Scaling-Up Commercial Batteries with High-Capacity Silicon Anodes

AABC Europe

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Co-Founder & Advisor

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Powering the Technologies of the Future

High energy density, high-capacity batteries without compromising safety

Our goal is to create a Li-ion battery that can exceed the performance demands of the technologies of the future, from IoT devices and consumer electronics to EVs.

- New mechanical design enables multiple advantages:
  - Enables materials with large volume changes (e.g. silicon)
  - Exceptional thermal performance enabling fast charge, reduced thermal gradients
  - Tolerance against thermal runaway with BrakeFlow™ safety system

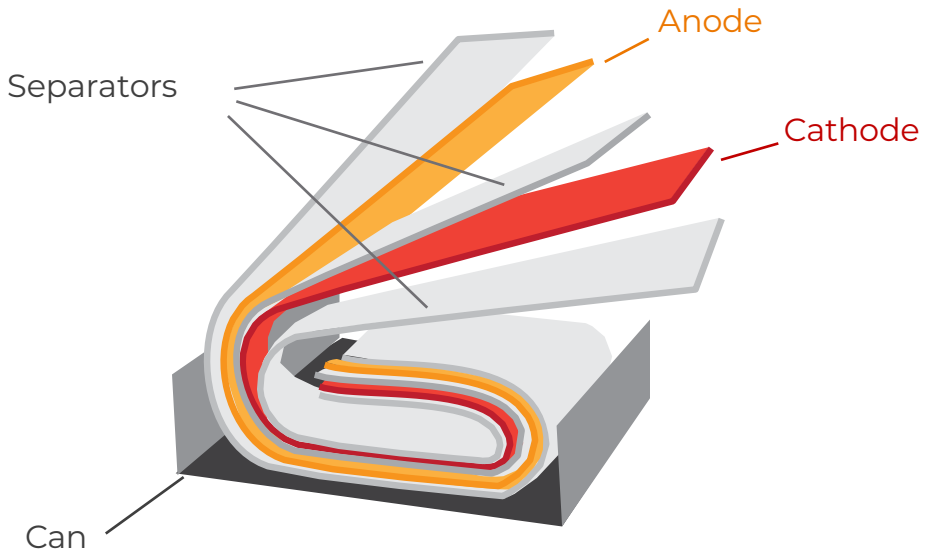
- Next-gen consumer battery manufacturer founded in 2007 with locations in Fremont, California & Penang, Malaysia

- Actively working with industry leading OEMs to extend into the EV market – Focus on JV/Licensing

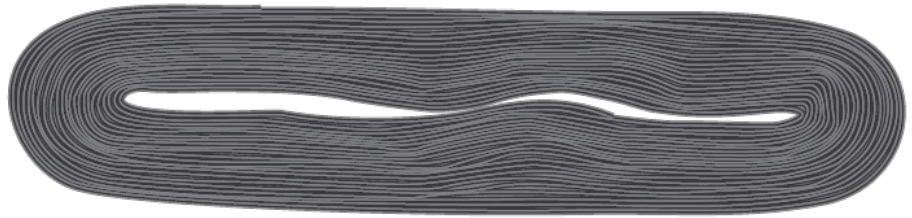
- More than 150 patents issued, 150 pending

