re-sourcing

Mobility Sector

Policy Makers

Roadmap for Responsible Sourcing of Raw Materials until 2050

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Abbreviations

ASM	Artisanal and small-scale mining
BEV	Battery electric vehicle
CD	Community development
CSOs	Civil Society Organisations
CSRD	Corporate Sustainability Reporting Directive
DG	Directorates-General
DRC	Democratic Republic of Congo
EC	European Commission
EHS	Environment, Health and Safety
EoL	End-of-life
EPR	Extended Producer Responsibility
ESG	Environment, Social, Governance
EU	European Union
EU27	27 Member States of the European Union
EV	Electric vehicle
FPIC	Free, prior and informed consent
G7	Group of Seven (Canada, France, Germany, Italy, Japan, United Kingdom, United States)
GHG	Greenhouse gas
GRI	Global Reporting Initiative
GSSB	Global Sustainability Standards Board
H&S	Health and safety
ICE(V)	Internal combustion engine (vehicle)
ICMM	International Council on Mining and Metals
IFC	International Finance Cooperation
IRMA	Initiative for Responsible Mining Assurance
LCA	Life cycle assessment
LFP	Lithium iron phosphate
LIB	Lithium-ion batteries
LSM	Large-scale mining
NGO	Non-governmental Organisation
NMC	Lithium nickel manganese cobalt oxide
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturer
R&D	Research and development
RS	Responsible Sourcing
SDGs	Sustainable Development Goals
SE	Sharing economy
SIA	Social impact assessment
SLO	Social licence to operate
SME	Small and medium-sized enterprise

Executive Summary

The transformation of the mobility sector is essential in order to meet the Paris Agreement's goals. A 90% reduction in transport-related emissions by 2050 is needed to achieve climate neutrality. To achieve this, a major contribution will come from new technologies: the battery electric vehicle technology is the most promising technology today. The roadmap for the mobility sector therefore focuses on lithium-ion batteries (LIBs). While the global market for this technology is growing rapidly, production and end-of-life are linked to major environmental and social impact concerns. To ensure a just transition, it is crucial to implement high social and environmental standards in production and sourcing along the entire supply chain including end-of-life.

Following the State of Play and Roadmap Concepts for the Mobility Sector – a stock-taking report of the current sustainability challenges in the mobility sector – this report by the RE-SOURCING project focuses on the road towards achieving a sustainable mobility transition by 2050. The roadmap addresses four relevant raw materials used in LIBs (lithium, cobalt, nickel and graphite) and three supply chain stages (mining, cell manufacturing and OEMs, and recycling). Recommendations for EU policy makers, international industry (cell and battery producers, OEMs, recyclers, etc.) and Civil Society Organisations (CSOs) were developed to achieve the identified three main targets needed for a sustainable mobility sector (see figure below):

- **Circular Economy & Decreased Resource Consumption**
- **Responsible Procurement**
- **Level Playing Field**

For the development of the Roadmap, the RE-SOURCING project relies primarily on bringing together existing knowledge from key stakeholder groups and regions. A series of six webinars during October 2021 and June 2022, supplemented by additional expert consultations, were used to elaborate the recommendations presented in this report. It is obvious, that **we need to act now** without any further delay to ensure changes in these long-lasting processes of a life cycle of a mine, production facilities and recycling strategies. This is why there is a very high number of recommendations up to 2030. These actions are the basis for achieving milestones for 2040 and 2050.

The key issues for all three targets are **communication** between all stakeholder groups and along the whole value chain as well as **transparency** to provide the basis for changes. In addition, the **rethinking of transport** in general as well as **thinking about the end of a material or production from the very start** (e.g., design for recycling) are essential for a sustainable mobility sector.

In this document, the recommendations for EU policy makers are presented, with corresponding milestones and required actions for short- (2025), medium- (2030 and 2040) and long-term (2050) time frames. The numbering of the targets does not imply any priority. All three targets are interlinked and must be pursued simultaneously to achieve the vision developed in the State of Play report for the mobility sector.

Target 1 'Circular Economy & Decreased Resource Consumption' addresses the need for changes in behaviour and the economic system to stay within planetary boundaries. A transition to a mobility sector without direct CO_2 emissions will not be possible or not be enough to mitigate all negative impacts from the mobility sector without improvements in energy efficiency and decreased demand. Additionally, end-of-life LIBs need to be seen as a strategic source of raw materials, with improved

collection and recycling systems. Policy makers in particular need to ensure economic viability of recycling and support the creation of a market for secondary raw materials.

Milestones and recommendations in **Target 2 'Responsible Procurement'** focus more on the organisations themselves, considering the entire supply chain. Recommendations include transparency as a prerequisite for supply chain due diligence, support for sustainable development, the fair distribution of benefits and burdens, stakeholder engagement, and finding a European and worldwide common understanding of a sustainable product.

Finally, **Target 3 'Level Playing Field'** aims at harmonising requirements for companies operating and trading across the value chain in and with the EU. Raw materials or products that are produced with lower standards should be disadvantaged in the future or no longer allowed. However, creating a level playing field also implies supporting companies, regions and countries in improving their practices and achieving the required standards.

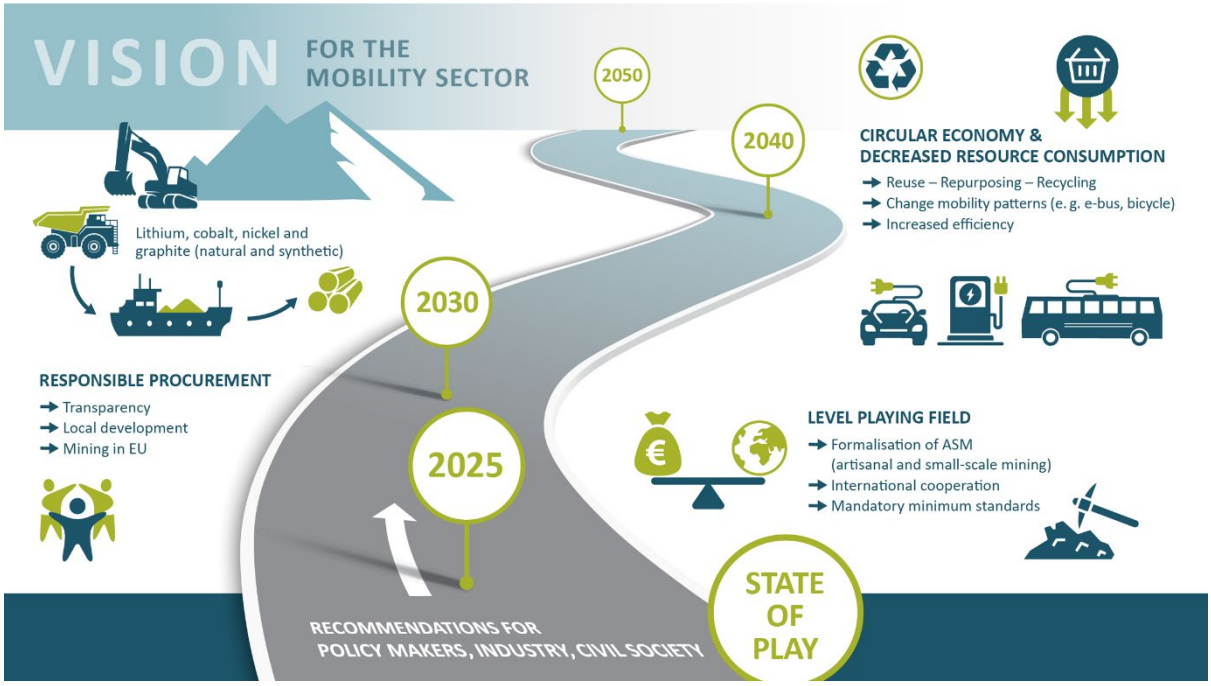

Figure: Roadmap for the mobility sector up to 2050

Keywords:

Mobility Sector, Lithium-Ion Batteries, Responsible Sourcing, Sustainability, Circular Economy

1 Introduction

1.1 The Mobility Sector

Work on the mobility sector started with the State of Play report which was published in April 2021. The aim of this report was to investigate the current state of the mobility sector with the focus on the lithium-ion battery (LIB) as the key component of electric vehicles. (Betz et al. 2021)

The mobility sector plays an important role in worldwide efforts to achieve the goals of the Paris Agreement. The legally binding international treaty on climate change was adopted in 2015 and entered into force in 2016. Its goal is to 'strengthen the global response to the threat of climate change' (Art. 2), among others by limiting the increase in the global average temperature to well below 2 °C, preferably below 1.5 °C, compared to pre-industrial levels. In order to achieve the temperature goal, 'Parties aim to reach global peaking of greenhouse gas emissions as soon as possible' (Art. 4). (UNFCC 2015)

In December 2019 the European Commission (EC) presented the European Green Deal with the aim of making 'Europe the first climate-neutral continent by 2050' (European Commission 12/11/2019). The European Green Deal requires a 90% reduction of emissions from transport by 2050 to achieve climate neutrality. However, this must be achieved without creating negative impacts in other environmental fields. To reach these targets, the EC proposes a 55% reduction of emissions from passenger cars by 2030 and emission-free new cars by 2035 (European Commission 2022a).

In 2019, the mobility sector accounted for 31% of total EU greenhouse gas (GHG) emissions, as can be seen in Figure 1 below. Road transportation is of highest relevance, with more than 70% of the GHG emissions from this transportation sector (aviation, navigation and railways play a minor role).

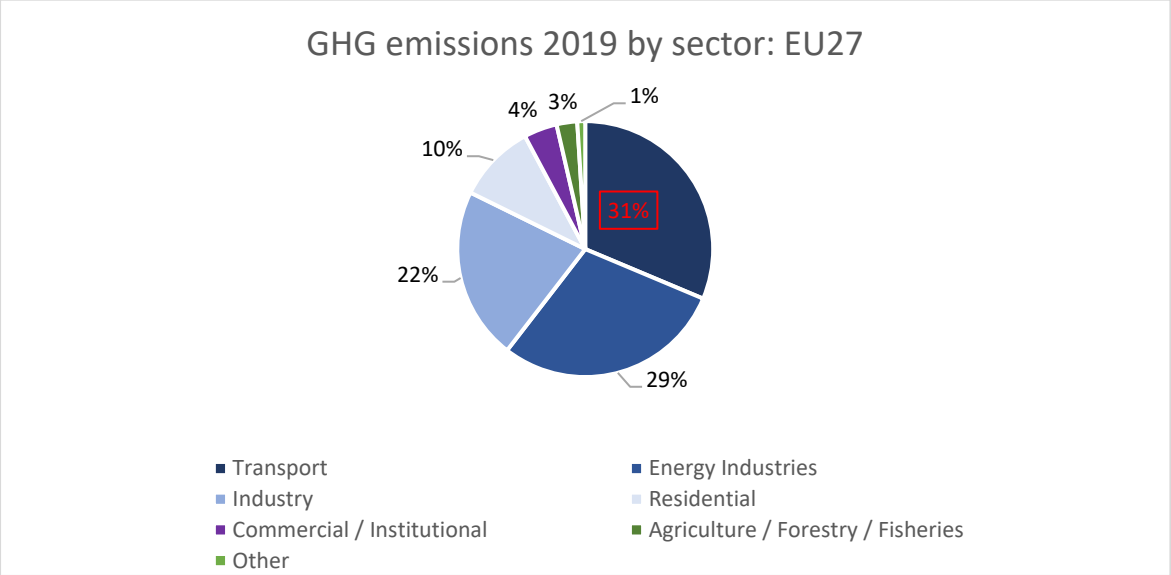

Figure 1: Greenhouse gas emissions 2019 by sector in the European Union (EU27) (data source: European Commission 2021a)

This project focuses on road transportation due to its significant contribution to overall GHG emissions. The project's focus on the mobility sector value chain therefore concentrates on a future technology in road transportation – electric vehicles – as this is seen as key for a transition to

transportation with lower GHG emissions. In 2050, it is predicted that 80% of all newly registered passenger vehicles worldwide could be equipped with alternative drive systems (Oeko-Institut 2019). Figure 2 shows the significantly lower GHG emissions of battery electric vehicles (BEVs) compared to internal combustion engine vehicles (ICE(V)s), even in countries with a high share of coal-based electricity.

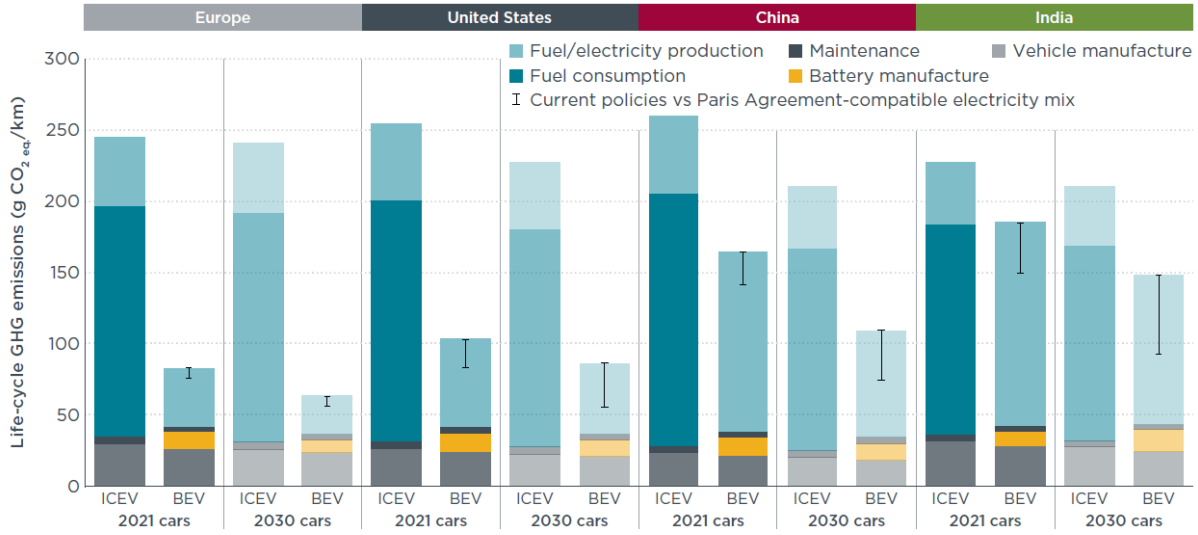

Figure 2: Life-cycle GHG emissions of average medium-size gasoline ICEVs and BEVs (Bieker 2021)

As a result, batteries are currently the main source of propulsion for cars to help achieve the Paris climate targets. The supply chain stages that are assessed in more detail in this roadmap are mining of the relevant minerals and the manufacturing of battery cells and their recycling.

