Trends in battery pack technologies and challenges that may exist
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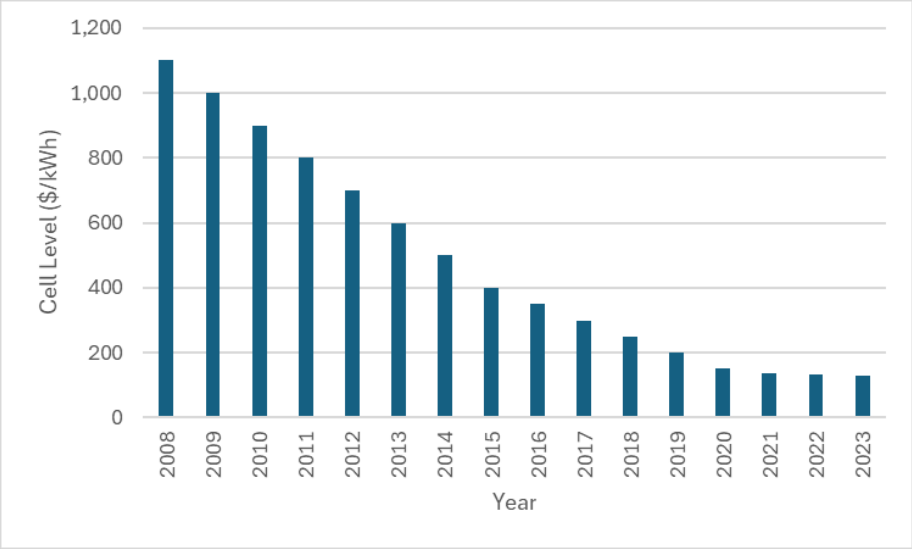
Trends in battery pack technologies and challenges that may exist

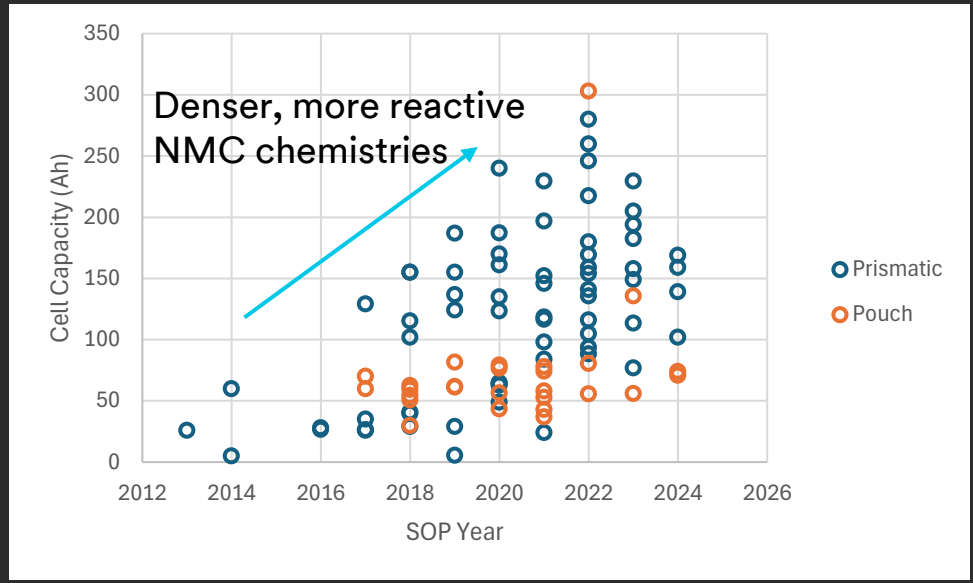
Brandon Bartling

Battery System Architect, 3M

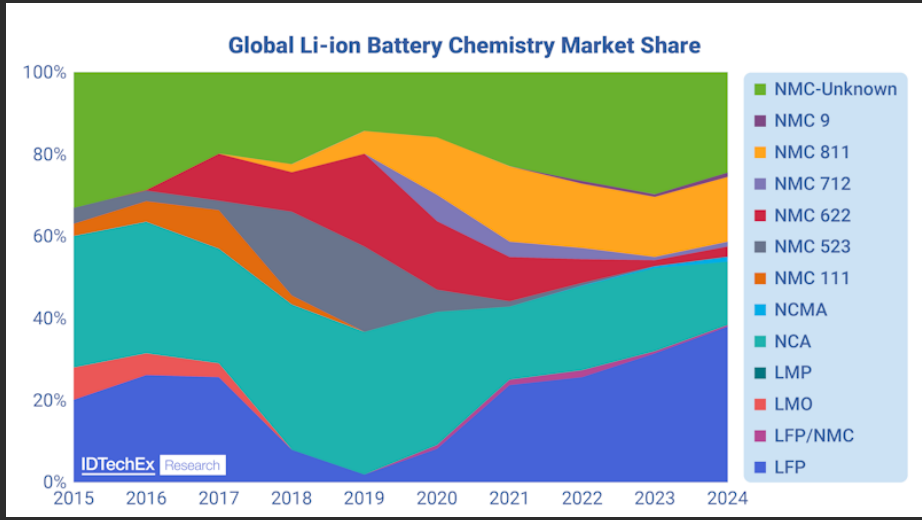
Trends in cell chemistry driving market adoption



- Cell level cost beginning to plateau



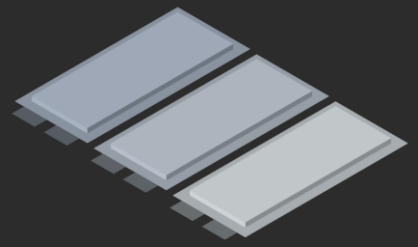
- Energy per cell is becoming larger



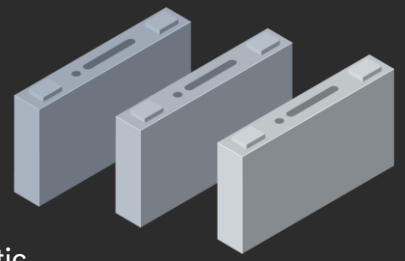
- Mix of chemistry changing (LFP increase)

