



E Source

Safety without compromise

High-performance thermal protection in
battery energy storage systems with
GORE Battery Insulation Technology

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Executive summary

Battery energy storage systems (BESS) face critical safety challenges in managing thermal runaway events while maintaining optimal performance. Traditional thermal barrier layers can lose performance under the extreme conditions of runaway, where temperature and pressure reach critical levels simultaneously. This white paper demonstrates how a new developmental technology from W. L. Gore & Associates, Inc. (Gore), known as GORE Battery Insulation (GBI) provides a mechanically stable thermal barrier that maintains excellent protective properties even under severe compression and at elevated temperatures, enabling safer, higher density BESS.



Figure 1. GORE Battery Insulation (GBI) is a non-fluorinated insulator available in mechanically stable, laminatable, low-particulating sheets ideal for high-precision manufacturing.

Lab testing shows that GBI maintains high thermal resistance during simulated thermal runaway events, resulting in lower temperatures for adjacent cells, and a safer overall structure. Real-world testing by Our Next Energy, Inc., validates that GBI prevents thermal propagation in battery modules “at practical thicknesses and costs.” (1) The stability and consistency of GBI against creep, even at high temperatures, enables cell-to-pack structures, permitting design of high energy density BESS containers without compromising safety.

The challenge of thermal runaway in prismatic lithium-ion BESS

Thermal insulation materials in BESS systems are deployed between individual lithium-ion cells and serve two purposes: (1) Prevent thermal propagation during runaway events, and (2) provide mechanical compliance during normal charge cycling.

Thermal barrier materials in between cells constrain propagation of heat during a thermal runaway event and improve outcomes of UL9540A tests. The physical requirements for such barriers are severe: During thermal runaway, lithium-ion cells expand significantly due to rapid gas generation and internal pressure buildup as temperatures reach or exceed 500°C. Thermal barrier performance in a real-world environment, therefore, cannot be inferred based on behavior during normal operational temperatures and pressures. Instead, design and testing must consider the extreme and uncontrolled conditions that could arise during runaway events.

Further, modules and packs must accommodate cell thickness changes during regular operation: As lithium ions intercalate and de-intercalate from electrode materials, cell volume can fluctuate between 2% and 5%. This cyclic mechanical strain requires including compliant layers between cells to maintain uniform pressure distribution and prevent mechanical damage to components.

With only one space available between cells, manufacturers have settled on a dual-use design for the interposing layers, relying on thermal barrier materials to perform both functions. This creates a fundamental design conflict, where engineers must avoid barrier materials that are too stiff to accommodate battery cycling while also steering clear of materials that are too

compressible to provide reliable thermal protection. Since they can't tune these properties independently, system architects have limited options to design modules and packs that accommodate high pressure. These constraints compromise energy density, increase testing requirements, and create overly conservative designs to ensure safety.

GORE Battery Insulation: A low-compression, high-performance thermal barrier

During a thermal runaway event, local temperatures may rapidly exceed 500°C, expanding the liquids and gases within the cell and increasing pressure on the thermal barrier material tenfold (from about 0.1 MPa to 1 MPa). Any compliance in the thermal barrier will cause it to thin, and in thinning it will lose thermal resistance, as described by the formula below.

$$\text{Thermal resistance } (R) = \frac{\text{thickness } (L)}{\text{thermal conductivity } (k)}$$

As a result, thermal barrier performance measured during atmospheric pressure and room temperature testing may differ substantially from critical conditions.

GORE Battery Insulation is a non-fluorinated, flexible, bondable, low-particulating thermal barrier material. While still in development, it promises exceptionally low thermal conductivity at high temperature (around 0.05 W/m-K at 500°C), ideal for lithium-ion battery applications. Most importantly, GBI is mechanically robust under high heat and pressure. It offers a paradigm shift in BESS thermal management, providing stable barrier properties throughout cycle life, as well as during a thermal runaway event.

The stress-strain curve in Figure 2 illustrates the vast difference between GBI (green curve) and conventional aerogels (blue and orange curves). While aerogel products can compress between 30% and 40% (even as much as 60%) at pressures of 1 MPa, the mechanics of the GBI material are tightly controlled, thinning by less than 5% under the same conditions.

