the technical dimension, the focus of the projects regarding the components, types of batteries, steps of the value chain and aspects addressed is huge.

Projects are grouped by the agency/DG in charge of their grants because this division represents to some extent the specificity of the calls and of the funding schemes.

Projects granted by DG Research and Innovation (R&I) through INEA. The H2020 call of 2019 is the cross-cutting call *Building a Low-Carbon, Climate Resilient Future: Next-Generation Batteries* (H2020-LC-BAT-2019-2020). It is organised in 15 topics covering a relevant spectrum of activities in the field of electric batteries technology: short term research for advanced Li-ion electrochemistry and production processes, short to medium term research for solid-state electrochemistry, modelling tools, new materials for stationary electric batteries, hybridisation of battery systems, next generation batteries for stationary energy storage, next generation and validation of battery packs and battery management systems, networking of pilot lines and skills development and training. Four of them kick-start a large-scale research initiative on Future Battery Technologies that will ensure the European knowledge base in long term battery research. This new large-scale, long-term research initiative was announced in May 2018 as part of the Third Mobility package, with its research activities starting to receive support in 2020 from Horizon 2020. In addition to the COP 21 Paris Agreement and decarbonisation, all topics under this call are in line with the Energy Union policies as well as the SET-plan and STRIA. This call has been managed by INEA.

From the 2019 call, 20 projects were selected for funding. They started this year and so no relevant results are yet available. However, some of them participated in the stakeholders consultation implemented in the framework of the preparation of the regulation addressed in the present document.

Under the topic LC-BAT-1-2019 - *Strongly improved, highly performant and safe all solid state batteries for electric vehicles* (RIA, TRL from 3 to 6), the following projects are funded:

- **Astrabat** (All Solid-sTate Reliable BATtery for 2025);
- **SAFELiMOVE** (advanced all Solid stAte saFE LIthium Metal technology tOwards Vehicle Electrification);
- **SOLiDIFY** (Liquid-Processed Solid-State Li-metal Battery: development of upscale materials, processes and architectures); and

- **SUBLIME** (Solid state sUlfide Based LI-MEtal batteries for EV applications); aims at developing further the current solid state battery technology and present solutions beyond the current state-of the art of solid state electrolytes for electric vehicles.

For the topic LC-BAT-2-2019 - *Strengthening EU materials technologies for non-automotive battery storage* (RIA, TRL from 4 to 6), projects are:

- **CoFBAT** (Advanced material solutions for safer and long-lasting high capacity Cobalt Free Batteries for stationary storage applications);
- **ECO2LIB** (Ecologically and Economically viable Production and Recycling of Lithium-Ion Batteries); and
- **NAIMA** (Na+ Ion materials as essential components to manufacture robust battery cells for non-automotive applications); address the development of more price competitive, better performant and highly safe battery storage solutions taking into account aspects such as safety and sustainability, including recycling.

The projects **CompBat** (Computer aided design for next generation flow batteries); and **SONAR** (Modelling for the search for new active materials for redox flow batteries), selected under the topic LC-BAT-3-2019 - *Modelling and simulation for redox flow battery development* (RIA), aims at developing mathematical models for numerical simulation and high-volume pre-selection of multi-species electrolyte flow and electrochemistry validated with experimental examples from known chemistries and representative prototypes, and show how new chemistries can be explored.

Under the topic LC-BAT-4-2019 - *Advanced redox flow batteries for stationary energy storage* (RIA, TRL from 3 to 5) the projects are:

- **Baliht** (Development of full lignin based organic redox flow battery suitable to work in warm environments and heavy multicycle uses);
- **CuBER** (Copper-Based Flow Batteries for energy storage renewables integration);
- **HIGREEW** (Affordable High-Performance Green Redox Flow Batteries); and
- **MELODY** (Membrane-free Low cost high Density RFB); will develop and validate Redox flow batteries based on new redox couples and electrolytes that are environmentally sustainable, have a high energy and power density, maximise lifetime and efficiency, while minimising their cost.

