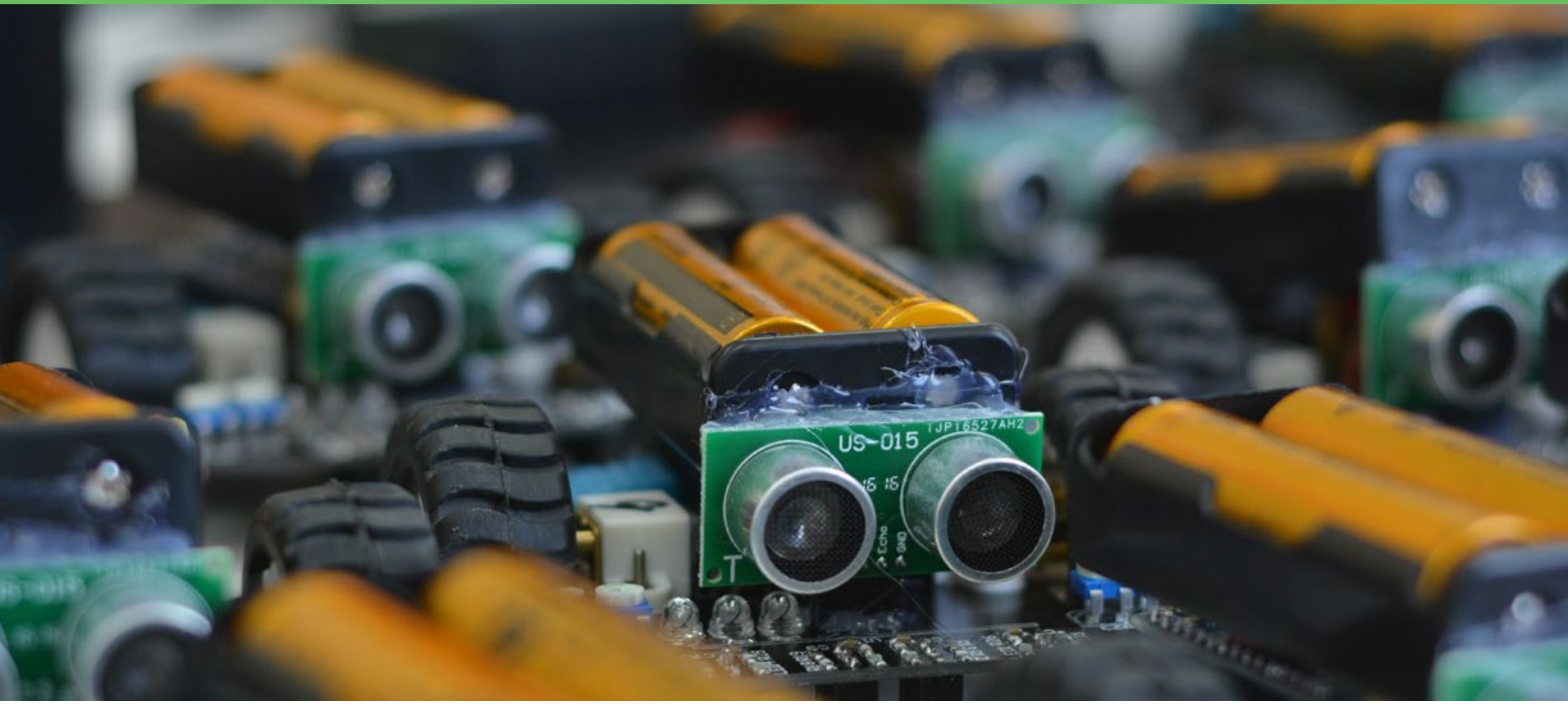
BATTERY CELL, MODULE & PACK TESTING

The Basics



ENERGY ASSURANCE

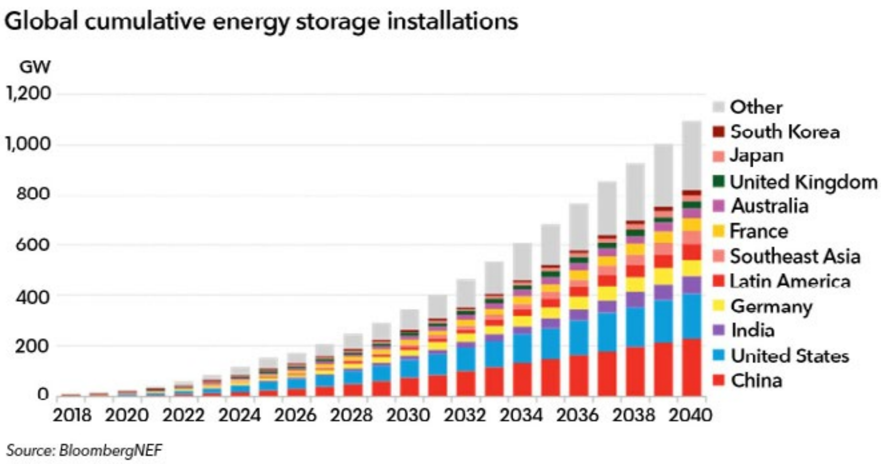
TABLE OF CONTENTS

Electrification & Battery Testing

Industries from automotive to aerospace and energy are all-in on electric power. In the stretch between 2030 and 2035, many manufacturers of automobiles will complete full-scale transitions into EV production. The urgent electrification of cars, trains, aircraft, and our power grid itself has already begun…and it's about to send the battery market into a period of profound and rapid growth.

Research shows that the battery market — largely on account of the EV industry — is set to grow exponentially over the coming decade. Annual demand for EV Li-ion batteries will reach (and exceed) 1,748 GWh by 2030, according to a forecast from BloombergNEF (BNEF).

Perhaps even more surprising is the report's predicted growth in energy storage installations across the globe. With battery costs set to plummet as technology advances and capacity expands, the 9GW/17GWh total of deployed installations in 2018 will multiply to an astounding 1,095GW/2,850GWh by 2040 representing over a 150X increase over the period.



Worldwide electrification makes it critical that the engineering, research, and development professionals in these fields grasp the pivotal role of battery cell, pack, and module testing. The purpose of testing can range from performance benchmarking to regulatory compliance, safety, failure analysis, and more. In every case, the goal is to accelerate a high-quality product's time to market without sacrificing rigor or compliance.

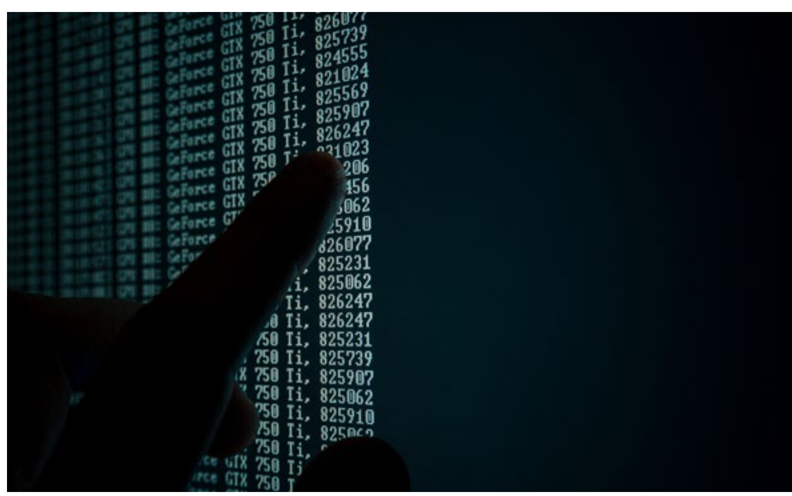