In addition to the issues focussing on individual steps, there are also several overarching steps towards further minimising the carbon footprint of BEVs. Fewer and smaller cars on the roads reduce the energy and material consumption. Another important factor is increasing the share of renewable energy used for all steps in the entire value chain of a LIB. Life cycle assessments (LCA) and GHG accounting and reporting systems help to identify where emissions and energy use can be reduced. However, strong standards[1] and effective regulations for recycling are also important to reduce resource consumption and thus GHG emissions. The aim should be to achieve net zero GHG emissions.

The following paragraphs provide a brief overview of the main challenges presented in the State of Play report. For details see: State of Play and roadmap concepts: Mobility Sector. (Betz at al 2021)

Mining faces a wide range of challenges that are raw material- and site-specific. Overarching challenges in hard rock or ore mining (for the selected materials lithium, cobalt, nickel and graphite) include heavy metal pollution, acid mine drainage, energy intensive processing, habitat fragmentation, disturbance of land areas and dust pollution. For lithium from brines, water scarcity and associated social tensions as well as dust emissions are major challenges. Social dimensions related to cobalt mining are an additional issue already in the public debate. The main cobalt-producing country, the Democratic Republic of Congo (DRC), has a relatively high share (10-20% of production from DRC) of artisanal and small-scale mining (ASM). ASM is the income basis of thousands

[1] See explanation and criteria on a strong standard in Degreif et al. 2022

of families in the DRC. But the often informal ASM sector is connected to child labour, forced labour, inadequate health and safety conditions and funding of armed conflicts.

Battery cell manufacturing is a very energy-intensive process and associated with high GHG emissions. The toxic substances in the battery cell also require proper handling. Additionally, high susceptibility to production errors for battery cells leads to high scrap rates in production. Resource efficiency is a relevant lever to reduce the negative impacts in primary extraction. There is a need for the decoupling of economic growth from resource consumption, especially when considering the rapidly increasing demand for raw materials in the growing market of electric vehicles.

At the end-of-life (EoL) of LIBs, **recycling** is indispensable because of the high risk of 'thermal runaway' from overheating batteries leading to fires. Adequate collection, storage, transport and treatment of used LIBs are therefore essential.

This project also analysed various regulations, standards, initiatives and guidelines promoting sustainable practices in the mining sector. The availability of standards and frameworks for the battery cell manufacturing and recycling steps are rather limited while other value chain steps are covered by numerous initiatives. A gap analysis was conducted to assess whether the standards and initiatives cover the challenges that exist in the supply chains. In the mining sector, one gap identified is the large number of guidelines that often lead to confusion when it comes to compliance. An international framework that provides mutual recognition of standards is, therefore, very important. Such a framework should define terms and provide guidance for companies on which standards to apply. For customers, knowing which standards and corporate qualities are relevant is also challenging. These issues in identifying best standards are also applicable to battery cell manufacturing and the collection and recycling of EoL LIBs. There are no international guidelines addressing the whole supply chain. The proposal for an EU Regulation on (waste) batteries could offer an important step to integrating crucial elements of the supply chain in a regulation (supply chain due diligence, product carbon footprint, material specific recycling targets, recycled content, etc.).

1.2 Vision

The horizon considered for the roadmap of the RE-SOURCING project is 2050. The vision for the mobility sector (Figure 3) was developed based on the underlying concepts of the Paris Agreement[2], planetary boundaries[3] and strong sustainability[4] and will be incorporated in the definition of responsible sourcing that is developed towards the end of the project. Further information on the RE-SOURCING project's vision for the mobility sector can be found in the State of Play report of the mobility sector.

The remainder of this report outlines three key target areas for achieving the RE-SOURCING Vision 2050 (Mobility Sector):

- Circular Economy & Decreased Resource Consumption
- Responsible Procurement
- Level Playing Field

The discussion of each area considers targets and milestones, followed by specific recommendations for three key stakeholder groups: policy makers, industry and civil society. This document only includes recommendations for policy makers (for the other stakeholder groups see here).

[2] For further information on the Paris Agreement, please refer to the UNFCCC and the legislation.
[3] For further information on planetary boundaries, please refer to Rockström et al. 2009 and Steffen et al. 2015.
[4] An explanation of the strong sustainability concept is provided by Ekins et al. 2003 and Dedeurwaerdere 2014.

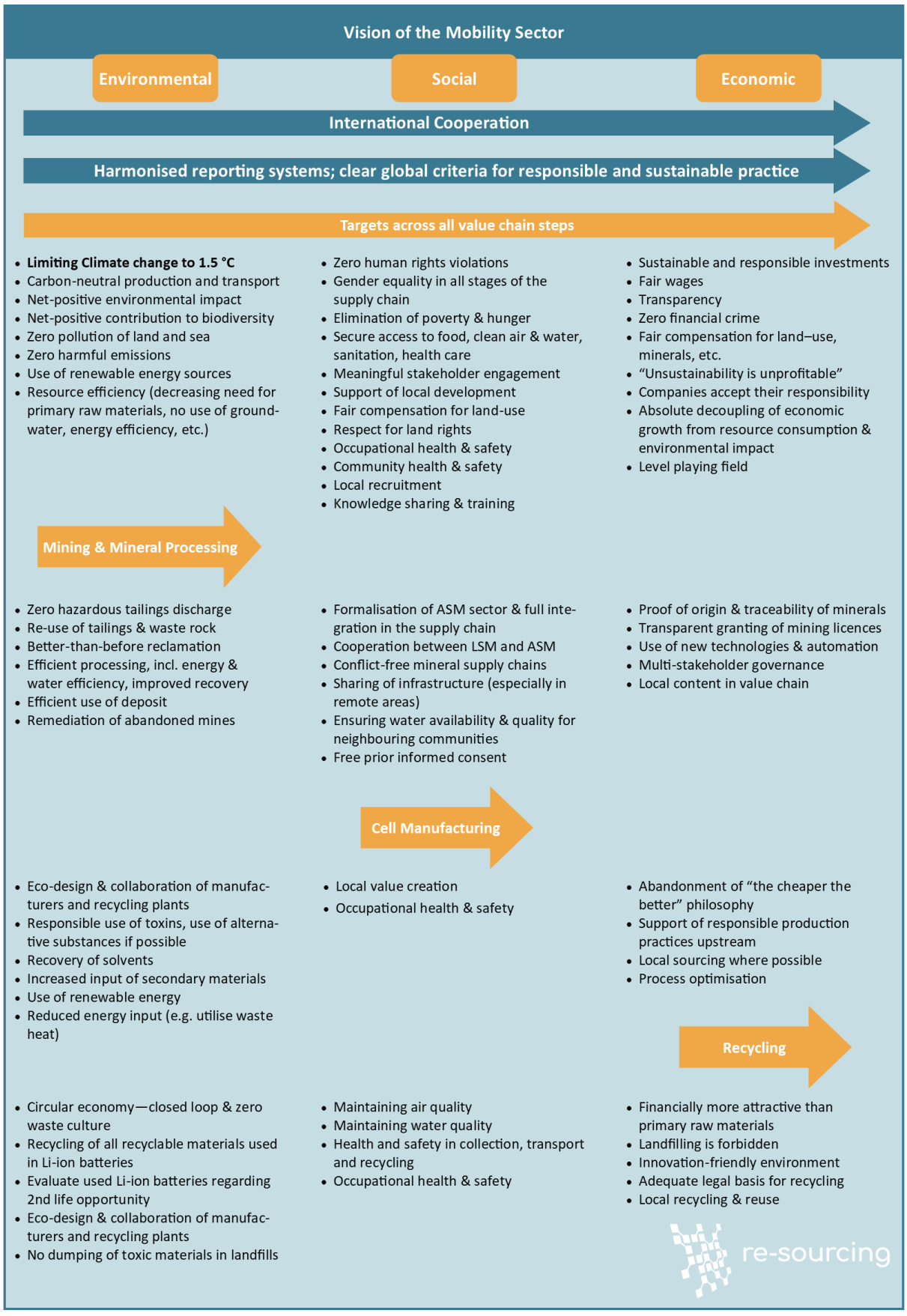

Figure 3: Vision for the mobility sector (Betz et al. 2021)

2 Pathway

The three overarching targets of the circular economy & decreased resource consumption, responsible procurement and level playing field are based on the concepts of the Paris Agreement, planetary boundaries and strong sustainability. Some approaches to reach these targets overlap each other as illustrated in Figure 4. There are therefore some cross-references between the target chapters.

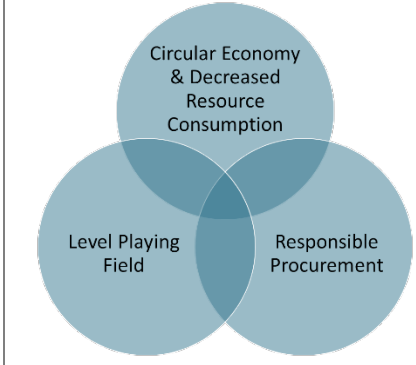

Figure 4: Three roadmap targets and overlaps

The following paragraphs explain the roadmap's scope, assumptions and limitations, and structure. In order to have a uniform project structure, these explanations are similar in the three sectors of the RE-SOURCING project.

Scope

The RE-SOURCING project provides a roadmap encompassing recommendations for actions for policy makers, industry and civil society. It does not propose new standards or guidelines for the mining step, nor does it attempt to 'reinvent the wheel'. For many areas, appropriate standards have already been developed and the first and most important step is to successfully implement these. Due to the existence of different standards and certification schemes, it is crucial to harmonise these standards. Alignment and mutual recognition are needed to avoid confusion for users and customers in the implementation. Implementation, alignment and mutual recognition of these standards is part of the roadmap's recommendations. It is important to have the foundation in place before thinking bigger. There is ample evidence of companies which, for example, do not respect basic human rights, or governments that fail to address the sustainability principles for protecting local communities.[5]

The State of Play report serves as a basis and baseline for the development of concrete recommendations for policy makers, industry and civil society for moving ahead from this baseline to the RE-SOURCING project's vision for 2050. The recommended actions for policy makers focus on the EU. The RE-SOURCING project recognises the important role of investors, insurance, logistics providers and other business service providers. However, they are out of scope for this roadmap as they are relevant for all three sectors (renewable energy, mobility, and electric and electronic equipment) included in the RE-SOURCING project.

As with the State of Play report, the roadmap focuses on the raw materials lithium, nickel, cobalt and graphite, the technology of the LIB and the supply chain stages mining, cell production and recycling. This scope was defined at the start of the project as part of the consultation. There are, of course, numerous other minerals and metals that are essential for the mobility sector, and many of the recommendations listed here can also be applied to other raw materials.

[5] For further information on sustainability challenges in the mobility sector supply chains, as well as existing standards and initiatives, please refer to the State of Play and Roadmap Concept report for the mobility sector.

Assumptions and limitations

The RE-SOURCING project roadmap for the mobility sector assumes technological advances but does not specifically address this issue, apart from the continuation of these advances and the necessary support from the public and private sectors. More information on the technological aspects can be found in various reports, such as Fraunhofer ISI (2015; 2022) and Battery 2030+ (2020).

The roadmap assumes the continuance of wider development and governance issues that address improved governance and business environments in a number of EU partner countries. This would include efforts to address poverty and to raise income levels, creating education and employment opportunities, and addressing gender and human rights at the country, non-sectoral level. This is addressed through support provided by EU Member States development institutions (such as GIZ, SEDA) as well as international organisations (World Bank, UNEP, etc.). This roadmap should therefore be considered as part of the larger development landscape where the wide-ranging challenges for governance and development are being tackled through multiple avenues.

The conclusions from the consultation process indicate the difficulty in setting specific targets for the use of secondary raw materials, the circular economy, etc., as the necessary research has not been fully carried out at this stage by either this project or other external stakeholders. Nevertheless, this report attempts ambitious but realistic assumptions indicating the pathway to achieve the three targets. This aspect will be highlighted in the relevant sections of the report.

Structure

The roadmap differentiates between targets and milestones. **Targets** define the desired end points and are kept at a high and aggregated level. They can be medium- (2030 and 2040) or long-term (2050). Targets were developed during a consultation process with the project's Platform Steering Committee and Advisory Board, as well as the Roadmap Workshop with participants from various stakeholder groups of the mobility supply chain. The targets consider all three pillars of sustainability: social, economic and environmental (Figure 5).

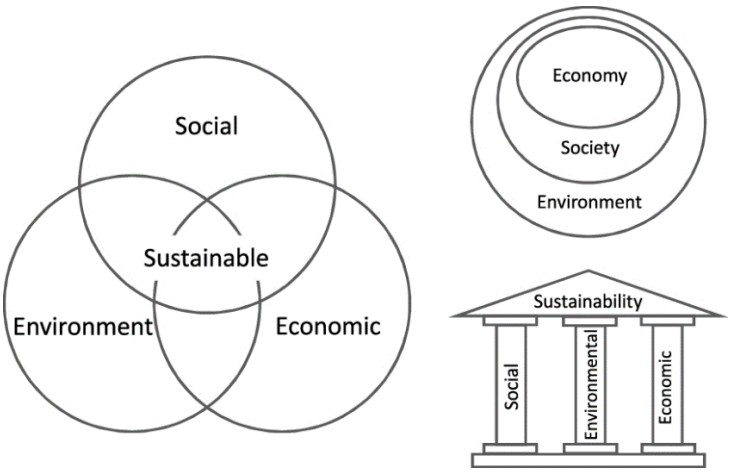

Figure 5: Depictions of the three sustainability pillars - social, environmental and economic (Purvis et al. 2019)[6]

[6] Please refer to the report The International Responsible Sourcing Agenda for more information on sustainability and responsible sourcing approaches.

Milestones are points along the desired trajectory from baseline to target and are intended to help track progress. They can be short- (2025), medium- (2030 and 2040) or long-term (2050). While 2025 milestones may appear as short-term considerations, they refer to the achievement of commitments already made or set the direction for future goals. Wherever possible, milestones are specified according to desired quantity, quality and/or time (Capacity4dev Team 7/8/2016). Milestones also include existing and agreed goals, such as the Sustainable Development Goals (SDGs) of the United Nations (UN) and the Paris Agreement.

However, the RE-SOURCING mobility sector roadmap only focuses on targets and milestones that are relevant for and an issue in the focus of the mobility sector. Targets and milestones that are not mentioned here are therefore not considered irrelevant but are beyond the scope of this roadmap. Nevertheless, there are milestones that can be transferred to other sectors, such as the global mandatory supply chain due diligence for all international actors by 2040.[7]

The classification of the milestones and recommendations into categories is based on the authors' preference and should not be regarded as absolute. The time frame for the achievement of milestones and targets shows the latest deadline. However, earlier completion is strongly encouraged.