Compressibility up to 1 MPa

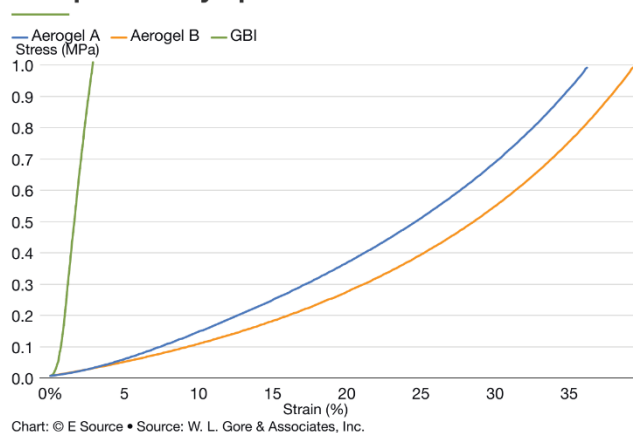


Figure 2. Unlike aerogels (blue and orange curves), GORE Battery Insulation (green curve) technology does not exhibit significant compressive strain, even at pressures of 1 MPa.

Because GORE Battery Insulation maintains thickness at high pressures, it provides high practical thermal resistance as batteries expand over their cycle life. GBI remains robust under pressure even in cell-to-pack (CTP) architectures, where long runs of cells create high compression after expansion. CTP could enable increases in system volumetric energy density of 10% to 25% relative to cell-to-module-to-pack designs, as long as cells remain thermally protected at these high stresses. The mechanical stability of GBI ensures good safety performance in CTP even when implemented at lower overall thickness compared to traditional aerogel alternatives.

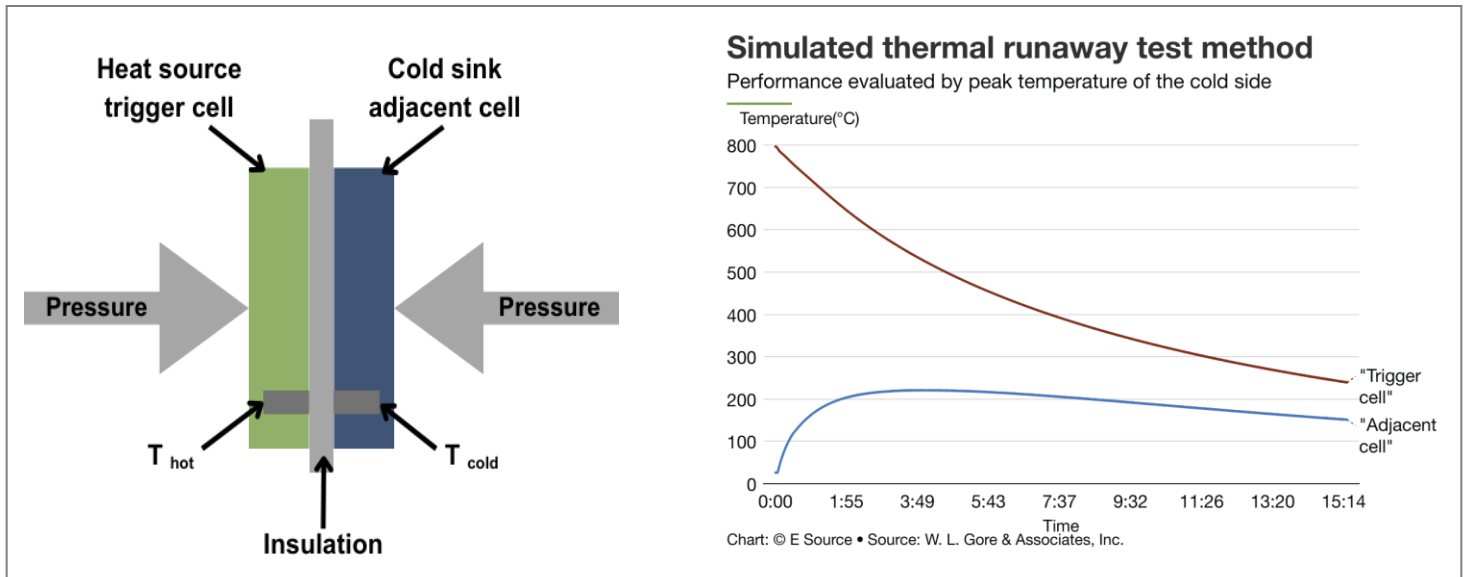
GBI maintains its mechanical properties and associated thermal resistance at the high temperatures seen in thermal runaway. The data in Figure 3 below shows Gore's

comprehensive simulated thermal runaway testing, which compared 2mm-thick layers of GBI and aerogel. The testing apparatus pressed an 800°C stainless steel mass against insulation (GBI or aerogel) under discrete variable pressure, measuring the resulting temperature at an adjacent mass:

- GBI maintains protective properties throughout the thermal event, with

low (<150°C) adjacent-cell temperatures under all compressive loads.