For the topic LC-BAT-5-2019 - *Research and innovation for advanced lithium-ion cells (generation 3b)* (RIA), the projects are:

- **3beLiEVe** (Delivering the 3b generation of LNMO cells for the xEV market of 2025 and beyond);
- **COBRA** (CObalt-free Batteries for FutuRe Automotive Applications);
- **HYDRA** (Hybrid power-energy electrodes for next generation lithium-ion batteries); and
- **SeNSE** (Lithium-ion battery with silicon anode, nickel-rich cathode and in-cell sensor for electric vehicles); have a multidisciplinary approach that includes the system knowledge for the most promising electrochemistries to achieve possible production-readiness by two to three years after the end of the project. The whole system performance for batteries are addressed and related monitoring systems / smart management are expected to be developed.

Under topic LC-BAT-6-201 - *Lithium-ion cell materials and transport modelling* (RIA, final TRL 5 or higher), the projects are:

- **DEFACTO** (Battery DEsign and manuFACTuring Optimization through multiphysic modelling) and
- **MODALIS2** (MODelling of Advanced LI Storage Systems) address advanced modelling approaches, systematic measurements of basic input parameters for modelling and manufacture of prototype cells or cell components.

For the topic LC-BAT-7-2019 - *Network of Li-ion cell pilot lines* (CSA), the project **LiPLANET** (Li-ion cell pilot lines network) was selected for funding.

The evaluation results for the topics of 2020 are not yet available.

Apart from this projects, the INEA portfolio on batteries also includes projects from other calls in the fields of mobile applications and energy storage, launched between 2014 and 2018. These projects already finished or are close to the end. The EC contribution accounts for ca. 53.4 Million Euros.

The following projects concern mobile applications:

- **eCAIMAN** (Electrolyte, Cathode and Anode Improvements for Market-near Next-generation Lithium Ion Batteries);
- **SPICY** (Silicon and polyanionic chemistries and architectures of Li-ion cell for high energy battery); and
- **FIVEVB** (Five Volt Lithium Ion Batteries with Silicon Anodes produced for Next Generation Electric Vehicles), finished in 2018 and were funded under the topic GV-1-2014 - *Next generation of competitive Li-ion batteries to meet customer expectations*.

These projects aimed at developing a multidisciplinary approach to pursue the optimisation of the electrochemistry to hone parameters critical to customer acceptance: cost, safety aspects, resistance to high-power charging, durability, recyclability and the impact of hybridisation with other types of storage systems, as well as consideration of scale-up for manufacturing.

For the same topic, in 2018, the project **i-HeCoBatt** (Intelligent Heating and Cooling solution for enhanced range EV Battery packs) was selected for funding. It will finish in 2021.

The projects **GHOST** (InteGrated and PHysically Optimised Battery System for Plug-in Vehicles Technologies) and **iModBatt** (Industrial Modular Battery Pack Concept Addressing High Energy Density, Environmental Friendliness, Flexibility and Cost Efficiency for Automotive Applications) were funded under the topic GV-06-2017 - *Physical integration of hybrid and electric vehicle batteries at pack level aiming at increased energy density and efficiency* (they will finish in 2021 and 2020 respectively).

The **IMAGE** (Innovative Manufacturing Routes for Next Generation Batteries in Europe) project was also funded by a topic of 2017, GV-13-2017 - *Production of next generation battery cells in Europe for transport applications*, and will finish in 2021.

In the field of energy storage, the projects:

- **NAIADES** (Na-Ion bAttery Demonstration for Electric Storage) was funded under the topic LCE-10-2014 - *Next generation technologies for energy storage, while*
- **BAoBaB** (Blue Acid/Base Battery: Storage and recovery of renewable electrical energy by reversible salt water dissociation) and

- **EnergyKeeper** (Keep the Energy at the right place!) under the topics LCE-01-2016 - *Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network*.

In summary, batteries thematic is addressed in INEA's H2020 portfolio for mobile applications and for stationary electric storage. INEA currently has 30 projects researching and developing innovative solutions for the different areas of the value of chain both in the transport and the energy sectors.