- Industrialization of battery packs squeezing out opportunities at cell level.
- Regulation changes driving mix in chemistry.
- Pack costs driving cell size

Evolution of battery pack designs – Cell-to-modules

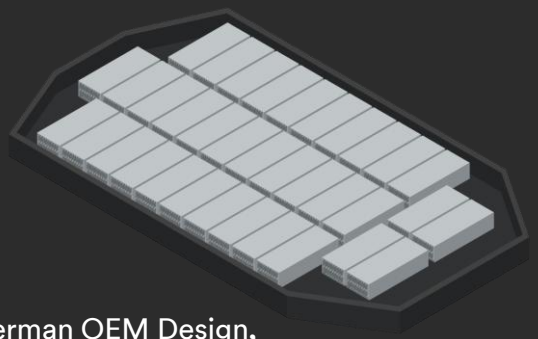


Pouch

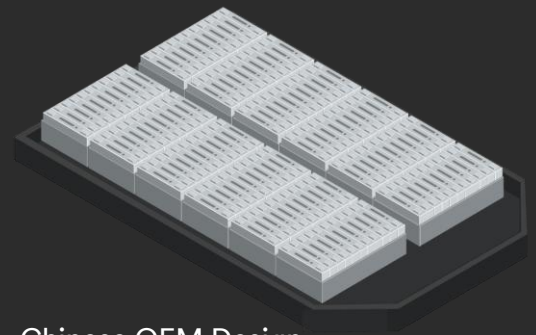


Prismatic

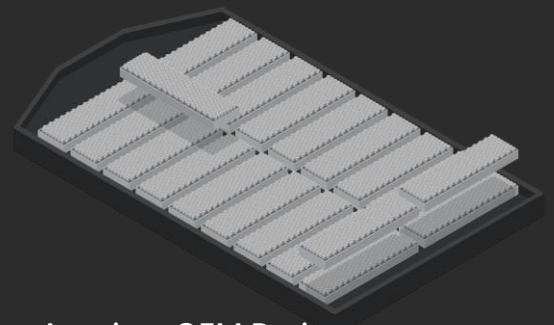
Cylindrical



German OEM Design,
35 Modules



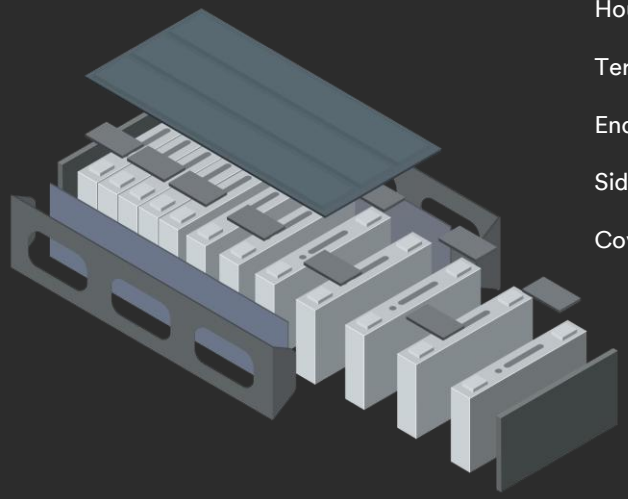
Chinese OEM Design,
12 Modules



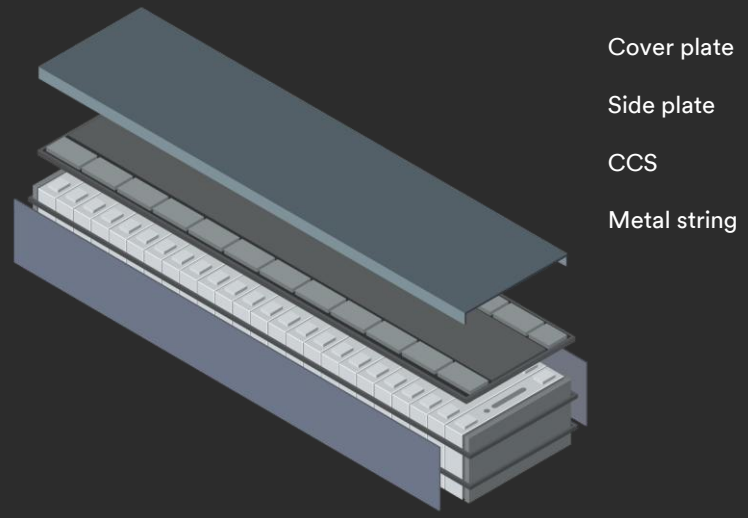
American OEM Design,
21 modules

- Cell-to-module-to-pack construction and assembly process commonly adopted to pouch, prismatic and cylindrical cell form factors
- Packaging at module level adds weight and redundancy that lead to similar gravimetric and volumetric energy density level

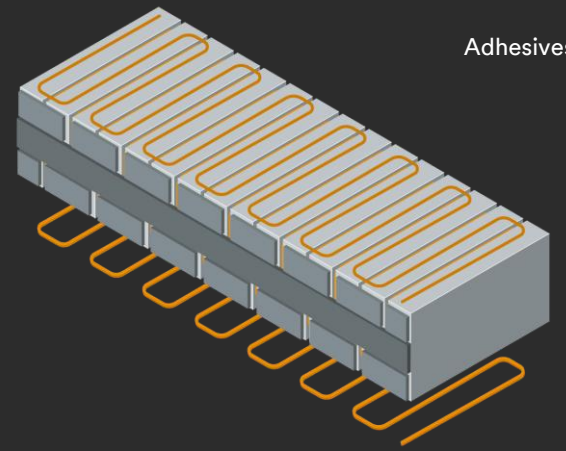
Evolution of battery pack designs – Reduction at module level



Traditional pack with module
Weight: 100%
Component number: 100%



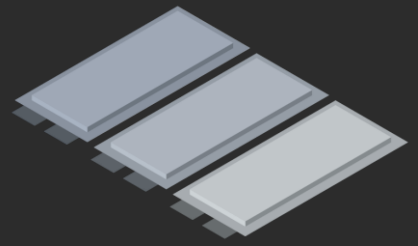
Large Module Design
Weight: 95%
Component number: 80%



