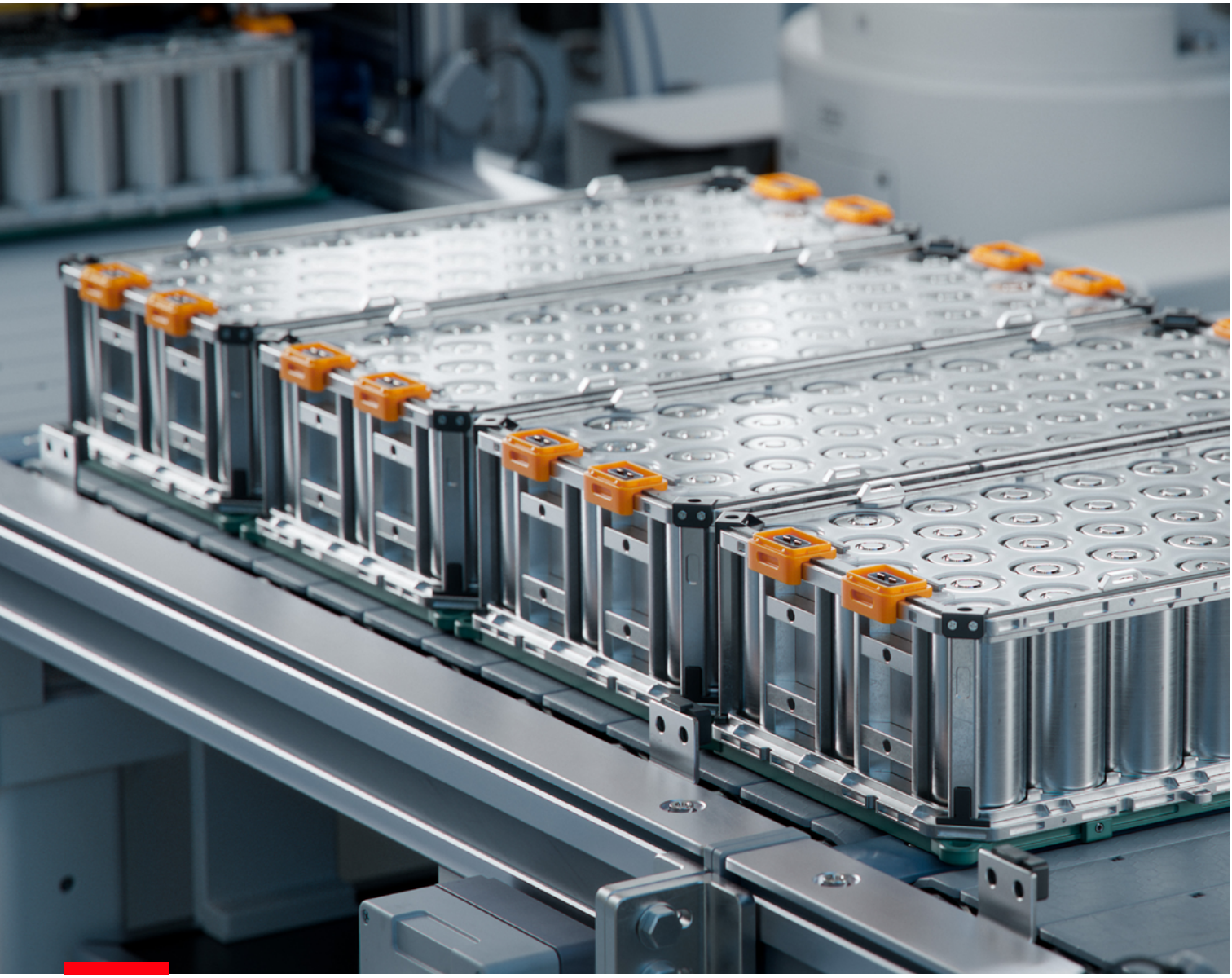

INDUSTRY PAPER

Battery manufacturing

An ecological assessment of sustainability in innovation

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Change is undeniable, but is it sustainable?