In regards to transport applications, the main goal of the research activities on battery is the increase of the energy density (volumetric and gravimetric), the increase of battery cycle life, the decrease of costs and the decrease of charging times. The achievement of these goals would allow electric vehicles to close the performance gap versus conventional powered vehicles (petrol and diesel), allowing EV to perform long trips with minimum travel interruptions.

The main focus in EU research for stationary batteries for energy applications is on lithium-based batteries and redox flow batteries. In the field of lithium-based batteries, the focus is on cost and the environmental impact over the product life-cycle. The current projects look at reducing the cycle-related costs per energy (€/kWh/cycle) while maximizing the recycling of lithium and the use of domestic materials. In the field of redox flow batteries, different projects focus on different technologies including copper-based technologies as well as technologies relying on organic electrolytes. The projects aim at costs reduction while increasing the number of cycles. All battery projects are planning tests with prototypes in laboratory and field test environments.

Other projects granted by DG R&I. Additionally to the previous projects granted through INEA, the portfolio of DG R&I on batteries includes 9 relevant projects in the field of batteries. They mainly focus in advanced systems and materials with very higher performance than the existing ones.

The projects **ALION** aiming at developing aluminium-ion battery technology for energy storage application in decentralised electricity generation sources; and **ZAS**, aiming at improving the performance of rechargeable zinc-air batteries, were selected under the topic NMP-13-2014 - *Storage of energy produced by decentralised sources*. They finished in 2019 and 2018 respectively.

The projects **ALISE** - Advanced Lithium Sulphur battery for xEV an **HELIS** - High energy lithium sulphur cells and batteries were selected for funding under the topic NMP-17-2014 - *Post-lithium ion batteries for electric automotive applications*. These type of batteries are considered a viable candidate for commercialization among all post Li-ion battery. The projects addressed the development and commercial scale-up of new materials and on the understanding of the electrochemical processes involved in the lithium sulphur technology and several issues connected with the stability of the lithium anode during cycling, engineering of the complete cell and questions about LSB cell implementation into commercial products (ageing, safety, recycling and battery packs). These projects finished in 2019.

The project **SINTBAT** - Silicon based materials and new processing technologies for improved lithium-ion batteries, recently finished, was selected under the topic NMP-16-2015 - *Extended in-service service of advanced functional materials in energy technologies (capture, conversion, storage and/or transmission of energy)*. It aimed at developing a cheap energy efficient and effectively maintenance free lithium-ion based energy storage system offering in-service time of 20 to 25 years.

Under the topic LC-NMBP-30-2018 - *Materials for future highly performant electrified vehicle batteries* (RIA, from TRL 3 to TRL 5) aiming at investigating phenomena and problems at the interfaces of the components of the battery cell electrode systems that are often not well understood and solving the safety issues encountered by the current Li-ion chemistries, including thermal runaway (e.g. through the use of solid-state electrolytes instead of flammable, liquid electrolytes), 3 projects were selected for funding – **SPIDER** (Safe and Prelithiated hIgh energy DEnsity batteries based on sulphur Rocksalt and silicon chemistries); **LISA** (Lithium sulphur for SAfe road electrification) and **Si-DRIVE** (Silicon Alloying Anodes for High Energy Density Batteries comprising Lithium Rich Cathodes and Safe Ionic Liquid based Electrolytes for Enhanced High VoltagE Performance.). They started in 2019 and will finish in 2022/23.

The project **NanoBat** (GHz nanoscale electrical and dielectric measurements of the solid-electrolyte interface and applications in the battery manufacturing line, 2020-2023), selected for funding under the topic DT-NMBP-08-2019 - *Real-time nano-characterisation technologies* (RIA), focus on the nanoscale structure of solid electrolyte interphase layer, which is of pivotal importance for battery performance and safety, but which is difficult to characterize and optimize with currently available techniques.