- The thermal barrier performance for aerogels degrades dramatically under high pressure.
- With GBI, thermal performance is stable (<7°C difference) across the entire pressure range.



Simulated thermal runaway test results

Peak temperature vs. pressure

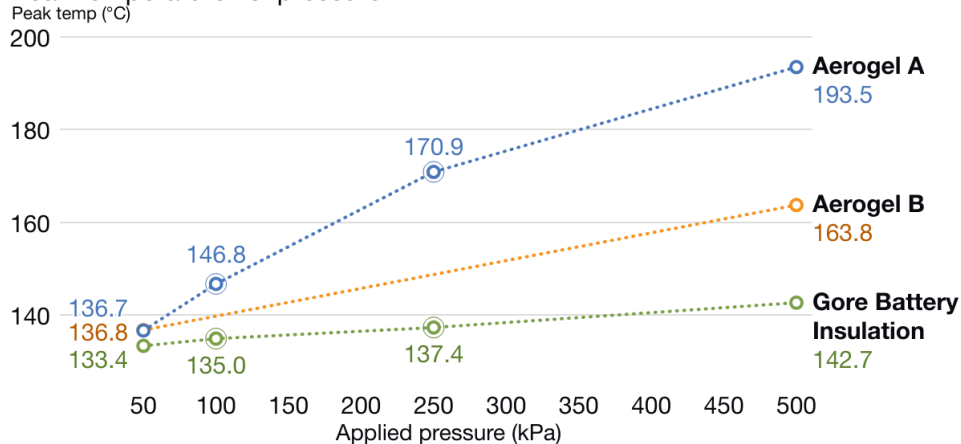


Figure 3. GORE Battery Insulation protects adjacent cells (green) from thermal runaway. **Figure 4.** The average temperature of the adjacent cell increases 25°–50°C for aerogels as applied pressure rises to 500 kPa (blue and orange curves) compared to a 7°C difference with Gore's insulation.

Protection in high-density BESS installations

GORE Battery Insulation's dimensional stability enables the separation of thermal protection and mechanical compliance functions. This architectural change allows engineers to:

- Select ideal compliant materials for cell-cycling requirements.
- Ensure consistent thermal protection through dimensionally stable layers.
- Simplify thermal modeling with fixed resistance values, rather than designing for variable resistances under multiple pressure conditions.
- Reduce validation complexity and accelerate design cycles.
- Optimize module and pack architecture to tolerate high pressures as cells expand over their cycle life.

The low compressibility of GBI ensures thermal barriers remain robust regardless of local variations that occur as the solid electrolyte interphase (SEI) layer builds up over cycling and protects cells in actual thermal runaway events. These improvements provide confidence that thermal barrier performance will remain reliable under any future cell conditions.

Gore's technology affords high-quality, consistent thermal barrier performance even at thicknesses below traditional options such as aerogel or cork. GBI layers have been manufactured with <0.1 mm variability in thickness, down to just 1 mm. This thin range is particularly valuable for insulating smaller-format cells, including those used in residential storage systems.

The trend in industry is to increase container energy density, installing larger cells packed more tightly into modules. For these high-energy cells, GBI is typically applied at ~2 mm, providing a meaningful

advantage over conventional barriers that require 3–5 mm. This thinner profile frees up volume for additional active material without compromising safety. Further, GBI's high mechanical stability and excellent barrier performance at high temperature and pressure will allow the architects of battery container systems to accommodate the next generation of larger cells, which provide more fuel—and therefore more heat—during runaway. The ease of integration and stability of GBI insulating layers have the potential to significantly speed up time to market when adopting new cell technology, while locking in the lowest possible insurance rates.

Real-world validation: Our Next Energy case study

Our Next Energy, Inc. (ONE), selected Gore's insulation technology after evaluating traditional aerogels, silicone foams, phase-change materials, and cork. Instead of placing insulation between every cell, ONE applies it strategically, breaking thermal conduction paths at key intervals to prevent cascading failures while minimizing material usage. At the remaining uninsulated interfaces, ONE uses low-cost, compliant pads optimized solely for mechanical performance.

