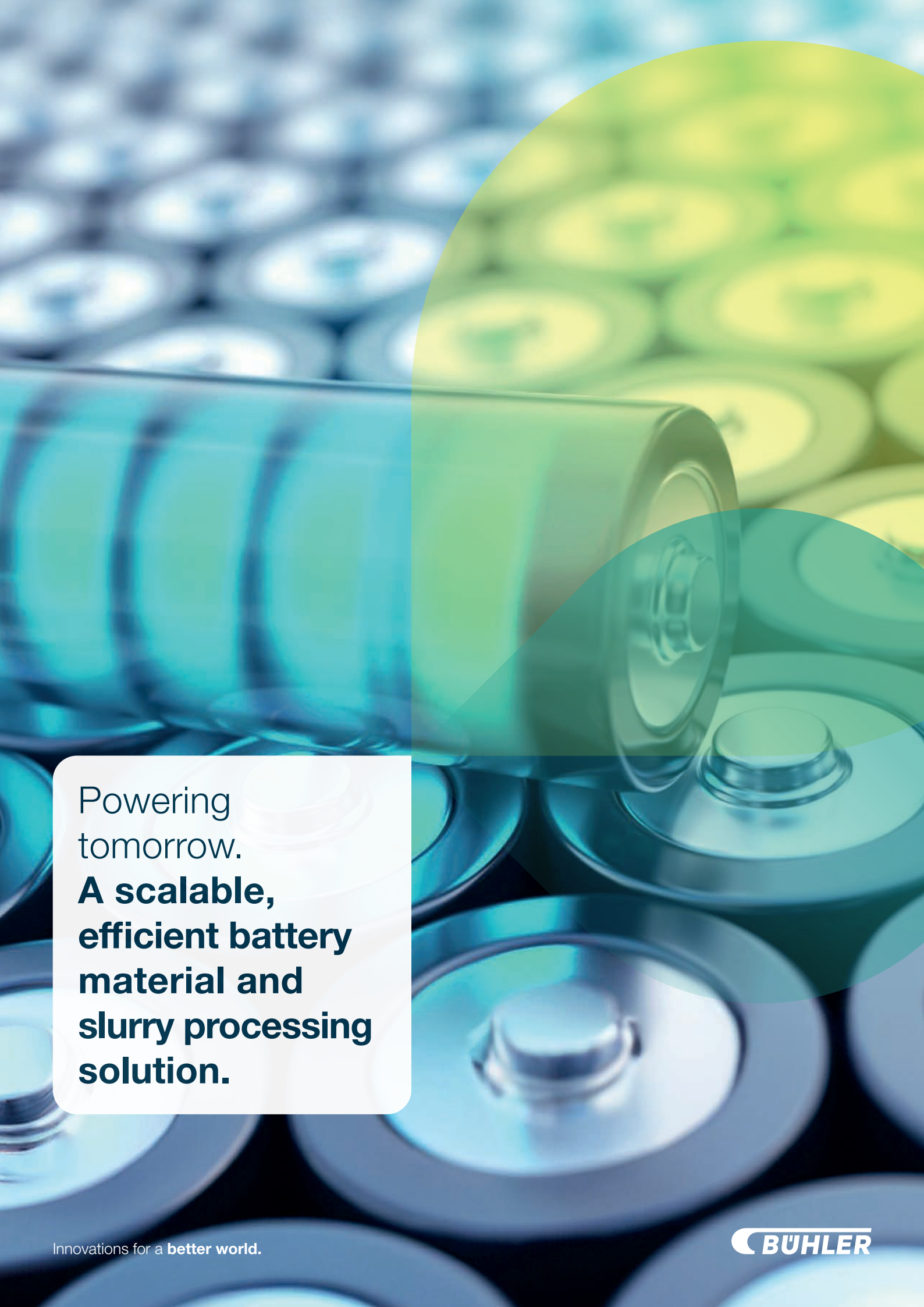
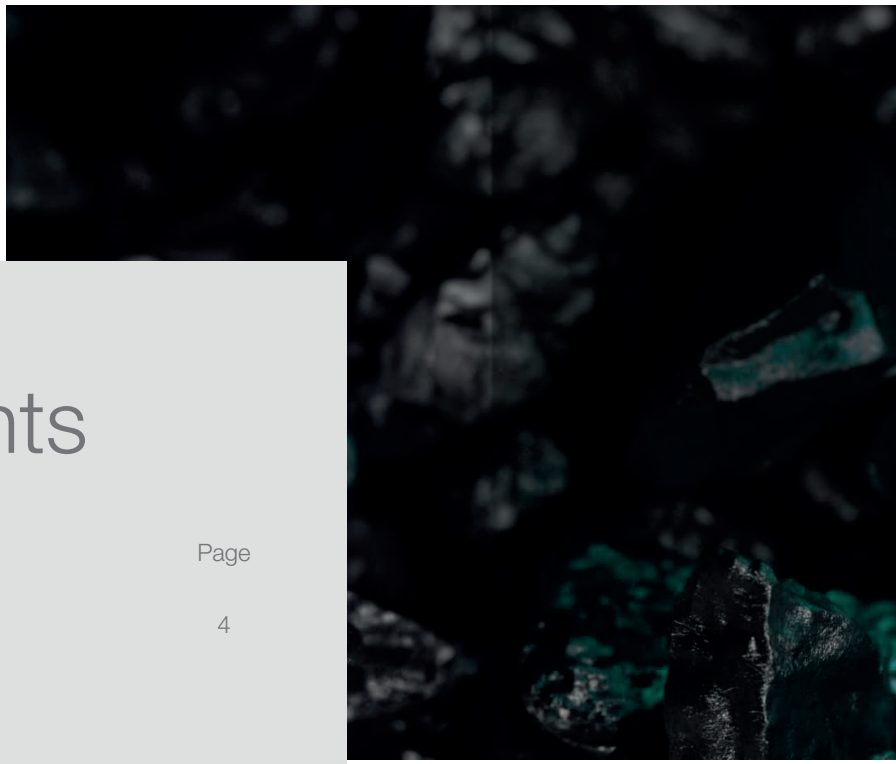

Powering
tomorrow.
A scalable,
efficient battery
material and
slurry processing
solution.
Innovations for a better world.
BÜHLER



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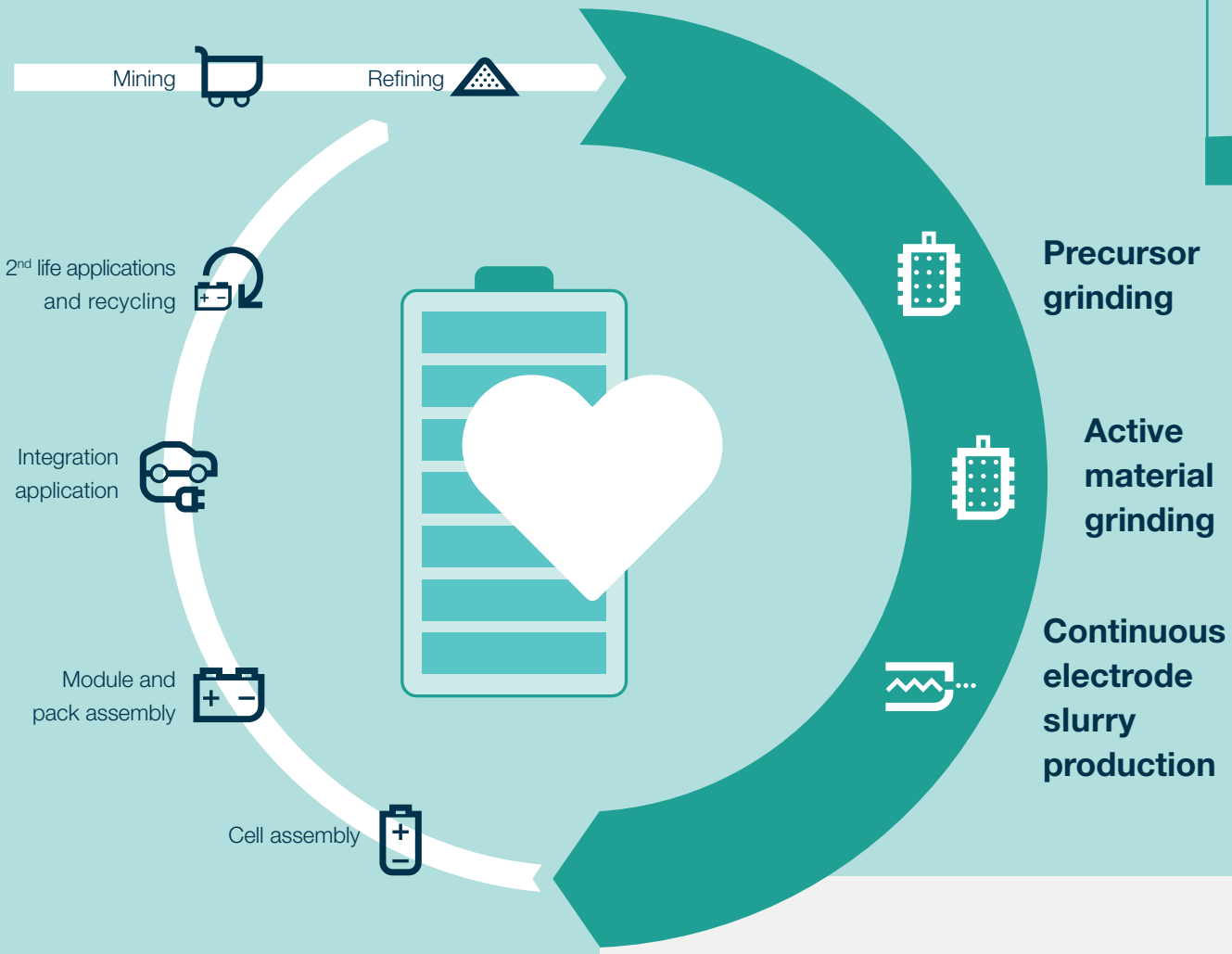
Battery-powered sustainability **with Bühler solutions.**