Conventional Cell Architecture

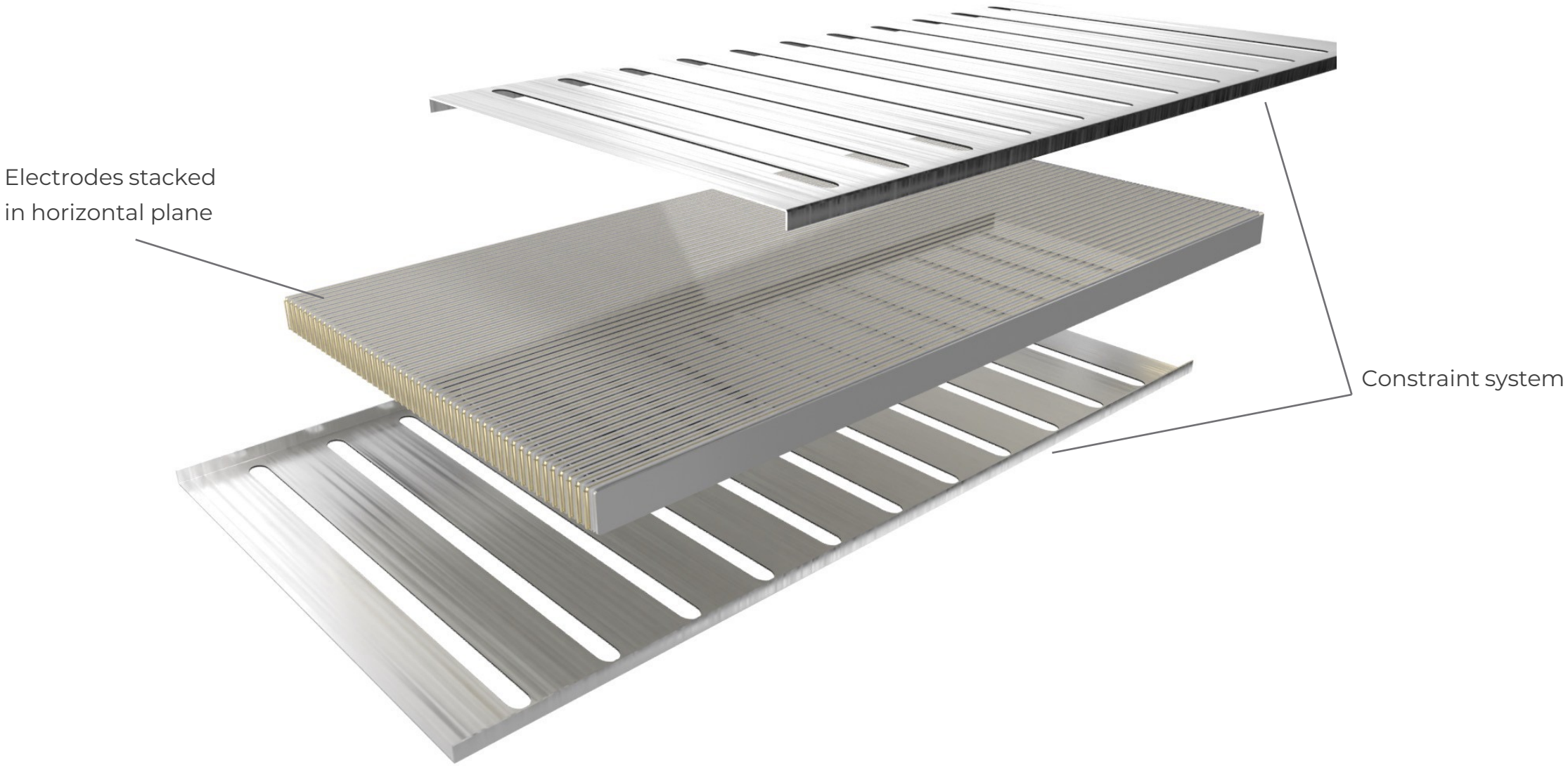
Conventional **Wound** Lithium-ion Cell



Illustrated Cross-Section

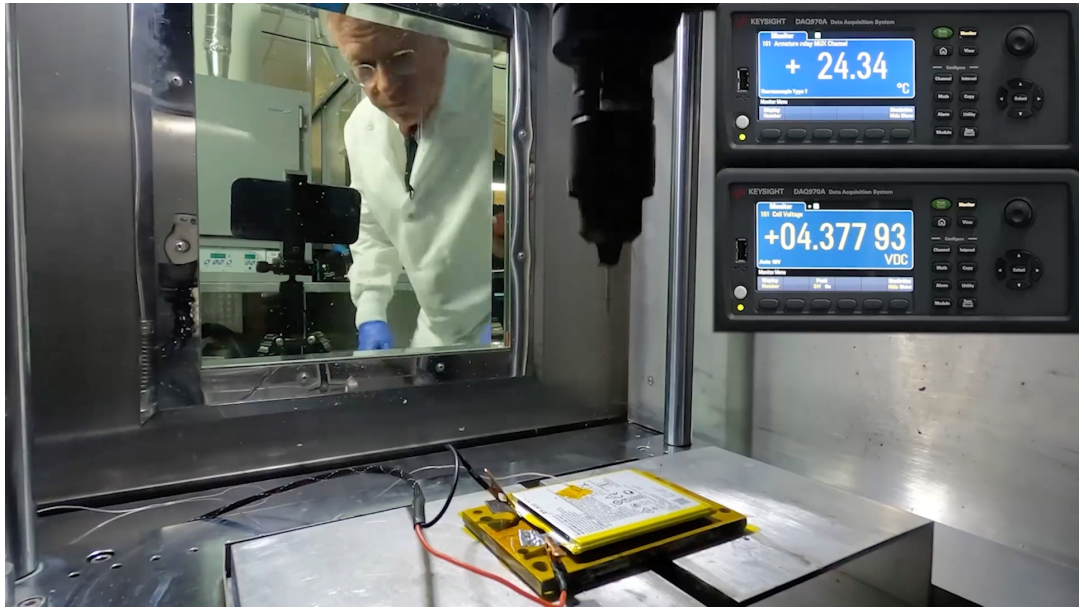


Enovix Cell Architecture

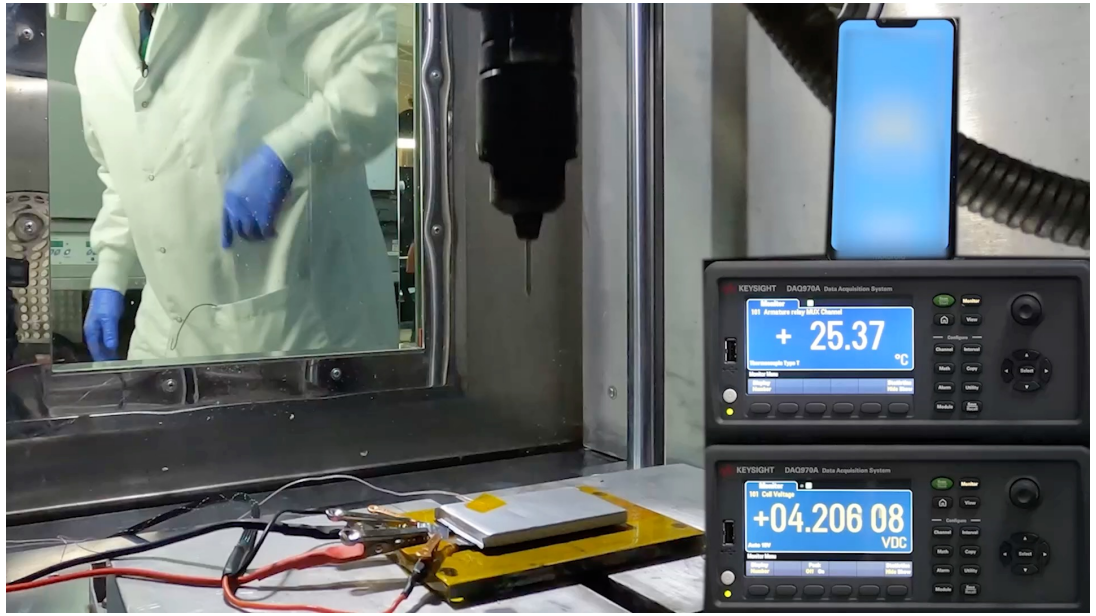


Our Innovative BrakeFlow™ Technology

Off-the-shelf Cell Fire vs. BrakeFlow™



Off-the-shelf cell phone battery at 0:04 min
T = 283°C & rising



Enovix BrakeFlow Battery at 4:00 min
T(max) = 74.8°C
https://vimeo.com/742273681 (full video)

Enovix **BrakeFlow™**
Technology

Powering the Technologies of the Future

IoT

'26 Battery TAM: $8B[1]

25%-124% Capacity Advantage[1]

Mobile

'26 Battery TAM: $11B[2]

31%-101% Capacity Advantage[1]

Electric Vehicles

'40 Battery TAM: $523B[3]

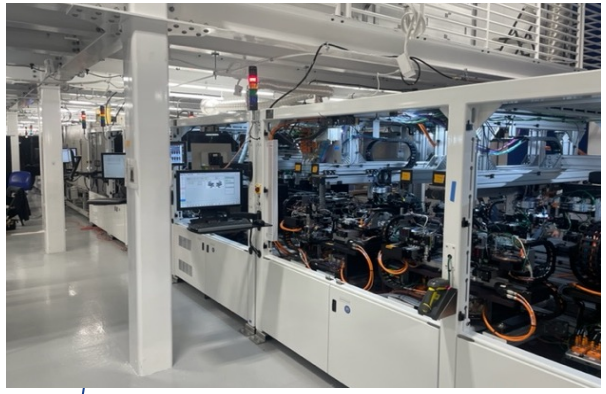