The global battery market is estimated to grow by over 30% every year until 2030, when it will reach a value of more than $400 billion and a market size of 4.7 TWh.[1] Although the growth of this market segment will be earmarked by multiple benefits for humanity, many challenges lay ahead to maintain true ecological balance.

The pursuit of sustainability in battery manufacturing is paramount in a time marked by environmental consciousness and rapidly advancing technological innovation. This paper examines the industry challenges, from energy-intensive production processes to ethical concerns surrounding material sourcing and disposal. Through analysis, this paper explores sustainable solutions to minimize environmental impact, optimize resource use, and enhance operational efficiency. These strategies encompass a variety of products to support energy-efficient practices while not compromising on cost or quality.

By embracing sustainability as a guiding principle, businesses can mitigate environmental risks and unlock opportunities for innovation, market differentiation, and long-term viability. Through case studies, industry insights, and pragmatic recommendations, this paper will cover the current state of battery manufacturing, shedding light on the industry's efforts to address these challenges and move toward more environmentally responsible practices. By examining recent advancements and emerging technologies, this paper aims to outline a sustainable future where batteries serve as enablers of progress without compromising ecological well-being. Through this lens, the paper guides industry players, policymakers, and researchers toward a sustainable future in battery manufacturing, fostering a greener, cleaner, and more resilient industry ecosystem.

The ever-changing need for sustainable production

The accelerated adoption of battery technologies across sectors like electric mobility and energy storage has propelled the battery manufacturing industry into a pivotal position within the global landscape. This surge in demand, fueled by the urgency to transition toward sustainable solutions, brings forth a profound responsibility for the industry to address the environmental and ethical dimensions associated with battery production.

The Environmental Protection Agency (EPA) classifies sustainable manufacturing as "the creation of products through economically sound processes that minimize negative environmental impacts while conserving energy and natural resources."[2] Historically, the battery manufacturing process has been marked by resource-intensive practices, reliance on finite materials, and environmental consequences stemming from extraction, processing, and disposal. As the world grapples with climate change and strives to achieve ambitious carbon reduction goals, there is an urgent need to identify the paradigms of battery production. In a rapidly evolving energy landscape, batteries play a critical role in the transition to a sustainable future. It is imperative to refine the manufacturing processes to align with broader ecological objectives.

The industry's key challenges include managing the energy intensity of manufacturing processes, reducing machine footprint, and environmental impact from production. The timeline of these endeavors is emphasized by sustainability initiatives, such as pledges to have carbon-neutral manufacturing or meet new demands for electric vehicles. In addition to such initiatives, compliance with environmental law is imperative to protect the environment against public and private harm.[3] Moreover, issues surrounding the availability of critical materials and geopolitical tensions affecting supply chains underscore the complexity of the sustainability landscape.

Ethical imperatives and business realities

Modern consumers demand ethical and sustainable production, crucial for businesses to remain competitive. Overreliance on resource-intensive processes inflates costs and leaves companies vulnerable to market fluctuations. Geopolitically sensitive supply chains add uncertainty, evident during events like wars and the pandemic, disrupting production and risking financial stability. The localization of supply chains has helped, but has also proved a challenge for growing OEMs, especially for battery manufacturers facing diverse end-use applications. Increasing production requires significant investment in expansion, equipment, and safety measures, yet it must ensure a viable return on investment. Manufacturers must adapt swiftly to market demands to secure their market share effectively.

To quickly adapt, it may seem logical to just speed up existing production lines, but this often leads to higher maintenance costs, reduced product quality, and increased waste. Such practices can damage a company's reputation and erode customer trust, especially among environmentally conscious consumers. Failing to adopt eco-friendly approaches in battery production risks alienating a growing market segment. Improper disposal of electronic waste exacerbates these issues. Moreover, compliance costs with environmental regulations add financial strain. Un-sustainable battery manufacturing practices jeopardize environmental integrity and the industry's long-term viability, prioritizing short-term gains over sustainability.