Growing while preserving natural resources is a key challenge that the world is facing today. Batteries are an important part of the fight against climate change. We need smaller, lighter, more powerful batteries that charge faster and last longer. The core of these batteries is formed with efficient and high-productivity manufacturing processes to produce active materials and electrodes.

Bühler is a global leader in wet grinding and dispersing technologies. We offer reliable, scalable, and industry-proven solutions for wet grinding of anode, cathode, solid electrolyte, and conductive materials and for continuous mixing of electrode formulations for lab, pilot, and large-scale production.

Our innovative solutions for producing electrode active materials and slurries support battery manufacturers in meeting demand for li-ion batteries more effectively, both now and well into the future.

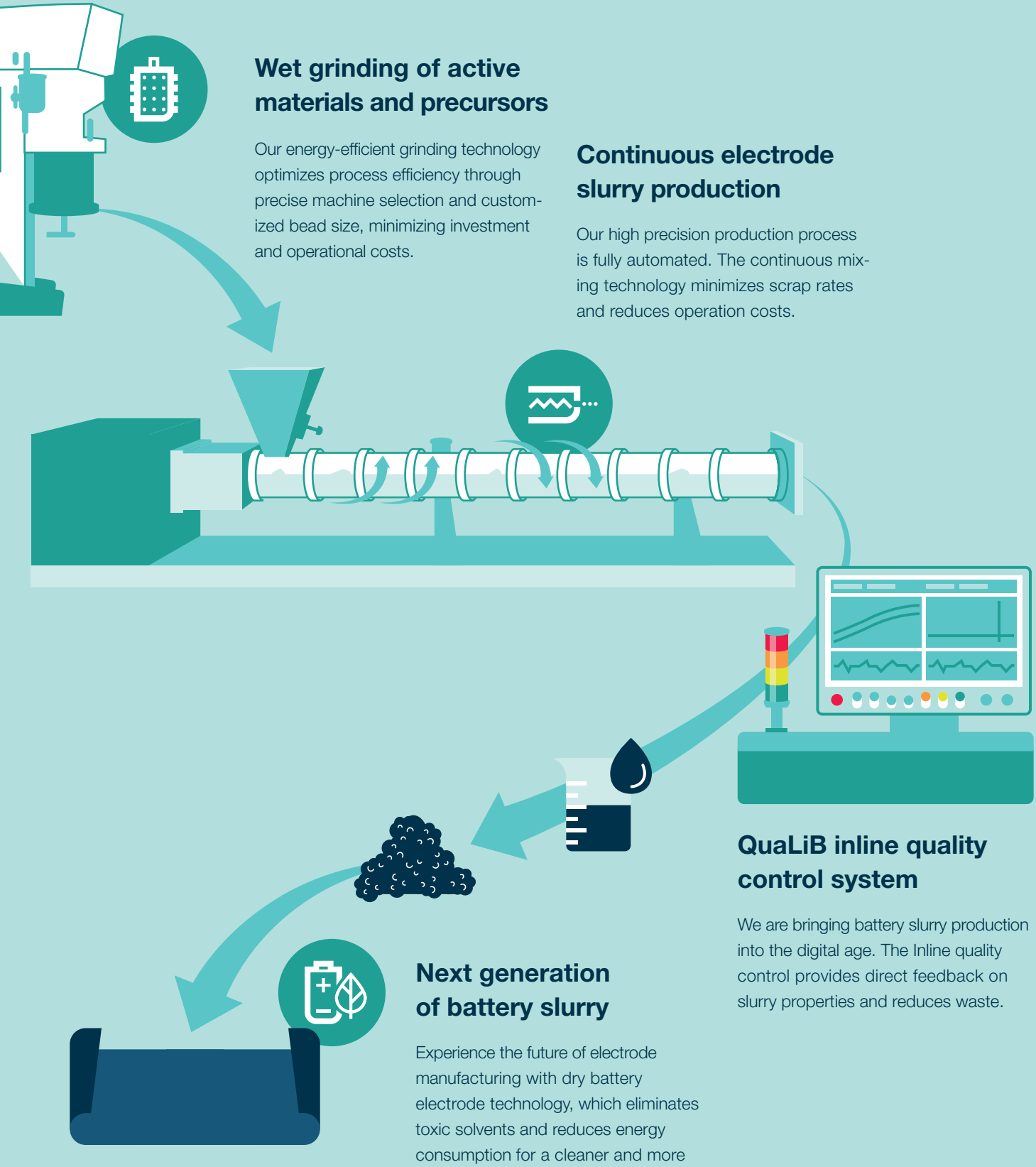
Bühler at the heart of **battery manufacturing.**



01

Your global technology partner

We support you in every phase of your project, from start to finish, including plant engineering. In our Bühler Application Labs, we develop and test every process. Bühler Services offers partnerships for better outcomes in your solution.



Wet grinding of active materials and precursors

Our energy-efficient grinding technology optimizes process efficiency through precise machine selection and customized bead size, minimizing investment and operational costs.