Thermal Advantage, Material Agnostic

[1] Calculated advantage based on existing battery in select currently available products compared to Enovix EX-1 battery at end-of-life dimensions
[2] Company estimates as of January 2023; IDC Worldwide Mobile Phone Forecast Update 2022-2026
[3] The New Oil: Investment Implications of the Global Battery Economy - Morgan Stanley Research, Nov. 15, 2021

Scale-Up Strategy

Fab1

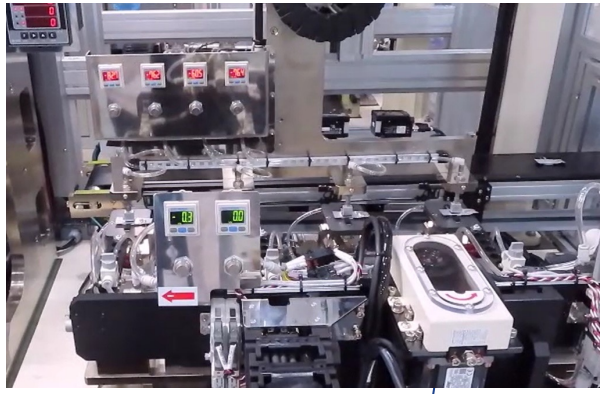
Fremont, CA
In production today on Gen1
Output target: 180K units (2023 plan)
Agility Line for Custom Cells[1]



Fab2

Penang, Malaysia

Output target: 9.5M-18.9M units per Gen2 line based on cell size



Capacity Expansion Optionality

- Additional “Copy Exact” Gen2 lines in Fab2
- Lines placed and/or funded at customer sites
- JV/Licensing for EV market