The **term 'responsible sourcing'** is not considered as a simple supplier-manufacturer business transaction in the RE-SOURCING roadmap for the mobility sector. In this project, the term represents the idea that RS engages **all stages of the supply chain** and should be understood as a joint effort to make each stage sustainable. The recommended actions and milestones that follow therefore do not merely focus on procurement but on all stages of the supply chain, and touch upon sector-specific issues.

Recommendations were developed by the report team and discussed and further revised during the consultation process. The authors' aim is to set recommendations that are ambitious but also realistic, in order to achieve the milestones and targets. The recommendations were developed for policy makers, industry and civil society; however, this document focuses only on CSOs. The recommendations are also divided between the three steps of the mobility roadmap: mining, cell production and recycling. This differentiation represents the authors' view and is illustrated with the following icons in the text:

- Mining
- Cell production and OEMs (Original equipment manufacturer)
- Recycling

[7] See also the Roadmap for the renewable energy sector.

2.1 Target 1: Circular Economy & Decreased Resource Consumption

A Circular Economy is a framework based on three principles:

- Eliminate waste and pollution
- Keep products and materials in use
- Regenerate natural systems

It therefore goes beyond recovering resources from waste through recycling by including sufficiency[8], the intensified use of a product and the rehabilitation and secondary land-use of mine sites after production.

As described in the Roadmap for the renewable energy sector, continuing with business-as-usual consumption patterns while using renewable energy can be described as a 'low-carbon destruction of planetary resources' (Swilling 2020, p. 101). New systems for both consumption and production are required to satisfy human needs and universal wellbeing while staying within planetary boundaries (Brand-Correa and Steinberger 2017; Raworth 2017; Swilling 2020).

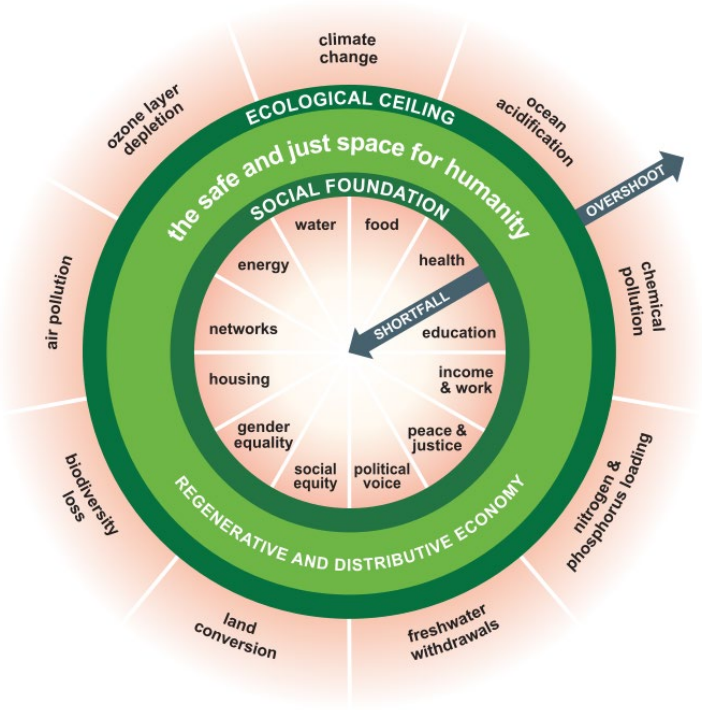

Figure 6: Doughnut Economics - combining social and planetary boundaries (DEAL 2021)

Absolute decoupling of economic growth, resource consumption and environmental impact is one of the proposed measures to tackle price shocks and resource scarcity and to halt environmental degradation (UNEP 2014). Decoupling relies on decreasing resource consumption by improving

[8] For more information about sufficiency, see Thomas Princen's book 'The Logic of Sufficiency' published in 2005, in which he argues that 'seeking enough when more is possible is both intuitive and rational - personally, organizationally and ecologically. And under global ecological constraint, it is ethical.' (Princen 2005)

resource efficiency through technological improvements, substitution of non-renewable by renewable resources, waste prevention through reuse and recycling, etc. The concept of decoupling also faces criticism as current research has not reached a consensus on whether absolute decoupling of economic growth, consumption and environmental impact is in fact possible (Parrique et al. 2019; Strand et al. 2021; Wiedmann et al. 2020). Similarly, 100% circularity of resources within an economy will not be possible, due to physical and economic constraints and in some cases will not be desirable due to the high negative environmental impacts of certain recycling processes driven to their limits (Moss 2019; UNEP 2013).

This roadmap follows a two-pronged approach for the mobility sector: (i) increasing resource efficiency, recycling and reuse rates is a prerequisite for achieving the transition away from fossil fuels and meeting the growing demand from a growing population and (ii) reengineering the current economic system with a focus on changing existing consumption patterns. These considerations are addressed by the Doughnut Economics Principles of Practice: 'Think in systems' – aim for continuous improvements; 'be regenerative' – the 6Rs of sustainability (reduce, reuse, recycle, repair, rethink and refuse); and 'aim to thrive rather than grow' (DEAL 2021).

Following this approach, the project came up with several milestones to be achieved over the coming decades. To achieve these milestones, a set of recommendations for actions are outlined. As mentioned earlier, the recommendations in this document are aimed at EU policy makers.

This report does not directly address research and academic institutions but does include some recommendations for these stakeholders to support a circular economy. They have a primary role in developing new technologies and advancing existing ones to reduce both the resources and the energy used in their production. It is also important for them to pay attention to the subsequent reuse and recovery of materials when designing products (design for recycling). When developing new technologies in the future, attention must be paid to the raw materials used from the very beginning. Interdisciplinary cooperation should be significantly improved and expanded for this purpose. Direct cooperation with industry needs to be intensified to effectively develop viable new products. Interdisciplinary cooperation should be strengthened not only in the technical field in relation to the use of raw materials, but also between engineering, social sciences, ecology, sustainability research, etc. Environmental and social impacts have to be considered, for example in the form of (social and environmental) life-cycle assessments, and in product development from the start of a project.

The following milestones and recommendations will form the basis for reaching the four main sub-targets:

- Create a circular economy
- Transform the transport sector to only BEVs on the road
- Reduce the number of cars on the road
- Make LIB production more energy and resource efficient

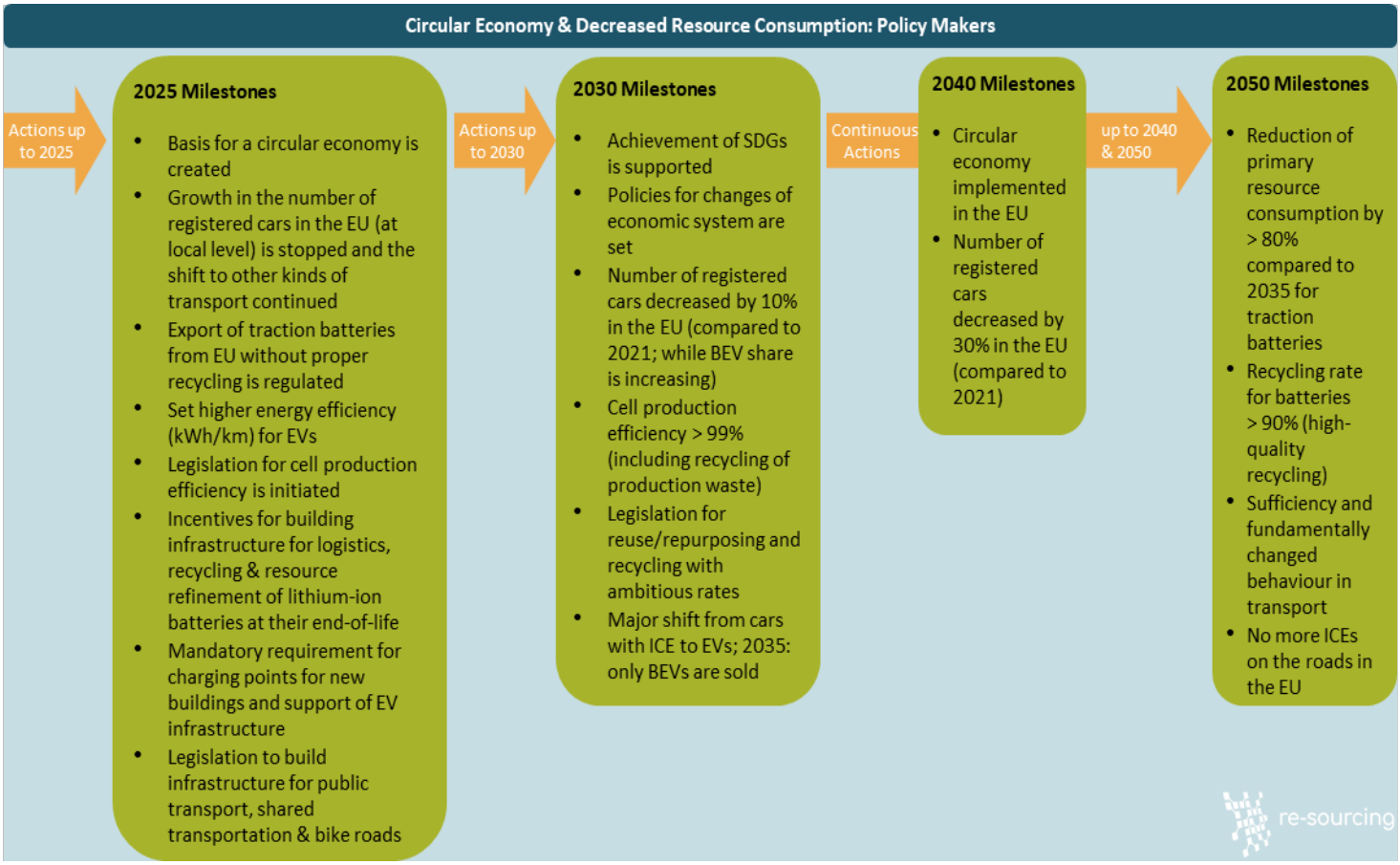

Figure 7: Milestones for policy makers towards a circular economy and decreased resource consumption by 2050

2.1.1 Milestones 2025

- **Basis for a circular economy is created**

Based on the principles mentioned previously, policy makers need to create a legislative basis to enable the development of a circular economy. This includes the development and implementation of policies for sustainable consumption, production, resource efficiency and waste for the mobility sector.

Policy makers also should recognise that the industry will struggle to achieve resource efficiency and energy reduction targets in the absence of significant changes in consumption. The mining and battery production companies must reduce their own carbon footprint while extracting minerals and producing metals and batteries to reduce the overall carbon footprints of the sector. Consumption and a shift in mobility patterns is an essential lever to address this challenge. This milestone can therefore only be reached if the other related milestones are also achieved.

One example of the necessary legislation is the introduction of eco-design policies for batteries, including minimum longevity standards (Electrive 2021a), something that is also partly included in the new proposal for an EU battery regulation (European Commission 2020). When setting circularity targets, policy makers should keep potential downcycling in mind. Currently, downcycling already enables circularity rates of 90% for cars (Kohlmeier 2012). However, it is important to consider the

raw materials from battery cells as a strategic source of materials for the sector and keeping this within the sector should be fostered (by providing the necessary regulatory framework, supporting R&D and developing recycling facilities, etc.). When designing new legislation and measures, several aspects have to be considered, some of which can be found in the Case Studies & Guidance Document about the new proposal for an EU battery regulation.

Since recycling alone will be unable to provide sufficient amounts of raw materials for the mobility sector, it is important to avoid resource consumption wherever possible, as well as to address the high levels of current and future waste. Investment in cutting edge research is required for the EU to become a global leader and innovator in recycling. Furthermore, the recycling industry needs to be considered as an important source of employment, especially considering a likely loss of jobs in the fossil fuel sector.

Recommendations:

- Define and implement policies for sustainable consumption, production, resource efficiency & waste
- Create an overarching binding legislative framework by implementing a law at the highest level (EU regulation, not directive)
- Combine different interests and create political support by using sustainability as a competitive advantage
- Ensure high-quality legislation through proper funding of essential legislative processes

- **Growth in the number of registered cars in the EU (at a local level) is stopped and the shift to other kinds of transport continued**

Without a decrease in resource use in car manufacturing, it will be difficult to achieve the overarching principles of the circular economy. It is therefore important that measures are taken to make other, less resource- and energy-consuming modes of transport more available and attractive. One of the measures is the simplified use of and concessions for multimodal transport. When using shared mobility, it is often necessary to switch to other modes of transport for parts of the journey. Examples are the use of bicycle, e-scooter or ride-sharing services. Making it easier and cheaper to take bicycles on buses and trains can help to make this mode of transport more attractive. At the same time, motorised individual transport, especially with fossil-fuelled cars, must be made less attractive. One step in this direction is the provision of fewer and more expensive parking spaces in cities where other means of transport are available. For people with limited physical mobility, either exceptions must be made or these people must be financially compensated for the increased costs. The topic of necessary infrastructure for other means of transport is addressed in another milestone below.

In many countries in the EU company cars are also supported by tax credits. It is relatively easy to give this subsidy an ecological direction. For example, tax credits should only be applicable to fully electric EVs and incorporate a threshold of energy consumption per kilometre to further decrease energy use. An exception should be made for families, as with more people to transport, additional engine power is necessary. These exceptions should not encourage the use of heavier vehicles like SUVs when unnecessary. The use of smaller batteries should be incentivised as well. Other financial incentives for changing behaviour are necessary to support this shift. (Blanck et al. 2020)

Recommendations:

- Facilitate & cut the cost of using multimodal transportation
- Fewer and more expensive parking slots in cities
- Company cars: only fully electric EVs; with a threshold of energy consumption per kilometre (exception for families)
- Incentivise buying smaller cars with smaller traction batteries
- Financial incentives for changing behaviour

- **Export of traction batteries from EU without proper recycling is regulated**

The technologies for recycling LIBs are now largely available. The challenge lies with the economic viability of the recycling processes (e.g., high costs work against low resource prices). This viability is a prerequisite for the achievement of recycling and circularity goals.

There is a transition in cell chemistries away from expensive resources like cobalt- and nickel-containing lithium nickel manganese cobalt oxide (NMC) towards cheaper materials like lithium iron phosphate (LFP). Unlike Renault, who decided against it because of the expensive recycling, several car companies will use LFP batteries in the lower electric vehicle classes (Electrive 2021b). There is as yet no recycling concept specified for LFP, as the focus of material recovery has been on cobalt, nickel and copper. Lithium is not yet recycled in the EU.