The benefits of better manufacturing

Introducing eco-friendly approaches in battery manufacturing yields multifaceted benefits for businesses, ranging from enhanced operational efficiency to bolstered environmental stewardship. This translates into cost savings and contributes to a more resilient energy infrastructure. This reduces reliance on non-renewable resources, aligning with long-term sustainability goals.

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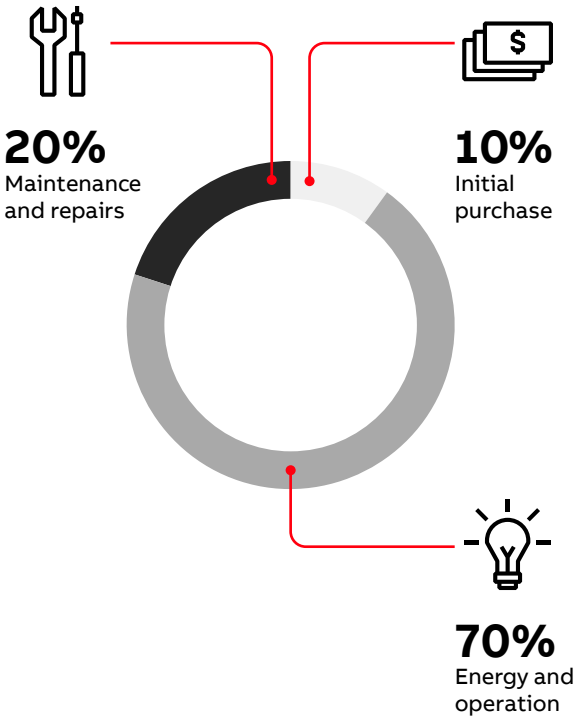
Total cost of ownership for battery manufacturing systems



Embracing sustainable solutions enables businesses to maximize production space utilization, thereby optimizing operational efficiency and resource allocation. By adopting modular and space-saving manufacturing configurations, businesses can minimize the physical footprint of their production facilities while maintaining or even increasing production capacity. This streamlined approach reduces overhead costs associated with facility maintenance and builds a more agile and adaptable manufacturing environment. Furthermore, efficient use of production space allows businesses to capitalize on economies of scale, facilitating scalability and accommodating fluctuations in market demand with minimal disruption.

Implementing sustainable solutions in battery manufacturing delivers substantial environmental benefits. By prioritizing the use of recycled materials, minimizing waste generation, and implementing eco-friendly production processes, businesses can significantly reduce their environmental impact. This proactive approach mitigates the depletion of natural resources while alleviating pollution and mitigating climate change risks. Additionally, by adhering to stringent environmental regulations and demonstrating a commitment to sustainability, businesses can enhance brand reputation, attract environmentally conscious consumers, and access new market opportunities in the growing green economy.

ABB’s vision for transformative battery manufacturing

Battery manufacturing undergoes a transformative enhancement when embraced through a holistic approach. It efficiently manages the energy intensity of manufacturing processes, minimizes production footprint, and reduces environmental impact. Balancing the energy demand of manufacturing processes can be achieved through distributed loads, peak shaving, and building meticulously planned electrical systems to support energy needs. Simultaneously, a smaller production footprint, achieved through advanced engineering and modular configurations, maximizes space utilization, and reduces resource consumption, minimizing the overall environmental footprint of manufacturing facilities. By integrating recycled materials into battery production, manufacturers contribute to circular economy principles, mitigating the demand for raw materials and reducing waste. This harmonious merger of streamlined manufacturing processes, eco-awareness, and material sustainability enhances operational efficiency and underscores a dedication to responsible practices within the battery manufacturing sector.

