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# Lignode - Making batteries out of trees

Using lignin-based hard  
carbon to make lithium-ion  
batteries more sustainable

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# Welcome movie



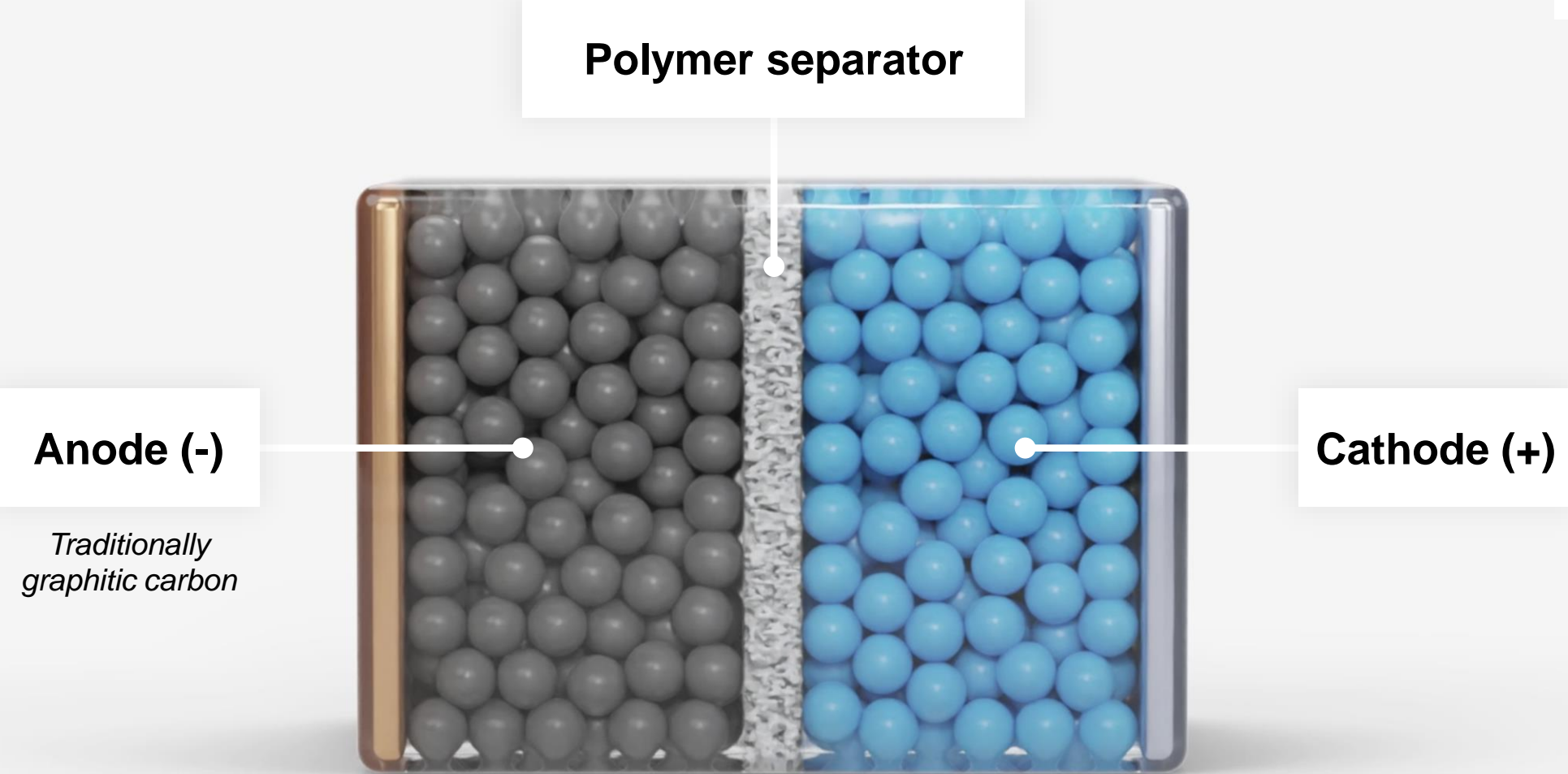
Lignode® by Stora Enso - Bio-based materials | Stora Enso