2023 **2024** **2025** **2026+**

[1]Higher speed pilot line to produce custom size batteries

Gen2 Designed to Build Batteries over 10x Faster Than Gen 1

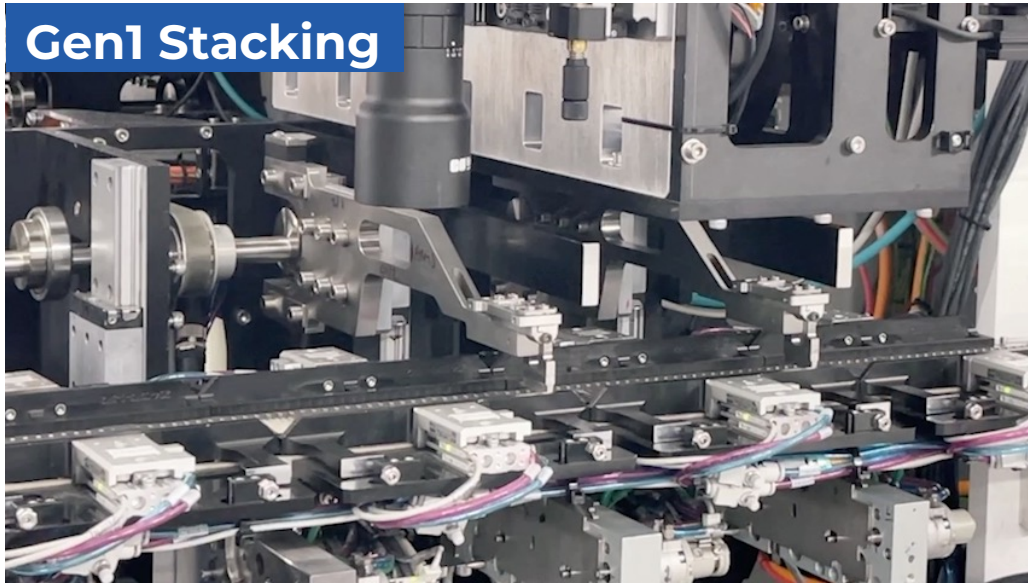
Significant Learning from Gen1 Captured; Upgraded Automation and Parallelism

Gen1

200W Laser Patterning
100 Units Per Hour (UPH)[1]
Partial Automated Production

Gen2 Design

1,000W Laser Patterning (Cut Speed Improved 5x)
Designed for 1,350 UPH[2]
High Speed Automation
Enhanced Parallelism and Metrology



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[1] Q4 2023 Gen1 production UPH when in operation goal
[2]Gen2 design (equipment currently being built to this specification)

Enovix Architecture

- High Energy Density
- High Cycle and Calendar Life
- Fast Charge
- Excellent Thermal Performance

Enovix Architecture

High Energy Density

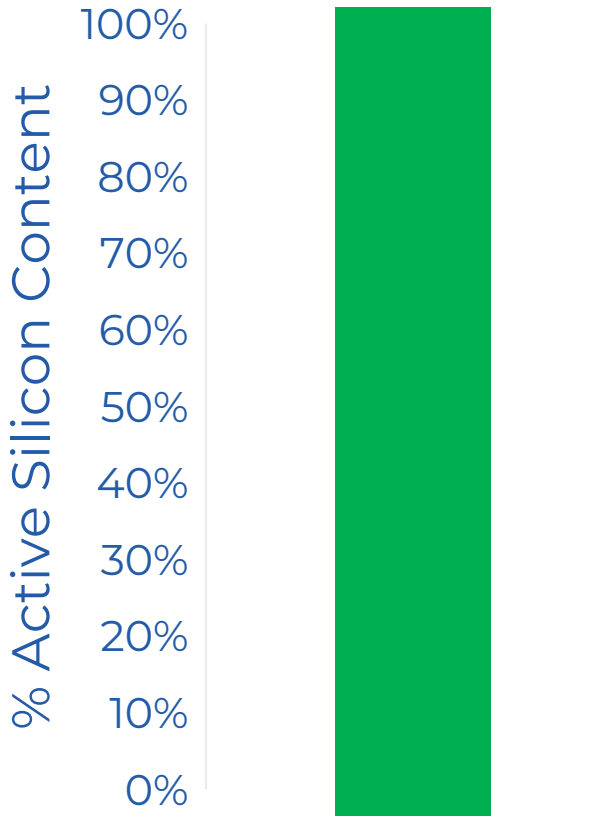
High Cycle and Calendar Life

Fast Charge

Excellent Thermal Performance

Maximizing Silicon to Drive High Energy Density

Silicon Can Theoretically Store Over 2x the Lithium in the Anode than Graphite[1]

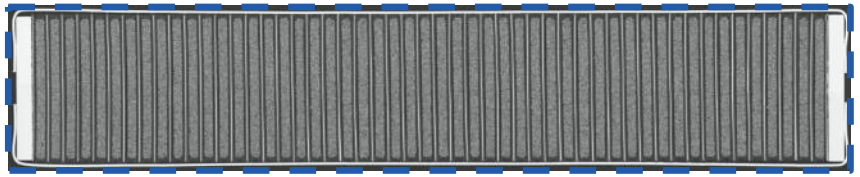


Lithium-Ion Incumbents[2]

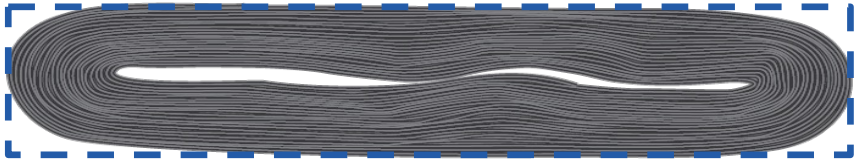
3-7%

Increased Silicon Content Enabled by Advanced Architecture

Enovix 3D Architecture + Integrated Constraint



Conventional Wound Lithium-Ion Cell



[1] Silicon anode material capacity: 1,800 mAh/cc (de-rated from theoretical capacity of 2194 mAh/cc for Lithium trapping losses). Graphite anode material capacity: 800 mAh/cc (nominal capacity between host capacity of 841 mAh/cc and lithiated capacity of 719 mAh/cc)