So far, the majority of OEMs in the EU believe that most cars will continue to be exported and/or there will be competition for the battery at the end of its first life. While the latter is debateable, exports without minimum standards for the state-of-health and quality of the batteries and an obligation to recycle them must be prevented. In LFP batteries, there is minimal recoverable material using traditional recycling technology that would enable coverage of the recycling cost. The recovered copper does not achieve this on its own, and lithium recovery is minimal so far. However, this could change if lithium were extracted at high yields, given that the higher commodity prices recorded in early 2022 continue. Nevertheless, regulations should be put in place to ensure that these batteries are recycled in compliance with the EU battery regulation and that there are no loopholes such as export (EU legislation obliges recycling but allows the export of ‘still functioning’ products, without specifying exactly what this means). This also includes appropriate EHS (Environment, Health and Safety) regulations for the recycling process.

There is currently a trend to ‘donate’ used batteries to other countries outside the EU. Many manufacturers argue that used batteries can still be used – for example in solar projects in Africa. More and more projects and press releases are praising this so-called repurposing approach as a solution (e.g., African GreenTec 2021). Repurposing of used LIB can certainly yield many environmental benefits. But it is difficult to establish reasons for shipping old batteries to low- and middle-income countries while using new batteries to cover the need for electricity storage in the EU. In many countries around the world, recycling structures for LIBs are still lacking. Exporting the batteries back to Europe for recycling, as often announced, is also currently nearly impossible, as shipping companies are very reluctant to take on board LIBs at their end-of-life due to the risk of fire and the resulting insurance costs. This differs for batteries which can still be used. In addition, the

permit for transporting these batteries across several countries is very expensive and difficult and time-consuming to obtain.

Recommendations:

- Restrict export of used batteries and cars from the EU (mandatory recycling, etc.)

- **Set higher energy efficiency (kWh/km) for EVs**

The energy efficiency of an electric vehicle is defined by the energy it requires to travel a certain distance (kWh/km). At the moment, energy is readily available due to the burning of fossil fuels. Removing or limiting fossil fuel use will lead to energy being even more costly, as many processes rely on additional electrical energy being available for the production of alternatives like e-fuels for planes and hydrogen for industrial processes. Saving energy therefore becomes even more important.

In addition, the higher energy needs in a EV require not only longer charging times but also larger batteries to achieve a similar driving range. As batteries are very resource intensive, increasing energy efficiency also gives the possibility of reducing resource consumption by reducing the required battery sizes.

To increase the energy efficiency of EVs, policy makers can introduce energy efficiency thresholds, similar to fleet emission limits.

Recommendations:

- Use incentives and restrictions to help impose higher energy efficiency on EVs

- **Legislation for cell production efficiency is initiated**

Lithium-ion battery cell production is very resource and energy intensive. To decrease the impact of battery cells, legislation has to support production efficiency. This can be done by subsidising efficiency measures which do not pay off themselves, by reducing costs and introducing thresholds on energy and resource consumption for batteries distributed on the EU market.

Recommendations:

- Put legislation into place to support battery cell manufacturers to increase their production efficiency.

- **Incentives for building infrastructure for logistics, recycling & resource refinement of lithium-ion batteries at their end-of-life**

Using batteries as long as possible (intensified use) requires collection after their first life. The life cycle management approach has to be considered in order to extend the life of a LIB for as long as possible. After their first life, LIBs have to be checked, possibly disassembled and prepared for another

application, if suitable. This also needs a dismantling network for traction batteries (Circular Economy Initiative Deutschland 2020). For batteries without the possibility of reuse/repurposing, a recycling infrastructure has to be created, which is able to cope with the rising amounts of batteries and applies the best available recycling technology with high recovery rates. As the transport and storage of batteries at their end-of-life creates major challenges due to their high safety risk, this has to be included in the infrastructure.

In Switzerland, companies bringing batteries to market have to pay a fee to an installed system that takes care of recycling the batteries or they have to organise the battery recycling themselves. For the latter, companies in Switzerland have to prove that they achieve an equal or even better recycling performance. Frontrunners like KYBURZ use this incentive to fund their own LIB recycling operation (for more information on approach of KYBURZ please see Guidance Document; Degreif et al. 2022).

Recommendations:

- Incentivise building infrastructure for EV, logistics, recycling & resource refinement

- **Mandatory requirement for charging points for new buildings and support of EV infrastructure**

Transforming the mobility sector from fossil fuel driven cars to BEVs and other forms of electric transportation requires an improvement in the availability of the infrastructure that supports them, first of all parking spaces with charging points. Although the number of EVs is still comparably low, it is crucial to enable this network for the future by including charging points in new buildings, as buildings have a long lifetime. If the parking spaces for cars do not include the possibility to lay cables for a charging station, this is very difficult to modify in the future. To further modify buildings that already exist, renovations could also be used to install charging points.

While keeping most cars out of residential areas to support other uses of transport is desirable, there still have to be parking spaces. To come to a complete transition to EVs, these parking spaces should have the availability for charging. There are several examples of laws addressing this topic[9], however not all of them go far enough.

Recommendations:

- Introduce a mandatory requirement of charging points for new buildings

[9] https://www.bundesregierung.de/breg-de/themen/meseberg/ausbau-ladeinfrastruktur-1722304 (last checked 20/06/2022), https://www.electrive.com/2021/11/22/uk-requires-all-new-buildings-to-offer-charge-points-by-2022/ (last checked 20/06/2022), https://indianexpress.com/article/cities/mumbai/ev-charging-points-set-to-be-mandatory-in-new-buildings-of-mumbai-7901893/ (last checked 20/06/2022), https://www.brusselstimes.com/159400/charging-points-for-evs-become-mandatory-for-new-buildings-and-major-renovations-electric-vehicle-energy-performance-building-directive-epbd-green-deal (last checked 20/06/2022), https://www.fleeteurope.com/en/new-energies/europe/features/new-buildings-europe-required-have-ev-charging-points?a=BUY03&t%5B0%5D=Charging&t%5B1%5D=Electrification&curl=1 (last checked 20/06/2022)

- **Legislation to build infrastructure for public transport, shared transportation & bike roads**


A shift in mobility patterns away from motorised private transport should be enabled to reach the overall goals of a circular economy. This should be supported by increasing the availability and attractiveness of the other means of transport.

Possible substitutes for motorised private transport are public transport, car or ride sharing and, for shorter distances, (e-)bikes and walking. Public transport networks and efficiency in particular need to be expanded by policy makers to enable the transportation of an increasing number of passengers. Here, public transportation should also use alternative technologies like LIB. To increase the use of bikes also requires certain infrastructure to be provided. This includes a bike road network in cities as well as connecting different locations over longer distances. Good examples are bike highways in the Netherlands and Germany, which are long cycle paths without crossings on which cyclists can travel long distances.

Recommendations:

- Introduce legislation or policies to build infrastructure for public transport, shared transportation & bike roads

2.1.2 Milestones 2030

- **Achievement of SDGs is supported**


The SDGs are global goals to be achieved by 2030. These are very overarching goals, some of which go beyond the reach of EU policy makers and beyond the scope of this roadmap. The SDGs to be achieved in order to reach a circular economy in the mobility sector are the following:

SDG 3: Good health and well-being

- Substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

SDG 6: Clean water and sanitation

- Improve water quality by reducing pollution, eliminating dumping and minimising release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
- Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
- Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies

SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all

- Increase substantially the share of renewable energy in the global energy mix. Double the global rate of improvement in energy efficiency

- Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

- Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors
- Support of local development
- Ensure a fair compensation for land-use, respect for land rights, formalisation of ASM sector and full integration in the supply chain as well as local value creation
- Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalisation and growth of micro-, small- and medium-sized enterprises, including through access to financial services. Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead

SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation

- Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
- Upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities
- Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending

SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable

- Provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
- Reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
- Provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
- Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

SDG 12: Ensure sustainable consumption and production patterns

- Substantially reduce waste generation through prevention, reduction, recycling and reuse. Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle
- Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
- Achieve the sustainable management and efficient use of natural resources
- Achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimise their adverse impacts on human health and the environment
- Ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature
- Support developing countries to strengthen their scientific and technological capacity to move towards sustainable patterns of consumption and production
- Rationalise inefficient fossil fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimising the possible adverse impacts on their development in a manner that protects the poor and the affected communities

SDG 13: Take urgent action to combat climate change and its impacts

- Integrate climate change measures into national policies, strategies and planning

SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

- Prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
- Minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

- Ensure zero pollution of land and a net-positive contribution to biodiversity

One crucial step for reaching the SDGs is the support for other countries in creating a circular economy. They need to have the possibility of building capacities for recycling their battery waste stream and push for a reduced resource consumption. The technological advantages should be shared and knowledge of how to regulate a sector must be provided. Otherwise, countries with low and medium incomes will face challenges in achieving a circular economy in time for the global targets.

Recommendations:

- Support other countries in creating a circular economy

- **Policies for changes of economic system are set**

 Our economic system is based on growth. Many people have to work more than 40 hours a week to be able to keep up with the ever-rising prices. To put it in simple words, the state's debts and budget rely on the growth of the economy. As discussed at the beginning of Chapter 2.1, the decoupling of economic growth and resource consumption is strongly debated. Instead of economic growth, policies should focus on wellbeing as an important indicator. As a result, decreasing resource consumption requires a change in the economic system itself. Examples could be a tax on resources (Buchert et al. 2017) or a focus on lowering the working hours per week (Rosswog 2018). However, a decision on which measures should be taken goes beyond the scope of this report. It is important that a future economy ensures higher wellbeing, while curbing the system of unlimited consumption.

As described by Kügerl et al. (2021), for developed countries such as EU Member States, it is crucial to start rethinking mainstream economics now, in order to increase resource efficiency and decrease consumption.[10] The five countries Finland, Iceland, New Zealand, Wales and Scotland are already in the process of implementing a wellbeing economy.[11] Even though their economic plan still includes the aim for GDP growth, they have also introduced wellbeing indicators to guide cross-policy decisions. In Iceland, societal indicators include, for example, mental health or work-life balance; environmental indicators include air quality and climate, as well as recycling (Prime Minister's Office Iceland 2019). This is an important step towards an economy that has the wellbeing of the people at heart and is addressing the need for environmental protection while at the same time staying within planetary boundaries.

Recommendations:

- Introduce measures to curb unlimited consumption, for example a tax on resources
- Focus more on wellbeing than on GDP

- **Number of registered cars decreased by 10% in the EU (compared to 2021; while BEV share is increasing)**

 In 2019 the German Environment Agency published a vision of the city of tomorrow, which proposed a car density of 150 per 1000 inhabitants (including taxis and ride sharing vehicles). This is about a third of the number in 2017.

[10] We recognise the need for developing countries to continue their growth to bring people out of poverty and increase wellbeing in line with SDG8. In countries with a low GDP (below approximately 20,000 $) in particular, happiness or subjective wellbeing still increase significantly with only small increases in the GDP (Jackson 2017).
[11] For more information on the Wellbeing Economy Governments, see Wellbeing Economy Alliance (2021).

The focus of the study was on cities with over 50,000 inhabitants. (Umweltbundesamt 2017) This was to be achieved through a shift to other means of transport and car sharing. The vision proposed the following measures:

- Fundamental revision of the laws on passenger transport including sub-legislative regulations to simplify the introduction of innovative mobility services.
- Giving preference to car sharing over private motorised transport (e.g., revision of legal provisions in public service law, tax law, insurance law, etc.).
- Initiation of an integrated funding programme for electromobility for investment in the electrification of public transport and car-sharing fleets, municipal vehicles and trucks, mobile machinery and equipment.
- Integration of a smart charging infrastructure and charging areas for e-cars, e-trucks, e-two-wheelers and pedelecs in the planning and renovation of residential and commercial buildings by supplementing building regulations.
- Priority promotion of grid-based drives for trams and trolleybuses or buses with fast-charging systems.

While this is a worthy vision for a city, it seems impossible to achieve for villages and smaller towns without the infrastructure to support other means of transportation. Without a high density of inhabitants, more individual means of (motorised) transportation are necessary. The total number of cars will therefore have to be higher and, as a first step, only a 10% reduction is suggested as a milestone. The 10% reduction refers to new car registrations in 2030 compared to 2021 on average across the EU. This means that countries with a better developed infrastructure and a higher level of existing mobility will have to limit their new registrations even more to compensate for new registrations in other countries. The figure of 10% is based on several studies conducted for a German context (Dittrich et al. 2020, WWF 2014).

As described in the Roadmap for the renewable energy sector, sharing economy (SE) business models often struggle with the lack of policy, regulations, insurance and licensing (Hossain 2020). Policy makers can support an SE by implementing relevant policy changes and offering local government support (Mi and Coffman 2019). In addition, appropriate EHS (Environment, Health and Safety) regulations and taxation schemes are required to ensure that existing traditional businesses adhering to high European standards for labour, safety, etc. are not penalised (e.g., Uber vs Taxi) (Hossain 2020).

BEVs cause fewer emissions than ICEs (see Chapter 1.1). The share of BEVs in the number of vehicles still on the road therefore needs to increase. This is supported by the EC's proposal to allow only zero-emission cars from 2035 (European Commission 2022a), which was accepted by the Council of the EU (Electrive 2022) and still remains to be negotiated within the EU Parliament.

Recommendations:

- Fundamental revision of the laws on passenger transport including sub-legislative regulations to simplify the introduction of innovative mobility services
- Innovative, simple and overall lower pricing for public transport to make it more attractive
- Giving preference to car sharing over private motorised transport (e.g., revision of legal provisions in public service law, tax law, insurance law, etc.)
- Initiation of an integrated funding programme for electromobility for investments in the electrification of public transport and car-sharing fleets, municipal vehicles and trucks, mobile machinery and equipment
- Integration of smart charging infrastructure and charging areas for e-cars, e-trucks, e-two-wheelers and pedelecs in the planning and renovation of residential and commercial buildings by supplementing building regulations
- Priority promotion of grid-based drives for trams and trolleybuses or buses with fast-charging systems.

- **Cell production efficiency > 99% (including recycling of production waste)**

 A cell production efficiency of over 99% means that almost no waste is generated during production and the remaining is reused or recycled into the production process. This helps to reduce resource demand. It is crucial to reduce waste and recycle all the remaining waste with as high an efficiency as possible. It also includes designing a circular production model, saving energy, and choosing technologies and cell chemistries, where this is possible.

In addition, the introduction of mandatory, maximum life-cycle carbon footprint thresholds for batteries based on a standardised calculation method also benefits this milestone.