## **The future is electrifying, and sustainable solutions are needed**

- It is expected that close to 80% of new cars sold in Europe by 2030 are electric
- Electric batteries are enabling this change; battery industry is expected to rise tenfold in ten years – scalable solutions are needed
- Over 50% of an electric car's carbon footprint comes from its battery; the electrified future needs sustainable development

# How a lithium-ion battery works



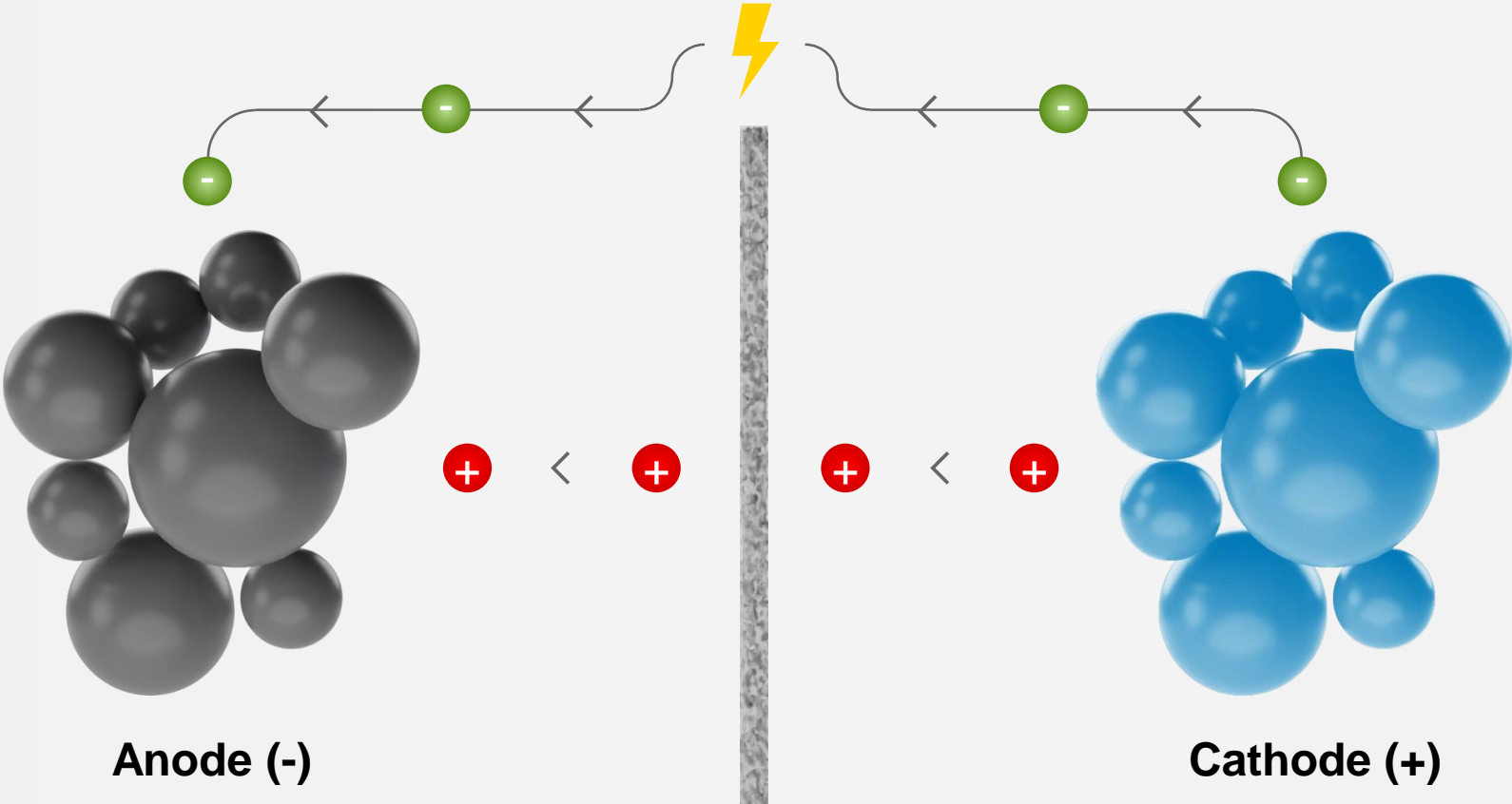
**Anode (-)**



*Traditionally graphitic carbon*