Continuous electrode slurry production

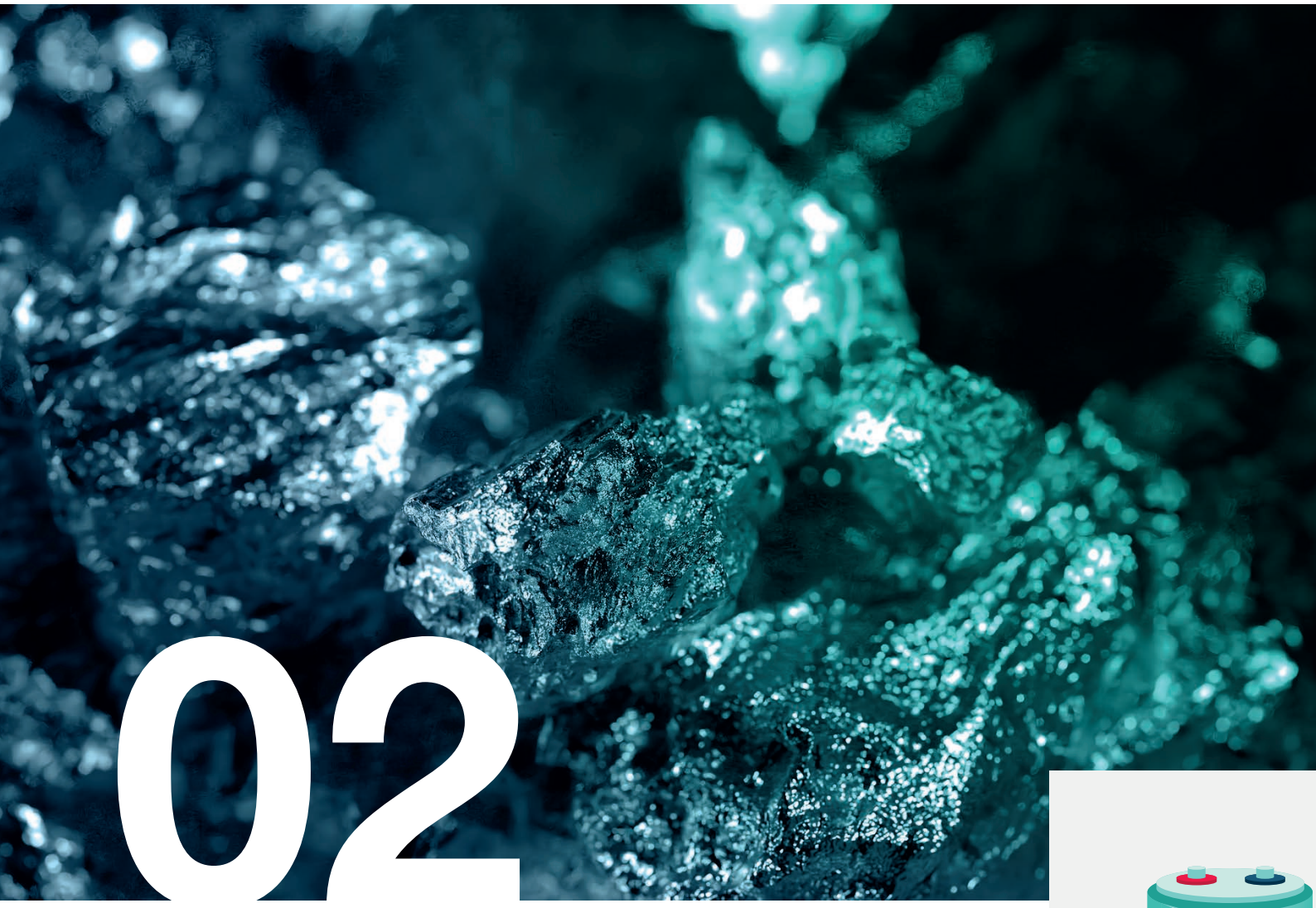
Our high precision production process is fully automated. The continuous mixing technology minimizes scrap rates and reduces operation costs.

QuaLiB inline quality control system

We are bringing battery slurry production into the digital age. The Inline quality control provides direct feedback on slurry properties and reduces waste.

Next generation of battery slurry

Experience the future of electrode manufacturing with dry battery electrode technology, which eliminates toxic solvents and reduces energy consumption for a cleaner and more sustainable energy industry.

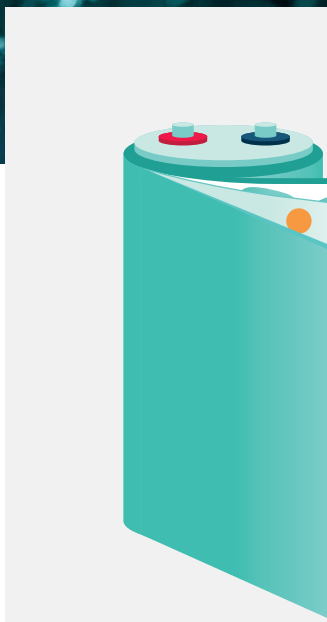


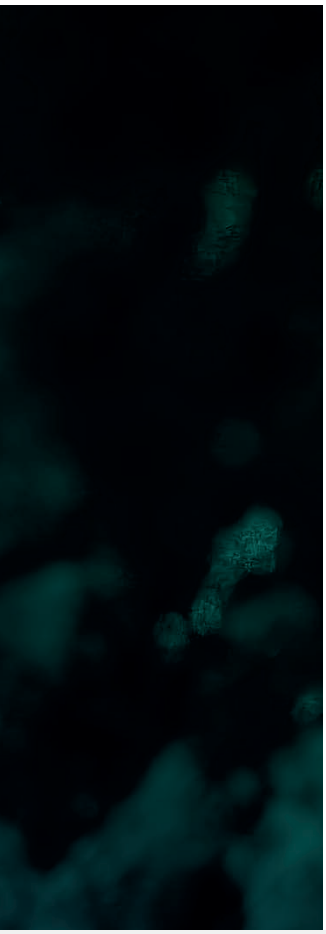
02

High performance bead mills for **precursor and active material grinding.**

With over 100 years of experience, we have unrivaled expertise in plant and machine solutions across all industries. We help you create higher-quality products with improved production processes at a lower cost.

We offer scalable, consistent and field-tested solutions to prepare active and separator materials for your li-ion battery production with our bead mill technologies.

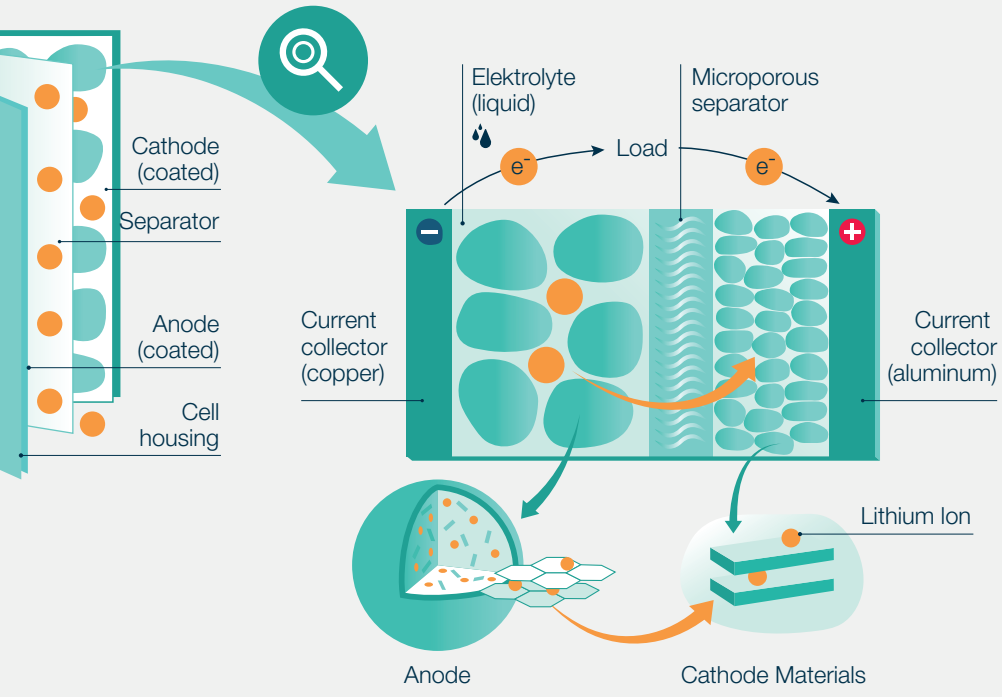




How it works

In the world of battery materials, the size and shape of the active ingredients play a crucial role in determining the final performance of the battery. This applies to anode, cathode, and electrolyte materials. For carbon nanotubes (CNTs), the degree of dispersion and homogeneity significantly affects the added value. Bühler's extensive portfolio of wet milling equipment is particularly well-suited to this industry.

Our global team assists you in selecting the appropriate type and size of machines to achieve your desired performance, eliminate unwanted contaminants, and maximize process yields. We offer comprehensive trials in our global test facilities to evaluate your specific requirements. Based on the outcomes of these trials and your unique needs, we can tailor and integrate comprehensive solutions for wet milling your active materials. We support you during the entire lifecycle of your plant with a customized service package.