As a global technology leader, ABB is uniquely positioned to offer comprehensive electrification solutions that revolutionize the landscape of battery manufacturing, mitigating key challenges and advancing sustainability objectives. ABB's expertise lies in optimizing energy consumption in manufacturing processes, targeting the demanding energy-intensive nature of battery production. This reduces operational expenses and aligns with broader environmental goals by promoting responsible energy consumption. Through innovative engineering, ABB products can enable compact and modular machine configurations that optimize space utilization, enhance overall operational flexibility, and decrease the environmental impact of large-scale production facilities.

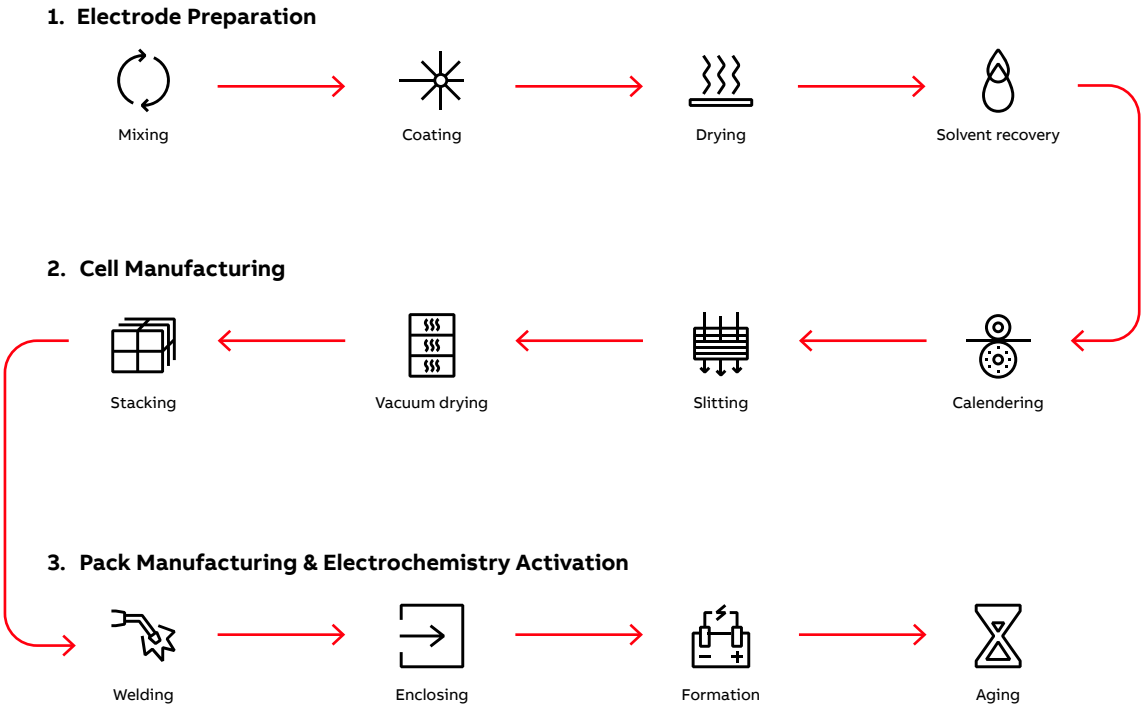
Precision and safety are paramount in battery manufacturing. ABB excels in delivering products that enable precise, reliable, and safe execution of automated tasks and accurate measuring/monitoring capability throughout production. Changing production needs that fluctuate with consumer demands and technological innovation, ABB is committed to changing with you as you design a battery production super-highway, allowing for the flexible integration of recyclable materials into the manufacturing process.

Managing electrical loads in manufacturing

Managing electrical loads in battery manufacturing involves optimizing energy usage, minimizing demand charges, and ensuring electrical system reliability. A key strategy is distributing electrical loads across the facility, leveraging distributed energy resources in the facility's design, and reducing strain on the grid during peak demand. ABB can aid with the strategic deployment of energy-intensive equipment, helping OEMs to save energy and reduce carbon emissions from power generation.

