International Copper Association
Copper Alliance

ARCADIS

Industrial Symbiosis opportunities for the copper sector

QUANTIFICATION THROUGH AN LCA STUDY AND A MARKET ANALYSIS FOR TWO OPPORTUNITIES

Agenda

- Introduction
- Iron Silicate from Cu Smelting and Refining
- Repurposing EV Batteries for Energy Storage Systems
- Conclusion

Cu

Antitrust Guidelines for Copper Industry Trade Association Meetings

The following guidelines with respect to compliance with antitrust laws of the United States, Japan and European Community[1] are intended to govern the conduct of participants in copper industry trade association meetings, both at the meeting itself and in informal discussions before or after the formal meeting.

Price: Competitors should not discuss future prices (including terms of sale) of their products. There is no blanket prohibition against the mention of or reference to current or past prices but limits must be observed. Such references or mentions should occur only when necessary in connection with the development of association programs. For example, reference to a particular price level in comparing the cost of a copper product to a competing product is permitted. Whenever possible, such references should be discussed in advance with legal counsel.

Competitive Information: Competitors should not discuss the market share of a particular copper producer or copper fabricator's products. Furthermore, nothing should be said at a meeting which could be interpreted as suggesting prearranged market shares for such products or producer production levels. The overall market share of copper products may be discussed with regard to competition with non-copper products and general market acceptance.

New Products: Competitors should not encourage or discourage the introduction of a new product by another competitor or reveal a particular copper company's plans to change the production rate of an existing product or to introduce a new product. No company should disclose to another company whether it is in a position to make or market a new product. New products may be discussed in a technical manner or from the standpoints of competition with non-copper products and general market acceptance. In addition, proposed methods for and results of field and laboratory testing can be considered.

The Role of Legal Counsel: Legal counsel attends association meetings to advise association staff and other meeting attendees regarding the antitrust laws and to see that none of the matters discussed or materials distributed raise even the appearance of antitrust improprieties. During the course of a meeting, if counsel believes that the discussion is turning to a sensitive or inappropriate subject, counsel will express that belief and request that the attendees return the discussion to a less sensitive area.

A paper entitled 'Copper Industry Trade Associations and Antitrust Laws' is available upon request.

10/92, 5/93, 10/10

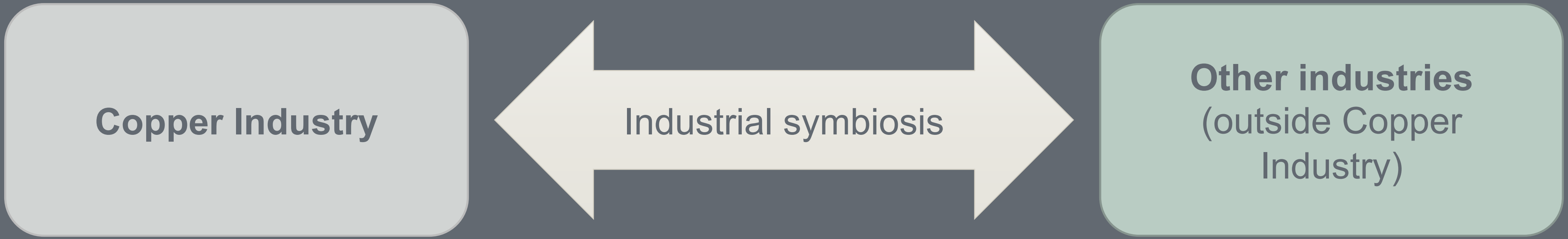
1. Other foreign competition laws apply to International Copper Association, Ltd. (ICA)'s activities worldwide.

Introduction

- **What is industrial symbiosis?**
- **Overview of definition, drivers and benefits of industrial symbiosis**

What is Industrial Symbiosis?
(Example for the Copper Industry)

- Industrial Symbiosis allows the **capture, recovery and reuse of previously discarded resources from one industrial operation by other** traditionally separate industries operating in close proximity, both gaining a competitive advantage
- **Industrial symbiosis** aims at extending the use-life of discarded resources (byproducts or waste) from one industry by another (**different one**), fostering re-use or repurposing for other applications
- With industrial symbiosis, the resource **remains in use in the economy** for a longer time in a different context
- It requires a **cooperation between actors** in different industrial sectors (only one of them is the copper industry)
- Industrial symbiosis is a way to implement **circular economy principles**



Drivers

- **Diversity** in industries
- Geographic **proximity** of actors
- **Mutual benefits** from participation in such practice (environmental, economic, social)
- **Regulatory framework** (Environmental (air/water quality, etc.) and waste requirements
- Availability of **information** to actors (benefits, available resources in the area, etc.)
- **High cost of raw materials** and waste treatment options
- Sustainability-oriented **mindset** of actors involved

Benefits

- **Environmental** impact reduction
  (**Resource efficiency / waste minimization, reduction of carbon footprint, avoidance of landfilling)**
- **Socio-economic** benefits
  (Cost reduction for raw materials mining and extraction, for waste treatment and recycling (along with associated tonnage losses), reduction of operational costs, increase in company income / job creation (quality of life), resources supply security

Industrial Symbiosis for Cu: Success Stories

- Is industrial symbiosis already in place? Are there successful examples?

Industrial Symbiosis for Cu: Copper Success Story

Iron silicate from Cu smelting and refining as an aggregate in the construction sector