[2] LG Chem and Panasonic; from UBS Global Research, May 2021

Enovix Architecture

High Energy Density

High Cycle and Calendar Life

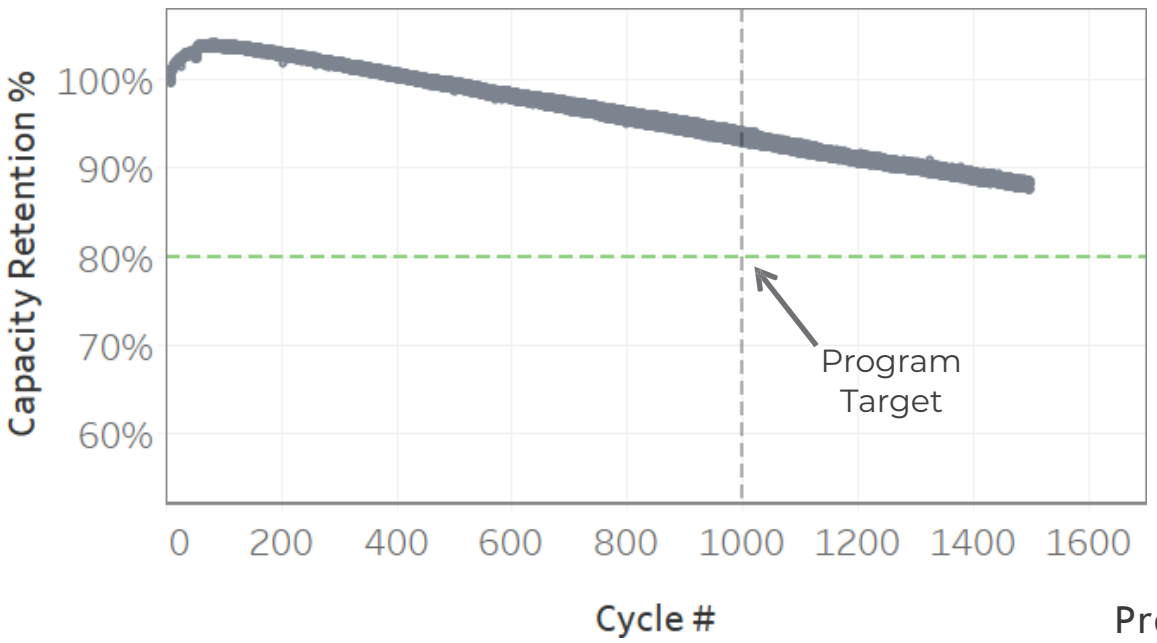
Fast Charge

Excellent Thermal Performance

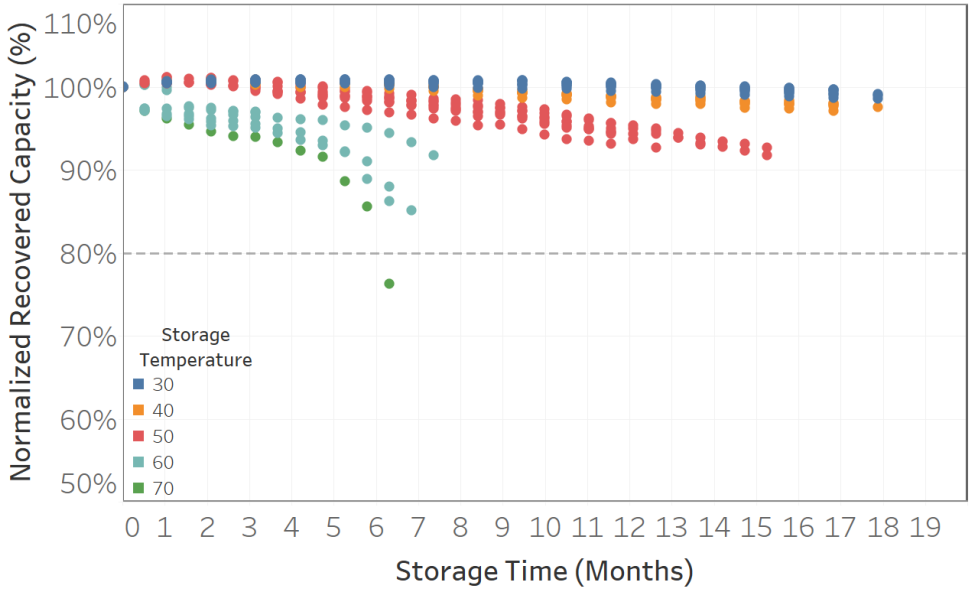
High Cycle and Calendar Life

Demonstrated development cell cycle life >1500 cycles and >10 year projected lifetime[1]

88% capacity retention after 1,500 cycles



Projecting >10-year calendar life based on high temperature testing performance



0.27Ah NMC-622 Cycle Life
267 mAh (29 mm x 17 mm x 3.4 mm)
541 Wh/l packaged energy density (889 Wh/l core)
695 Wh/l modeled packaged energy density for 55Ah cell
4.2 – 2.5V Cell Voltage @ 30 deg. C
0.33C CCCV Charge – 0.33C Discharge with periodic multi-rate diagnostic discharge steps

Program Collaborators

NREL Transforming ENERGY — Multi-component model predicting Si integrity

Mitsubishi Chemical — Optimized electrolytes for Si anodes

0.27Ah NMC-622 – Calendar Life
267 mAh (29 mm x 17 mm x 3.4 mm)
541 Wh/l packaged energy density (889 Wh/l core)
695 Wh/l modeled packaged energy density for 55Ah cell
0.33C CCCV Charge – 0.33C Discharge after storage at various temperatures at TOC voltage of 4.2V