Recommendations:

- Promotion of resource-efficient technologies

- **Legislation for reuse/repurposing and recycling with ambitious rates**

 To increase the ratio of reuse and repurposing of batteries after their first life requires the introduction of legislation. This should enable a high-quality reuse or recycling of traction batteries. It includes incentives for product and system design for circularity, the embedding of traction batteries in resource-producing ecosystems during use, assurance of a high collection rate at the EoL, and the description of meaningful definitions and binding high recovery rates. The last-named in particular play an important role in achieving closed loops.

As described in CEID (2020), the legislator should clearly define the rights and obligations of the relevant actors within a circular battery value chain, taking into account cost-benefit effects and fair distribution of these, among other considerations:

- Definition of reporting obligations: the information to be reported must be defined, taking into consideration costs/benefits. At the very least, however, this should include the origin, environmental and human rights effects of the battery materials and substances used, safety-related data, and the whereabouts of the batteries at the end of their life.
- Specification of the minimum standards in the circular battery design of the manufacturers, including under the Ecodesign Directive.
- Clarification of liability and warranty rules as well as return and take-back obligations between manufacturers and potential second life users. In particular, there should be the possibility of passing on the vehicle manufacturer's EPR (extended producer responsibility) obligation to other users (especially for second life) after the batteries are certified as suitable for this purpose at the end of their first life.
- Introduction of a second life duty of proof for the use of a battery in further or converted use (refurbishment / second life) to ensure the transfer of EPR obligations and the subsequent liability of second life users in order to prevent leakage.

Strengthening and significantly expanding research and development in the field of the circular economy, in particular for traction batteries, will ensure rapid implementation and successful closed-loop recycling. This includes in particular:

- Anchoring in research framework plans and development of circular economy-related funding announcements, as well as provision of the necessary funds for supporting collaborative projects;
- Establishment of professorships/chairs for the circular economy;
- Expansion of the research infrastructure at universities and non-university research institutions;
- Provision of funds for the transfer of research results into innovative implementations;
- Establishment of a technical advisory board with members of all affected stakeholders to develop and advise on support concepts and measures.

Examples for policies to increase recycling rates and create a market for reuse and secondary raw materials include a tradable recycling credit scheme (Söderholm and Ekvall 2020), i.e., requirement for a specified share of certain secondary raw materials in production, increasing the level over time, or the introduction of circular economy and product reuse targets, including measuring and monitoring mechanisms (Milios 2021).

Recommendations:

- Introduce legislation for mandatory reuse/repurposing and recycling with ambitious rates
- Minimum recycled content in the production of LIBs
- Implement minimum design-for-recycling standards
- Strengthen and significantly expand research and development in the field of the circular economy of batteries

- **Major shift from cars with ICE to EVs; 2035: only EVs are sold**

The OEMs need clear boundaries and investment security for the switch to electromobility. A ban on the distribution of cars with ICE creates this market. The time frame gives the countries time to adjust and build up the necessary infrastructure. This milestone is already well on the way to implementation since, as already mentioned, the EC and the European Parliament have decided to ban the sale of cars with carbon emissions during use from 2035 onwards (Electrive 2022). Before this ban, other measures like a bonus-malus system for EVs / cars with ICE and other advantages for EVs can support the shift.

Recommendations:

- Support and incentivise the major shift from cars with ICE to EVs
- From 2035 on, only allow the distribution of BEVs in the passenger car sector

2.1.3 Milestones 2040

- **Circular economy implemented in the EU**

By 2040, the legislation discussed before should be in place and a circular economy should be reached in the EU.

Recommendations:

- Ensure the recommendations mentioned previously
- Redesign the battery regulation to fit the current technological developments

- **Number of registered cars decreased by 30% in the EU (compared to 2021)**

Similar to the milestone of 10% reduction of cars by 2030, the decrease of 30% of registered cars refers to new car registrations in 2030 compared to 2021 on average across the EU. This means that countries with a better developed infrastructure and a higher level of existing mobility will have to limit their new registrations even more to compensate for new registrations in other countries, where a further market growth is expected. The figure of 30% is based on several studies conducted for a German context. (Dittrich et al. 2020, WWF 2014) Even if driven by renewable energies, the need for the reduction is determined by the limits in energy supply, the environmental strain of resource consumption and planetary boundaries. In addition, fewer cars could also increase the quality of life in cities.

Another factor in favour of fewer new cars brought to market is an intensified first use of EVs, including a longer lifetime of the vehicles. This should be incentivised by minimum performance standards for batteries or milage for EVs, for example 250,000 km without the battery reaching a state of health below 80%.

The measures are the same as before, e.g., introduction of innovative mobility services, increasingly attractive public transport, giving preference to bikes and car sharing over private motorised transport, and also include sufficiency and a major change in transport behaviour. If encouragement does not succeed, mandatory reductions could be used.

Recommendations:

- Implement and further develop the previous recommendations to shift to other means of transport
- If encouragement does not succeed in reducing the number of cars, mandatory reductions could be used

2.1.4 Milestones 2050

- **Reduction of primary resource consumption by > 80% compared to 2035 for traction batteries**

 A reduction of primary resource demand is crucial. In 2035, all passenger cars coming to market should be EVs. This means large amounts of primary resources are needed, as there is a growing market and only a small fraction of EVs will have reached their EoL to be available for recycling, especially if including intensified use. This could mean that the demand for primary raw materials for LIBs rises up to 2035.

To achieve a reduction of 80% in primary resource consumption for the market of traction batteries for passenger cars compared to 2035, several measures have to be combined:

- Less vehicles come to market (decreasing market by about 50% compared to 2021)[12]
- Batteries can be produced by resources coming from a greater number of recycled vehicles (assuming 60% of EVs brought to market in 2035 are available for collection).
- The resource demand per battery and kWh of battery capacity has to be decreased by downsizing the battery (20% possible through less energy consumption per distance), while at the same time increasing the specific energy (energy per weight) by 20% compared to 2035 (Ma et al. 2021, Betz et al. 2019)
- The technology and battery chemistry need to be chosen wisely to be able to use secondary resources
- Collection and recycling need to be established with high recovery rates (> 90% collection and > 90% recovery rate)
- New recycling and refinement technologies enable high recycled contents of plastics and other organic materials as part of the battery

Also, the primary resource demand is reduced by secondary material (post-consumer recyclate). Calculating the primary resource demand compared to 2035 using the figures assumed above, a reduction of over 80% in primary resource consumption seems possible, when further assuming a nearly closed circle (no downcycling). (Dittrich et al. 2020, WWF 2014) This includes the assumption that the recycled content in 2035 exceeds 20%.

To enforce this, apart from legislation to incentivise the reduction of cars, a high mandatory recycled content for the different materials should be introduced.

Recommendations:

- Reduce the number of cars and increase recycling efficiencies
- Set a high mandatory recycled content for key components of the battery

[12] In 2035, a reduction of 20% compared to 2021 is assumed, as 10% and 30% of the reduction are the milestones of 2030 and 2040, respectively. This leads to an overall reduction in 2050 of about 38% compared to 2035.

- **Recycling rate for batteries > 90% (high-quality recycling)**

 High-quality recycling of batteries is only possible if other measures support this. The technology needs to be developed further and battery chemistries need to be chosen accordingly. The materials need to be recovered as well as possible for use in new batteries. The recycling rate should be calculated from the ratio of the battery grade material resulting from the recycling process divided by the input weight of the battery. This is very ambitious and technologically impossible at present. The authors expect technological improvement that the milestone can be reached.

In addition, battery collection also has to be perfected in order to close the loop.

Recommendations:

- Set the mandatory recycling rate for batteries to 90%

- **Sufficiency and fundamentally changed behaviour in transport**

 A change in transport behaviour away from individual motorised mobility has to be achieved to enable the other goals. To reach this aim, many different measures have to be taken and all actors have to work together. The infrastructure for shared mobility and other more environmentally compatible means of transport has to be available and regulation favouring this established through financial incentives and regulative law. In addition, it is important to promote the general advantages (health benefits, more space in cities, less pollution). Consideration should also be given to providing essentials such as grocery stores and medical care in the immediate area to reduce the need for long trips.

Recommendations:

- Legislation has to be introduced promoting and incentivising resource efficient mobility behaviour and technologies
- Other recommendations and milestones that improve transport behaviour (such as innovative, simple and overall lower pricing for public transport) feed into this milestone and have to be fulfilled first

- **No more ICEs on the roads in the EU**

 The ban on the sale of ICEs in 2035 should achieve this milestone (see milestone 'major shift from cars with ICE to EVs; 2035: only EVs are sold'). There will still be ICEs on the roads in 2035, but these will become increasingly rare due to age and wear. With fewer cars on the roads requiring fuels (at high prices), the network of petrol stations selling fuels and car workshops specialising in ICEs will also gradually decline, leading to further disadvantages in the use of ICEs.

Recommendations:

- By 2035, no exceptions should be made for the ban on passenger car vehicles equipped with an internal combustion engine

2.2 Target 2: Responsible Procurement

As described in the roadmap for the renewable energy sector, responsible or sustainable procurement is defined as 'the process of making purchasing decisions that meet an organisation's needs for goods and services in a way that benefits not only the organisation but society as a whole, while minimising its impact on the environment' (ISO 2017, p. 2). The authors understand this citation to mean that organisations need to consider not only their own impact – positive and negative – from production or procurement but also the **associated impacts along the whole supply chain.** Value should be created wherever possible along the chain, especially at the mining site. It is important to note that there are differences between adverse impacts caused by, contributed to by, or directly related to the company's activities, products or services through a business relationship.[13]

However, it should be mentioned that the authors do not recommend ending business relationships with suppliers or countries that do not adhere to the required social and environmental standards to achieve responsible sourcing. The vision is rather to engage with and support them in improving their performance. Wilful use of forced and child labour, environmental pollution and other irresponsible practices at any stage of their supply chain should not be accepted from companies that want to have business relations and do business in or with the EU.

The recommendation to introduce a global mandatory supply chain due diligence for all international actors by 2040 is not intended to undermine current efforts by countries to introduce such a law. The time frame proposed in this roadmap, as mentioned in the introduction of Chapter 2, is only the latest date by which these measures should be implemented. It is also intended to encourage countries that are not yet planning to implement such measures to do so and to provide recommendations on what to include.

Policy makers need to develop and implement legislation to lay the basis for achieving responsible procurement in the EU. However, supply chains need to be seen in a global context. Policy makers should therefore enable companies to meet the legal requirements (e.g., an obligation to use sustainably sourced material requires a sufficient supply of such material on the market). The six main sub-targets for policy makers to achieve responsible procurement are:

- Define a 'sustainable product'
- Support positive impact on the ground (social license to operate (SLO), local development, sector alliance)
- Widen the view and efforts to all three pillars of sustainability
- Implement responsible public procurement
- Ensure transparency along the EU supply chain (aiming at improving it globally) and implement strong mandatory standards
- Keep Supply Chain Due Diligence at highest priority

[13] For further information, see the OECD Due Diligence Guidance for Responsible Business Conduct (OECD 2018, page 70). Additional information is given in the OECD guidelines for Multinational Enterprises (OECD 2011) and OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (OECD 2016).

In the following figure the milestones for policy makers for reaching responsible procurement are visualised. The grey coloured milestones aim at policy makers outside the EU. But EU policy makers can also support these milestones by initiating discussions and cooperation on these issues.

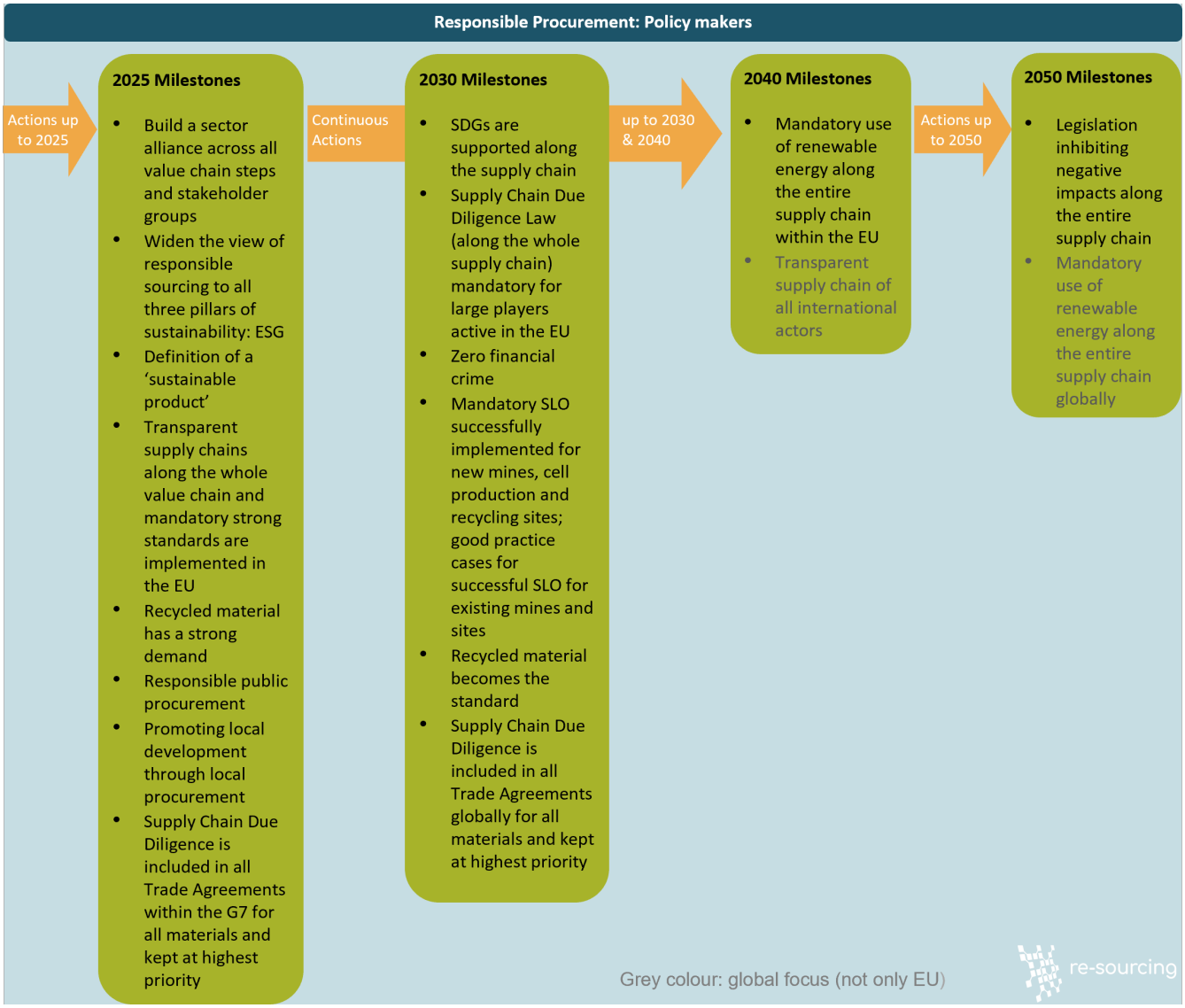

Figure 8: Milestones for policy makers towards a responsible procurement by 2050

2.2.1 Milestones 2025

- **Build a sector alliance across all value chain steps and stakeholder groups**

 To bring together the relevant actors in the supply chain of the mobility sector – in particuar for LIBs – a place for exchange and discussion needs to be formed. This requires the EC to establish a sector alliance where all stakeholder groups along the supply chain from industry to policy and CSOs should be involved. For example, this means that not only industry representatives from cell or battery production or OEMs are involved but the mining and processing companies in the mining countries also need to be brought on board. From the policy side, different Directorates-General (DGs) should be engaged, such as the DG Trade, DG Grow and DG International Partnerships as well as policy representatives from abroad. The location of the physical meetings in this sector alliance should alternate between the different locations (mine site, processing, production). As part of the alliance, local sustainability networks should be formed, including also players from other countries like China. An alliance like this allows a positive impact to be achieved on the ground, e.g., mining companies in one area work together and use their power for change on the ground.