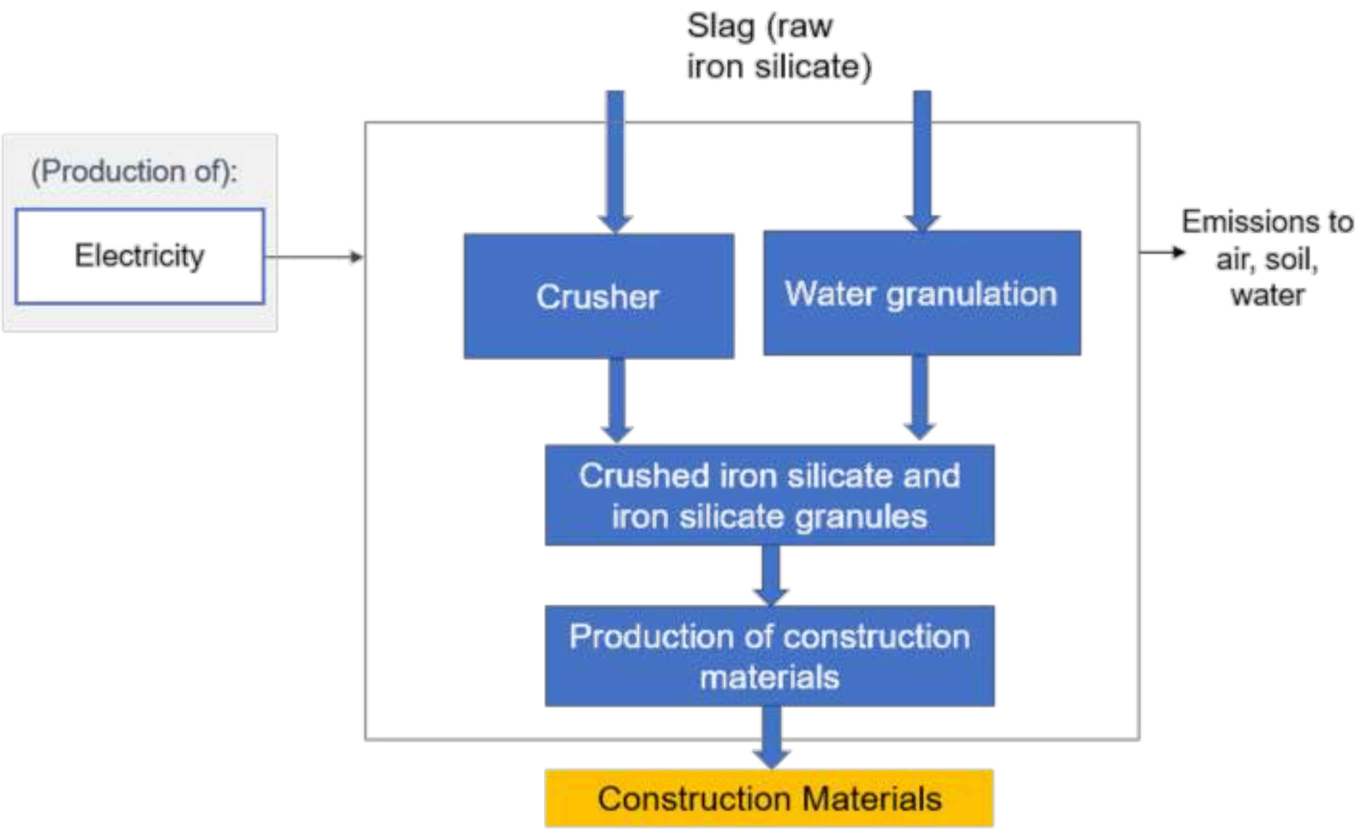
- Environmental Assessment
- Market Analysis

System boundaries

- Production of **Iron Silicate** (from cradle to gate) and its **substitution** in construction materials: **gravel and crushed stones for concrete**

- Functional unit: **1 tonne of gravel, 1 tonne of concrete**

- Substitution of virgin raw materials in construction with iron silicate:
  - **100% for gravel**
  - **43% in concrete mix**



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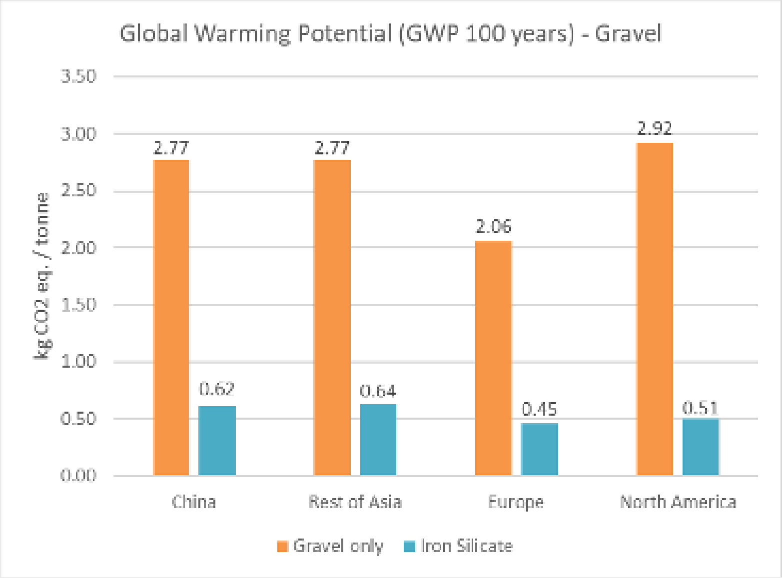
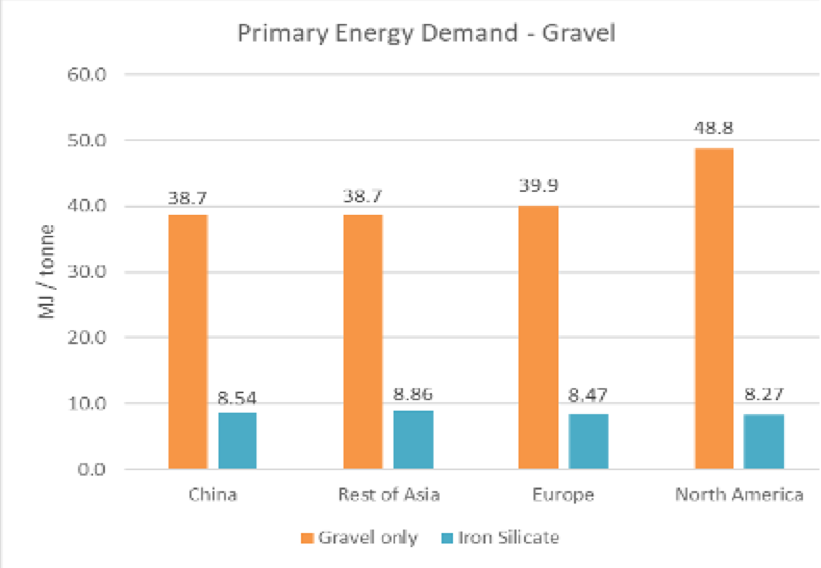
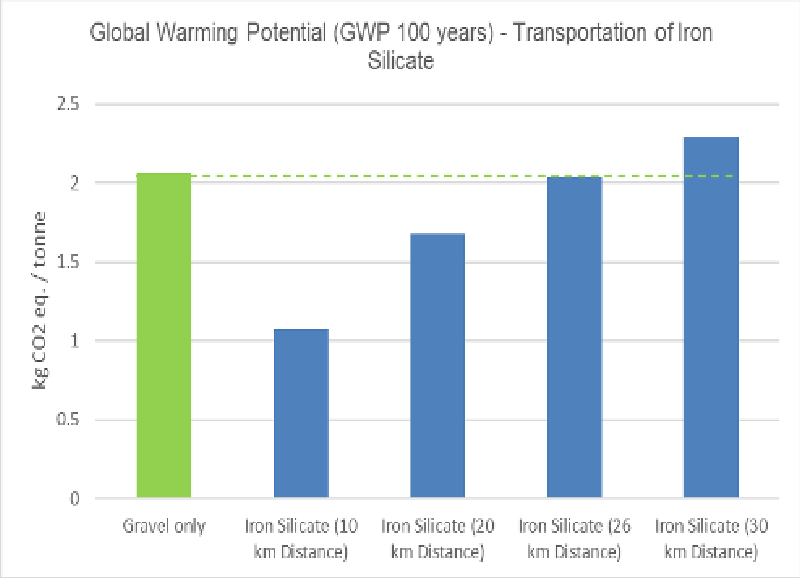
Environmental Benefits from Using Iron Silicate in Construction (1/2):
GRAVEL