For this group of projects the EC contribution accounts for ca. 62.5 million Euros

Projects granted by EASME. The portfolio of EASME in the field of batteries is very diverse – it includes actions funded under topics of societal challenge 5 (Climate Action, Environment, Resource Efficiency and Raw Materials) and by the SME instrument programme of H2020. Additionally there is one project on batteries, not funded under a Horizon 2020 call/topic but instead funded by the LIFE programme. The topics to which the proposals were submitted are not batteries-specific, they are calls/topics that address other more general areas such as raw materials, waste and circular economy, in which batteries are a possible target, among others, not always explicitly mentioned in the call texts.

Nine projects were funded under SC5 topics on waste (2 projects), raw materials (5 projects) and circular economy (2). The funding schemes includes CSAs (3), IAs (4) and RIAs (2) and they address raw materials processing (2), data collection (2), recycling/recovery (4) and battery integration application (1). Some of their objectives and results are presented below. The EC contribution for these 9 projects is ca. 56 Million Euros.

The project **ProSUM** (is Latin for "I am useful") - Prospecting Secondary raw materials in the Urban mine and Mining waste (2015-2017) is a CSA (Coordination and Support Action) funded under the topic WASTE-4c-2014 - *Secondary raw materials inventory. By establishing an EU Information Network (EUIN)*. The project gathered secondary CRM data and collated maps of stocks and flows for materials and products of the "urban mine". The scope is the particularly relevant sources for secondary CRMs: Electrical and electronic equipment, vehicles, batteries and mining tailings. A comprehensive inventory identifying, quantifying and mapping CRM stocks and flows at national and regional levels across Europe was constructed.

The project **CloseWEEE** - Integrated solutions for pre-processing electronic equipment, closing the loop of post-consumer high-grade plastics, and advanced recovery of critical raw materials antimony and graphite (2014-2018) is a RIA funded under the topic WASTE-3-2014 - *Recycling of raw materials from products and buildings*. It integrates three interlinked research and innovation areas for an improved, resource-efficient recycling of polymer materials and critical raw materials from electrical and electronics equipment (EEE): (1) Efficient and effective disassembly of EEE; 2) Developing resource-efficient and innovative solutions for closing the loop of post-consumer high-grade plastics from WEEE; and (3) Improved recycling of Lithium-ion batteries through increasing the recovery rates of cobalt and researching a recovery technology for the critical raw material graphite from those batteries.

Under SC5-11b-2014 - *Flexible processing technologies*, the project **FAME** - Flexible and Mobile Economic Processing Technologies (2015-2018) is a mineral processing RIA which seeks to provide novel mineral processing solutions to facilitate better exploitation of three types of ore that are commonly found throughout Europe, namely: skarn, greisen and pegmatites. These ore types contain a wide range of potential commodities including a large number of Critical Raw Materials and Lithium.

The CSA **CIRCULAR IMPACTS** - Measuring the IMPACTS of the transition to the CIRCULAR economy (2016-2018) was funded under SC5-25-2016 - *Macro-economic and societal benefits from creating new markets in a circular economy*. It aimed at developing a web based search tool that helps to make several relevant information collections funded by past EU research framework programs visible again, by connecting their evidence base to the circular economy agenda. The project collected missing information in 3 case studies having been one of critical raw materials. That case study deals with the end-of-life electric vehicle batteries which was selected due to the expected significantly increase of the electric vehicles demand over the next few decades and the fact that an electric vehicle battery is about one thousand times larger than a mobile phone battery.

The project **SIMS**-Sustainable Intelligent Mining Systems (2017-2020) was funded under the topic SC5-14-2016 - *Raw materials Innovation actions*. It aimed at developing, testing and demonstrating new innovative well-developed mining operations technologies. It has a work package on "Battery Powered Mining Equipment" that demonstrated state-of-the-art clean mobile-mining technology in use in a mining environment. This technology enables a diesel-free underground mine using mobile machinery powered by battery technology.

Under the same topic but in 2017 (SC5-14-2017) the project **CROCODILE**-first of a kind commercial Compact system for the efficient Recovery Of CObalt Designed with novel Integrated LEading technologies (2018-2022), was selected for funding. It aims at demonstrating the synergetic approaches and the integration of the innovative metallurgical systems within existing recovery processes of cobalt from primary and secondary sources at different locations in Europe, to enhance their efficiency, improve their economic and environmental values, and will provide a zero-waste strategy for important waste streams rich in cobalt such as batteries.