**Polymer separator**

**Cathode (+)**

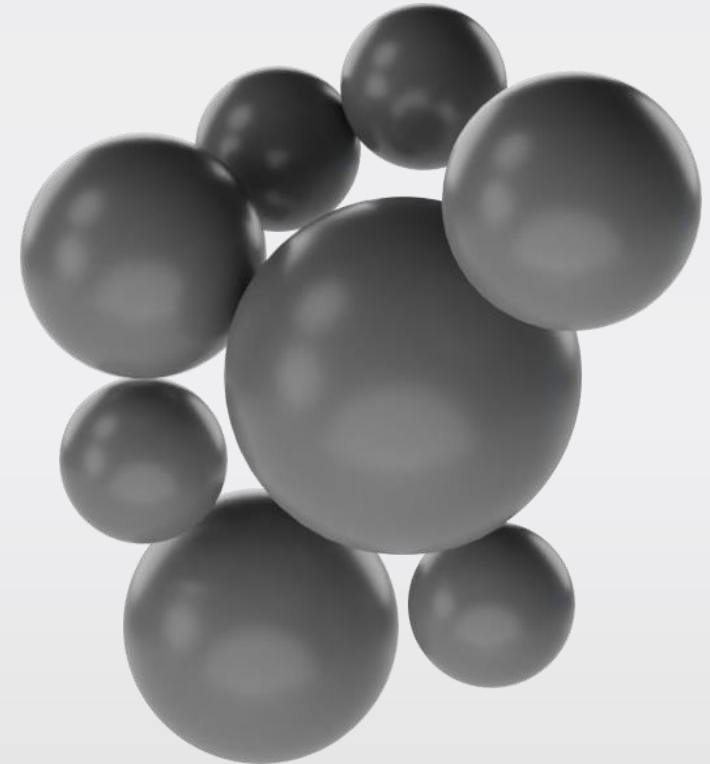
# How a lithium-ion battery works



 *Lithium ion*     *Electrode*

# What's the problem with graphite?

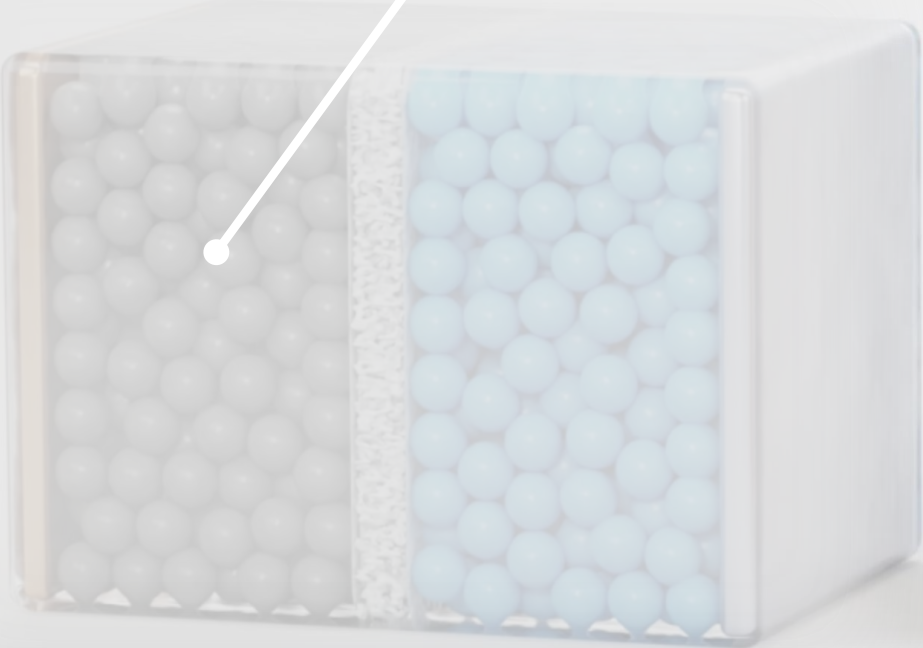
- The extraction of graphite through mining is often done **under less than satisfactory conditions**, mostly in China and Africa.
- **Environmental and societal consequences** as a result.
- Graphite is a strictly layered material which can be **slow to charge**.
- **Fossil-based** – it is not a sustainable material to rely on for future battery production.