The global warming and primary energy demand impacts associated with the production of Iron Silicate are less than half the impacts associated with the production of gravel for all regions (excluding transport distances)

The substitution of gravel with iron silicate results in less GWP impacts if the iron silicate is to be transported to distances less than 26 km (compared to the baseline).

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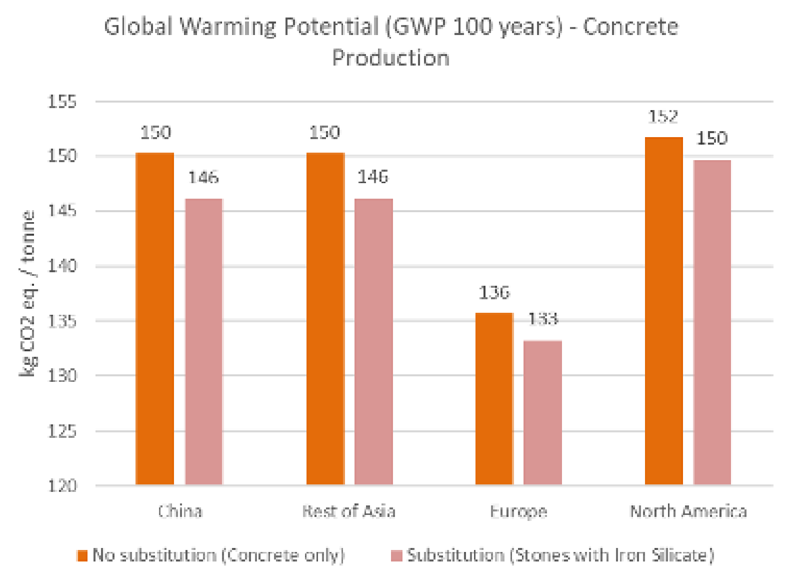
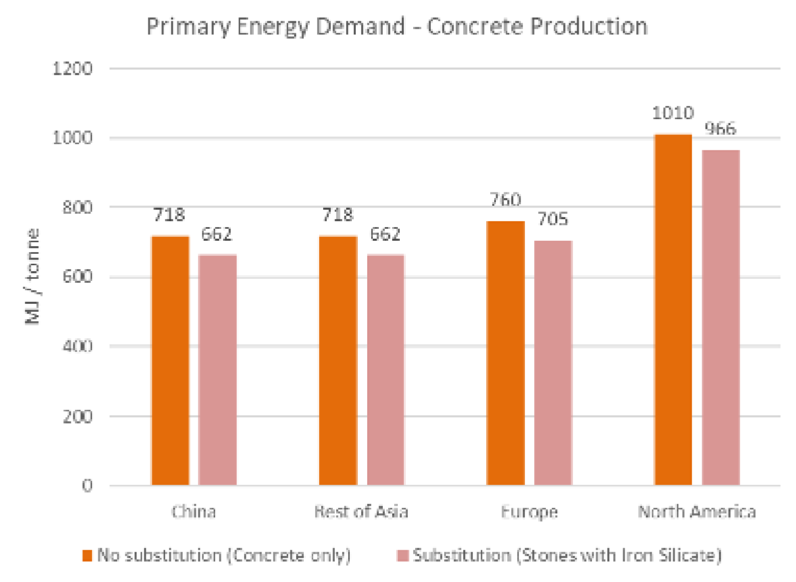
Environmental Benefits from Using Iron Silicate in Construction (2/2): CONCRETE





		Acidification Potential (kg SO2 eq.)	Eutrophication Potential (kg Phosphate eq.)	Photochem. Ozone Formation (kg NMVOC eq.)
Europe	No substitution (Concrete only)	0.18	0.028	0.23
	Substitution (Stones with Iron Silicate)	0.18	0.027	0.22
China	No substitution (Concrete only)	0.25	0.035	0.28
	Substitution (Stones with Iron Silicate)	0.24	0.033	0.27
Rest of Asia	No substitution (Concrete only)	0.25	0.035	0.28
	Substitution (Stones with Iron Silicate)	0.24	0.033	0.27
North America	No substitution (Concrete only)	0.29	0.041	0.31
	Substitution (Stones with Iron Silicate)	0.28	0.040	0.30

The impacts associated with the production of concrete decrease by at most 3 percent when Iron Silicate is used to substitute the stones in concrete production

The impacts associated with the production of concrete decrease by at most 8 percent when Iron Silicate is used to substitute the concrete stones in concrete production.

All impacts are lower when Iron Silicate is used to substitute concrete stones in concrete.