The project **ORAMA**-Optimising quality of information in RAw MAterials data collection across Europe (2017-2019) is a CSA selected for funding under the topic SC5-2017- *Raw materials policy support actions*. It focused on optimising data collection for primary and secondary raw materials in Member States aiming at to analyse data collection methods and recommendations from past and ongoing projects to identify best practices, develop practical guidelines and provide training to meet specific needs. For Mining Waste, Waste Electrical and Electronic Equipment, End of Life Vehicles and Batteries, the focus was on developing 'INSPIRE-alike' protocols.

The more recent and still ongoing projects are **CarE-Service** - Circular Economy Business Models for innovative hybrid and electric mobility through advanced reuse and remanufacturing technologies and services (2018-2021) and **CIRCUSOL** - Circular business models for the solar power industry (2018-2022). They are IAs selected for funding under the topic CIRC-2017-*Systemic, eco-innovative approaches for the circular economy: large-scale demonstration projects*.

CarE-Service aims at demonstrating at large scale the feasibility of innovative circular business models applied to Electric and Hybrid Electric Vehicles (E&HEVs). One of the objectives of this action is to establish three new circular European value chains for the re-use, remanufacturing and selective recycling of high added-value parts of E&HEVs (batteries, metal and techno-polymeric components). A demonstrator on the re-use of batteries is foreseen and it is dedicated to Li-ion batteries. It includes: Remanufactured/certified batteries will be used as stationary energy storage in solar panels produced by one member of the Stakeholder Group (SG); Remanufactured batteries will be produced by one beneficiary and will be used as components of electric bikes by another member of the SG; Li and Co recovered by recycled batteries will be used as pigments of coatings produced by one member of the SG; Functionalities of an ICT platform supporting the integration between beneficiaries and stakeholders for the information management and showcase of remanufactured/recycled batteries will be demonstrated. Quantitative simulation of the economic sustainability of the new batteries reuse business model and the Environmental impact assessment will be performed using real demonstration data.

CIRCUSOL will develop two main blocks of a circular PSS model: circular product management with re-use/refurbish/remanufacture ("second-life") paths in addition to recycling, and value-added new product-services for residential, commercial and utility end-users. Among others the foreseen demonstrators will explore and test the following value propositions: Storage-as-a-service with second-life batteries for an industrial end-user; Energy management service with second-life PV and battery and Market adoption of second-life PV and batteries without subsidy.

The only project of this document not funded under H2020 programme is the project **LIFE-LIBAT** - Recycling of primary Lithium BATtery by mechanical and hydrometallurgical operations. This project aims at developing and demonstrating the feasibility of an innovative technological solution for the recycling of primary lithium batteries, particularly lithium-manganese batteries. Its proposed process integrates mechanical pretreatment with a hydrometallurgical treatment. The project will design and construct a prototype plant in northern Italy, with a processing capacity of 50 Kg primary lithium batteries per day, with the aim of achieving targets set in the Battery Directive. It also aims to significantly reduce processing costs, by avoiding the transport and treatment of spent batteries at specialized industrial plants outside Italy. The EC contribution is ca. 0.8 Million Euros.

Additionally to these projects, EASME granted 15 projects of SME Instrument Phase 2 programme. This instrument, part of H2020 programme, offers small and medium-sized businesses funding for innovation projects in two phases; phase 2 targets innovation projects. Some of the projects related to batteries address aspects such as: next-generation charging station for electric vehicles (EVs); novel hydrometallurgical process technology to recycle waste Lead-acid batteries in a highly energy efficient, non-polluting and cost effective way, a car-starting battery, which contains no hazardous materials, with extended life time and significant CO2 savings. Some projects propose alternatives to conventional batteries. The total EC contribution for this group of projects is ca. 22 Million Euros.