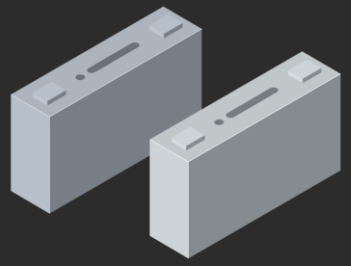
Structural Module
Weight: 92%
Component number: 65%

- Module construction optimized significantly with less redundancy, more integrated parts and lower number of parts
- Energy density and cost both improved by higher level of cell-to-module ratio
- Structural tapes and adhesives start to be used to construct structural modules for further cell-to-vehicle concept

Evolution of battery pack designs – Cell-to-pack

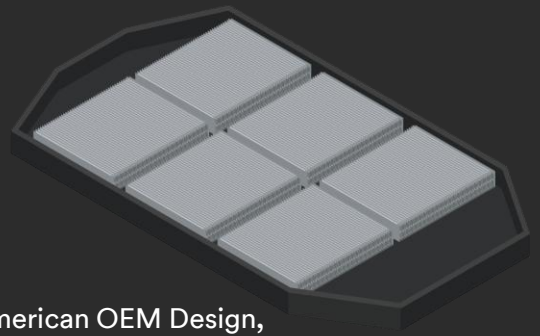


Pouch

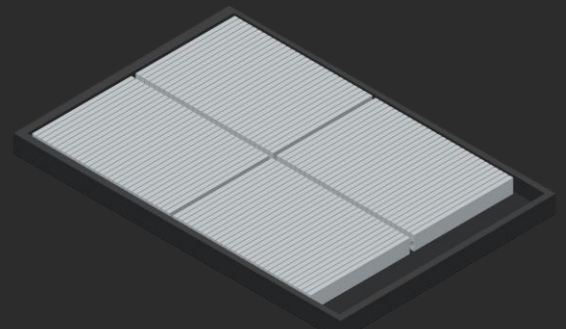


Prismatic

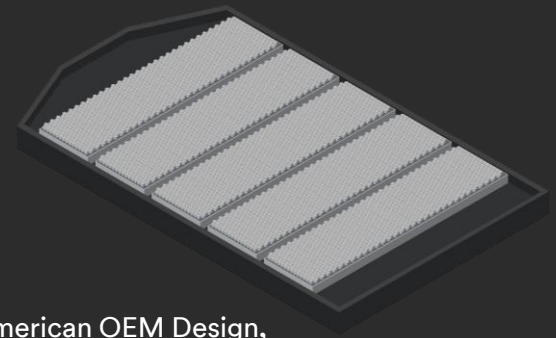
Cylindrical



American OEM Design,
Large Modular Architecture



European OEM NextGen Platform,
Large Modular Architecture



American OEM Design,
Large Modular Architecture

- Aimed at higher energy density, battery pack construction evolves to larger size and more compacted module design
- Most cell-to-pack designs still have the module construction with reduced module number

Challenges still exist to advance the industry

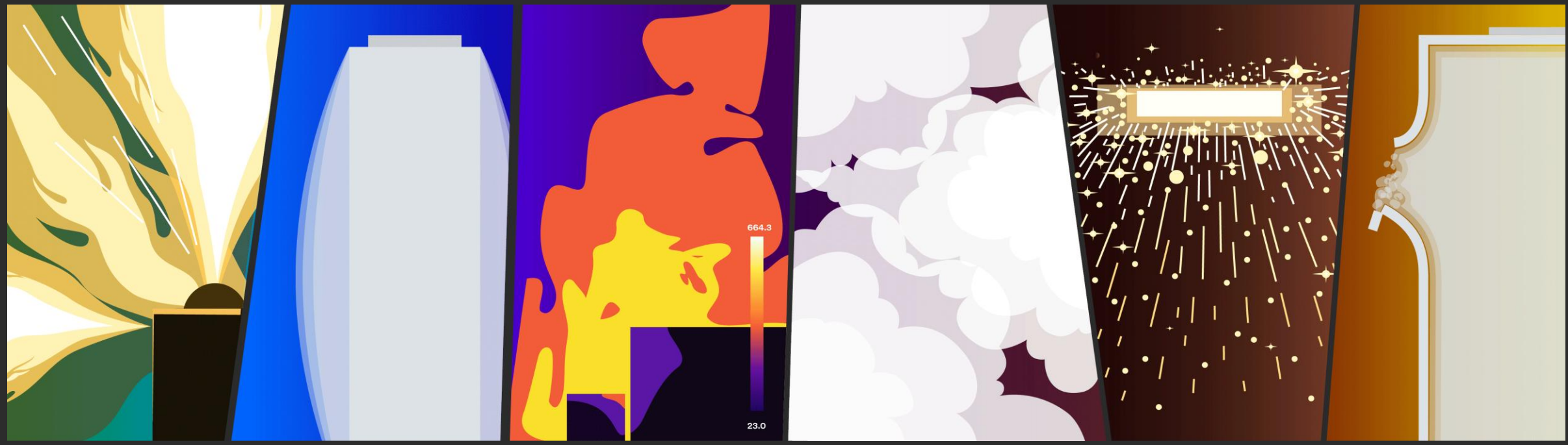
- Structural/mechanical
- Electrical
- Thermal management
- Battery pack regulations