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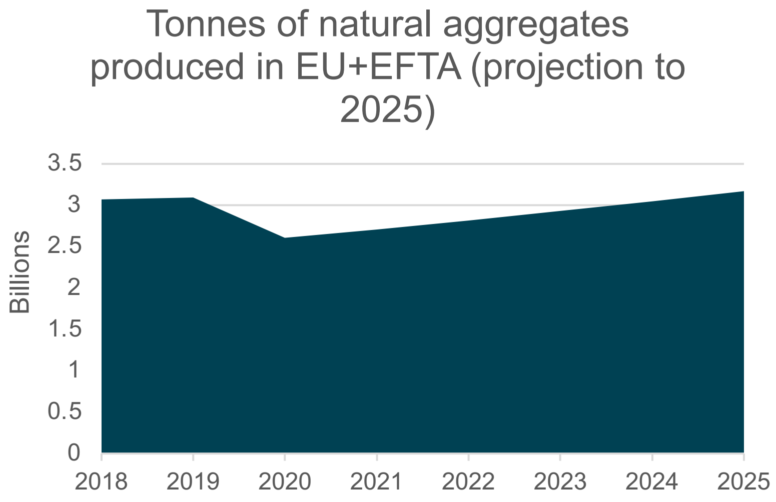
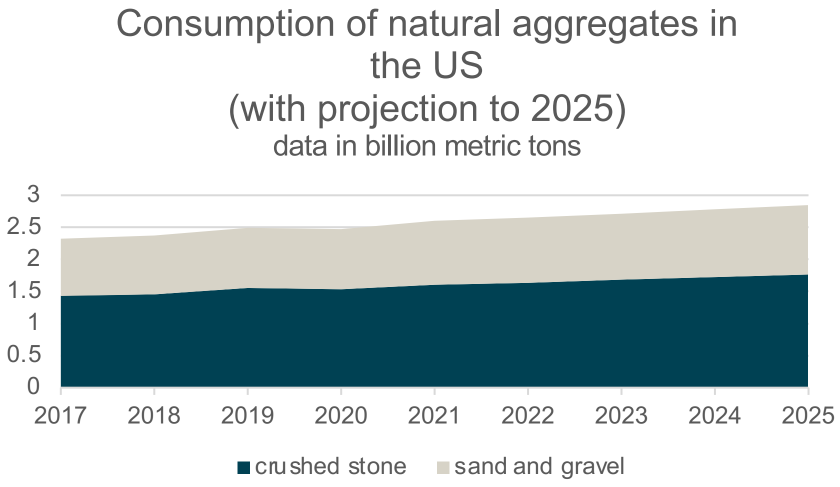
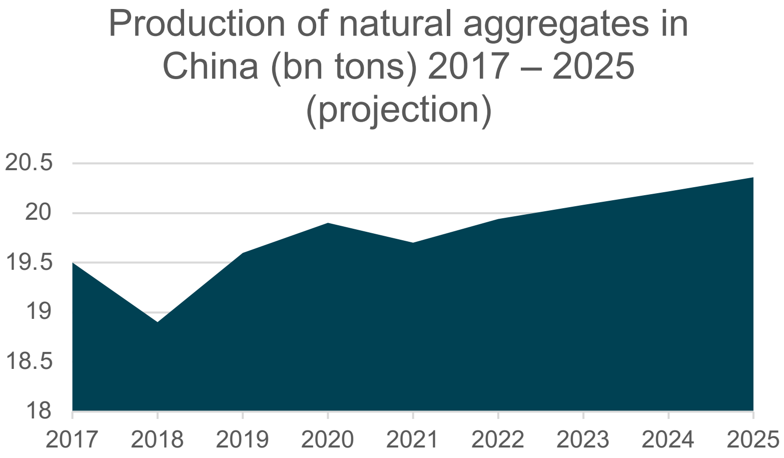
Market Size Estimation for Aggregates: Demand Europe, US, Asia





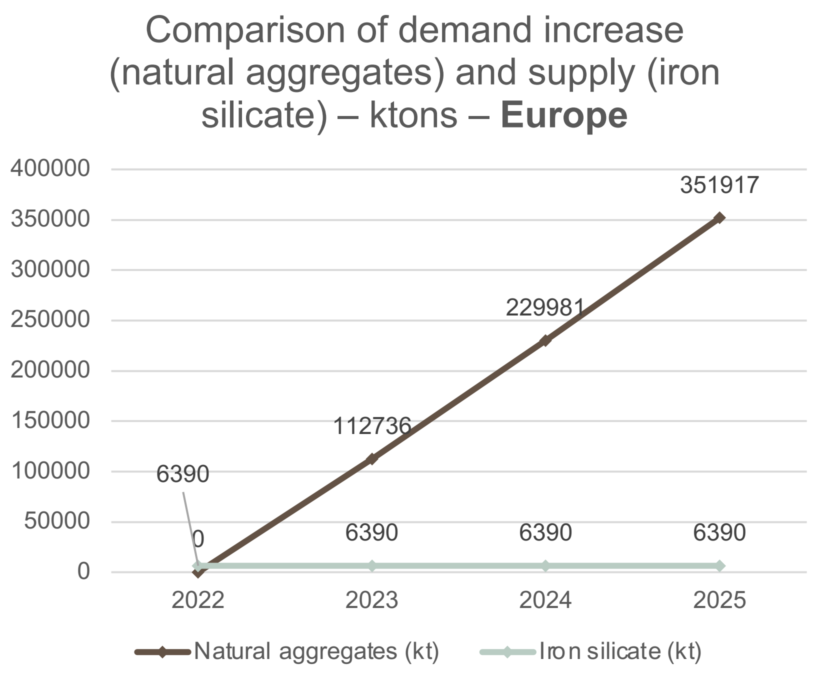


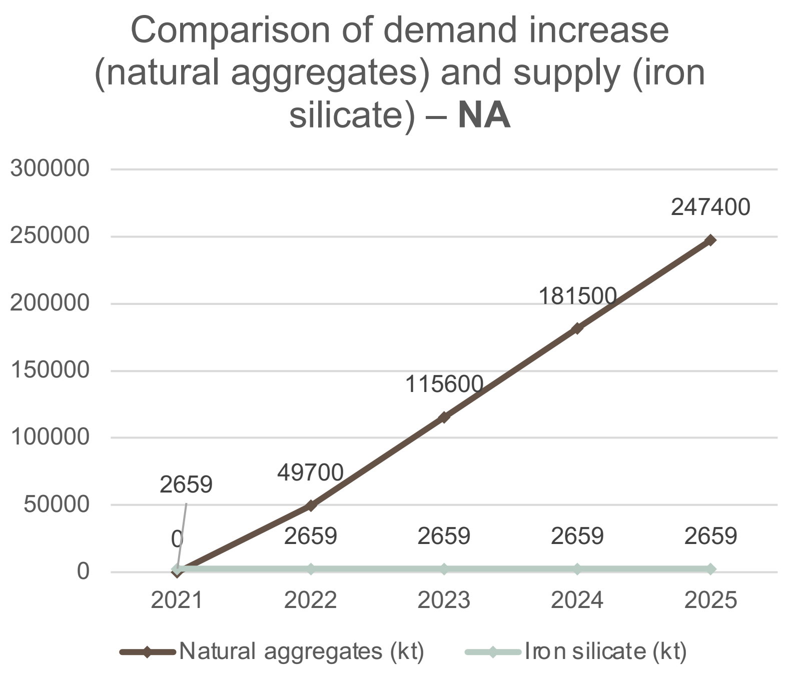
In 2018, the demand for natural aggregates in Europe was ~3 bn tons and is expected to grow to 3.2 bn tons in 2025