Projects granted by REA. The portfolio of REA on batteries accounts for 26 projects: 19 are MSCA-IF (Marie Skłodowska-Curie Actions - Individual Fellowships), 3 are MSCA-ITN (Marie Skłodowska-Curie Actions - Innovative Training Networks), and 4 are Research and Innovation Actions funded under FET Open (Future & Emerging Technologies). MSCA-IF actions are for experienced researchers from across the world; MSCA-ITN bring together universities, research institutes and other sectors from across the world to train researchers to doctorate level; FET OPEN programme invests in transformative frontier research and innovation with a high potential impact on technology, it aims at bringing together the brightest European minds at an early stage of research to pave the way for innovations, radical new ideas and novel technologies that challenge current thinking.

The project **VIDICAT** - Versatile Ionomers for DIvalent CAlcium baTteries (from 2019 to 2023) intends to develop a new material concept based on nanocomposite ionomers that will offer highly stable electrolytes. The project will also search for positive electrodes in its work towards building trustworthy and safe calcium batteries. It was funded under FETOPEN-01-2018-2019-2020 - FET-Open Challenging Current Thinking.

Two new types of batteries are proposed by projects (that will finish in 2020) funded under the call FETOPEN-01-2016-2017 - FET-Open research and innovation actions. The project **SALBAGE** - Sulfur-Aluminium Battery with Advanced Polymeric Gel Electrolytes aims at developing a new secondary Aluminium Sulfur Battery focusing in the synthesis of solid-like electrolytes based on polymerizable ionic liquids and Deep Eutectic Solvents. The new battery is expected to have a high energy density (1000Wh/kg) and low price compared with the actual Li-ion technology (-60%). The project **CARBAT** - CAlcium Rechargeable BAttery Technology, aims at achieving a proof-of-concept for a Ca anode rechargeable battery with > 650 Wh/kg and > 1400 Wh/l.

The project **LiRichFCC** - A new class of powerful materials for electrochemical energy storage: Lithium-rich oxyfluorides with cubic dense packing (finished in 2019) explored an entirely new class of materials for electrochemical energy storage termed "Li-rich FCC" comprising a very high concentration of lithium in a cubic dense packed structure (FCC). It was funded under the topic FETOPEN-RIA-2014-2015 - FET-Open research projects.

The EC contribution for these 4 FET-open actions is ca. 12 Million Euros.

The commitment to training and networking in the field of batteries are expressed in the 3 projects granted under MSCA-ITN (Innovative Training Networks) calls. The total EC contribution is ca. 8.4 Million Euros.

The project **POLYTE** - European Industrial Doctorate in Innovative POLYmers for Lithium Battery Technologies (from 2018 to 2021) aims at training scientists who may face some of the upcoming European energy and transportation challenges. The project will search the development of new polymeric materials to increase the performance and security of actual and future batteries. It was funded under the call MSCA-ITN-2017 and the funding scheme MSCA-ITN-EID - European Industrial Doctorates.

The projects **FlowCamp** – European Training Network to improve materials for high-performance, low-cost next- generation redox-flow batteries, and **POLYSTORAGE** – European Training Network in innovative polymers for next-generation electrochemical energy storage, are ongoing projects funded in 2017 and 2019 calls, respectively. They both have German coordinators.

The 19 MSCA-IF - Individual Fellowships granted by REA were funded under the calls H2020-MSCA-IF from 2014, 2015 (3 projects in each), 2016 and 2017 (4 projects in each) and 2018 (5 projects). They address aspects such as design, development of new or improved materials, characterisation, production, monitoring, modelling, safety, sustainability and cost-effectiveness for a wide range of batteries including Li-, Na- and Mg-ion, redox flow batteries and new concepts. The TRL of these projects is low, they are considered fundamental research and only 4 of them have a strong link to industry. The total EC contribution for these 19 actions accounts for ca. 3.8 Million Euros.