Single-cell thermal runaway videos, NMC vs. LFP

NMC, single-cell

LFP, single-cell

Potential harmful effects during thermal runaway

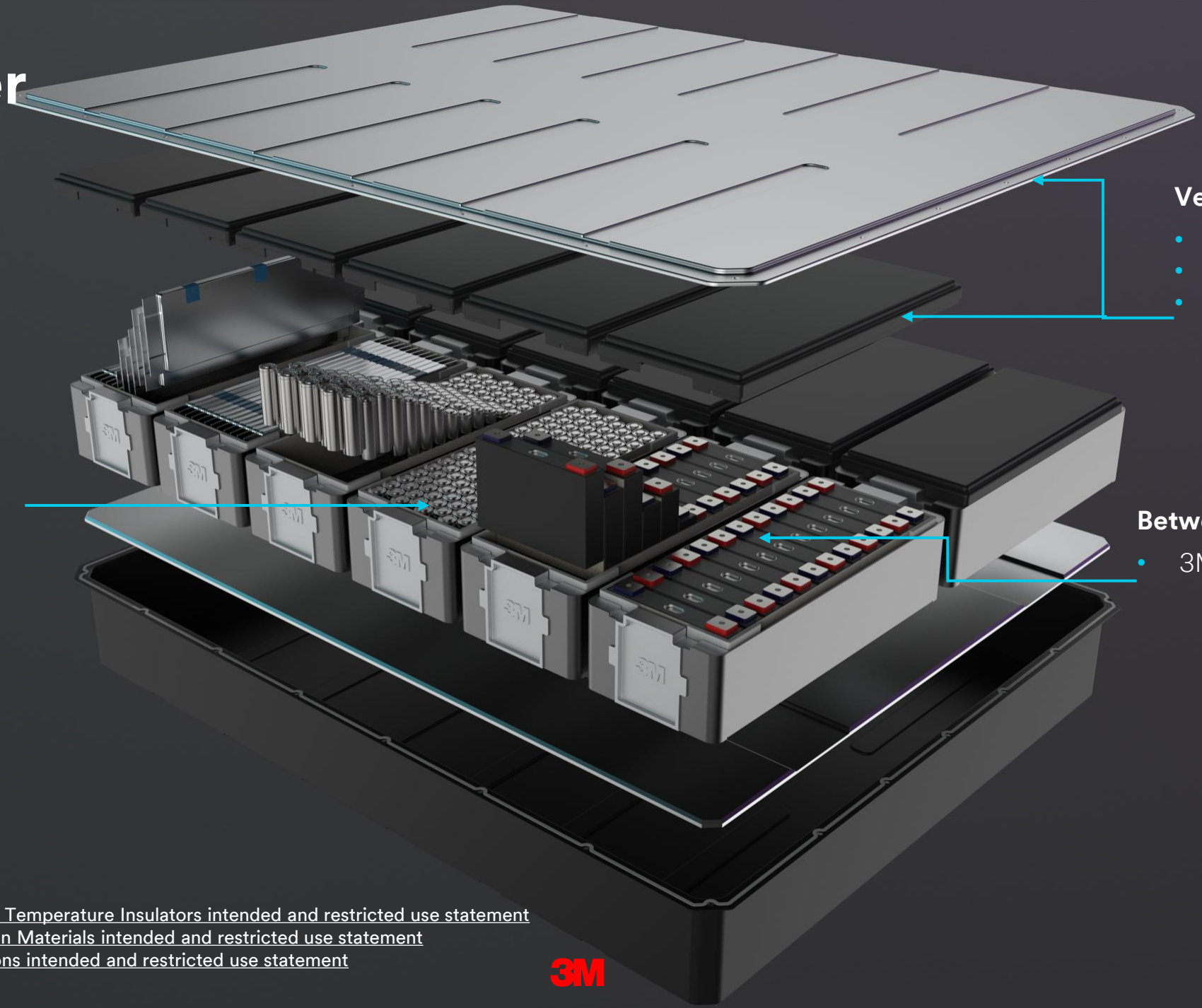


Large directed flames | Expansion | Rapid high temperatures | Smoke and particulate generation | Hot conductive particles | Vent misdirection

There are several potential issues that can occur when a cell goes into thermal runaway.

Understanding the what will significantly help in addressing the how.

3M Barrier Materials



Venting Path

- 3M TFRB-SE1**
- 3M TFRB-SE3**
- 3M Tape 91**

Above Cell Barrier

- 3M TB5000 Series***
- 3M FRB-NT*

Between Cell Barrier

- 3M TRB600/700 Series*

*Read our full Compressible High Temperature Insulators intended and restricted use statement
**Read our full Electrical Insulation Materials intended and restricted use statement
***Read our full Vent Path Solutions intended and restricted use statement

Challenges in structural assembly

Protection of cells

Impact resistance and rigidity (extra structure outside the pack vs. structure inside the pack)

Vibration resistance (shock-absorbing, durable connections inside the pack)

Pack density metrics

Creating more volume for cells, while maintaining thermal, electrical and safety performance

Lightweight to increase weight budget for other functions or capacity

Stress management/ Expansion of cells

Accommodation of cell dimensional changes

Balancing goals of:

i. Using cells as structural element
ii. Maintaining acceptable stress states on cells

Precision manufacturing

Managing tolerances on large pack scale

Disassembly

Repair

Reuse

Recycle

Costs and efficiency

Fast cycle times/assembly process

Reduction of complexity and parts to enable automation

Broad range of solutions across the bonding continuum

Adhesive Load Bearing Capability	
Product Category	**Overlap Shear (MPa)**
3M™ Structural Adhesives 3M™ Scotch-Weld™ Structural Adhesives	7.0 – 40
3M™ Structural Bonding Tape 3M™ Structural Adhesive Tapes	5.0 – 10 (avg.)
3M™ Scotch-Weld™ PUR Adhesives	2.8 – 7.0
3M™ Adhesive Sealants	2.0 – 5.5
3M™ Acrylic Foam and Acrylic *Plus* Tapes	0.3 – 3.0
3M™ Dual Lock™ Reclosable Fasteners 3M™ Hook and Loop™ Reclosable Fasteners	0.1 – 0.40
3M™ Adhesive Transfer Tapes 3M™ Double-Coated Tapes	0.01 – 0.1

3M™ Pressure-Sensitive Adhesives
3M™ Adhesive Transfer Tapes , Double-Coated Tapes and Wire Harness Tapes