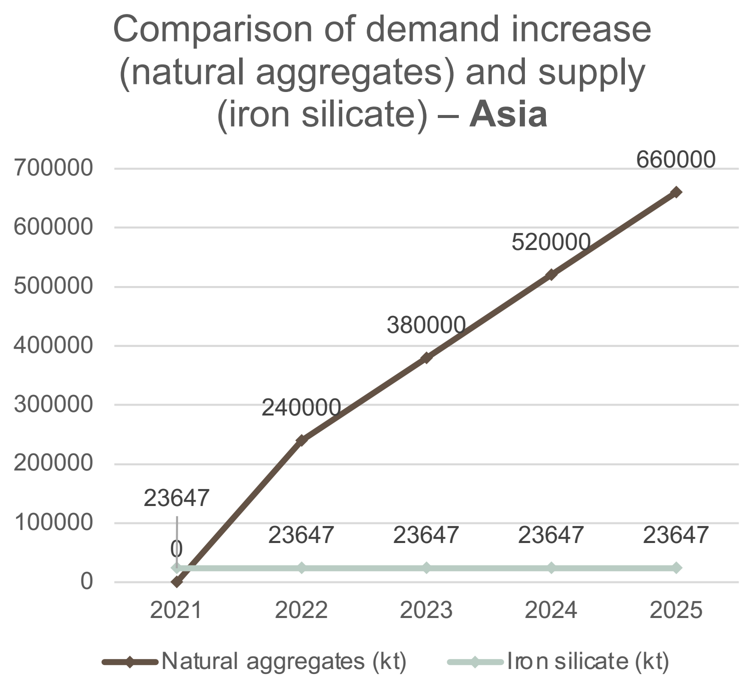
In 2021, the demand for natural aggregates in the US was ~2.6 bn tons and is expected to grow to 2.85 bn tons in 2025

In 2017, the demand for natural aggregates in China alone was ~19.5 bn tons and is expected to grow beyond 20 bn tons by 2025

Matching demand and supply: Europe, North America, Asia







There is a big opportunity for copper producers in all regions, as the amount of iron silicate generated will be able to substitute, or offset, natural aggregates, in a manner that will not significantly nor durably affect the aggregates industry or cause disruptions in the market (e.g., job loss).

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Cost-benefit analysis for the iron silicate case

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Cu producer perspective

Cost of landfilling slags > Cost of treating slags + Revenues from selling iron silicate

Status quo | Industrial symbiosis

Landfilling costs are company-specific

Slags treatment costs are company-specific

Landfilling costs and taxes vary greatly from region to region (in EU, can be 80+ €/ton)

Costs for landfilling are on the rise -> lower feasibility line

Natural aggregate user perspective

Price of natural aggregates in the region of reference > Price of iron silicate set by Cu producer based on the cost of treatment

Status quo | Industrial symbiosis

Natural aggregates costs are region-specific, and depend on the quality

(e.g., in US expected 13$/ton in 2025)

Natural aggregates costs are rising, especially in US and EU. This is good for Ind Symb ->lower feasibility line.

- A detailed cost-benefit analysis needs to be done on a company-by-company basis to conclude on feasibility

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Repurposing EV Batteries for Energy Storage System (ESS)

- Environmental Assessment
- Market Analysis

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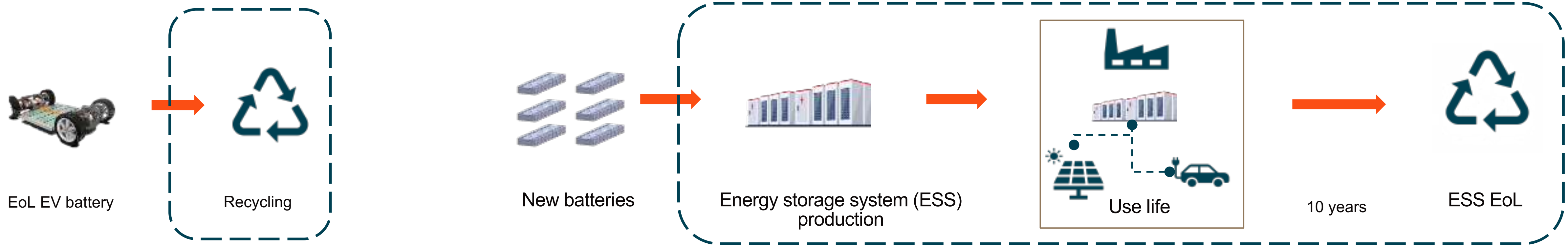
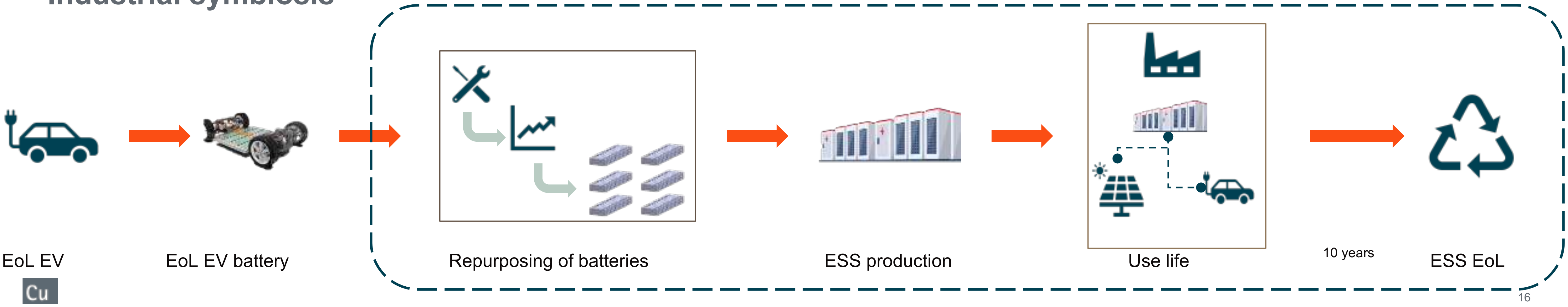
System boundaries