Battery production comprises of three main procedures: electrode preparation, cell assembly, and pack assembly/electrochemical activation. Electrode preparation processes consume nearly half the energy required to produce a battery.[4] Once the cell is assembled, the battery moves into the most expensive part of the battery manufacturing process, comprising more than half the operating expense and 35% of its energy consumption. Since electrical pricing varies based on demand on the grid at the time, these peak demand charges can represent over 30% of the total electricity bill.[5]5 However, this energy consumption can easily be optimized to prioritize ecological impact.

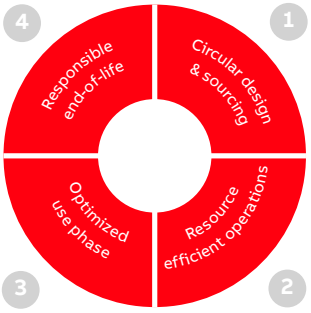
Within ABB's range of products, ABB Ability™ Energy Manager enables the digitalization of protection devices such as miniature circuit breakers and residual current devices, and other DIN-rail products. This is part of the ABB EcoSolutions™ portfolio which hosts products that comply with a set of key performance indicators (KPIs) and carry an environmental product declaration. Solutions like these enable full analysis of historical data to optimize performance. Another part of the ABB EcoSolutions™ portfolio is SACE® Tmax® XT and Emax 2 circuit breakers, which combine functionalities such as performance, control, and connectivity with reliability, integration, and ease of use.



Source:
Nelson et al.[4]

Criteria for the ABB EcoSolutions™ label

Circularity value



Primary KPIs

1	Design & Sourcing	Design sourcing
2	Efficient operations	Operations packaging & logistic
3	Optimized use-phase	Efficiency lifetime
4	Responsible end-of-life	Take-back recycling

Eco-transparency on environemntal impact

Independently verified Environmental Product Declaration (EPD)

Sustainability Key Performance Indicators

1 **Demand charge reduction rate**

Measures the effectiveness of strategies aimed at minimizing demand charges imposed by utility providers

2 **Renewable energy integration ratio**

Evaluates the proportion of renewable energy sources integrated into the electrical load management strategy

3 **Energy efficiency improvement index**

Assesses the improvement in the energy efficiency achieved through load management initiatives

All these KPIs can be measured and monitored with ABB products through system status emails, smart configuration and visualization via Bluetooth, and cloud computing platform ABB Ability™ Energy Manager. This enables real-time updates, energy forecasting, and grid management. Strategies targeting demand charge reduction aim to cut electricity costs and enhance financial stability. A higher renewable energy integration ratio indicates increased reliance on clean energy sources, reducing greenhouse gas emissions. The energy efficiency improvement index measures effectiveness in reducing energy usage and promoting resource conservation.

Assessing production footprint

Reducing machine footprint in battery manufacturing can offer significant benefits. ABB's products enable cost-effective consolidation of electrical equipment. Intelligent control systems integrate multiple processes into compact configurations, minimizing redundant infrastructure. ABB's space-saving products include miniature circuit breakers, SACE® Emax 2 and Tmax® XT circuit breakers, SMISSLINE TP touchproof system, compact contactors, and connection kits. These products help reduce construction, maintenance, and resource consumption costs.

In turn, smaller production spaces offer cost-effective and eco-friendly benefits to the battery manufacturing market. They require fewer materials and energy for construction, reducing costs and environmental impact. These spaces are inherently more energy-efficient, leading to lower operational expenses and resource consumption. Compact layouts optimize workflow efficiency, enhance productivity, and align with sustainability goals, driving operational excellence and cost-effectiveness in battery manufacturing.