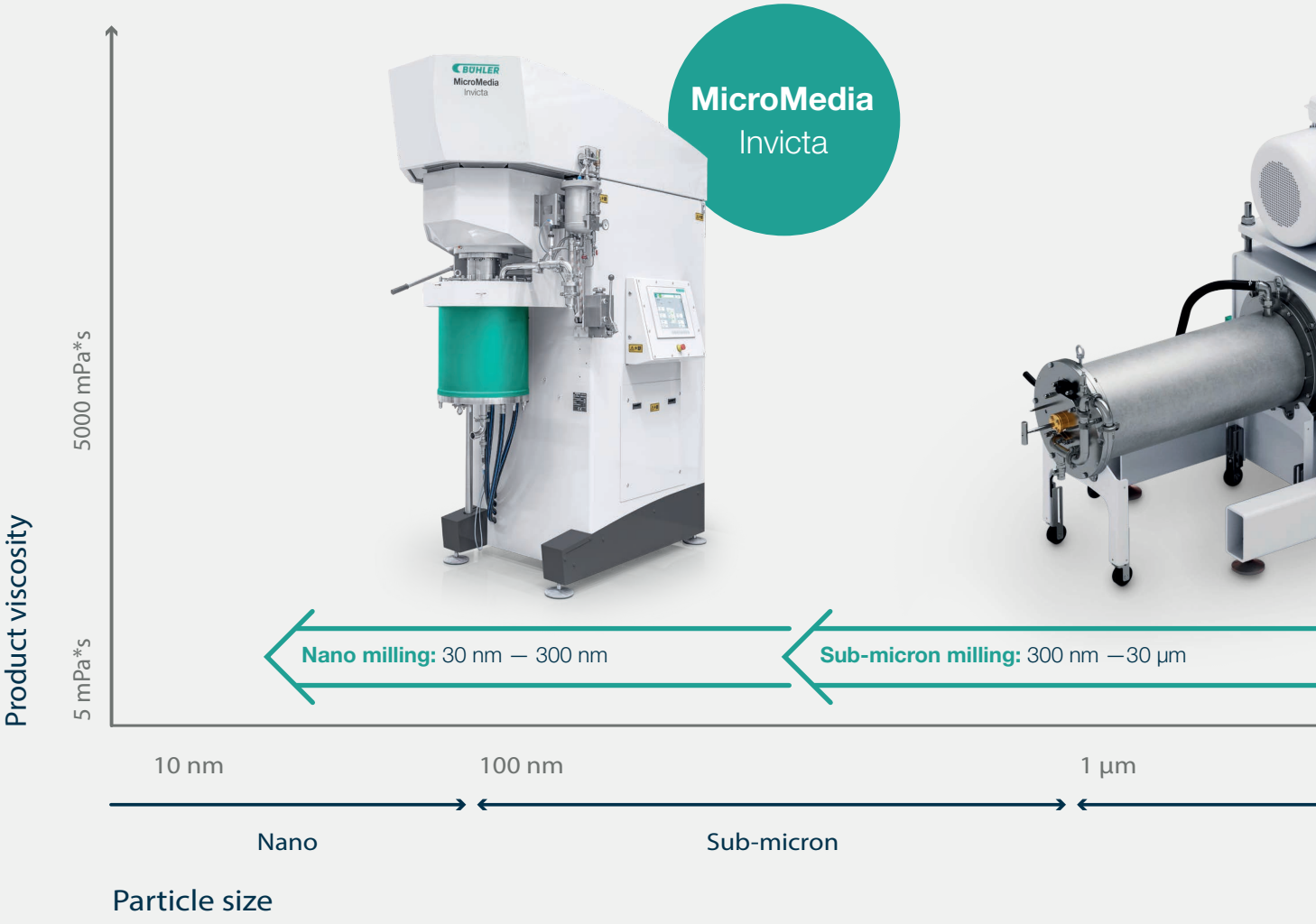
Cathode materials:

- LCO (lithium cobalt oxide)
- NCA (lithium nickel cobalt aluminum oxide)
- NMC (lithium nickel manganese cobalt oxide)
- LMO (lithium manganese oxide)
- LFP (lithium iron phosphate)

Anode materials:

- Silicon carbon composite

Wet grinding and dispersing. **Equipment map.**



MicroMedia Invicta

Drive	**5.5-110 kW**
Active volume of processing chamber	**1.6-40 l**
Applicable diameter of beads	**50-800 µm**
Flow rate	**up to 10,000 l/h**
Dimensions	**H: 2997 mm | L: 2250 mm | W: 1050 mm**
Weight	**4350 kg**

Cenomic

MacroMedia

Pre-milling: 30 µm — 1 mm

10 µm | 100 µm | 1 mm

Micron | Coarse

Cenomic

Drive	**315 kW**
Active volume of processing chamber	**10-1000 l**
Applicable diameter of beads	**300-2000 µm**
Tip speed	**8-13 m/s**
Dimensions	**H: 1800 mm | L: 2200 mm | W: 910 mm**
Weight	**2200 kg**

MacroMedia

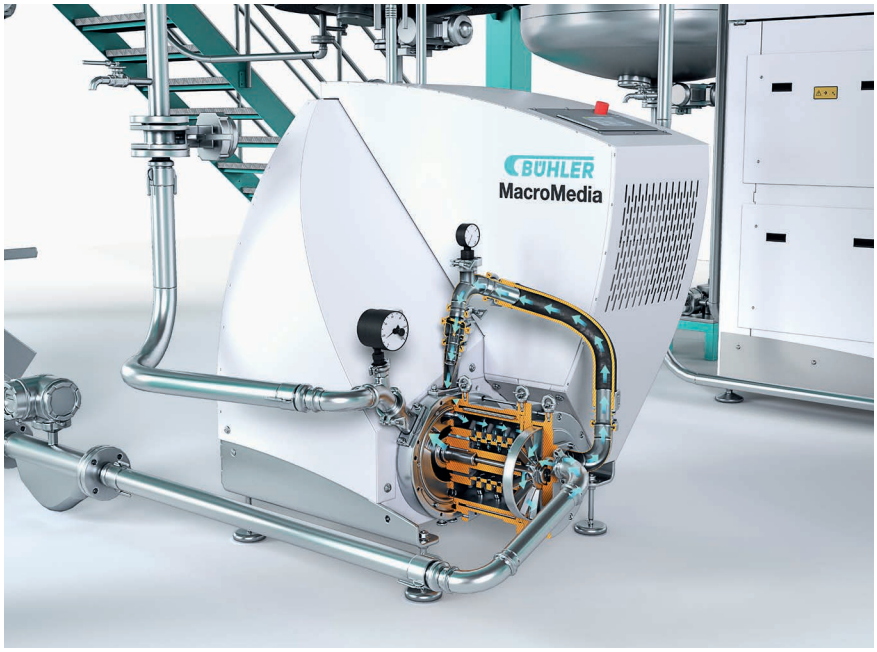
Drive	**18.5 kW**
Active volume of processing chamber	**up to 6 l**
Applicable diameter of beads	**3000-5000 µm**
Flow rate	**up to 15 m³/h**
Dimensions	**H: 1400 mm | L: 1250 mm | W: 900 mm**
Weight	**800 kg**

The right bead mill
for every precursor and active material.

Bühler offers a range of bead mill solutions designed to meet the specific needs of various materials. Understanding the particle size requirement is crucial in selecting the optimal option. No matter which cathode or anode material you're working with, we have customized solutions to optimize your grinding process

MacroMedia

The MacroMedia pre-dispersing solution is revolutionizing the wet grinding process. It improves the quality of the final product, speeds up processing and cuts costs. The MacroMedia is a profitable solution for companies of any size in a wide range of industries.