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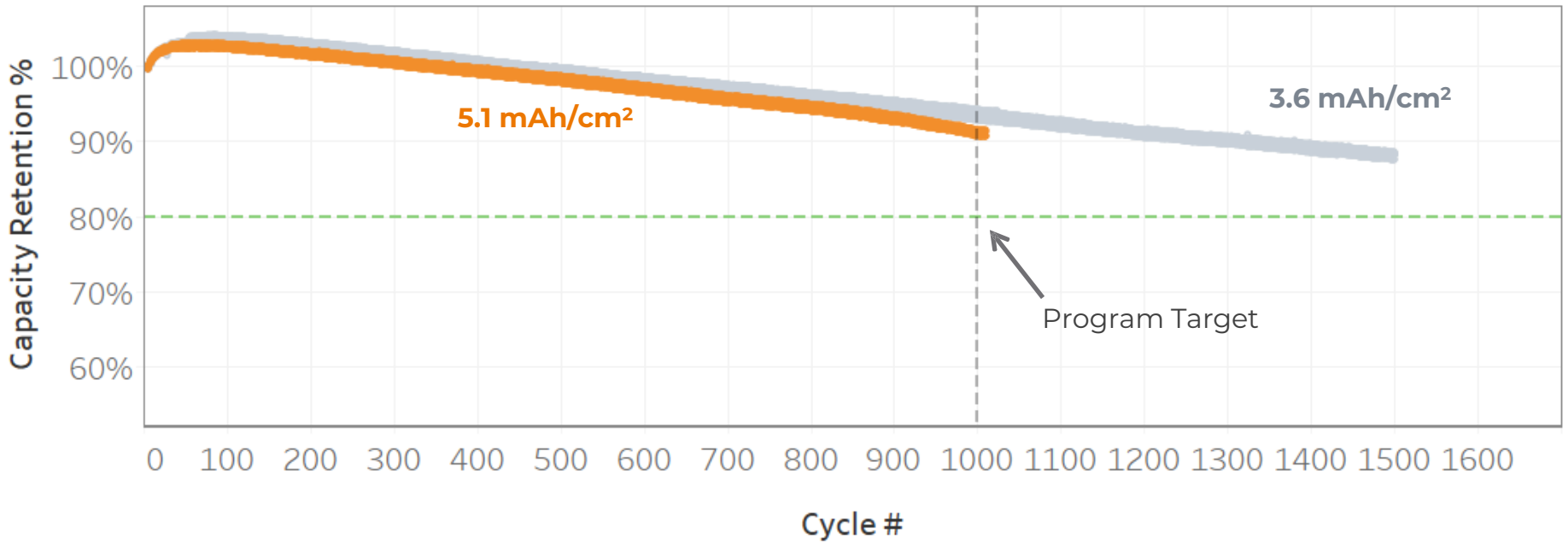
[1] As of November 2022

High Cycle Life

Demonstrating high cycle life across wide range of electrode loadings



3.6 mAh/cm2 NMC-622 CELL DATA

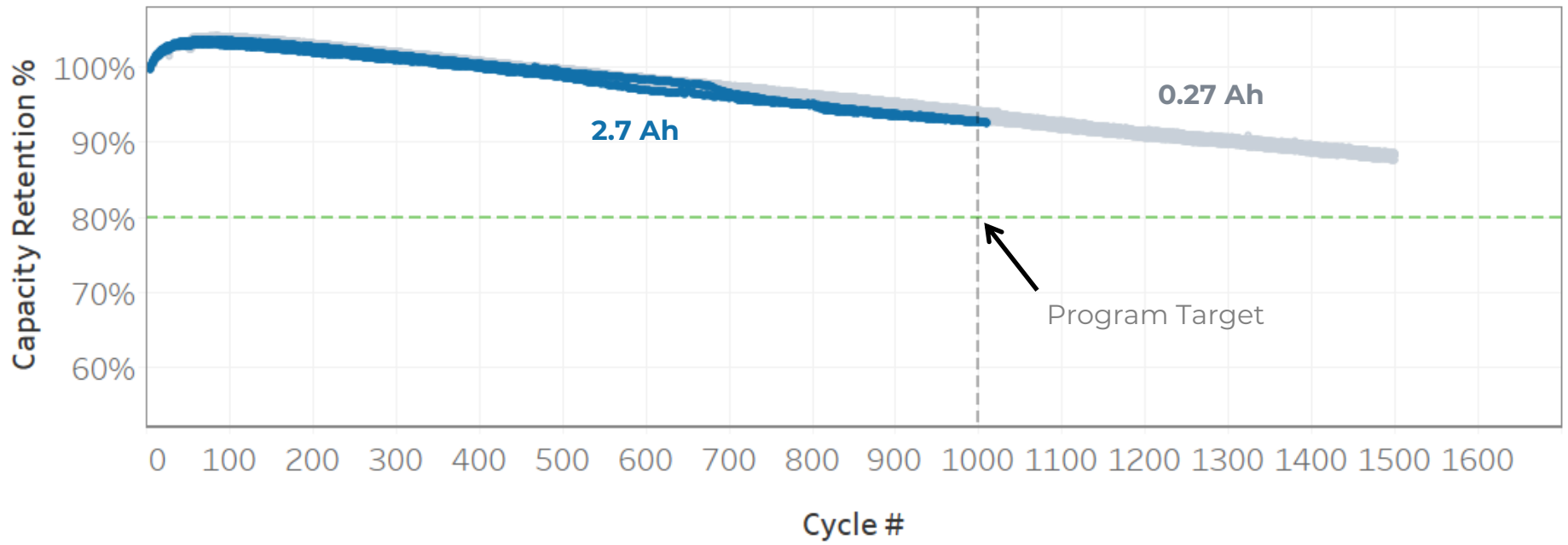
267 mAh (29 mm x 17 mm x 3.4 mm)
541 Wh/l packaged energy density (889 Wh/l core)
695 Wh/l modeled packaged energy density for 55Ah cell
4.2 – 2.5V Cell Voltage @ 30 deg. C
0.33C CCCV Charge – 0.33C Discharge with periodic multi-rate diagnostic discharge steps