A fully-equipped independent battery testing laboratory can help. You'll reach the market faster with an instant expansion to test capacity and a broad menu of testing capabilities without the commitment to high fixed costs that comes with an in-house lab. Energy Assurance is the largest independent battery cell, module, and pack testing facility in North America. Our battery testing services can give you the confidence, cost-efficiency, and speed that you need to keep up in a transforming market.

Challenges of Battery Testing

Testing labs are growing increasingly more complex and specialized as development times grow longer, regulations expand, and the globe nears its electrified future. To meet safety requirements and accurately simulate real-world conditions, test engineers must rely upon environmental chambers and advanced cycling capabilities. The inherent hazards in battery chemistry can make in-depth testing a challenge.

Test facilities must concern themselves with challenges including:

- Safety risks & safeguards for environmental issues and in-lab risks
- High fixed costs for specialized equipment and expert staff
- Facility footprint — it takes a large lab to house sufficient testing chambers & equipment
- A lengthy testing process that may span multiple years
- High channel counts to manage test volume fluctuations and minimize client delay
- Data management to include data security (which grows more complex each year)
- Supporting analytics capabilities to facilitate advanced data analysis
- Pioneering of new test protocols for emerging chemistries & technologies



Testing For Battery Cells, Modules & Packs

The types of testing required will vary depending on whether you're testing the chemistry of a stand-alone component (cell) or the engineering of a whole system (pack). Let's start by defining the three tiers of battery design:

Battery Cell — A self-contained, **component-level** device that converts chemical energy into electricity.