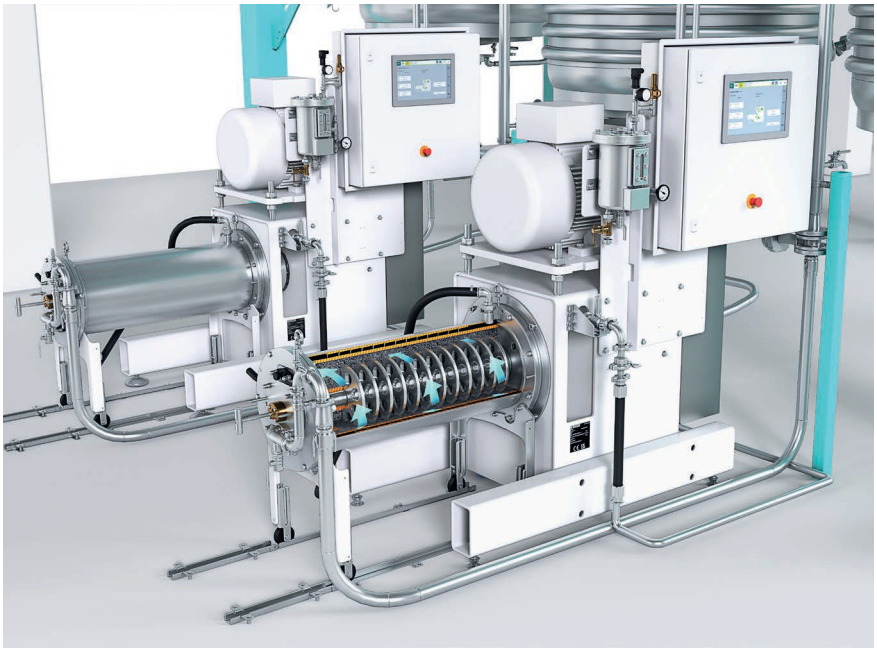


The combination of a high-performance pump and small volume grinding unit makes it unique in the market. Improved process control in the pre-grinding stage balances fluctuating raw material qualities and achieves uniform properties for the pre-ground intermediate products.

The MacroMedia achieves high throughput rates, homogeneous mix qualities and excellent particle size distribution with minimum space – providing the ideal basis for subsequent fine grinding, with a Bühler MicroMedia or Cenomic bead mill, for example.

Cenomic

The new Bühler Cenomic takes agitated bead mill technology to the next level, offering increased flow rates, higher power inputs and improved cooling to boost overall productivity by up to 25%-50% compared to conventional horizontal bead milling.



Ceramic inner liner for better cooling

The thermal conductivity of a ceramic jacketed chamber enhances cooling efficiency by six times compared to steel.

The material enhances the service life of the part, extending the time before it needs to be replaced.

More discs for better bead activation and faster wet grinding

More discs in the chamber lead to better bead activation, narrower particle size distribution, and extended service life. The Cenomic introduces innovative improvements for faster, smoother wet grinding, maintaining the same footprint for easy replacement or upgrade.

MicroMedia Invicta

The MicroMedia Invicta introduces a step-change in bead mill technology, with innovative chamber design and an improved bead separator system for remarkable benefits in wet grinding.

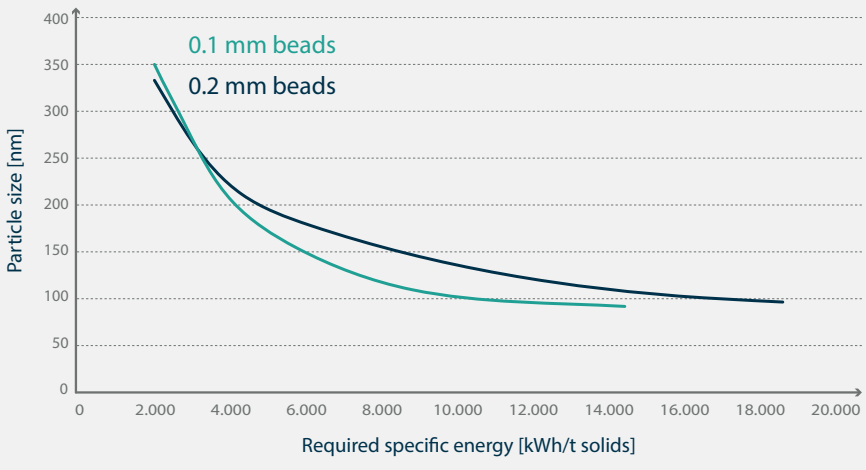
Unique design saves costs and energy

The unique vertical design of the Bühler Invicta uses gravitational pull to create less mechanical wear and tear on the shaft and seal mechanics while ensuring robust rotor control. It minimizes the distance between sieve and rotor for higher centrifugal force that prevents bead blockage. We can use much smaller beads compared to a typical horizontal design, resulting in higher energy efficiency. With Invicta technology, we can go below industry-standard 0.2mm size bead and use 0.1mm, 0.05mm and 0.03mm beads in the grinding process.

New bead separation system for more reliable process

The re-modelled bead separation system and a new screen design reduce blockages and speed up flow rates. This not only helps you to achieve your target particle size faster but ensures improved process safety with maximum reliability.

Efficiency comparison: smaller beads = higher efficency



Advantages of our wet grinding solutions

From single machines to entire plants

We cover the whole process chain of wet grinding and dispersing. Depending on your product and needs, we design, plan, and build your specific solution – a single bead mill, an embedded system, or a full plant from material intake to product packaging.

From lab solutions to large-scale production

Our tailored solutions overcome the challenge of scaling up battery production. Meet the ever-increasing demand for active materials in every stage of production: Lab solutions for precise product testing, while large-scale machines are optimized to manage big volumes.

Top-tier solutions for energy efficient processes

Leveraging Bühler's experience, we adapt bead requirements based on initial particle characteristics for energy-efficient processing. Our machine configuration enables lower rpm, lower tip speed, a higher filling degree of beads and homogenous distribution.

Improved process stability and product quality

Our machine design prioritizes process safety by minimizing blockages and ensuring reliability as well as efficiency. Bead mills achieve target particle sizes, and we introduce advancements in bead separation systems. The systems provide flexible, customizable options for all production requirements.

From manual operation to fully automated plants

We offer solutions tailored to your needs and requirements. Through collaboration with your team, we define the optimal automation level. Our Bühler Insights solution opens new possibilities for your process digitalization.

Lower investment and operation costs

Our machine designs focus on extending the lifespan of machine parts through deliberate technological choices. Integrated technological improvements make optimal grinding quicker and processes faster.

03

Efficient continuous **electrode slurry production.**

The preparation of electrode slurries is a critical step in battery production. Years ago, Bühler pioneered the development of the continuous mixing process based on the twin-screw extruder. Our innovation streamlines operations, ensuring higher consistency, improved quality, and reduced waste.

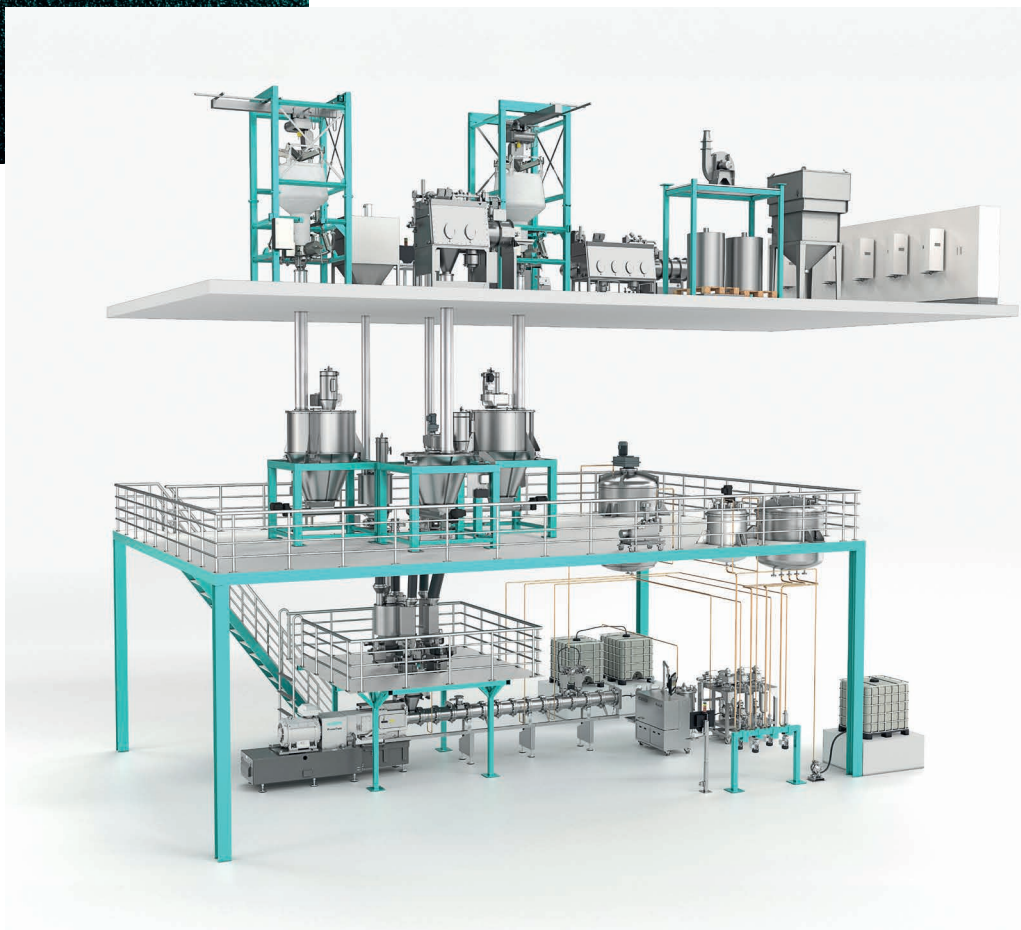
By leveraging our knowledge of continuous production in food products and applying technologies used in other business areas, we created a radical alternative to the traditional batch-mixing method for the production of electrode slurries.