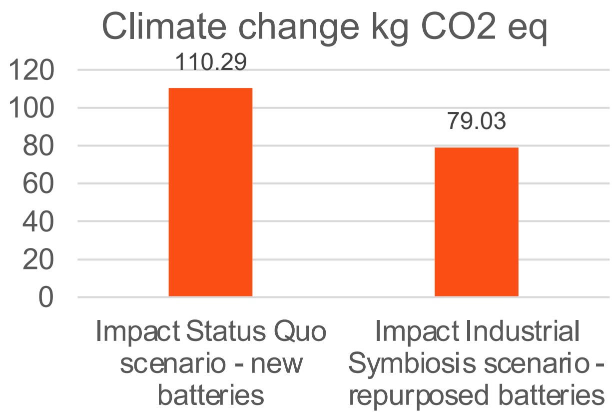
Status quo

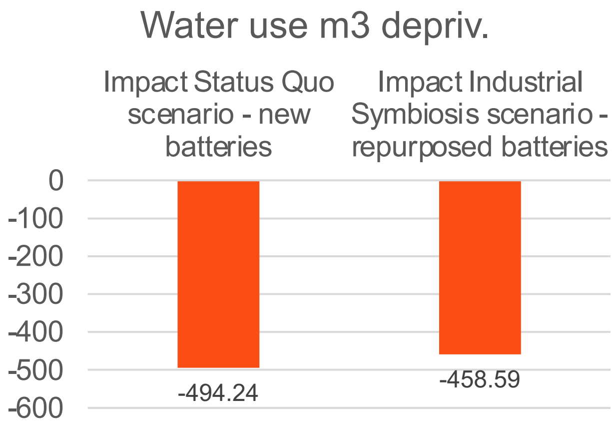


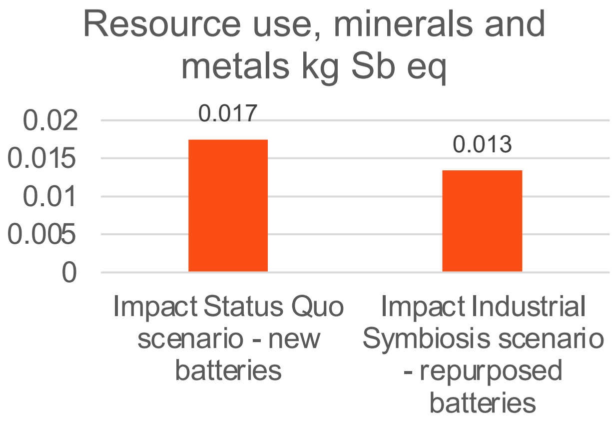
Industrial symbiosis

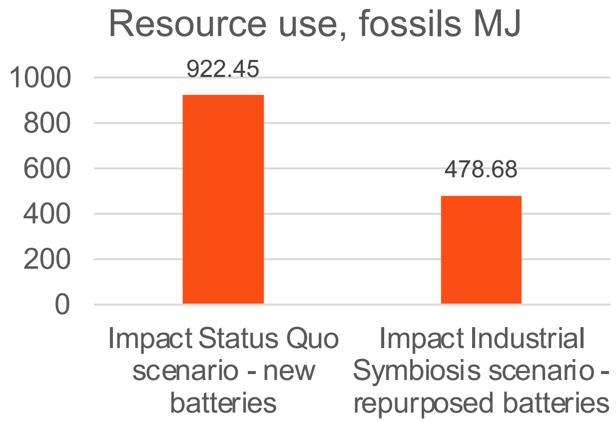


Environmental benefits









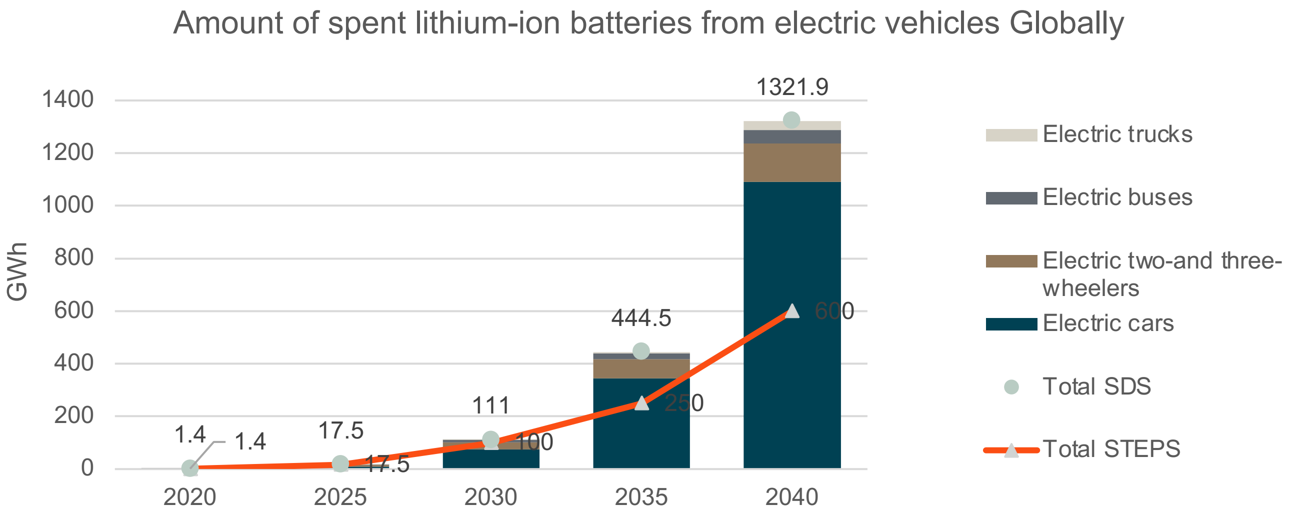
- The industrial symbiosis scenario scores better in the impact categories climate change, resource use, fossils, and resource use, minerals and metals.
- The status quo scores better in water use, but this is due to a double presence of the recycling stage.