The engagement should not only be targeted at the three actor groups that are the focus of this document (policy industry, CSOs). The view should be widened to finance, distribution, trade and logistics companies. However, CSOs need to be more (financially) supported. This should be done by politics and not by the industry, to enable the most objective criticism possible. (see also target 3 milestone ‘Voice of civil society in producing countries in the permitting process as a mandatory step’)

Recommendations:

- Build a sector alliance for LIBs
- Financial support of CSOs by politics

- **Widen the view of responsible sourcing to all three pillars of sustainability: Environment, Social, Governance (ESG)**

As described in Figure 5, sustainability consists of the three pillars social, environmental and economic sustainability. Often, the focus is confined to one pillar of sustainability, e.g., Due Diligence's focus on the social aspect. However, to reach responsible procurement, it is important to consider and balance all three pillars. In addition, a multi-pronged approach to the LIB mineral value chain should be designed, so that all nodes of the chain are addressed at the same time rather than in a linear progression.[14] When developing and reviewing policy instruments, all three pillars should be kept in mind.

Recommendations:

- Consider all three pillars of sustainability

- **Definition of a 'sustainable product'**

Strong and effective regulations need clear definitions. Regulations concerning the purchase of sustainable products need to define what is meant by 'sustainable products'. The definition should be clear enough to avoid loopholes that could favour products that do not contribute to sustainability. All stakeholder groups should be engaged in the definition to ensure a consensus in the definition of a sustainable LIB.

Recommendations:

- Clear definition of a 'sustainable product' avoiding loopholes

- **Transparent supply chains along the whole value chain and mandatory strong standards are implemented in the EU**

Transparency is an important milestone and gives indications of sustainability and traceability. To reach transparent supply chains along the whole value chain, the discussion on transparency needs to be intensified in the producing and recycling companies and countries, as well as at the smelters. Policy makers support this by making transparency of the supply chains mandatory in the EU. The EC's proposal for a supply chain law (European Commission 2022b) and the German supply chain law[15] are a good first step. However, to reach fully transparent supply chains, more far-reaching regulations are necessary, which also include the start of the supply chain (see also OECD 2016). The chain of custody, origin of raw materials and the production conditions (as well as support

[14] Further information on this good practice is provided in the good practice guidance document on mobility (Degreif et al. 2022)
[15] For further information see 'Gesetz über die unternehmerischen Sorgfaltspflichten in Lieferketten vom 16. Juli 2021'

processes) of all materials need to be known. Initiatives are already in place, e.g., the Battery Passport of the Global Battery Alliance (GBA 2022), but these need to be taken further.

Another important aspect besides supply chain transparency is the risk assessment of suppliers and supply chains. A mandatory risk assessment prevents or excludes negative (social and environmental) practices. At the same time, it promotes the improvement and development of the suppliers.

In addition to a transparent supply chain, there is a need for strong standards in mining, manufacturing and recycling. Especially in the mining sector, strong standards do exist, but they are not mandatory.[16] The EU needs to implement mandatory standards. Once the supply chain is known, compliance with these standards can be verified. However, audit fatigue might arise with too many standards, and requirements could be cascaded and pushed upstream, something which policy needs to balance.

Recommendations:

- Intensify discussion on transparency in producing companies/countries
- Make transparency of supply chains mandatory in the EU

- **Responsible public procurement**

 Public institutions should set a good example of responsible procurement to demonstrate and promote opportunities as a pioneer, e.g., by using exclusively BEVs in their vehicle fleet much earlier and having strong criteria for responsible sourcing, such as recycled content for batteries in their vehicles. The list of selectable company cars should exclusively contain BEVs and take stringent environmental and social considerations into account.

Recommendations mentioned previously such as intensifying the discussion on transparency, as well as mandatory transparency, recycled content and labelling of LIBs help to achieve this milestone.

Recommendations:

- List of cars to be selected takes account only BEVs and stringent environmental and social requirements
- Intensify discussion on transparency in producing companies/countries
- Make transparency of supply chains mandatory in EU
- Implement a minimum recycled content
- Implement mandatory labelling of LIBs

[16] For further information on standards see Betz et al 2021 and for criteria on strong standards see Degreif et al 2022

- **Promoting local development through local procurement**

 Through the use of local content and local procurement policies, a contribution needs to be made to local and regional development (as well as the national economy), particularly for operations in developing countries. This includes local procurement, jobs creation, infrastructure and local content[17].

However, there is no commonly accepted way of reporting this topic globally. Policy makers, therefore, need to develop rules for mandatory site-specific reporting of local development. Examples are the LPRM[18] (Local Procurement Reporting Mechanism) created by the Mining Shared Value initiative of Engineers Without Borders Canada, the GRI 204 standard (Global Reporting Initiative) for local suppliers (GSSB 2018) and ICMM[19] (International Council on Mining and Metals), with a new social and economic reporting framework from May 2022. This ICMM framework focuses on taxes, employment, workforce development, procurement, education & skills, and capacity & institutions (ICMM 2022).

There should be a fair distribution of the benefits arising from the production of an LIB along the supply chain such as through living wages. For example, in the DRC, where most of the cobalt comes from (see also Betz et al. 2021), exploitation and labour rights abuses are widespread (RAID 2021).

In the EU, the proposal for a Corporate Sustainability Reporting Directive (CSRD) (European Commission 2021b), adopted in April 2021 and provisionally agreed by the Council and the European Parliament in June 2022 (European Council 2022), is a valuable starting point to provide comparable social and environmental information.

In order to be able to compare the data worldwide, the published criteria must be coherent. And also, the criteria need to be coherent in terms of horizontal and vertical alignment within the EU (European Financial Reporting Group 2021, p. 44).

Recommendations:

- Globally accepted rules for mandatory site-specific reporting of local development (LPRM, ICMM)

- **Supply Chain Due Diligence is included in all Trade Agreements within the G7 for all materials and kept at highest priority**

 Even if they do not consist exclusively of EU countries, it is important to bring together the Group of 7 (G7: includes Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) because of their market power and already existing close relationships. The members are already supporting an international consensus on business and human rights including mandatory measures (Business & Human Rights Resource Centre 2022) but it should go further. The states should find a common understanding of criteria/schemes and how to monitor these. Compliance with the criteria should be included in all future trade agreement. This applies to all materials as well as semi-

[17] The local content is the proportion of materials, labour, etc. used in the production of a product that originates in the area where the product is produced and is not imported.
[18] For more detail, see the website of Mining Shared Value and MSV (2017).
[19] For more detail, see the website of ICMM.

finished and finished products. The criteria should be reviewed and adjusted every 3-5 years in order to consider technical development and changes in the supply chain, and to consider further improvements. With the Minerals Security Partnership, the US has already made a start, along with Australia, Canada, Finland, France, Germany, Japan, the Republic of Korea, Sweden, the United Kingdom and the European Commission in order to build 'robust, responsible, critical mineral supply chains to support economic prosperity and climate objectives' (U.S. Department of State 2022). However, such agreements should also include social sustainability.

Recommendations:

- Find common understanding within the EU and G7 on Supply Chain Due Diligence Criteria and Schemes and include this in the trade agreements

2.2.2 Milestones 2030

- **SDGs are supported along the supply chain**


The SDGs, as described in Chapter 2.1.2, are global goals to be achieved by 2030. The SDGs to be achieved in order to reach responsible procurement in the mobility sector are mainly SDG 1, 2, 3, 5, 6, 8, 10, 12, 14, 15, 16 and 17. For more information, see the Renewable Energy Sector Roadmap (Kügerl 2021).

Recommendations:

- Support achieving SDGs, especially SDGs 1-3, 5, 6, 8, 10 and 14-17

- **Supply Chain Due Diligence Law (along the whole supply chain) mandatory for large players active in the EU**


After the G7 countries have introduced supply chain due diligence in their trade agreements, there needs to be a supply chain due diligence law in the EU. This must be mandatory along the whole supply chain for all large international players active in the EU and should be accompanied by mandatory non-financial reporting (see Corporate Sustainability Reporting Directive). Besides the large players, however, SMEs (small and medium-sized enterprises) should not be forgotten. There have to be measures to assist SMEs in the implementation of Supply Chain Due Diligence (see also Target 3 milestone 'Harmonised sustainability & reporting criteria').

Recommendations:

- Introduce a supply chain due diligence law in the EU

- **Zero financial crime**

 Financial crime such as corruption, fraud, money laundering and financing terrorism leads to several problems in the supply chain, such as poor and unequal pay and environmental pollution. Financial crime exists among policy makers as well as in industry. With more and strengthened audits, policy makers can reduce financial crime in the industry. It should be noted, however, that financial crime is much more difficult to address at the political level, e.g., when a government decides on the granting of mining licences. There are many corruption risk indicators (OECD 2021) that can be taken into account when concluding contracts.

Recommendations:

- More and strengthened audits
- Check contracts for corruption risk indicators

- **Mandatory SLO successfully implemented for new mines, cell production and recycling sites; good practice cases for successful SLO for existing mines and sites**

 A Social License to Operate (SLO) is key, especially for mines but also for production and recycling sites. It ensures the inclusion of the public perspective.[20] By 2030, SLO should be successfully implemented for new mines, cell production and recycling sites. Some key elements are necessary in order to obtain a SLO. First, there needs to be an economic benefit to the local community. Second, there needs to be a contribution to the well-being of the community and respect for the local way of life. Finally, there needs to be equity from the stakeholder's perspective. This includes, for example, fair compensation for land-use and minerals, as well as rehabilitation of abandoned mines. This requires the various stakeholders affected by the company's activities to be involved. New mines are only to be opened with a consensus of the affected communities. Good practice cases for existing mines with successful SLO[21] can be helpful. These should therefore be made public by the policy makers. The Horizon 2020 project MIREU[22] developed SLO guidelines and tools for all stakeholder groups. A common understanding can help future stakeholder engagement and the development of joint SLO targets (Tost et al. 2021a). There are many governance tools for SLO in mining: Corporate Social Responsibility (CSR), Community and stakeholder engagement, Environmental Impact Assessment (EIA), Social Impact Assessment (SIA), Social Impact Management Plans (SIMPS), Free,

[20] According to JRC, a formal and agreed definition of SLO is not yet available 'The concept of "Social Licence to Operate" (SLO) refers to a local community's acceptance or approval of a project or a company's ongoing presence, beyond formal regulatory permitting processes (e.g., public hearing and rights for written interventions). SLO derives from the acknowledgement that stakeholders may threaten a company's legitimacy and ability to operate through boycotts, picketing or legal actions. From a company perspective, obtaining a SLO is essential for reducing the risk of public criticism, social conflict and damage to the company reputation, which could reduce its profitability.' (JRC 2022).

[21] For example, ASSIMAGRA, the Portuguese association of the mineral resources industry which takes the approach of engaging the municipalities in the licensing process. Further information in English is provided on the SUMEX website (https://www.sumexproject.eu/wp-content/uploads/2022/07/NCristo_DraftPres_ASSIMAGRA_SEVILHA2022.pdf)

[22] More information about the MIREU project can be found here https://mireu.eu/

Prior and Informed Consent (FPIC), a grievance mechanism for complaints and Community Development (CD) (Sairinen 2022). All these need to be considered.

SLO should not only be mandatory for new mines or production and recycling sites: they also need to be achieved for existing mines and production and recycling sides.

Recommendations:

- Legislation for mandatory SLO for new mines and production and recycling sites
- Developing requirements for SLO for existing mines and production and recycling sites

- **Recycled material becomes the standard**

 As the LIB market is currently experiencing large growth and forecasts indicate that this growth will intensify in the coming years, secondary battery materials will not be able to meet the majority of the demand for LIB resources. Nevertheless, use of recycled material in LIB production has to become the first choice by 2030. Policy makers therefore have to boost support for purchasing recycled material and increase the minimum recycled content.

Recommendations:

- Intensify support for purchasing recycled material and increase minimum recycled content

- **Supply Chain Due Diligence is included in all Trade Agreements globally for all materials and kept at highest priority**

 With the due diligence criteria / scheme between EU and G7, the next step is to start discussions on supply chain due diligence requirements globally. Supply Chain Due Diligence should be included in all Trade Agreements globally for all materials. With this continuation of the 2025 milestone, supply chain due diligence is included in all trade agreements globally with the target that countries develop and enforce rules to decrease the negative impacts of mining, cell production and recycling.

Recommendations:

- Find common understanding globally on Supply Chain Due Diligence Criteria and Schemes and include this in the trade agreements

2.2.3 Milestones 2040

- **Mandatory use of renewable energy along the entire supply chain within the EU**

 By 2040, there should be a mandatory use of renewable energy along the entire supply chain of LIB in the EU (see also Kügerl and Tost 2021). This should be required by law.

Recommendations:

- Legislation requiring the use of renewable energies in the EU

- **Transparent supply chain of all international actors**

 As described for 2025, transparency is essential for responsible procurement. Even though the recommendations are directed at EU policy makers, it is still necessary to achieve transparent supply chains of all international actors. EU policy makers can support this approach for global coverage by addressing transparency in exchanges and discussion with other international policy makers and sharing their experiences and good examples.