3M™ Reclosable Fasteners
3M™ Dual Lock™ and Hook and Loop Reclosable Fasteners

Acrylic Foam Tapes
3M™ Acrylic Foam and Acrylic Plus Tapes

Polyurethane and Hybrid Adhesive Sealants
3M™ Adhesive Sealants

Polyurethane Adhesives
3M™ Scotch-Weld™ PUR

Structural Tapes
3M™ Structural Bonding Tape
3M™ Structural Adhesive Tape

Structural Adhesives
Acrylic Adhesives
1K /2K Epoxy Adhesives
3M™Structural Adhesives
3M™ Scotch-Weld™ Structural Adhesives

Structural Adhesives

- Strong portfolio of 2K epoxies
- Developing low-temp 1K epoxies
- Unique acrylic adhesives: low odor, non-flammable, impact resistant, strong adhesion to low surface energy substrates
- Reactive polyurethanes for a variety of applications
- Structural liquid, film and tape adhesives

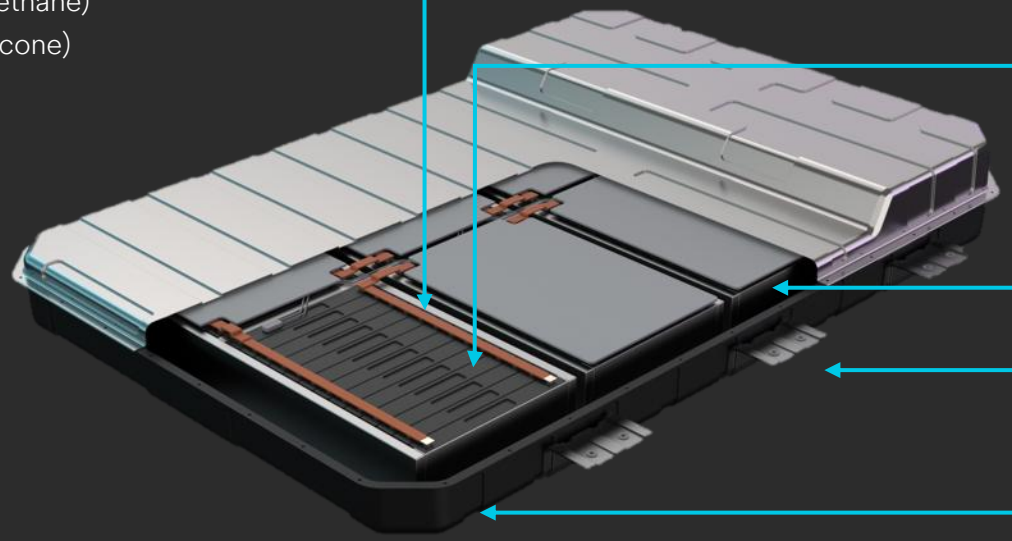
Load Bearing Capability

Adhesive Technology

APPLICATION AND DESIGN RQMT (BiW, Exterior/Glass, Interior, etc.) → MATERIAL AND SUBSTRATE COMBINATION → MODELING, PERFORMANCE AND MATERIAL SPEC TESTING → AUTOMATION ANDLINE INTEGRATION (GAD&DC) → OEM MODEL, SOP PLATFORM, MFG PLANT, SUPPORT

3M Assembly | Disassembly Materials

(**E** – Epoxy)
(**U** - Urethane)
(**S** - Silicone)



Cell | X Structural Bond

Prismatic cells
- DP6300 Series (U)*

Cylindrical cells
- DP100 Plus Series (E)*
- DP400 Series (E)*

Cell | X Non-Structural Bond

Prismatic cells
- 200 MP Series*
- 300 LSE Series*

Pouch cells
- 300LSE Series*

Lid Seal

Structural adhesive
- DP100 Plus Series (E)
- VHB™ Extrudable Tape GP

Serviceability
- SZ1000 (S)**

Pack | Chassis

Injectable structural
- SA9844 (E)**

Thixotropic structural
- SA9860 (E)**

Bolted Connections
- 3M™ Friction Shims

Battery Box Assembly

Structural adhesive
- DP6300 Series (U)

Tape
- 200MP Series*

Specialty solutions

Bonding composites:
Debonding solutions

- DP6300 Series (U)
- SNPE2027

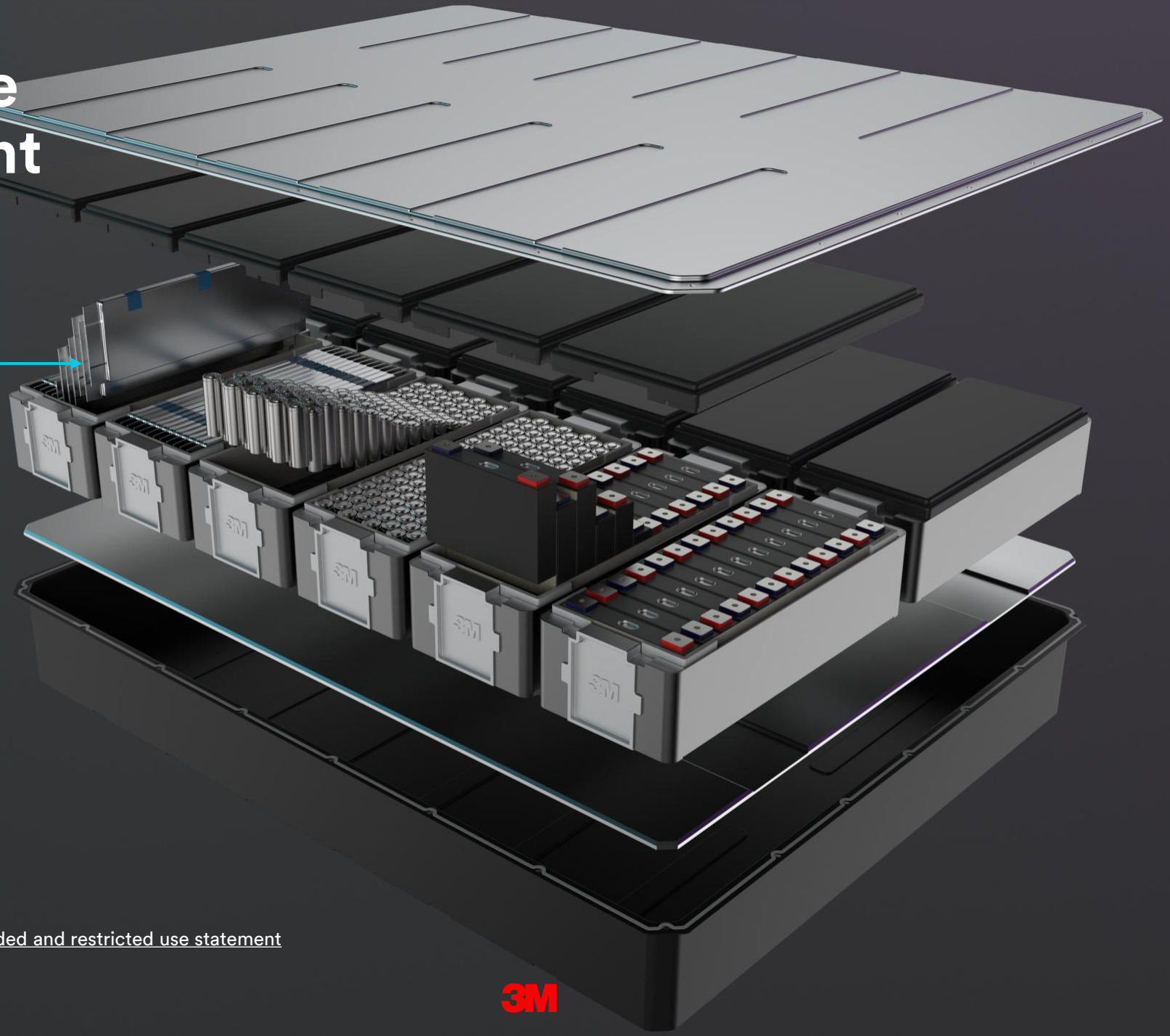
*These assembly products are industrial products and were not designed for automotive applications. Additionally, not all assembly products have been tested or validated for automotive applications.
Read our full Automotive Disclaimer