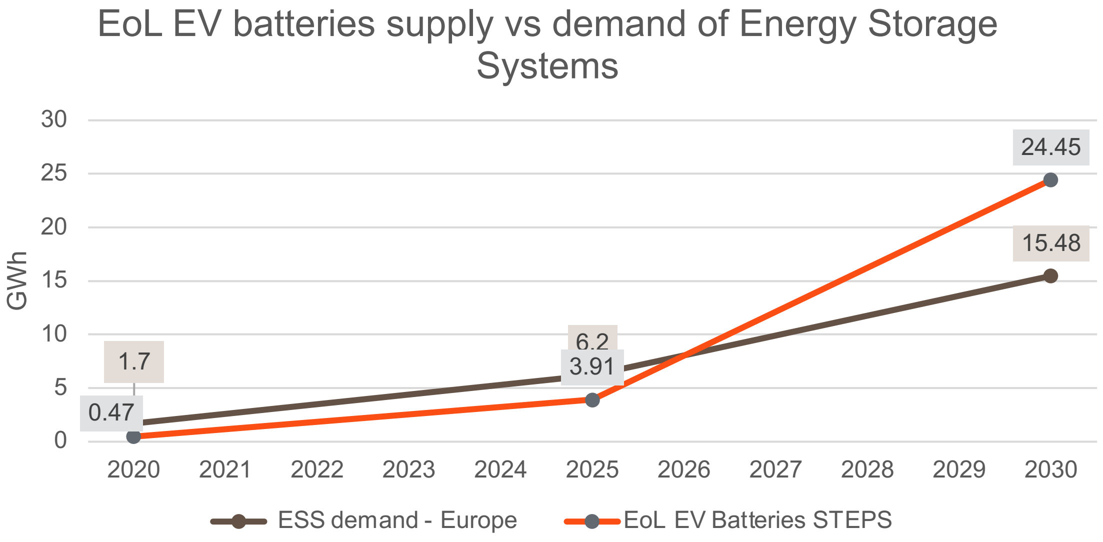
The environmental impacts associated with the use of repurposed EV batteries instead of new ones for Energy Storage System applications favor the Industrial Symbiosis scenario

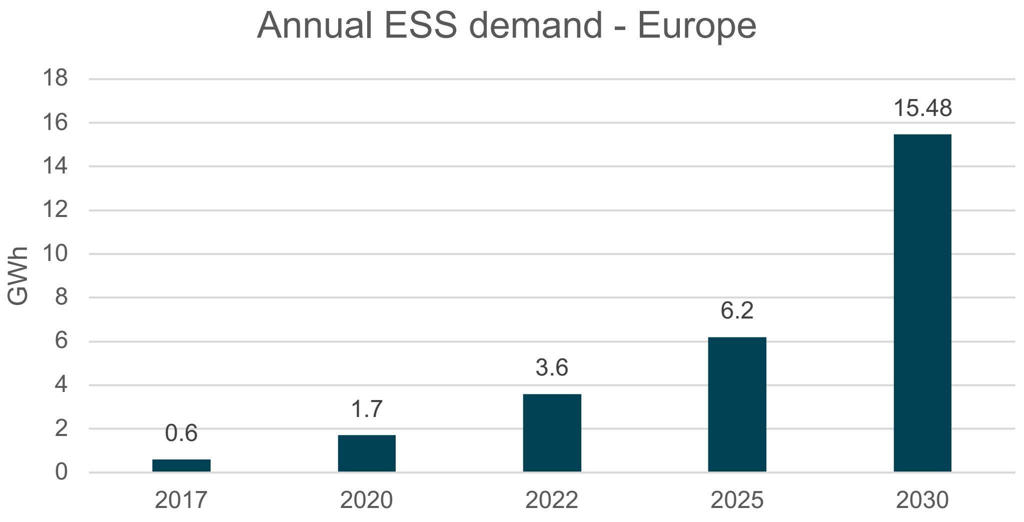
Matching demand and supply

By 2030, the volume of EV batteries reaching the end of their first life will rise from 1.4 to about 100-178GWh globally, and to 25GWh In Europe.

By 2030, the market demand for Li-ion batteries could grow from 75 to ~860 GWh at a global level, 8% of which will be installed as energy storage solutions, and to 16GWh in Europe.







Sources: IEA. and IDTechEX projections
SDS: in IEA sustainable development scenario (i.e., indicating what would be required in a trajectory consistent with meeting the Paris Agreement goals)
STEPS: in IEA's stated policies scenario (i.e., indication of where today's policy measures and plans might lead the energy sector that fall far short of the world's shared sustainability goals)
* Including electric cars, buses, two and three wheelers, and trucks

Battery producer

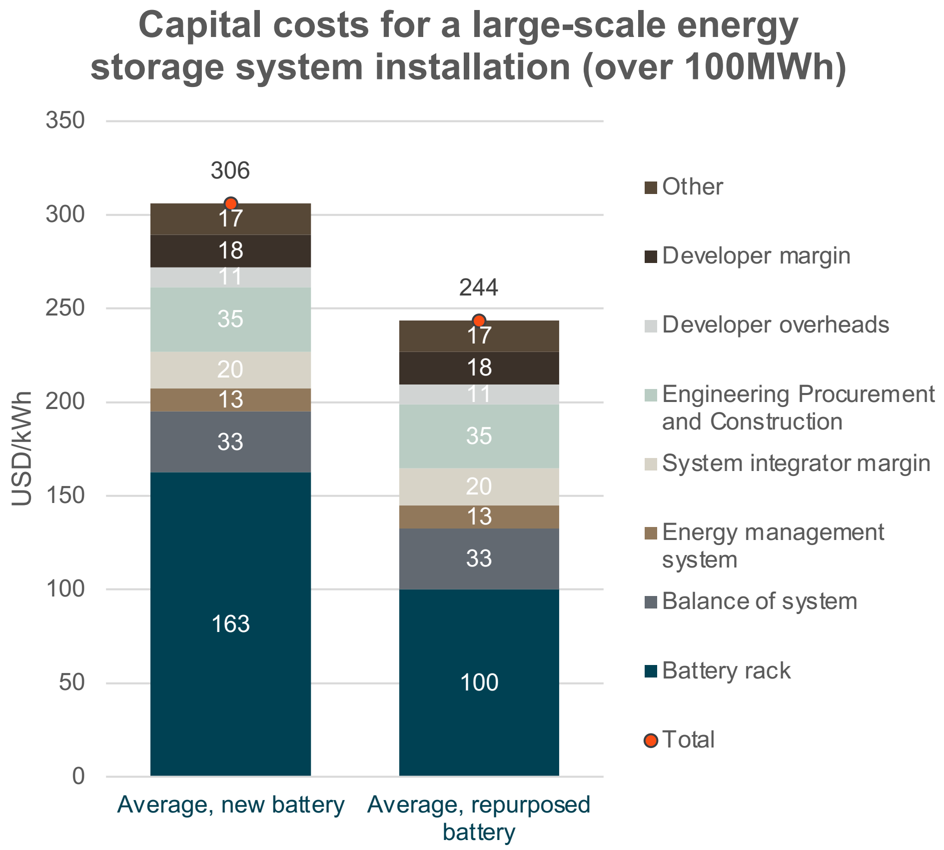
- Cost of recycling: 2,000 – 3,000 EUR/ton of battery recycled
- Cost of repurposing: Zero (this cost is borne by the user)