Recommendations:

- Addressing transparency in exchanges and discussions with other international policy makers

2.2.4 Milestones 2050

- **Legislation inhibiting negative impacts along the entire supply chain**

 By 2050, there needs to be legislation reducing negative impacts to a minimum along the entire supply chain. This includes responsible use of toxins and the use of alternative substances if possible. In addition, toxic materials have to be treated and discarded in a responsible way, and landfilling should be forbidden where possible. To achieve this, a harmonised definition of toxic materials needs to be established or existing definitions have to be agreed upon. In addition, mines must be designed and operated in such a way that no negative impacts like acid mine drainage or tailing dam failures can occur (e.g., drying or thickening of tailings[23]).

Recommendations:

- Establish a harmonised definition of toxic materials
- Legislation reducing negative impacts to a minimum at mine site level

- **Mandatory use of renewable energy along the entire supply chain globally**

 As a continuation of the 2040 milestone, it must be mandatory to use exclusively renewable energy along the entire supply chain globally, wherever possible. EU policy makers should start and push forward discussions on this globally and support approaches for the use of renewable energy.

Recommendations:

- Addressing use of renewable energy with other international policy makers

[23] E.g., Dundee Precious Metals mine site in Bulgaria (see presentation on their approach of thickening tailings here https://www.sumexproject.eu/wp-content/uploads/2022/07/SUMEX-presentation_Dundee-Precious-Metals.pdf)

2.3 Target 3: Level Playing Field

The consultation process showed that the development of a level playing field (not only) for the mobility sector needs to be one of the major targets in a roadmap for responsible sourcing in the mobility sector. The current system focuses on producing the cheapest product, mostly ignoring the way in which the products are produced and their quality or durability. This system encourages companies to locate production in countries with low social and environmental standards and is based on a 'throwaway society'.

With globalisation, supply chains do not end at EU boarders, so the RE-SOURCING project supports the idea of a joint effort to reach more responsible supply chains globally. The roadmap not only encourages the introduction of requirements for social and environmental standards for doing business in the EU but puts forward milestones and recommendations that include cooperation with and support for companies, organisations and governments that currently do not fulfil those requirements globally.

A level playing field should achieve a fair distribution of costs and benefits along the supply chain.

In the discussion about a level playing field, seven main issues are of relevance:

- Quality over Price
- International cooperation
- Producer Responsibility
- Polluter Pays and Border-Tax Adjustment
- Harmonisation of mining and production policies
- Harmonisation of sustainability and reporting criteria
- Formalisation of artisanal and small-scale mining (ASM)
- Mandatory minimum standards

In the beginning of each chapter, figures provide an overview of the milestones for supporting the target of level playing field identified in the project. To achieve these milestones, a set of recommendations for actions are outlined. In the following sub-chapters, the milestones and recommendations are developed for the different stakeholder groups: EU policy makers, internationally operating companies and CSOs.

In the sub-chapters, the milestones are given as bulleted lists in bold type. The explanations and their recommendations follow each milestone. For quick access to the recommendations for action, these are summarised in the coloured boxes at the end of each milestone.

The following Figure 9 gives an overview of the milestones focussing on the target group policy makers to achieve a level playing field. In the RE-SOURCING project, the policy level aims at EU policy makers. However, the level playing field is a global target where EU policy makers also should focus on discussions abroad. This gives the floor to international discussion and cooperation on a global level playing field. The grey coloured milestones aim at policy makers outside the EU. But EU policy makers can also support these milestones by initiating discussions and cooperation on these issues.

The following sub-targets give an overview of the milestones and recommendations for policy makers to achieve a level playing field:

- Create a level playing field
- Communicate and collaborate with EU / EU Member States and producing countries

- Find a common understanding of sustainability criteria for mining, production and recycling and their international application
- Support formalisation of ASM
- Strengthen CSOs
- Strengthen transparency

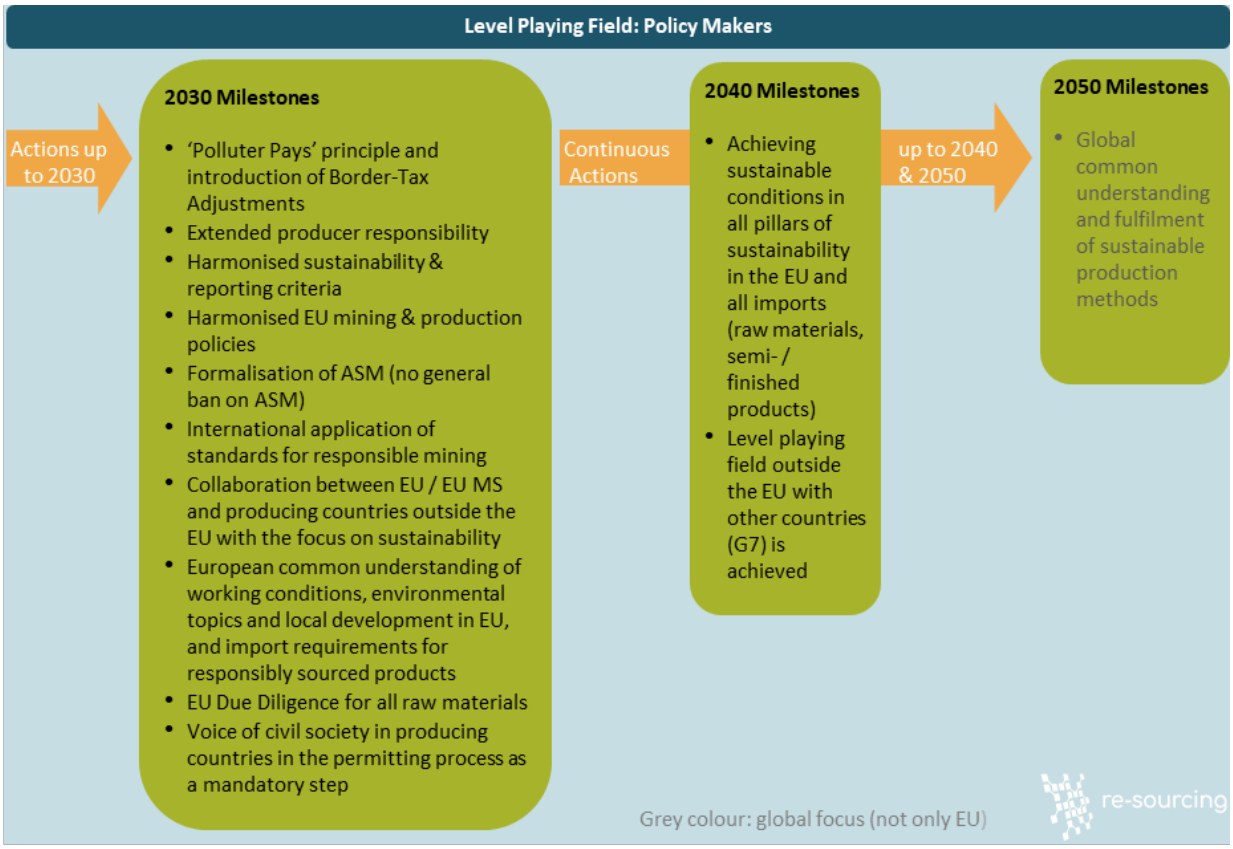

Figure 9: Milestones for policy makers towards a level playing field by 2050

2.3.1 Milestones 2030

- **'Polluter Pays' principle and introduction of Border-Tax Adjustments**

To reduce the economic benefits of unsustainable practices in mining, production and recycling, economic regulations within the EU Members States (and later globally) are needed as a first step towards a level playing field. These include approaches such as i) social and environmental border tax adjustments and ii) the 'polluter pays' principle, where the external costs are internalised within the company with the aim of demonstrating that 'unsustainability is unprofitable' (Kügerl and Tost 2021). A border-tax adjustment aims at production processes outside the EU and accounts for differences in environmental performance (e.g., CO_2 emissions) and compliance with social standards (e.g., occupational health and safety (H&S), community H&S, fair wages, supporting local development, etc.). While having EU-wide binding criteria for production, border-tax adjustments support the competitiveness of European producing companies. In every country where they produce, European companies must apply the same high social and environmental standards as required within the EU. The application of lower standards in non-EU countries should be penalised – a bonus-malus-system could support this. Nevertheless, mandatory minimum criteria like the absence of child labour need to be set. Companies adopting high standards at their production sites and in their supply chains

could be financially rewarded while companies using lower standards are penalised through increased taxes.

In developing countries, consideration needs to be given as to how these countries can be supported in drafting and enforcing regulations to reach the criteria required by the EU. This support needs to be discussed and developed in cooperation with and on equal terms between the EU and the developing countries.

To implement these approaches, the EC should develop a set of social and environmental criteria for sustainable practices and associated payments for non-compliance with the criteria. The criteria subsequently need to be implemented in an EU regulation. The proposal of the EU Battery Regulation shows a good practice approach with mandatory social and environmental standards for critical metals in products to ensure the ethical sourcing of materials (see Degreif et al. 2022). The criteria need to be transparent and communicated openly among the stakeholders in the EU but also internationally from the beginning of the development. Minimum quality standards but also ambitious sustainability qualities can be set on trading exchanges like the London Metal Exchange[24].

While implementing these financial approaches, discussion and cooperation on transparency needs to be intensified in producing companies / countries.

Recommendations:

- Develop and implement a set of social and environmental criteria for sustainable practices and associated payments for non-compliance with the criteria
- Open and transparent communication is needed within the EU and abroad from the start of developing the criteria and support

- **Extended producer responsibility (EPR)**


The EPR is a policy approach that gives the producers the financial or physical responsibility for treatment of post-consumer products (OECD 2022). This also relates to the circular economy, in that the producer needs to think about the end of a product and how to collect and treat these EoL products in a sustainable way (see also target 1 Milestone ‘Legislation for reuse/repurposing and recycling with ambitious rates’). In terms of LIBs, the collection, storage, transport and treatment of EoL batteries need to be guaranteed in a sustainable and safe manner.

While implementing these financial approaches, the discussion and cooperation on transparency needs to be intensified in producing companies / countries.

Recommendations:

- See also target 1 Milestone ‘Legislation for reuse/repurposing and recycling with ambitious rates’

[24] The LME started an approach on disclosure sustainability data and the first sustainability disclosures listed on the LMEpassport in 2021 (LME 2021)

- **Harmonised sustainability & reporting criteria**


Within the EU a set of reporting criteria on sustainability need to be agreed and implemented as mandatory reporting. In June 2022, the Council and European Parliament reached a provisional political agreement on the Corporate Sustainability Reporting Directive (CSRD), which envisages the adoption of EU sustainability reporting standards (European Council 2022; see also target 2 milestone 'Promoting local development through local procurement'). National legislation and implementation of the directive must first be evaluated in order to assess the reporting. For a comparison between companies, it is essential that the criteria are clearly defined, reporting is mandatory, and the criteria are accessible to everyone. This applies to all the value chain steps. In this roadmap we focus on mining, cell production and recycling. In the development of the mandatory set of sustainability criteria, the size of a company and capacity needed for reporting need to be considered. For example, the reporting requirements for SMEs should be less extensive than for large internal producing companies, in order to have an equal share of the costs of reporting. This sustainability reporting goes beyond due diligence requirements. However, in terms of the due diligence requirements, support for SMEs is further be needed to fulfil these.[25]

When developing the reporting criteria, existing regulations need to be considered. Criteria given in EU regulations like the Battery Regulation need to be included in this reporting scheme.[26] This reporting should be mandatory for all the production sites of an EU-based company, both within the EU and abroad. The set of criteria should not only include environmental issues but also social data on local development. (see also target responsible procurement milestone 'Promoting local development through local procurement')

A great deal of communication and effort has already been made in developing global harmonisation of sustainability reporting. This still requires open and transparent communication with countries abroad and discussions on bridging documents and defining criteria (see also the role of international organisations in Chapter 2.3.4).

Recommendations:

- Assess the implementation of the CSRD
- Further international cooperation, communication, and exchange on global harmonisation of sustainability reporting

- **Harmonised EU mining & production policies**


EU mining and production policies need to be harmonised focussing on responsible mining with high social and environmental standards, with the aim of achieving sustainable mining practices (see also SUMEX sustainability framework (Tost et al. 2021b)). EU policy makers need to support sustainable mining in the EU financially, so that mining companies can undertake the transition to responsible mining practices and become sustainable. Harmonised policies result in clear criteria for

[25] The European Commission has developed 'Due diligence ready!' to support SMEs in fulfilling due diligence requirements (see https://single-market-economy.ec.europa.eu/sectors/raw-materials/due-diligence-ready_en)
[26] For a globally harmonised reporting scheme, other regulations and their criteria should also be screened.

sustainable mining and production. The proposed EU Battery Regulation is a blueprint in developing an overarching regulation with sustainable criteria for all EU Member States, where no implementation in national law is needed. Criteria should be applied equally to imported products and those produced in the EU.

Recommendations

- Develop an overarching EU regulation with sustainability criteria for mining in the EU

- **Formalisation of ASM (no general ban on ASM)**

Artisanal and small-scale mining (ASM) is relevant for the livelihood of thousands of people and families, e.g., in the DRC, but also in other parts of the world. The often informal ASM sector is connected to child labour, forced labour, inadequate health and safety conditions, and funding of armed conflicts, which is why policy makers have tended to impose an import ban on ASM products. However, it is important to avoid restricting ASM if the sourcing complies with standards like the OECD Due Diligence Guidance and when there is a continuous improvement in the sourcing conditions. In order to protect the livelihoods of the people, formalisation of ASM should also be supported by actions to start formalisation on the ground. Such actions include the CTC[27], cooperation with organisations such as ARM (Alliance for Responsible Mining)[28] and IMPACT[29] to support the responsible development of ASM. The Responsible Minerals Initiative also started the better mining programme which is a monitoring programme for ASM mines.[30] The CRAFT initiative can serve as a guidance book but is not appropriate as an assurance system for purchasers.[31]

Policy makers shall also support companies in their approaches on the ground and by using ASM material. With the formalisation of ASM under responsible and continuously improving conditions, there is also a requirement to ensure easy access to the market.

EU policy makers shall also support development to establish a framework supporting formalisation of ASM, ideally in partnership with policy makers from other countries. The basis for this is an open discussion and knowledge sharing on an equal footing between all partners. Even though the overall policy goal might be to reduce ASM in general by providing other means of livelihood, the formalisation of the ASM aspect should not be neglected.