A huge benefit of this process is its automation capability, enabling uninterrupted 24-hour operation without the need for manual interventions. This serves the need for large-scale battery manufacturing, significantly lowering the total cost of ownership.

How it works

The continuous mixing process is based on a co-rotating twin-screw extruder, which combines the basic operations of continuous raw material dosing, pre-mixing, kneading, fine-dispersing, and degassing in a single device.
In a conventional batch mixing system, the pre-weighed liquid and solid components are added, followed by subsequent distribution of the solid components in the liquid phase.
To achieve the required homogeneity at macroscopic and microscopic level, several hours of process time are typically required.

In contrast, the continuous mixing process consists of highly accurate continuous dosing of solid and liquid components, micro-distribution of the solid particles in the liquid phase, deagglomeration and dispersing. Due to the small extruder volume, every particle experiences the same forces along the process zone which results in a very consistent mixing result.



Mixing goals

- Homogenization
- Binder — Dissolution
- Conductive additive — Dispersion
- Active Material — Deagglomeration

Advantages of continuous mixing technology

A mixing solution for all scales

Our continuous mixing solution works at all throughput levels. From laboratory-scale — allowing process and formulation optimization at a few liters per hour — to high-throughput production lines reaching 3000 liters per hour, our solution meets all needs.

Flexible mixing process for versatile compatibility

Our mixing process is also highly flexible, making it possible to adapt the equipment so it can work with all established formulations as well as next-generation material systems.

CAPEX reduction potential

The continuous mixing process with its impressive productivity per mixing line has the capacity to replace multiple batch extruders with a single, fully continuous production line and reduces the factory's footprint, process energy, scrap rate, operator count and maintenance effort.

Reduced material losses

We ensure consistency and eliminate batch-to-batch variations with the fully automated continuous process and the QuaLiB inline quality control system. The small active mixing volume enables an accurately controllable process and minimized scrap rates during cleaning events.

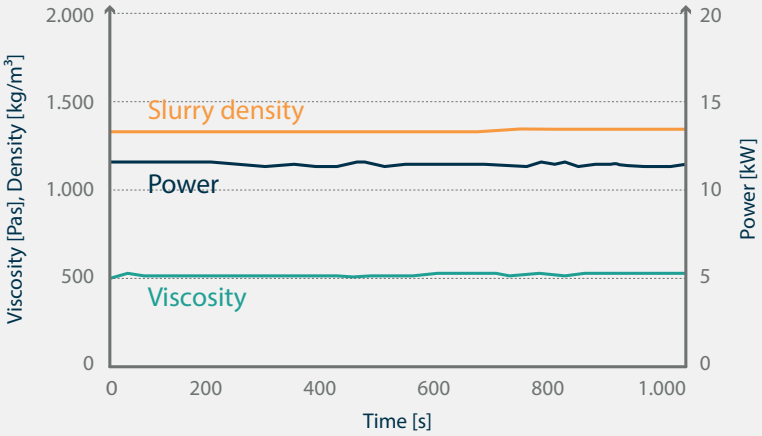
Four times less energy consumption

Due to accurate energy dissipation, the continuous mixing process makes it possible to significantly reduce the specific process energy. Conventional batch mixing needs 224 kWh/t for 1 ton of battery slurry. Our continuous mixing technology needs just 56 kWh/t.

Reduced operator count and labor cost

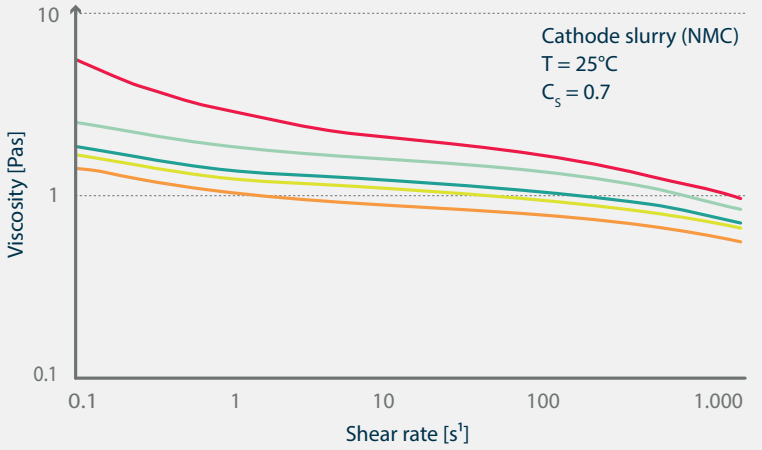
A high degree of automation reduces the need for multiple operators and allows instant adjustments to process settings in response to raw material variations. Only 1-2 operators are required in each line, to handle the provision of raw materials primarily.

Improved process stability and high yield figures



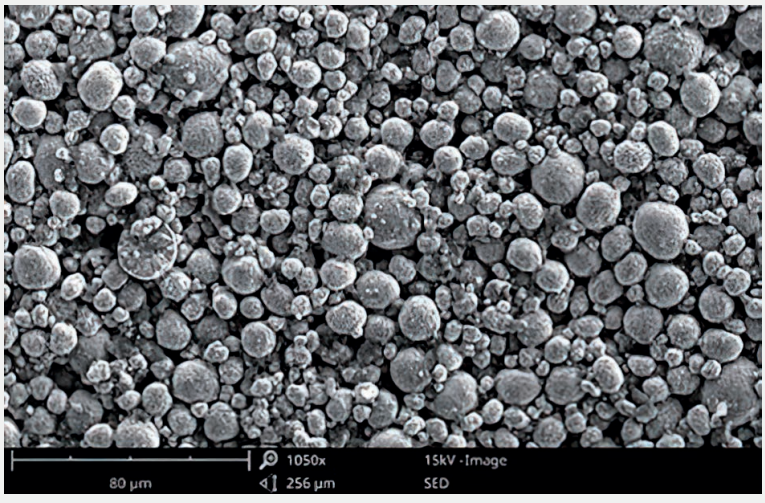
Excellent process stability

Highest powder- and liquid-dosing accuracy offers superior process stability and consistent slurry properties, eliminating batch-to-batch variations.



Optimized rheological behavior

Our continuous slurry mixing technology provides numerous options for tweaking the rheological behavior of battery slurries by adjusting the operating parameters without making any changes to the slurry formulation.



Controlled dispersion

Battery slurries processed on our continuous mixing systems show homogeneous dispersion of active materials and conductive additives. Carbon black agglomerates are distributed homogeneously without being damaged. This can be attributed to the process conditions being optimized for each of our customers' formulations.