It is attractive for the EV manufacturers to repurpose their spent batteries compared to paying the cost of recycling

Battery user

- Cost of ESS with new battery: 149–176 USD/kWh
- Cost of ESS with repurposed battery: 40–160 USD/kWh

According to 2019 battery prices, the cost of a repurposed battery could be potentially lower than that of a new battery if the repurposing costs remain competitive



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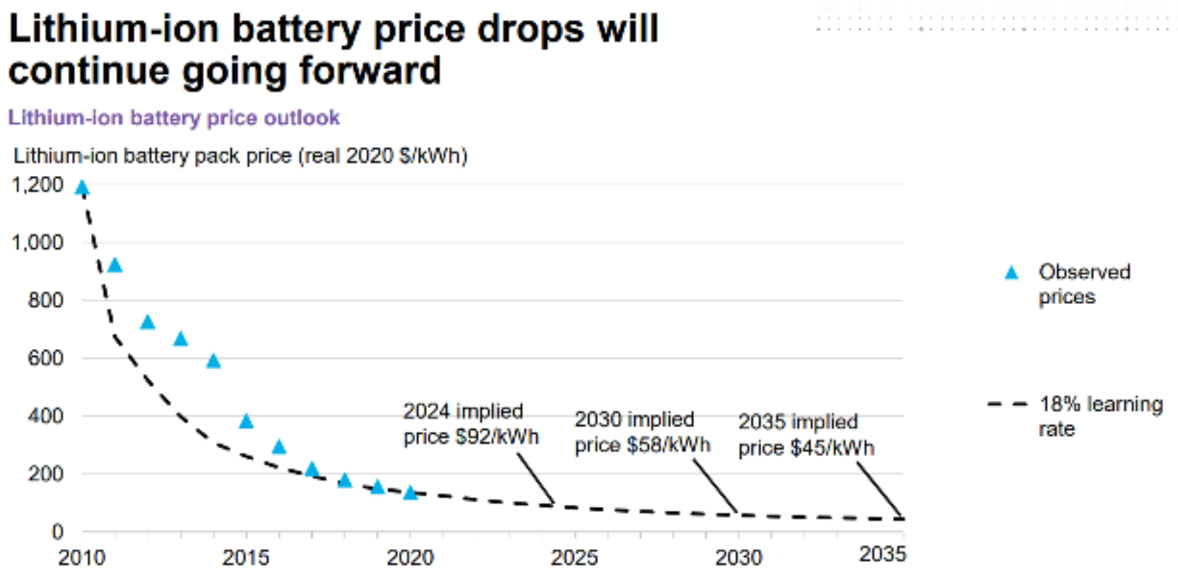
EoL EV Batteries: Cost Analysis

Cost range of new ESS (resources user perspective)

- Cost of new Li-ion batteries for ESS between 149-176 USD/kWh as of 2020
- There is a clear trend in the forecasts that **cost will tend to go below 100 USD/kWh** within the next decade
- Being the key drivers:
    - Improvement of the manufacturing processes
    - Use of materials that cost less or use of materials that provide greater energy density in the anode
    - Growth of the EV market which will drive economies of scale in battery production



Sources: Bloomberg NEF 2021 (Note: Data based on a 2020 battery price survey) and Zhu J., et al 2021.

This price trend must be considered by battery repurposers, since the cost of repurposing must remain lower than the costs of new batteries to ensure feasibility

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Conclusions

- Other aspects to be considered

Industrial Symbiosis for Iron Silicate: Conclusions

Main benefits of industrial symbiosis

- Environmentally speaking, production and use of iron silicate and its substitution in in construction materials such as gravel and stones for concrete results beneficial compared to the status quo
- From a market perspective, opportunities for iron silicate producers to find a market for iron silicate are on the rise
- From a cost-benefit perspective, price trends tend to go in favour of industrial symbiosis, in general

Considerations and challenges

- Transport can have a negative effect on the environmental and economic feasibility of industrial symbiosis
- From a societal perspective, if industrial symbiosis is not economically feasible for one or both stakeholders involved,
  - It can still be made possible if a public authority intervenes by incentivizing it because of sustainability reasons, including circular economy considerations

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Industrial Symbiosis for EoL EV Batteries: Conclusions

Main benefits of industrial symbiosis

- Environmentally more advantageous than the status quo in terms of carbon emissions and resource use (both mineral and fossil)
- From a market perspective, current data and forecasts indicate enough supply of spent EV batteries to cover the demand of ESS in large-scale commercial applications
- From a cost-benefit perspective, the capital costs for large-scale ESS installations with repurposed batteries are lower than those of using new batteries
- It is cheaper for the EV manufacturers to repurpose spent batteries than recycling them

Considerations and challenges

- From the battery repurposer and ESS user perspective, it is crucial that the repurposing costs + residual battery value remain lower than the cost of a new battery to ensure economic feasibility
- EV manufacturers may be reluctant to repurpose spent batteries to avoid having their batteries copied and to retain the access to raw materials for new batteries. This is a potential barrier to industrial symbiosis

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Thank you!

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