By adopting this approach, ONE:

- Reduces material costs through increased ratio of compliant pads to thermal barriers.
- Maintains full thermal protection.
- Simplifies design and validation.

Testing results were definitive. Temperature monitoring showed adjacent cells protected by 50% thicker cork exceeded 500°C, while cells insulated by GBI remained at <150°C—well below the thermal runaway threshold.

The results are promising.

- **Cork configuration:** Thermal propagation across the module.
- **GORE Battery Insulation configuration:** Thermal events were limited to the initiated and adjacent cells. The GBI barrier fully contained propagation, preventing spread through the rest of the module.

Cork Insulation

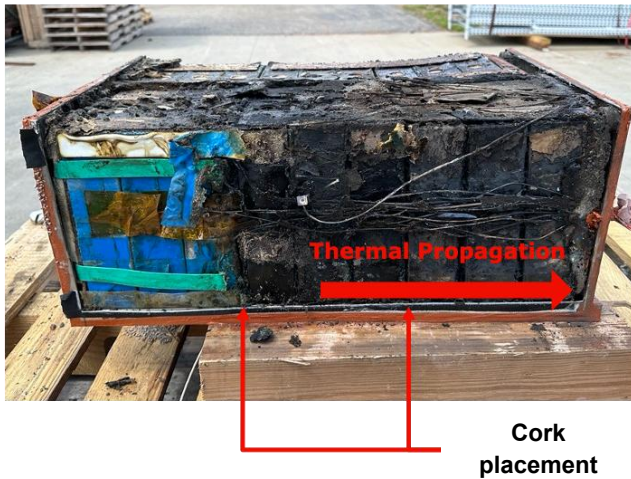


Figure 5. A cork barrier is unable to contain thermal runaway, as shown in the test battery rig. (Image courtesy of Our Next Energy).

GORE Battery Insulation

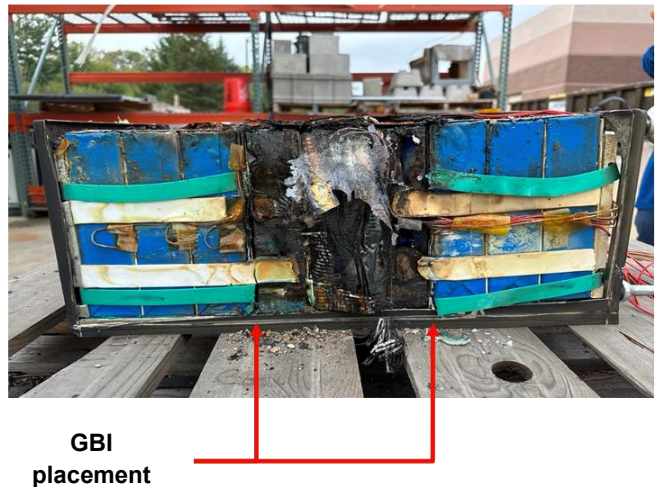
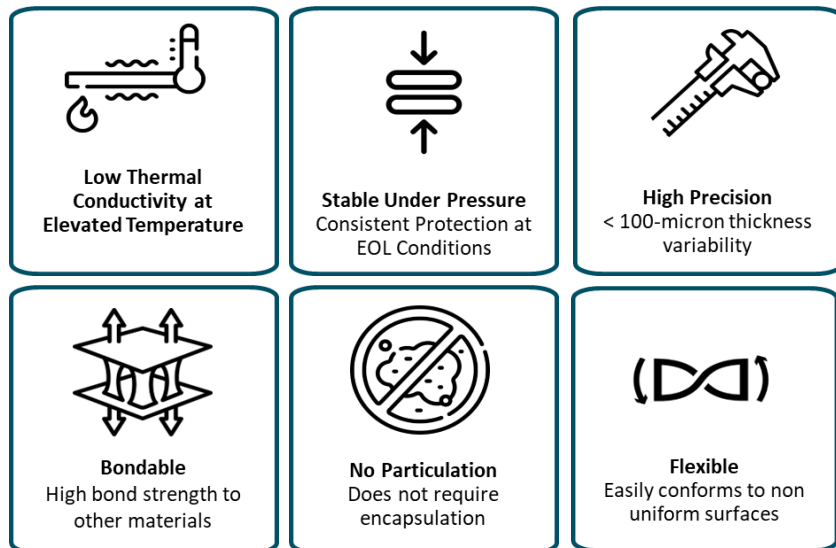


Figure 6. The insulating GORE material (GBI) was placed as a barrier at every third cell effectively isolating the thermal event within the prescribed region. By solving for mechanical compliance and thermal conductivity independently, GBI solutions improve safety while enhancing design flexibility. Image courtesy of Our Next Energy.