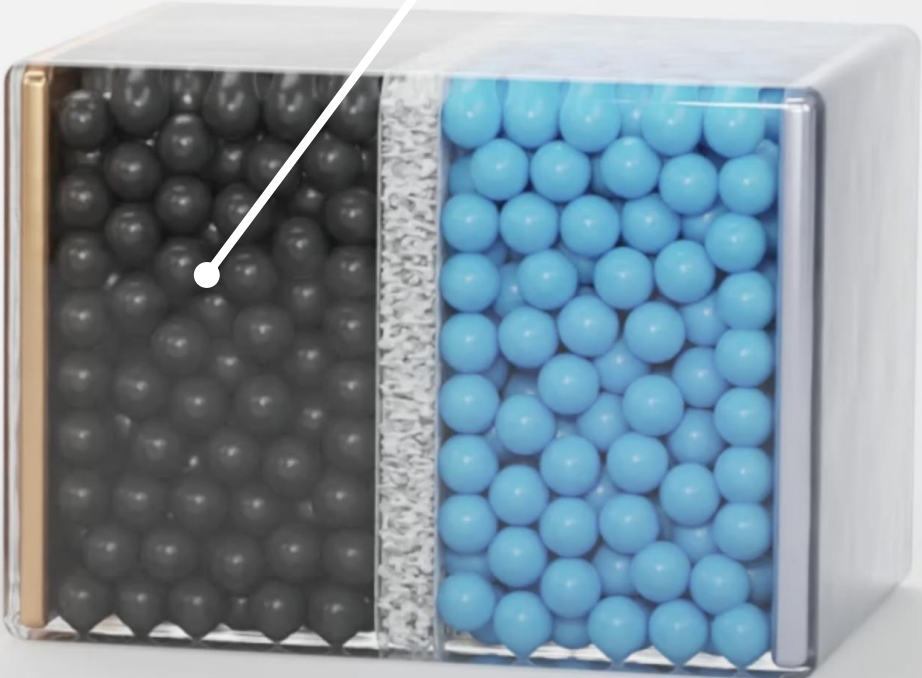
# A more sustainable alternative to graphite



**Graphitic carbon**



**Renewable hard carbon**







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# What is renewable hard carbon?

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## Hard carbon is made from lignin

- Trees consist of 30–40% lignin
- Lignin is already a by-product in the renewable production of cellulose fibers
- Millions of tonnes produced in Europe every year
- From traceable and certified sources

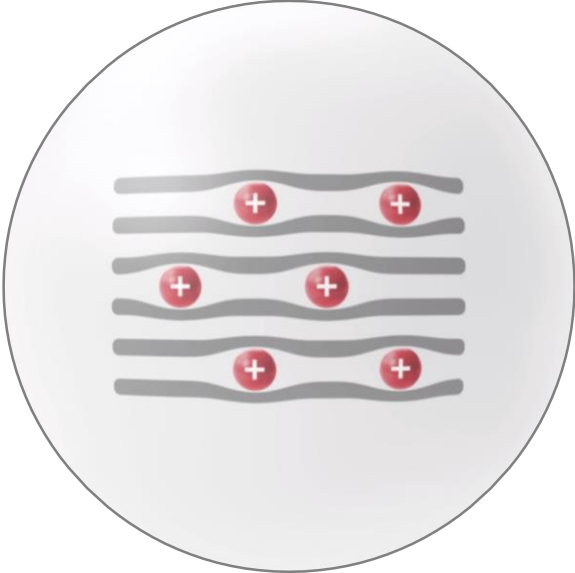
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## Technical advantages of hard carbon

- Faster charging and discharging
- Higher cycling stability
- Performs better at low temperatures
- Can be mixed with graphite for some applications, for mixed properties

# An amorphous, highly open structure – enabling faster charging and discharging



**Graphitic carbon**



**Lignin-based hard carbon**



# Hard carbon to complement or replace Graphite as Anode Material in Lithium-Ion Cells



	Pure hard carbon	Hard carbon / graphite mixtures	Pure graphite
Fast charging/ discharging ability	+++	++	0
Low temperature performance	+++	++	0
Electrolyte versatility	+++ <sup>(1)</sup>	0	0
Cycling stability	+++	++	0
Cell voltage	–	0/– <sup>(2)</sup>	0
Energy density, gravimetric	0/– <sup>(2)</sup>	0/– <sup>(2)</sup>	0
Energy density, volumetric	– –	0/– <sup>(2)</sup>	0