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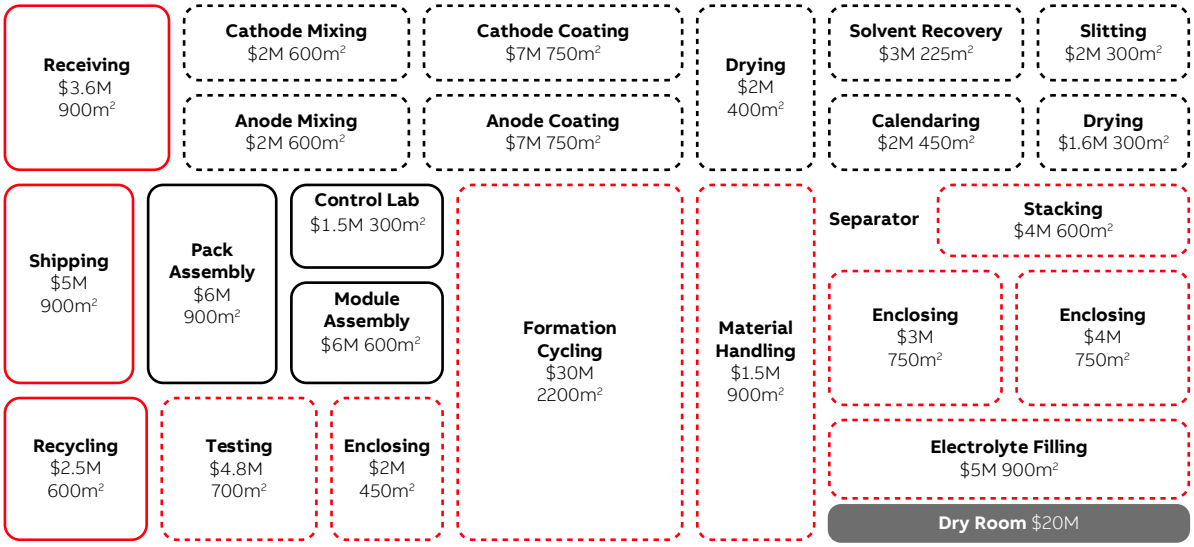
Typical layout of a lithium-ion battery manufacturing plant



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Source: Gupta 2021[6].

Environmental impact

When it comes to environmental impact, one does not often think of the environment as the factory ecosystem. Production facilities are teeming with manufacturing processes, all of which have an impact on the environment. Most movement is automated, coming from motorized transport methodologies. ABB offers softstarters to help curb the energy intensity of those start-up electrical loads. Temperature control is also essential in electrode preparation, cell assembly, and pack assembly/electrochemical activation. Temperature relays and contactors with efficient coils help thermal management equipment run at its best. A variety of ABB smart devices, including SACE® Tmax® XT and Emax 2 circuit breakers, Molded Case Circuit Breakers (MCCB), PSTX softstarters, UMC100.3 universal motor controllers, ABB variable frequency drives, and Ekip UP+ all have measurement and communications capabilities required for digital management of a modern manufacturing facility.

Precision and safety are paramount considerations in manufacturing tasks. No matter what part of the battery manufacturing process a company is involved in, ABB does not compromise on such crucial aspects. Precision is important because if electrical loads fall outside the recommended operating ranges, then production does not run at its intended capacity. ABB has voltage monitoring and surge protection devices to help avoid this. Additionally, Jokab Safety products offer premium, intelligent machine safety products that integrate with any system and make your machine safety system easy to build and maintain.

Advanced manufacturing techniques and quality control processes ensure that recycled materials meet stringent safety and performance standards, maintaining the reliability and durability of battery products. Additionally, precision engineering allows for the precise incorporation of recycled materials into battery components, ensuring consistent product quality while minimizing material wastage. By prioritizing precision and safety in manufacturing tasks, businesses can effectively leverage recycled materials to enhance sustainability without compromising product integrity.

Designing for flexibility and scalability in production models is essential to enable the seamless integration of recyclable materials into battery manufacturing processes as this projected need comes to fruition. Modular manufacturing configurations and adaptable production lines facilitate agile responses to changing material availability and market demands. This flexibility allows manufacturers to adjust production volumes and optimize material usage based on real-time data and market dynamics. By designing for scalability, businesses can future-proof their operations and accommodate fluctuations in supply and demand, ensuring continuity in sustainable practices and minimizing environmental impact throughout the product lifecycle.