Battery Module — A **sub-system level** unit containing any number of cells in addition to connectors, other electronics, or mechanical packaging.

Battery Pack — A **system-level** unit that may include multiple battery modules in addition to connectors, other electronics, or mechanical packaging.

Testing for a battery cell is largely focused on electrochemical performance. Test techniques will investigate the efficiency, output, and safety of internal chemical reactions. In general, the goal is to evaluate the viability of the cell's chemical reactions and understand its overall dynamics. Test sequences can be used to measure current, voltage, resistance, stability, and the rates of chemical reactions in various temperatures and environmental or physical contexts.

Testing for a battery module or pack is not so much focused on the internal dynamics of cells or their chemical reactions as the overall dynamics of the battery unit. Tests must assess system-level performance and safety with application-specific tests. The testing regimen will answer engineering questions about the design or build of the system as a whole — it's durability, performance in specified use-scenarios, peak power, and failure risks.

THE 3 STAGES OF BATTERY TESTING:
DESIGN, SUB-SYSTEM, AND SYSTEM VALIDATION

Cells must be tested before they are integrated into modules, and modules must be tested before they are combined into packs. In addition to this sequence of system-level battery testing, a product must also be tested at each stage of the design & manufacturing process. This begins with an engineering characterization to validate the design, followed by sub-system and system validations in manufacturing, and eventually regulatory compliance testing of the completed product.

1

Engineering Characterization: At the engineering stage of the design process, the basic properties of the internal chemistry of the battery concept must be validated (with cell testing). Modules and packs must also go through design validation to ensure that their basic battery engineering concepts are sound and will meet design specification requirements.

2

Sub-System Validation: Modules and packs must undergo testing during the manufacturing production stage of product development, where sub-systems will be tested and optimized for the good of the end system. The goal is to verify that manufacturing will meet design specifications.

3

System Validation: This is the final, pack-level stage of manufacturing production testing, where all components are integrated and the entire battery system must be tested, benchmarked, and checked for regulatory compliance. Chemistry-related tests are no longer of concern. In fact, some tests may only involve the battery itself in a secondary role, focusing instead on the integrity of the surrounding components and how they react to the battery at different temperatures and charge states.

HOW BATTERY TESTING HAS CHANGED

Battery testing has undergone a series of transformations as automation has streamlined the work for test engineers and reduced the complexity of manual testing procedures. Computer technology has taken a central role in the immense data management and analytics burdens that accompany today's sophisticated testing regiments.

Evolution of Testing Procedures:

Legacy Testing Methods: Older battery testing methods were manual. The tests generally required a number of individual instruments to be manually set up, operated, and recorded by the test engineer. Often, this meant a pair of set-ups, each to cycle the same battery, for the purpose of comparison. While they are legacy methods, manual processes are still sometimes used today.

Electronic Source & Load Testing: Most power electronics laboratories today contain DC source and DC load instruments. Engineers can assemble their own general-purpose setup that offers a basic level of automation — it's possible programming test parameters within the source and load of the instruments. However, they'll still need to be operated and controlled separately (and require additional external test equipment to collect data).

Automated Battery Testing Systems: The most advanced and streamlined test setups today are fully automated. They integrate an electronic DC source and load in a single test unit and allow for precision measurements and high-speed data acquisition within the system itself. Such systems also are flexible in that they include a programming environment and advanced communications capabilities. With everything in a single product, automated systems eliminate the need for extra equipment, reduce the footprint of the lab, and simplify setup, operation, and control.

Emerging Testing Solutions: The next generation of battery testing solutions will build upon the automation introduced at the facility-level by providing rapid, real-time access to robust data, even before all testing has been completed. Cloud-based software and online portals that integrate with battery testing systems can make collected data readily available very quickly. Manufacturers and suppliers benefit from the ability to access insights and automated reports from remote locations without waiting for the testing laboratory to manually report results. Such systems may also offer advanced battery analytics of value to more technically sophisticated clients. Energy Assurance uses software from Voltaiq, for example, to provide real-time data access and analytics to all customers.

COMMON TYPES OF BATTERY TESTS

This is not an exhaustive list, but examples represent some of the most common battery testing types and purposes. Tests can range from internal and chemistry-related (when testing cells) to more comprehensive analysis of the entire functioning system of the battery (when testing packs).