Reducing the risk

GORE Battery Insulation's mechanical stability ensures a module's designed thermal protection remains effective throughout product lifecycle, and during catastrophic events.

Technical benefits:

- Predictable safety margins
- Long-term reliability through compression fatigue resistance
- Worst-case protection under extreme conditions
- Enablement of cell-to-pack and other high-pressure architectures, which create margin for a 10% to 25% increase in container energy density
- Enhanced safety brings the potential to increase site-level energy density

Economic advantages:

- Reduce material usage through strategic placement of GBI
- Accelerate design and validation cycles
- Enhance protection of entire BESS investment

GORE Battery Insulation technology addresses critical limitations of traditional dual-function insulation materials by

maintaining dimensional stability under extreme conditions and separating thermal protection from mechanical compliance.

The advantages are validated by comprehensive testing and industry leaders. They include:

- **High thermal resistance** under extreme-stress conditions (relative to alternative materials)
- **Dimensional stability** ensuring consistent protection
- **Proven thermal propagation prevention** in real-world configurations
- **Design flexibility** through functional separation
- **Container level energy gains** through a switch to cell-to-pack architectures

As the energy storage industry grows, Gore's developmental battery insulation material provides the technical foundation for safer, more reliable, and cost-effective battery systems powering sustainable energy infrastructure.

For more information about testing GORE Battery Insulation in your BESS designs, or to discuss GBI for your adjacent battery applications, please contact your Gore representative.

(1) Aubuchon, S. R., Wikol, M. J., Czerwinski, T., & Hillen, K. (2025). *Mitigating the risk of thermal runaway propagation with GORE Battery Insulation Technology*. W. L. Gore & Associates, Inc.

About E Source and Team

E Source has been a leader in battery technology analysis and cost modeling since acquiring Cairn ERA in 2021, building upon 30+ years of thought leadership and modeling in the energy space. E Source specializes in providing curated market intelligence, data-backed industry research, and benchmarking to inform investment decisions, technology adoption, and strategic business decisions. E Source methodology for battery industry analysis entails employing a first principles analysis to examine emerging battery technologies and model their impact on battery costs. E Source forecasts battery prices with our Battery Cost Model, which contains over 3,000 inputs and 30,000 formulas that models battery component, cell and system production. E Source forecasts technology adoption and battery demand for over 50 different battery markets based on our analysis of the technical requirements and economics of each application. Forecasts are broken down by application and segmented into global regional distribution, energy capacity, power capacity, cathode technology, anode technology, and cell revenue. Forecasts are then stress-tested against top-down historical proxy growth curves to determine how other historical examples have grown under similar supply/demand circumstances.



Dr. Seth Miller is Director of Electrochemistry at E Source and President of Heron Scientific, a boutique consulting company specializing in R&D strategy and investment planning for companies leveraging cutting edge materials science, especially new battery chemistries. As an entrepreneur, Dr. Miller has served as founding CEO of ClearMark Systems, a developer of anti-counterfeiting software for DARPA; CSO of Fluonic, a microfluidic flow sensor for medical infusion; and CSO of EverSealed, a developer of vacuum sealed windows. He also served as CTO of Technology Reserve, an IP licensing company, and Managing Director of Xnova after its acquisition of Technology Reserve. Dr Miller has served as an expert witness and testified at trial in several high stakes patent infringement cases, most recently in SK Innovations vs LG Energy Systems regarding battery packaging. He is author or co-author on 93 issued US patents, and received a Ph.D. in chemistry from the California Institute of Technology in 1998.



Ben Campbell is Manager of Battery Research at E Source, where he leads product strategy and delivery for the Battery Next research and advisory service. His work spans the business models, manufacturing processes, and electrochemistry of batteries for both stationary energy storage and electric transportation. At E Source, he has developed technoeconomic models for various energy storage technologies and market forecasting models. Prior to E Source, Ben was a Lead Analyst at Cairn Energy Research Advisors (ERA), a specialty consulting firm focused on batteries that E Source acquired in 2021. At Cairn ERA, he co-developed an industry-leading model of battery manufacturing costs and forecasted markets for batteries and charging infrastructure, which he continues to advance at E Source. He holds a BA in philosophy from Wake Forest University.