Conclusion

As the need for batteries continues to grow, it will be imperative for battery manufacturers to be able to produce at the speed of demand. While the industry grapples with multifaceted challenges spanning environmental, economic, and operational domains, it is difficult to predict the precise trajectory of future developments and advancements. However, these challenges and future innovations only emphasize the urgency for comprehensive ecological efficiency in battery manufacturing. Fluctuating commodity prices, geopolitical tensions affecting supply chains, and stringent regulatory requirements further motivate battery manufacturers to get on board with implementing sustainable manufacturing processes. These challenges are imperative to foster a more sustainable and resilient battery manufacturing ecosystem capable of meeting the growing global demand for batteries while minimizing environmental impact and maximizing operational efficiency.

Pursuing sustainable solutions in battery manufacturing entails a multifaceted approach aimed at addressing environmental, economic, and operational opportunities. Implementing energy-efficient practices helps to minimize the energy intensity of manufacturing operations while reducing operational costs and environmental impact. Embracing circular economy principles through the integration of recycled materials into battery production mitigates the demand for raw materials, minimizes waste generation, and conserves resources. Furthermore, designing for flexibility and scalability in production models enables the seamless integration of recyclable materials and facilitates agile responses to changing market dynamics, ensuring continuity in sustainable practices. By prioritizing precision, safety, and efficiency, businesses can leverage sustainable solutions to enhance environmental stewardship, promote economic resilience, and drive innovation in battery manufacturing.

References

(1) McKinsey & Co. (2023, January 16). Battery 2030: Resilient, sustainable, and circular. https://batteriesnews.com/mckinsey-battery-2030-resilient-sustainable-circular

(2) United States Environmental Protection Agency. (2024, January 2). The Business Case for Sustainable Manufacturing. EPA. https://www.epa.gov/sustainability/sustainable-manufacturing

(3) Legal Information Institute. (2022, December 1). Environmental Law. Cornell Law School. https://www.law.cornell.edu/wex/environmental_law

(4) Nelson, P. A., Ahmed, S., Gallagher, K. G., & Dees, D. W. (2019, March 1). Modeling the Performance and Cost of Lithium-Ion Batteries for Electric-Drive Vehicles, Third Edition. U.S. Department of Energy Office of Scientific and Technical Information. https://www.osti.gov/biblio/1503280

(5) Tango. (2018, February 27). Peak Load Management Strategies. WatchWire. https://energywatch-inc.com/peak-load-management-strategies/

(6) Gupta, N. (2021, June 11). Setting up a giga factory: what does it take? Emerging Technology News. https://etn.news/energy-storage/setting-up-a-giga-factory-what-does-it-take.

Customer cases

ABB MECHANICSVILLE FACTORY

ABB's new Mechanicsville factory will manufacture and distribute such compo-nents as batteries, compact and auxiliary converters, EV chargers, and energy storage for electric trains, heavy mining machinery, and buses.

NORTHVOLT BATTERY MANUFACTURING

Northvolt chose ABB to help fast-track project execution with inte-grated electri-fication, instrumen-tation, control, and digitalization solutions that would also enable efficient operations.

ABB FROSINONE FACTORY

ABB's Frosinone factory is a 150,000 m2 facility that produces more than three million circuit breakers every year. Achieving zero production waste to landfill was a whole-factory program.

VIVO SMARTPHONE BATTERIES

ABB is supplying innovative sus-tainable energy supply solutions at six Vivo smartphone manufactur-ing sites. These advanced solutions enhance safety, productivity, and energy efficiency.

To discover more

SUSTAINABILITY

Learn about what ABB is doing to contribute to a more sustain-able future.

ECOSOLUTIONS

Learn more about the criteria for the ABB EcoSolutions™ label and its environmental impact.

CONTACT

Do you have a similar project and are you searching for the right application configuration? Contact us and talk to our experts!

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