(1) Hard carbon allows the use of EC-free electrolytes (EC = ethylene carbonate)

(2) Effect depends on amount of hard carbon





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## Large scale production underway

- We're now prototyping for large scale production
- Sunila plant is up and running



## Sunila Plant

- 50,000 tonnes of lignin capacity in Stora Enso's Sunila Mill, Finland
- Largest producer in the world
- Nordic softwood from certified forests
- Lignin is extracted during existing cellulose fiber production
- Can provide the market with hard carbon at commercial scale – without any additional use of forest resources

# With Sunila plant we are validating our earlier work and completing customer qualification work



**Anode manufacturing**



**Cell testing**

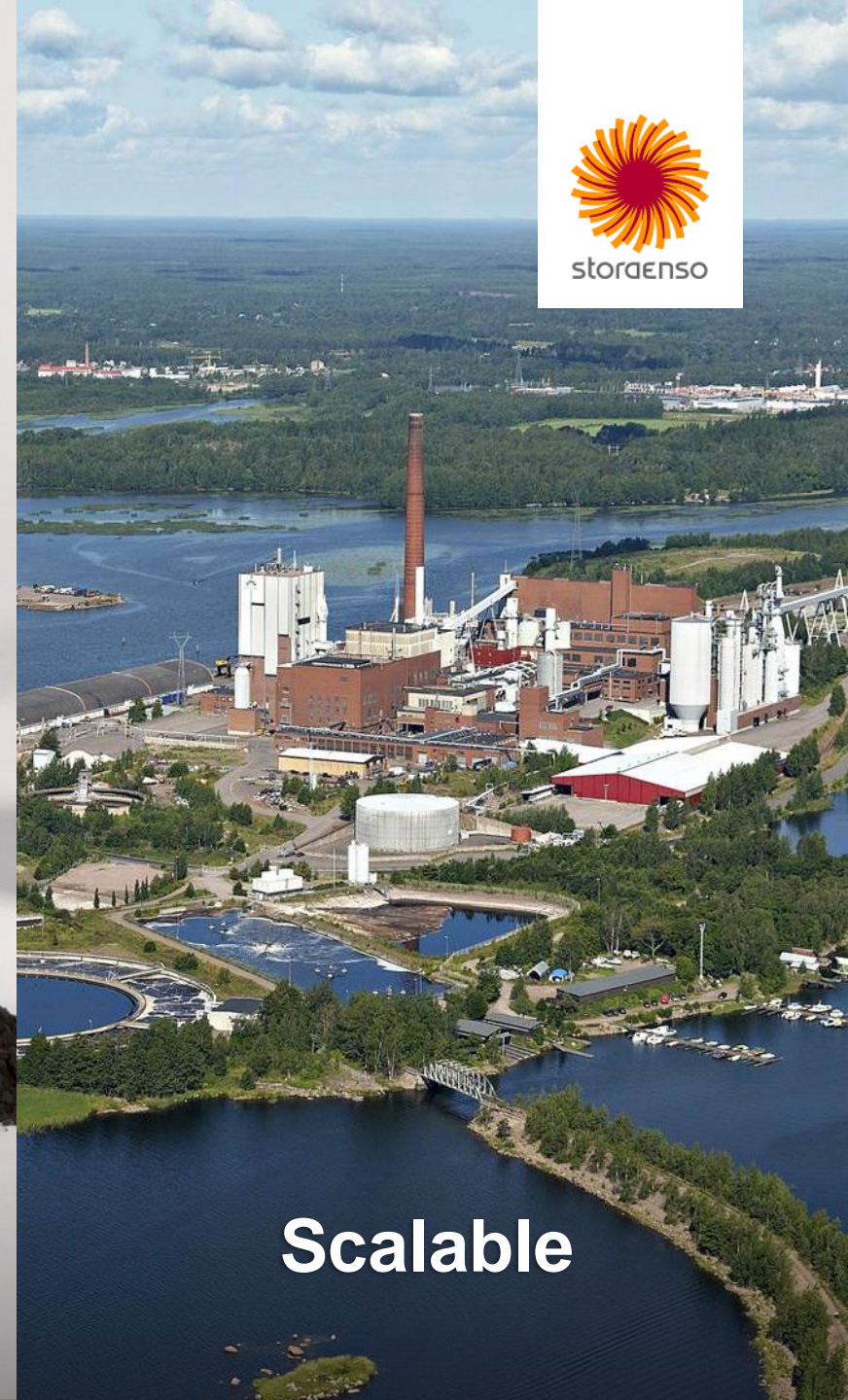


# Summary

**Sustainable**



**Competitive**



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**Scalable**



## Sustainable

- Anode active material based on lignin – a renewable biorefinery product from trees.
- Target to offer the most sustainable and lowest impact anode material available, to meet the eco-friendly mindset of future consumers.
- Effective use of the whole tree; using an existing by-product doesn't increase the consumption of forest.
- Superior traceability with sustainable raw material management certificates.



## Competitive

- Hard Carbons can replace natural or synthetic graphite in parts or completely.
- 100% hard carbons are state of art for high power cells or high-rate cells.
- Mixtures result in hybrid cells with disproportional benefits from both sides.
- An amorphous, highly open structure enables faster charging/discharging and higher cycling stability.



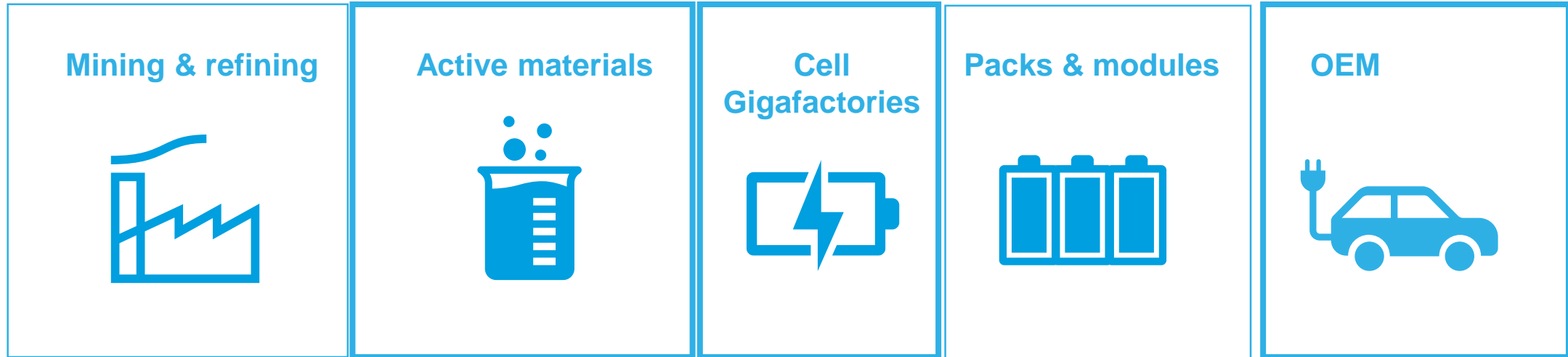