Charge/Discharge Tests: These relatively straightforward tests assess the battery's overall capacity and measure the DC internal resistance at various states of charge (SoC). Charge/discharge tests are used for purposes such as to verify manufacturer capacity ratings or discover how hot the battery will become when discharged at different rates.

Battery Cycling & Stress Tests: It's not unusual to see multiple types of cycling tests employed for the same battery. Cycling tests aim to re-create real-world conditions that could be faced by the battery and assess performance in that context. Instruments can be used to define drive cycles, grid cycles, and flight profiles. When the conditions are particularly harsh, this becomes a "stress" test. Stresses could include extremely high or low temperatures, strong vibrations, high humidity, and other physical conditions. Combinations of stress types in a single test offer further semblance to real world usage. Such multiple-stress testing can also provide a more efficient manner to precipitate failure modes for engineering evaluation.

Reference Performance Tests: An RPT is intended to reveal the performance of the battery over time while measuring a carefully selected combination of variables. A common example might be a lithium-ion battery for an electric vehicle. The battery could be tested at regular measured intervals — after the vehicle has traveled 100, 500, or 1,000 miles — to evaluate changes in storage capacity. The periodic testing can shed light on how the battery performs over time.

Competitive Benchmark Testing: Battery products are competing against other similar chemistries and designs. A benchmark test is designed to measure how the performance of one battery stacks up against one or more of its competitors. Tests can span a custom range of traits, depending on what's being benchmarked. For instance, storage temperature, forced discharge, low-pressure/altitude, crush/impact, capacity, cycle life, overcharge, vibration, and more.

Product Teardowns: Battery teardowns and cell construction analyses aim to identify potential design, performance, or safety issues and illuminate cost structure. Studying what's inside a battery also allows you to benchmark against competing products or determine whether a product is counterfeit or if patent infringement applies.

Engineering & Failure Analysis: Whether it's pre-launch or in the wake of field issues, a failure analysis provides valuable insights into safety-related failures and reliability attributes. Battery modules, packs, and component cells may undergo failure analysis to determine the root cause of failure, evaluate a new supplier, identify patent infringement, or drive lessons learned for next-gen products. This often involves technologies and techniques like x-ray imaging, CT scanning, product dissection, abuse testing, and replication testing.

Battery Management System Data Validation & Hardware Testing: Detailed BMS data is critical to the optimization of battery module and pack design. The BMS is a subsystem that coordinates with other subsystems (e.g. chargers, EV powertrains, and other connected electronics), leaving room for major errors if BMS is programmed incorrectly or its recorded data is inaccurate. BMS software and hardware can be tested and validated at both the module and pack level with a combination of stress and cycling tests. Measurements of voltage, current power, energy, state of charge, and other indicators derived under various conditions can validate the measurements reported by the BMS to ensure it is calculating accurately.

Subcomponent & Environmental Tests: Protective, connective, or functional components on the exterior of the battery help it to tolerate its intended environment and support its application. Connectors, cables, fuses, and other components must be thoroughly tested for safety and efficiency. Tests generally involve charging and discharging the battery while measuring the mechanical, structural, and thermal impact on these auxiliary systems.

Prepare For the Future

Test complexity, demand for battery testing, and the number of new chemistries in need of validation are always increasing. In-house testing labs will struggle to keep pace with the rapid expansion of the battery market while pioneering new test protocols for the next generation of batteries. A partnership with a third-party testing lab can make solutions like the ones described in this resource available to you while saving both time and money.

Energy Assurance is the largest accredited independent cell and battery testing facility in North America. When you partner with us, you'll gain access to over 3,000 cycling channels coupled with a multitude of environmental chamber capacity (across 200+ chambers). The extra capacity of an accredited third-party lab acts as an "on-call" resource to get your products to market faster. This avoids the need to deploy capital towards constructing and outfitting a large internal lab and further keeps the associated labor as a variable cost versus a fixed cost. Equally important, our staff is continually trained on the latest industry standards and test methods, and our facilities are audited annually by multiple bodies to ensure our quality system compliance and technical competence.

From battery performance testing to failure analysis, engineering analysis, and safety testing, a properly equipped battery testing partner can offer a combination of experience and capabilities to ensure reliability and compliance as the battery market evolves.

Get in touch with us today to discuss your next project and learn more about how Energy Assurance can help.

SOURCES

1. Energy Storage Investments Boom As Battery Costs Halve in the Next Decade

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