Projects granted by ERCEA. The portfolio of ERCEA on batteries includes 36 individual grants – mainly starting, advanced, or consolidator grants. These type of grants are submitted by one main researcher but more beneficiaries may be involved. Subjects are diverse. **Alternatives to batteries** are addressed by the projects Powering_eTextiles, NANOGEN, Portapower and 3DScavengers; **Electrochemistry of batteries** including electrodes, electrolytes, corrosion and redox work are considered in projects CAMBAT, BATNMR, FUN POLYSTORE, CAPSEL and INTELLICORR; **Advancements in Li-ion batteries** are targeted in the projects ARPEMA, BATMAN, Worlds of Lithium and HDEM; **Materials for batteries**, including additives, films and aerogels are in the objectives of projects, 3D2DPrint, ReSuNiCo, MOOiRE, MAEROSTRUC, ELECNANO and CORRELMAT; **Computational modeling of batteries are addressed in projects** COMBAT, ARTISTIC, StruBa, AMPERE; **Supercapacitors**, including structures, chemistries and integration are addressed in the projects SuPERPORES, CapTherPV, CITRES, IMMOCAP and 3D-CAP; **Flow batteries** are in research in the projects MFreeB, NanoMMES, ELECTRO-POM; Additionally, **other subjects** such as printed batteries, high-energy and stretchable batteries, oscillating heat pipes and software for embedded batteries are addressed in projects such as iPES-3DBat, OMICON, GEL-SYS, POHP and POWVER. The TRL of these projects is very low, they are considered as fundamental research and bottom-up initiatives. The total EC contribution is around 5.7 Million Euros.

Additionally to the projects mentioned above it was identified a project granted and coordinated by EMPIR (The European Metrology Programme for Innovation and Research) in the framework of EURAMET, (The European Association of National Metrology Institutes). The project **LiBforSecUse** "Quality assessment of electric vehicle Lithium-ion batteries for second use applications" will develop a robust measurement procedure and the supporting metrological infrastructure to measure the residual capacity of Li-ion batteries, recycled from electric vehicles, by using fast and non-destructive impedance based methods; the feasibility to predict premature failure will also be investigated. Such procedures are required to enable economic and environmental reasonable re-use of large numbers of used Li-ion batteries expected to be available in the near future. Impedance based measurement and evaluation methods could serve this purpose but the underpinning metrological framework, including traceability, quantified measurement uncertainties and defined measurement procedures in order to guarantee comparability of the results, is currently lacking. Consequently, standardised protocols for life cycle testing and impedance measurements as well as practical calibration concepts and standards for impedance measurement devices must be developed. This project started in 2018 and will finish in 2021. The consortium involves 14 partners from European metrology institutes, research institutions, universities and companies. The total EC contribution is 1.8 million Euros.

8.3. Conclusion

The support and commitment of the European Commission in the research in the field of batteries are expressed by the number of projects funded under the H2020 programme (over to 100 projects) and the financial contribution to their implementation (in the region of 500 Million Euros). The interest of the stakeholders in this field started, at least, at the beginning of the current MFF (and the associated research program, Horizon 2020) but it was boosted by the emergence of the Batteries Alliance, in 2017. Some projects are already finished but the majority are ongoing.

The types of calls and topics are varied, from the most recent very high specific and dedicated call - as the cross-cutting call on batteries launched in 2019, to bottom-up initiatives - like the ones granted by ERCEA, REA and EASME (SME instrument) which are focused on innovation but open to a wide range of subjects. The expected TRLs are various. There are funded actions associated to very low TRL, usually considered fundamental research - to works with very high TRLs developed in consortia with a significant number of partners from several countries and types, as universities, research institutions, non-profit organisations, etc., and representing all steps of the value chain. Training opportunities are also addressed in some funded projects.

The subjects addressed by the projects are wide, focused in solving current problems and in the future of the field: from developments and improvement of materials to batteries recycling, projects are covering the entire value chain of different types of batteries, the existing ones but also new systems and even alternatives to the conventional batteries. In terms of batteries dimension, the variety is also significant, from batteries such as the EVs batteries to micro-batteries integrated into functional textiles. Some projects include circular economy business models in their expected results.

The results of these projects will support and promote innovation for the batteries industry in Europe. New and improved materials and batteries´ systems, improved characteristics in terms of capacity storage, lifetime, safety, sustainability and cost-effectiveness are anticipated. These will be essential to ensure the competitiveness of Europe in this field as well as to boost its economy, growth and well-being.