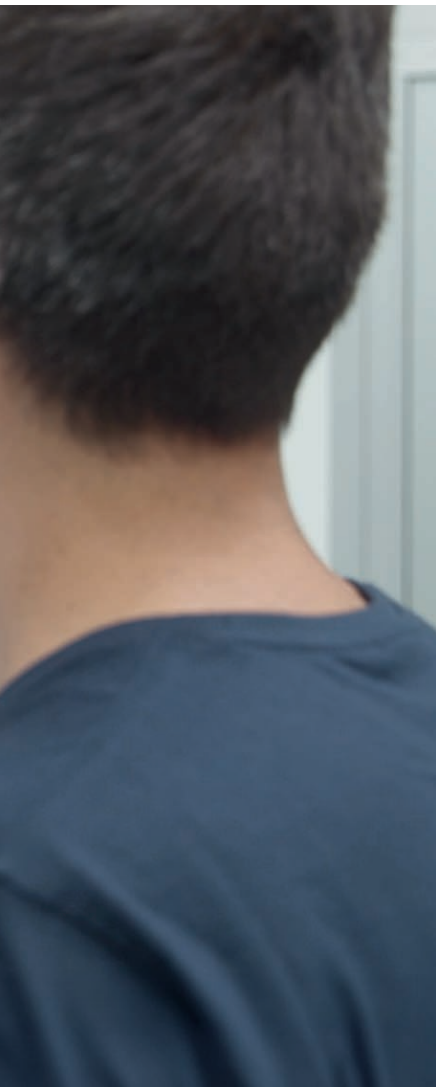
04

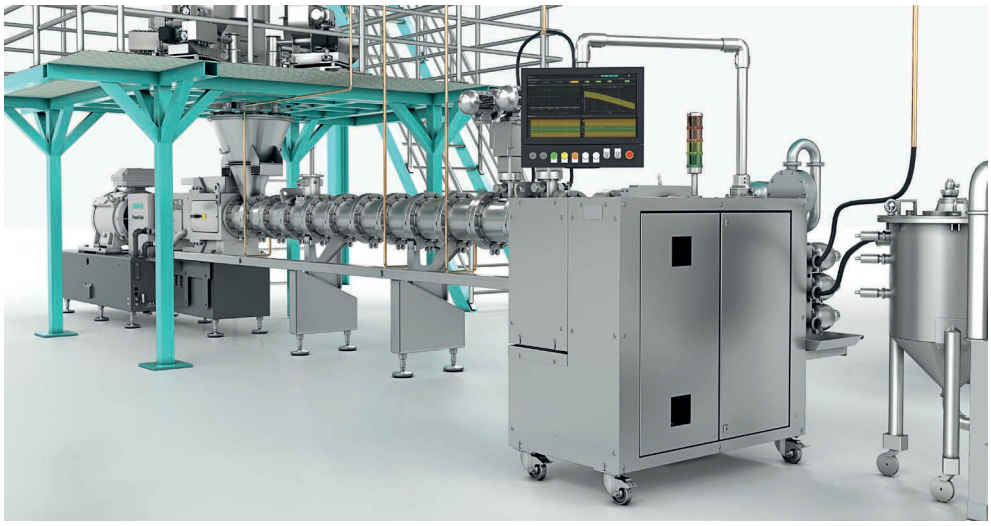
QuaLiB is bringing battery slurry production **into the digital age.**

Bühler has launched QuaLiB, a quality control expert system where we provide real time digital data on automated mixing parameters and continuously measured slurry properties and its quality.

The QuaLiB system takes process control to the next level by enabling inline monitoring and control of the electrode slurry parameters. All critical process parameters such as viscosity, density, flow rates, temperatures, conductivity, solid as well as oxygen content and pH level are constantly measured and monitored. Overall, this enhances mixing process, process control and raw material traceability.

Using critical product and process parameters, QuaLiB enables the analysis of the electrode slurry quality at any time and the identification of possible rejects.





Benefits of QuaLiB

Realtime monitoring

Improved process understanding

Visualizing product properties

Interface for big data applications and digital twins

Automatic quality selection function

Seamleass integration into plant control system

Increasing productivity and reducing scrap rates

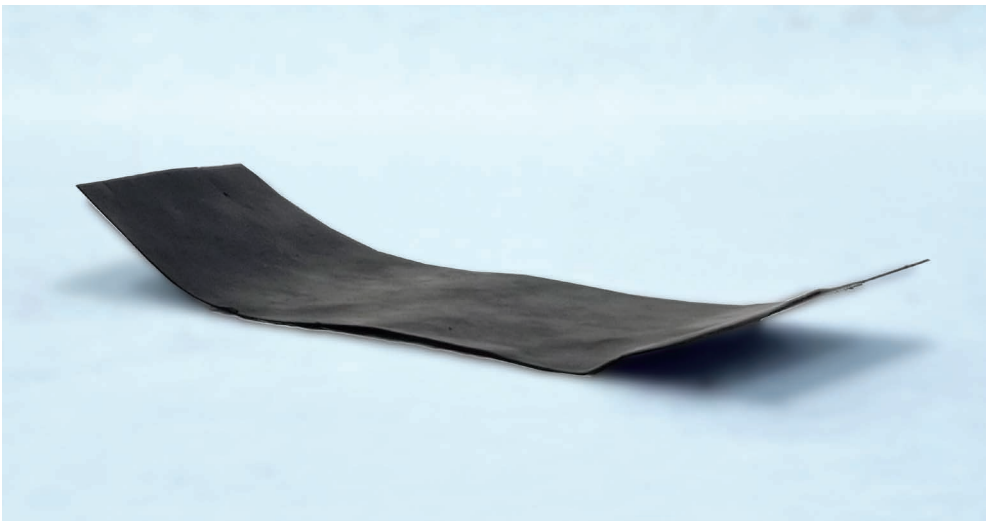
Integrating procedure for fast and easy cleaning

05

Dry battery electrode (DBE).
The next generation of electrode manufacturing.

Traditional electrode manufacturing involves mixing components into a liquid paste and casting it on a foil to dry – a time and energy-consuming process that uses toxic solvents. Bühler is revolutionizing it with dry battery electrode (DBE) technology. DBE is applicable to binder systems such as polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF) and others. The most prominent activities are based on PTFE binder systems. Here, the unique properties of PTFE are harnessed: It fibrillates under shear, creating a polymer fiber network that immobilizes the electrode components.
The result is a cleaner, more efficient, and sustainable process solution known as dry battery electrode: In continuous DBE mixing, raw materials are continuously fed into the extruder and the soft composite structure is discharged from the extruder. The resulting flaky product is pressed into an electrode layer, followed by lamination to the current collector foil, yielding the final electrode structure.

The key benefit is the omission of toxic solvents and reduced production costs due to elimination of the energy and CAPEX intense drying and solvent recovery steps. DBE technology has the potential to improve battery performance.



Benefits of DBE

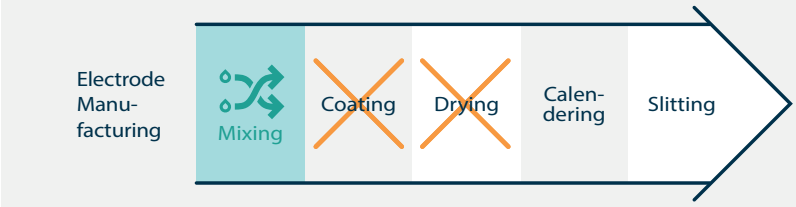
Less energy, no toxic solvents

Ideal platform for solid state technology

Smaller footprint

Lower CAPEX/OPEX

We have developed the continuous mixing process for DBE and for high-viscous (low solvent) processing of electrode masses. With product and process know-how, we are optimizing the continuous mixing process, catering to the requirements of next-generation process technologies. Experience the future of electrode manufacturing with dry battery electrode technology for a cleaner and more sustainable energy industry.