## Highly scalable

- Commercial lignin extraction at Sunila Mill, southern Finland.
- EUR 10 million investment into pilot production line for anode production, operational in 2021.
- Scalable to more than 300+ ktons per year of carbon anode powder in Europe alone.
- Addressing European supply chain needs.

# Partnering in the value chain is key to get speed



## Value chain



- **Gain credibility as a supplier in the battery value chain**
- **Speeding scaling up of the technology: process scaling and product acceptance/qualifications**

# Enabling a faster scale-up to reach our ambition



For the partnership company the ambition is 5 anode mills in the next 5 years, 80-100ktons

- ~ 15% market share in Europe
- ~ EUR 1 billion sales
- ~ 50% EBITDA margin potential
- ~ Estimated investment EUR 1.0-1.5 billion for the partnership

Our existing pulp mill base in the Nordics serves as basis for the initial locations

Mills outside of Stora Enso base are also viable candidates for supply of lignin



\*Subject to completing piloting in Sunila

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# Pathway to the ambition

- Single production unit timeline from design to production is traditionally 4 years, design phase work has started early 2021. Partnering important to reduce these timelines
- Qualification processes with battery manufacturers and OEMs can take 3 years, partnering plays a very important role to reduce these timelines
- Plan includes concurrent construction of several production sites in a partnership setting with value chain partners
- Scale-up is built on standardized 20kton manufacturing units
- Building 1-2 plants/yr after piloting phase, which is estimated to take 1-2 years





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