**These Assembly products are validated for Automotive use.
Read our full Intended Use and Restricted Use Statement

3M Pressure Management Materials

Between Cell Cushion

- 3M™ Cell Expansion Foam SJCEF



Read our full Cushioning Materials intended and restricted use statement

Electrical insulation – Industry trends and design challenges

Electrical Equipment Design Challenges

- Higher efficiency standards are increasing transformer size
- Pressure for higher-efficiency motors that are smaller, faster and lighter
- Manufacturing teams need to increase uptime and throughput
- Demanding sustainability requirements

EV Battery Design Challenges

- Global Safety Regulation & Standard
- Journey to $70/KWh
- Cell to Pack/Chassis Design
- Higher Pack Energy Density, ≥250 Wh/kg
- High C Rate Charging, ≥350 kW
- Pack Manufacturing Automation

Potential Battery Applications to Explore

- Electrical insulation of battery cells, modules, cooling plates, bus bars, wire harness, and power electronics components
- Electrical insulation post cell burst





3M Electrical Insulation Technology and Experience*

3M has a long history of providing electrical insulation products for industrial use. Now we are applying our expertise to explore how these products could potentially be used in automotive applications.

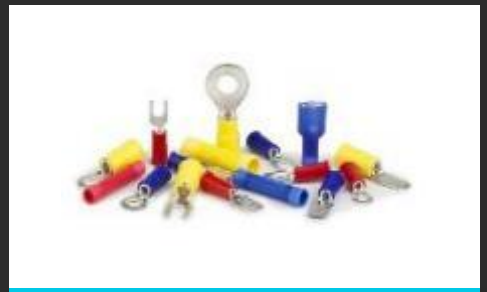
Vinyl Tapes

Heat Shrink Tubing

Flexible Insulation (Papers & Laminates)