06

Your global technology partner. **Support from start to finish.**

Our global team provides full support in all phases of your project and beyond.
This includes:

Process development	**Engineering**	**Manufacturing**	**Process automation**	**Installation**	**Start-up**	**Training**	**Customer services**

Excellence in plant engineering

At Bühler, we are redefining plant engineering. Our systems prioritize efficiency, sustainability, and reliability, ensuring a quick return on your investment.
Choose Bühler for:

Availability and reliability

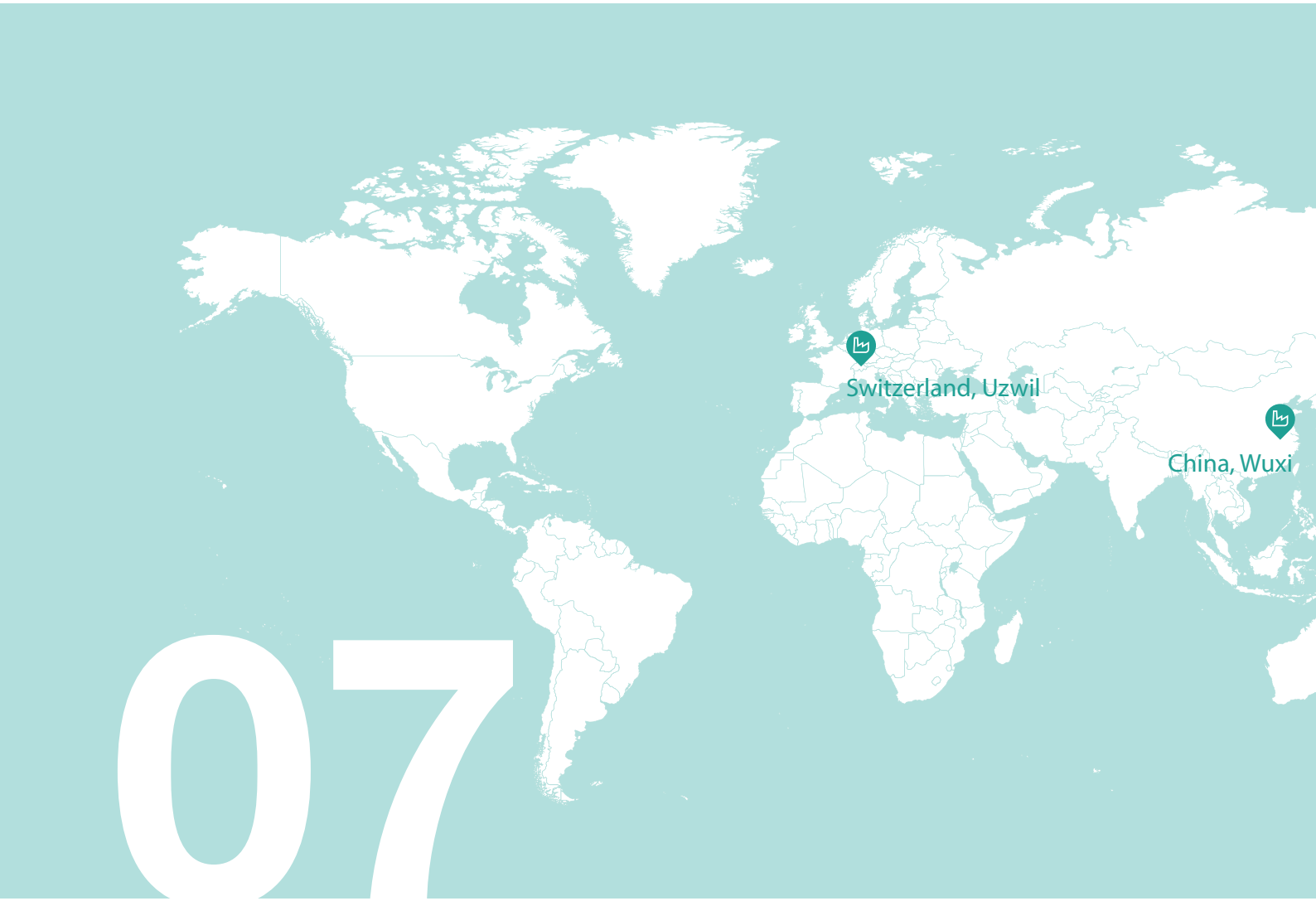
Sustainability and efficiency

Our portfolio

One-stop shop

Complete and tailored solutions

Sustainable processes



07

Bühler battery application center.
Demonstration, optimization and development.

We operate our own battery testing facilities and laboratories worldwide for process demonstration and optimization purposes with regard to product quality, yield, throughput and energy requirements.

Professional trials and collaboration

Our dedicated test facilities offer process testing and optimization for battery applications. Conducted by experienced battery process experts alongside your team, these trials can be lab and pilot scale, providing crucial insights for your required plant dimensioning and realistic product/process optimization.

You can also benefit from interdisciplinary exchange and collaboration with other areas of expertise within the Bühler Group, along with universities and research institutes worldwide.

Location	Application
Switzerland, Uzwil	Precursor and material grinding
	Continuous mixing for electrode slurry and DBE
China, Wuxi	Precursor and material grinding
	Continuous mixing for electrode slurry and DBE
Japan, Kita Kanto	Precursor and material grinding

08

Our Bühler Services.
Partnering for better outcomes.

Lab services

The laboratories offer a broad range of analyses and testing of technical materials in order to innovate processes and improve equipment for our customers.

Spare and wear parts

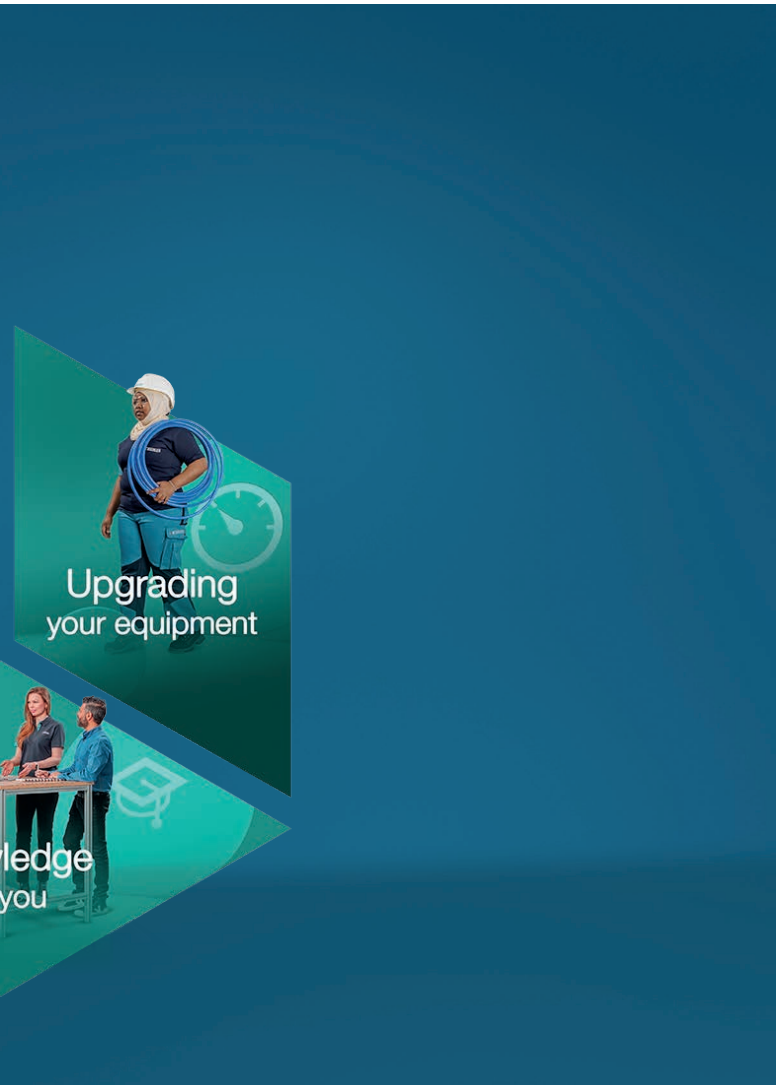
The highest standards of reliability apply to original Bühler spare and wear parts. They are perfectly adjusted and ensure performance and production safety.

Training

At Bühler training centers – or at any site worldwide – specially trained experts pass on their hands-on expertise and knowledge to customers' employees.

Reconditioning

Bühler evaluates, overhauls, adjusts or renews customer installations, including Bühler and non-Bühler machines.



Consulting

Strategic, plant performance, or energy consulting are just some of the consulting services to improve product quality, production processes and energy efficiency.

Repairs

Dedicated to minimizing downtime in the event of an incident: Fast and reliable technical repair service with the Bühler eTicket or the Bühler Helpline.

Maintenance

Packages are adjusted to fit production cycles to prevent downtime, loss in production efficiency or product quality, ranging from individual services to completely out-sourcing maintenance.

Retrofitting

With individual performance upgrades and conversion kits, time-worn Bühler machines can perform to current standards of technology and efficiency.

Bühler AG

CH-9240 Uzwil, Switzerland

T +41 71 955 11 11 | F +41 71 955 31 49

grinding.dispersing@buhlergroup.com
buhlergroup.com