5.1 mAh/cm2 NMC-622 CELL DATA

293 mAh (30 mm x 17 mm x 3.5 mm)
570 Wh/L packaged energy density (976 Wh/L core)
750 Wh/L modeled packaged energy density for 55 Ah cell
4.2-2.5 V cell voltage @ 30 deg. C
0.33C CCCV Charge – 0.33C Discharge with periodic multi-rate diagnostic discharge steps

High Cycle and Calendar Life

Cycle life testing of >2.5 Ah cells tracking 0.27 Ah cell performance



NMC-622 CELL DATA

267 mAh (29 mm x 17 mm x 3.4 mm)
541 Wh/l packaged energy density (889 Wh/l core)
695 Wh/l modeled packaged energy density for 55Ah cell
4.2 – 2.5V Cell Voltage @ 30 deg. C
0.33C CCCV Charge – 0.33C Discharge with periodic multi-rate diagnostic discharge steps

2.7Ah NMC-622 CELL DATA

2.72 Ah (71.4 mm x 38.7 mm x 5.3 mm)
644 Wh/L packaged energy density (886 Wh/L core)
695 Wh/L modeled packaged energy density for 55 Ah cell
4.2-2.5 V cell voltage @ 30 deg. C
0.33C CCCV Charge – 0.33C Discharge with periodic multi-rate diagnostic discharge steps