Electrical Insulating Resins & Powders

Cold Shrink Tubing



Lugs & Terminals

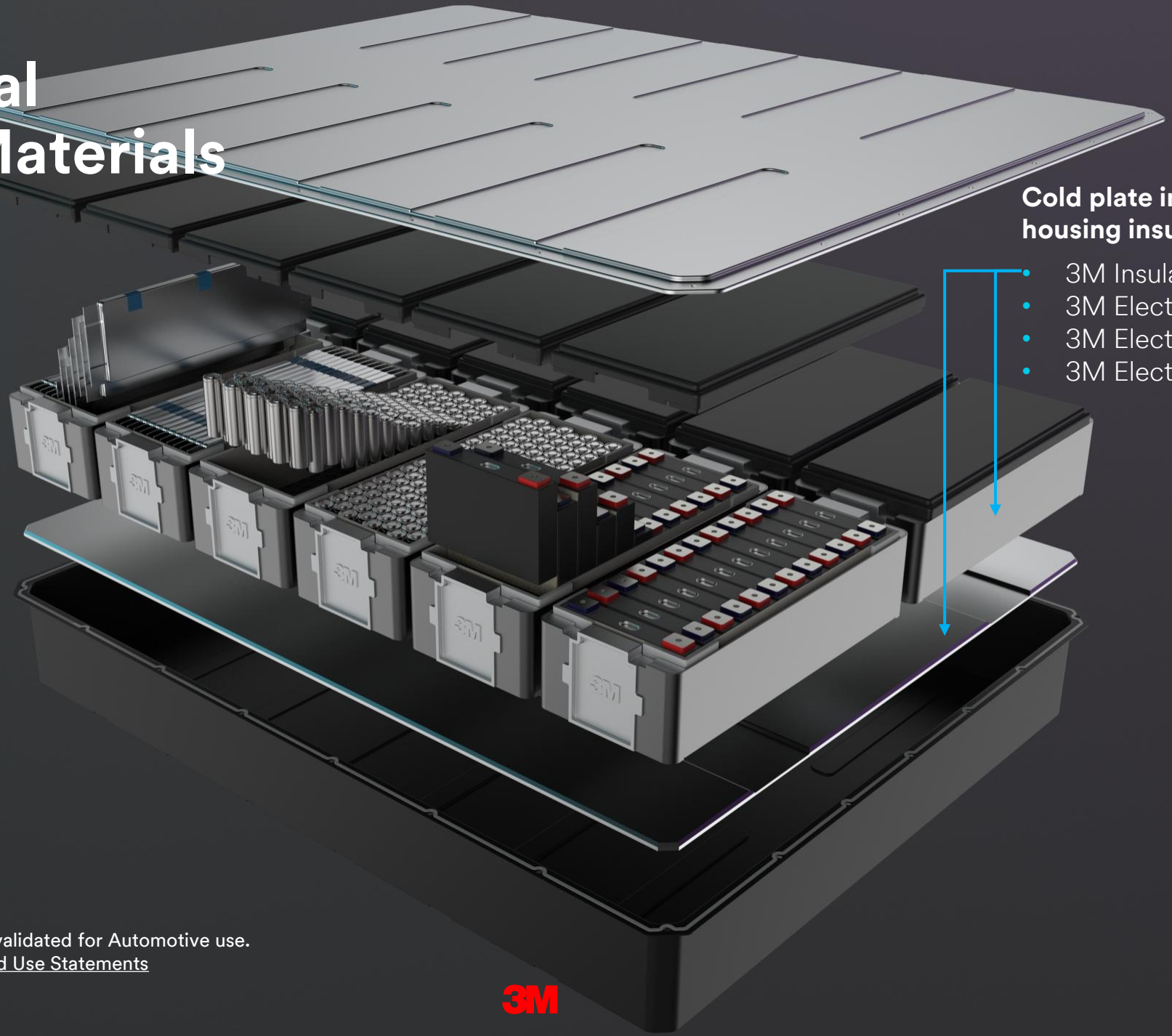
Conducting Tapes

Insulating Tapes

These electrical insulation products are industrial products and were not designed for automotive applications. Additionally, not all electrical insulation products have been tested or validated for automotive applications. Read our full Automotive Disclaimer

Please reach out to your 3M Application Engineer to discuss potential applications.

3M Electrical Insulation Materials

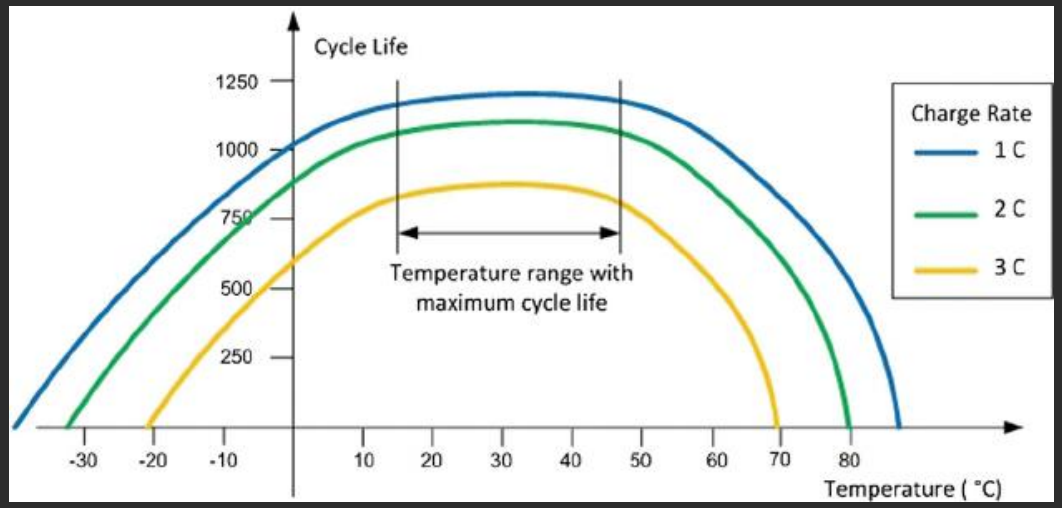


Cold plate insulation/Module housing insulation

- 3M Insulation Tape 1924B-1
- 3M Electrical Tape 1350F-1
- 3M Electrical Tape 1350F-2
- 3M Electrical Tape 1351-1

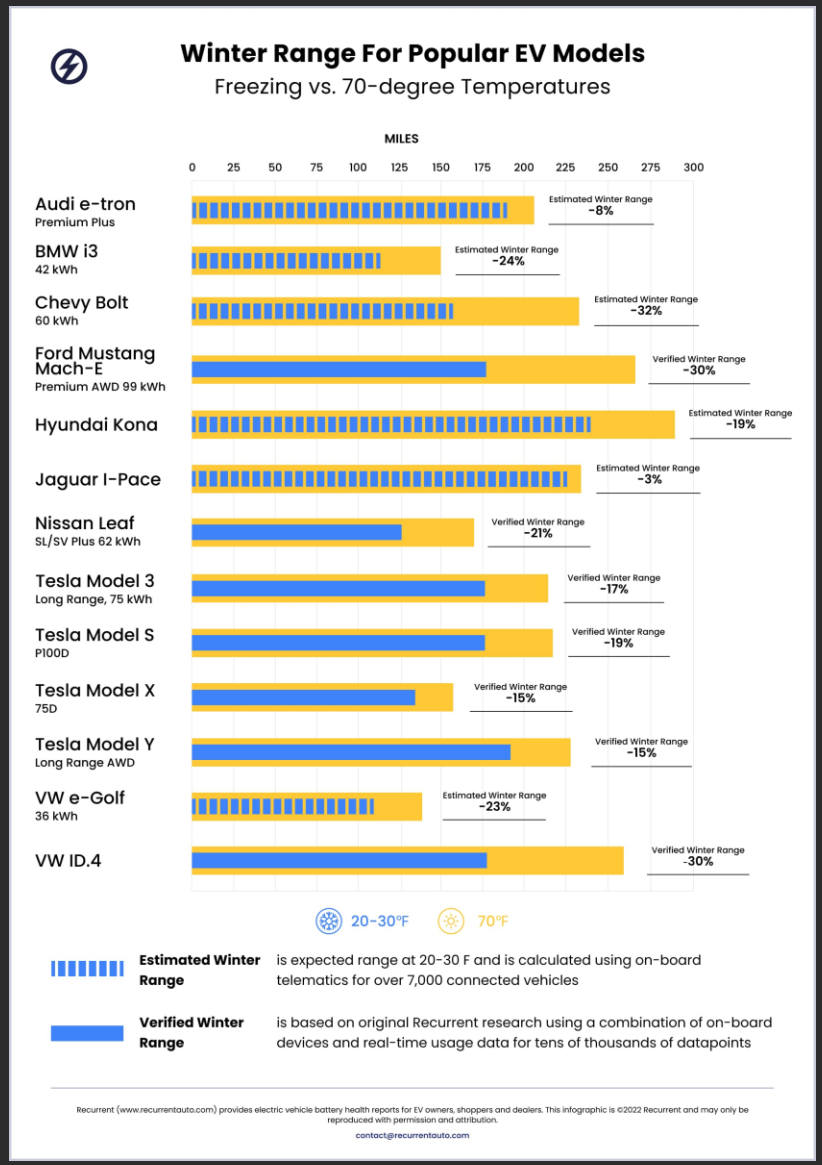
These electrical insulation products are validated for Automotive use.
Read our full Intended Use and Restricted Use Statements