Recommendations:

- Support formalisation of ASM
- Support companies in ASM formalisation approaches (no ban on ASM)

- **International application of standards for responsible mining**

There is a wide and diverse landscape of standards on responsible mining available globally. They all have different scopes in terms of region (e.g., Great Lakes), raw materials (e.g., conflict materials, copper, overarching e.g., OECD), LSM (large-scale mining) versus ASM, focussing on social aspects or overarching (e.g., IRMA), and also with reference to the development itself (e.g., company driven or with a broad engagement). To develop harmonised mining standards for responsible sourcing or the mutual recognition of standards, there is a need to strengthen international cooperation and

[27] Certified trading Scheme https://www.bgr.bund.de/EN/Themen/Min_rohstoffe/CTC/Concept_MC/CTC-Standards-Principles/ctc_standards-principles_node_en.html
[28] See further information on ARM on the website https://www.responsiblemines.org/en/
[29] See further information on IMPACT Transforming natural resource management. Empowering communities on the website https://impacttransform.org/en/
[30] For further information see https://www.responsiblemineralsinitiative.org/minerals-due-diligence/cobalt/
[31] For further information on CRAFT see https://www.responsiblemines.org/en/2020/10/craft_v2-0/

discussion. As a first step, European policy makers should have an open discussion on a definition and clear criteria for responsible and later sustainable mining in the EU. The EU has already started this process and published the EU principles for sustainable raw materials in 2021 (EU 2021). In a comparison between different sustainability schemes, the BGR (2022) stated that this approach gives rather general principles. Further concrete sustainability criteria should be developed. With this common understanding of responsible / sustainable criteria for a mining project within the EU, the EU should financially support new mining projects in the EU with the focus on these responsibility / sustainability criteria. These projects can be frontrunners and good practice examples to be transferred within the EU but also abroad.

To strengthen these criteria on responsible / sustainable mining, imported raw materials need to fulfil the same standards for extraction and processing as those mined in Europe. If these standards are not met, the border-tax adjustment supports the level playing field (see milestone '"polluter pays" principle and introduction of border-tax adjustment').

Recommendations:

- Further development and agreement on concrete sustainability criteria for responsible / sustainable mining within the EU and later globally
- Support development of new mines fulfilling these criteria

- **Collaboration between EU / EU MS and producing countries outside the EU with the focus on sustainability**

The LIB value chain is very diverse and involves many players around the world. It is essential not only to discuss sustainability within the EU but bring different stakeholders together for an exchange of ideas and in order to understand each other's viewpoint and arguments. This exchange should be organised not only at the highest levels but also at the workers' level and with a sharing of knowledge and experience on the ground. Discussion of visions, challenges, opportunities, best practices, etc. should be organised. By means of site visits in the EU and abroad, knowledge transfer and an understanding of each other's viewpoint can be achieved. This collaboration can be supported by EU funded projects on sustainability in the different steps of mining, cell production and recycling. In the discussion with policy makers outside the EU, the EU policy makers can maintain an awareness of issues on the ground and draw attention to the aspects of a level playing field and challenges. When the European companies need to fulfil sustainability criteria for imported products/materials, policy makers need to ensure that these sustainably produced materials/products are available on the global market.

Recommendations:

- Initiate further collaboration and discussion between EU MS and abroad

- **European common understanding of working conditions, environmental topics and local development in EU, and import requirements for responsibly sourced products**

 In the EU, the political perspective on appropriate working conditions, environmental impacts and local development is very diverse. There are different national legislations, not only as a result of political viewpoints, but also driven by the different attitudes and power of national industry and NGO/CSO actors.

As a basis for an agreed European legislation on due diligence, it is essential to have a common understanding of working conditions, environmental topics and local development in EU and import requirements for responsibly/sustainably sourced products (see milestone 'Harmonised sustainability and reporting criteria'). To achieve this, the EU should provide further support on the exchange and discussion of these conditions, not only at the policy level. A lot of effort has already been made and projects are currently running, such as STRADE[32], RE-SOURCING[33] and SUMEX.[34] The other stakeholder groups such as CSOs/NGOs and industry should also be involved on an equal footing.

Recommendations:

- Give the floor to dialogue and discuss a common understanding of appropriate working conditions, environmental topics and local development in EU, and import requirements for responsibly sourced products

- **EU Due Diligence for all raw materials**

 A common legislation is needed, based on a common understanding of working conditions, environmental topics and local development in Europe, and import requirements for sustainable products. The focus should be not only on specific raw materials such as 3TG (as in the Conflict Minerals Regulation) but required for all raw materials used.

Within the EU a comprehensive und common legislation is needed to ensure a level playing field within the EU. In February 2022, the EU adopted a proposal for a Directive on Corporate sustainability due diligence (EC 2022b). This proposal is aimed at large companies and SMEs are not included in the beginning. To ensure a level playing field, the SMEs should also be responsible for their due diligence – even though this should be adapted according to their size (see also target 2 'Supply Chain Due Diligence is included in all Trade Agreements within G7 for all materials and kept at highest priority').

Recommendations:

- Mandatory EU Due Diligence for all raw materials used

[32] See STRADE (Strategic Dialogue on Sustainable Raw Materials for Europe) project website https://www.stradeproject.eu/home
[33] See RE-SOURCING (A global stakeholder platform for responsible sourcing in mineral value chains) website https://re-sourcing.eu/
[34] See SUMEX (Sustainable Management in the Extractive Industries) website https://www.sumexproject.eu/

- **Voice of civil society in producing countries in the permitting process as a mandatory step**

Mining sites in Europa and abroad often face criticism from civil society and local communities. To ensure the engagement of local communities in the development of a mining site, the voice of civil society – including legal communities – should be a mandatory step in the permitting process. The effort and positive impacts of this approach can be seen in initial projects like ASSIMAGRA in Portugal.[35] Here, the involvement of local communities and civil societies (e.g., on environmental aspects) is necessary for the permitting process. Even though this approach is time-consuming in the beginning, the result of supporting communities and CSOs facilitates the production start and the production phase without further delay from lawsuits. In the long term, involvement of the CSOs should be a continuous process over the entire site lifecycle and not end with the granting of a licence to ensure an SLO.

Often, CSO representatives are willing to engage meaningfully in processes or events but lack the capacity to do so. To ensure that CSOs have enough capacity to engage in the permitting process but also in communication and engagement with industry and the public, they need to be supported financially by the government. This support should come from the EU in the case of European-based CSOs, and from the UN in developing countries.

Recommendations:

- Mandatory CSO involvement in the permitting process
- Financial support of CSO by governments to have enough capacity for engaging

[35] See further information on ASSIMAGRA's approach in the presentation on the SUMEX project website https://www.sumexproject.eu/wp-content/uploads/2022/07/NCristo_DraftPres_ASSIMAGRA_SEVILHA2022.pdf

2.3.2 *Milestones 2040*

- **Achieving sustainable conditions in all pillars of sustainability in the EU and all imports (raw materials, semi- / finished products)**

 In 2040, the sustainable conditions in all pillars of sustainability in the EU should be achieved for the LIB supply chain. Imported products, including raw materials as well as finished and semi-finished products, shall also meet the EU requirements in the same way. This applies to mining as well as production and recycling issues.

The development and implementation of the recommendations for all targets explained above should achieve this milestone.

Recommendations:

- Follow the recommendations mentioned before
- Report on sustainable criteria to ensure compliance with the requirements

- **Level playing field outside the EU with other countries (G7) is achieved**

 In France, Germany, and Italy, the level playing field should already be achieved in 2030. The involvement of the other G7 Member States is already included in the milestone 'Supply Chain Due Diligence is included in all Trade Agreements within G7 for all materials and kept at highest priority' in the target responsible procurement and serves as a basis for a level playing field.

The milestones for the level playing field in the EU mentioned above need to be broadened to the G7 member states of Canada, Japan, the United Kingdom and the United States. They should apply these standards not only in their territory but also in the countries where they operate.

To achieve this, the EU representatives as well as the policy representatives from EU Member States (especially the G7 partners France, Germany and Italy) need to continuously discuss and engage in achieving the level playing field within the EU and G7.

Recommendations:

- Agreements EU / EU Member States with G7 on a level playing field milestone within the EU with equal environmental and social standards

2.3.3 *Milestones 2050*

- **Global common understanding and fulfilment of sustainable production methods**

 In global terms, based on approaches from Europe and abroad, a global common understanding and fulfilment of sustainable production methods in mining, cell production and recycling should be achieved.

To achieve this global common understanding, a lot of communication and exchange are essential. As a first step, there is a need for a global common understanding of what sustainable production methods look like and which criteria are appropriate. Countries and regions face different challenges and are at different development stages. Even though the milestone is for 2050, the exchange and discussion should start now to enable an open discussion on a common footing.

A common understanding and exchange on how to achieve this are needed, plus transferrable good practice cases should be exchanged and supported.

Recommendations starting now:

- Exchange on common understanding of sustainable production methods

2.3.4 Role of International Organisations (UN/OECD/IFC)

The LIB supply chain is very complex and has a globally interlinked structure. This applies not only to the LIB sector but also to renewable energy and electronics.[36] It is therefore important that international organisations, such as the United Nations and OECD, are strengthened. These organisations can make an important contribution to a level playing field and to harmonising requirements for companies globally. To make it easier to hold internationally active companies accountable for financial crimes as well as crimes against the environment and humanity, the role of the UN's international justice system should also be extended to companies.

The UN, OECD and IFC already provide important templates for responsible behaviour by international companies in general. In addition, there are specific guidelines for mining, manufacturing, and responsible sourcing of raw materials, all either specific to or applicable to the commodities under consideration. These guidelines need to be implemented by member states on a mandatory basis and without delay, thereby also supporting an international level playing field.

[36] See also the roadmap on renewable energies and the state-of play report on electronics.

3 Conclusion of the overall Roadmap

Even though the roadmap has a time frame until 2050, it is clear that there is no time to waste - we **need to act now**! Changes are needed and cannot be postponed to the next generation or next legislation period. All targets need to be addressed simultaneously and all with the same importance and power from the stakeholder groups. The targets are also interrelated, e.g., to make procurement sustainable by obtaining only responsibly recycled materials, the latter is needed on the market.

One of the key findings of the roadmap and the consultations is the importance of **communication and cooperation between stakeholders along the whole value chain** for all three targets: none of the targets can be resolved by only one stakeholder group. Challenges must be tackled together without ending relationships when problems arise.

A **change in thinking** is needed for all actors – policy makers (e.g., by setting overarching regulations with concrete criteria), industry (e.g., by implementing quality over price), civil society (e.g., by promoting good practice cases) and also the general public (e.g., a change in transport behaviour) – who need to understand, support and embrace the new way of thinking.

A **shared goal** must be pursued. This must be addressed through joint actions with the different stakeholder groups (policy, industry and civil society). The decisions that are taken need to follow this common target to build trust between the stakeholder groups and among the general public. This is also the basis for a change in behaviour. Frontrunners and role models are needed in all stakeholder groups where others can follow.

This roadmap supplies only very few specific details on actual data for increases or decreases. Further **research** is needed to set ambitious but realistic targets and be as precises as possible to define the necessary measures.

A variety of recommendations are developed for all stakeholder groups. Some are specifically for the project's focus on lithium-ion batteries (LIBs) with the materials lithium, cobalt, nickel and graphite. However, recommendations are identified that are valid for other raw materials and other sectors and technologies. This underlines the complexity of raw material supply chains and the interlinkages between the different sectors.

The overview of the three main targets is illustrated in the roadmap figure (see Figure 10). **Target 1 'circular economy & decreased resource consumption'** needs fundamental changes in transport behaviour and also systemic changes for the recycling and use of secondary raw material. By 2040 the circular economy needs to be implemented for LIBs in the EU. In addition, the resource intensity of batteries should be reduced by more than 50% compared to 2021. By 2050 the primary resource consumption for traction batteries needs to be reduced by more than 80% in the EU compared to 2035 and ICEs should no longer be on the roads globally.

The recommendations for **Target 2 'responsible procurement'** and **Target 3 'level playing field'** need to be implemented as soon as possible in order to first reach a common understanding of a 'sustainable product' in the EU and abroad as a basis for implementing a fair distribution of benefits and burdens in the transition to e-vehicles. Responsible procurement in all EU firms (including SMEs) needs to be implemented by 2040, and globally by 2050 at the latest. A level playing field should be achieved within Europe in all three pillars of sustainability by 2030 and globally by 2050 at the latest.

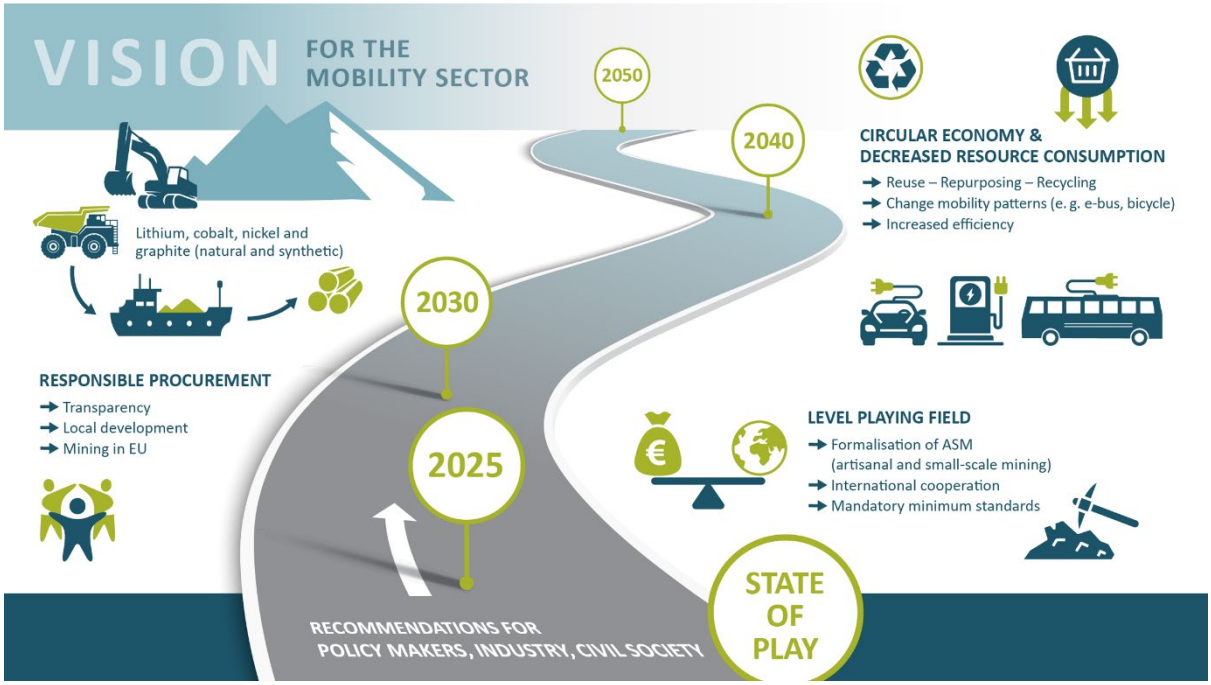

Figure 10: Roadmap for the mobility sector up to 2050

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