Thermal management challenges in battery packs



Journal of Power Sources 256:110–124

- Proper temperature maintenance of lithium-ion cells is critical to cell operation
- Environmental temperatures must be maintained to prolong cycle life and safety
- Thermal uniformity and peak temperatures must be maintained during cell cycling



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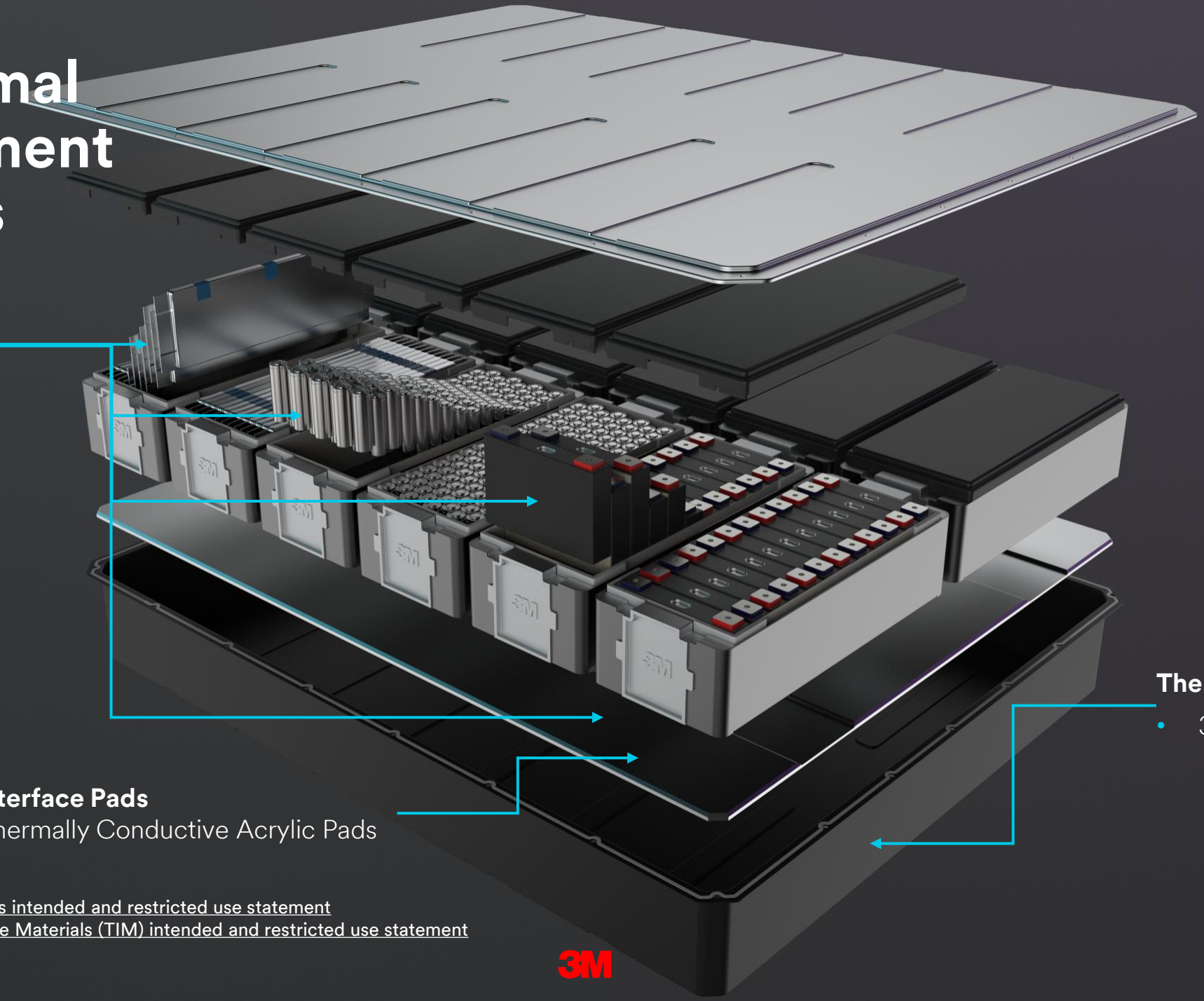
3M Thermal Management Materials



Thermal Fillers:

- 3M™ Glass Bubbles for insulation
- 3M™ Boron Nitride Cooling Fillers for conductivity

Thermal Insulation Mat

- 3M BEM 1807S

Thermal Interface Pads

- 3M™ Thermally Conductive Acrylic Pads

*Read our full Thermal Insulators intended and restricted use statement
**Read our full Thermal Interface Materials (TIM) intended and restricted use statement

Enabling mobility for a better world.

- Advancements in battery chemistry and manufacturing have led to significant growth in system electrification
- New chemistries and cell designs have opened the door to new pack designs
- Challenges in new pack designs include:
  - Structural
  - Electrical
  - Thermal management
  - Battery pack regulations
- Leveraging a complete system mentality can enable new opportunities but demands materials innovation to unlock its potential