Enovix Architecture

High Energy Density

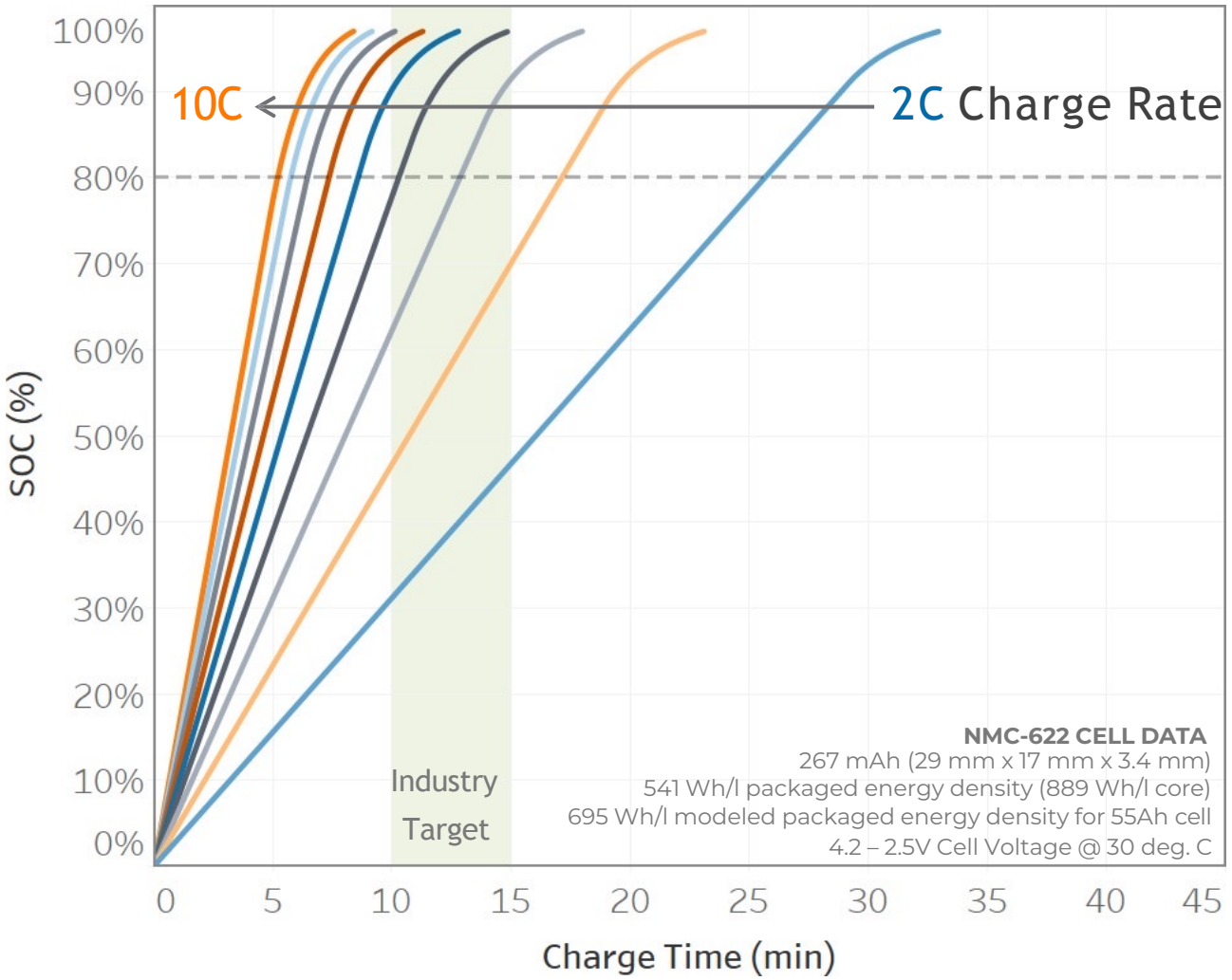
High Cycle and Calendar Life

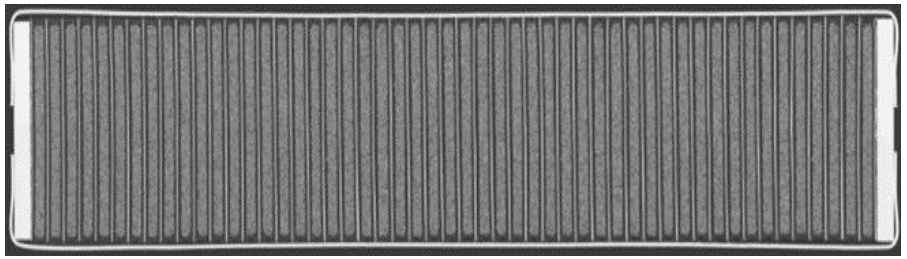
Fast Charge

Excellent Thermal Performance

Architecture & Chemistry Built for Fast Charge

0.27 Ah EV test cells achieved 0-80% state-of-charge in 5.2 minutes





Fast Charge Enabled by Silicon

~ **56%** thinner anode than graphite[1]

~ **140mV** higher lithiation potential[2]

[1]100% active Si anode de-rated from a fully-lithiated theoretical capacity of 2194 mAh/cc to account for Li-trapping and pre-lithiation
[2]0.22V vs Li/Li+ for Si; 0.08V vs Li/Li+ for Graphite

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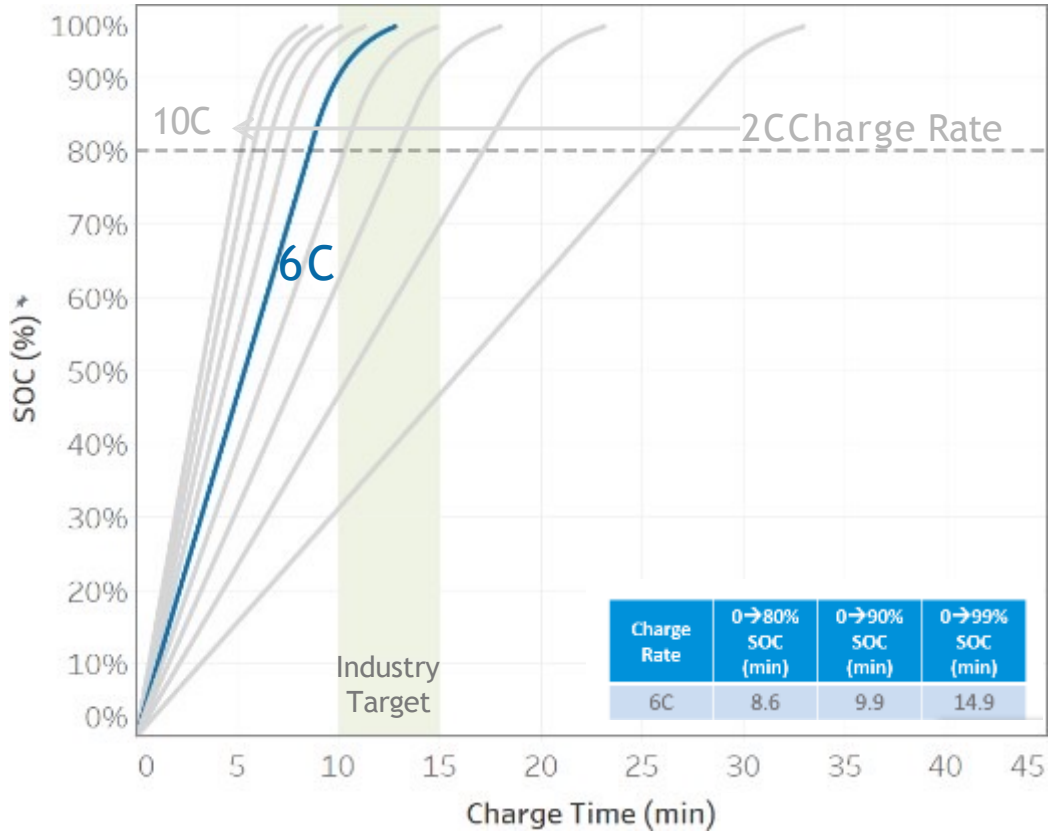
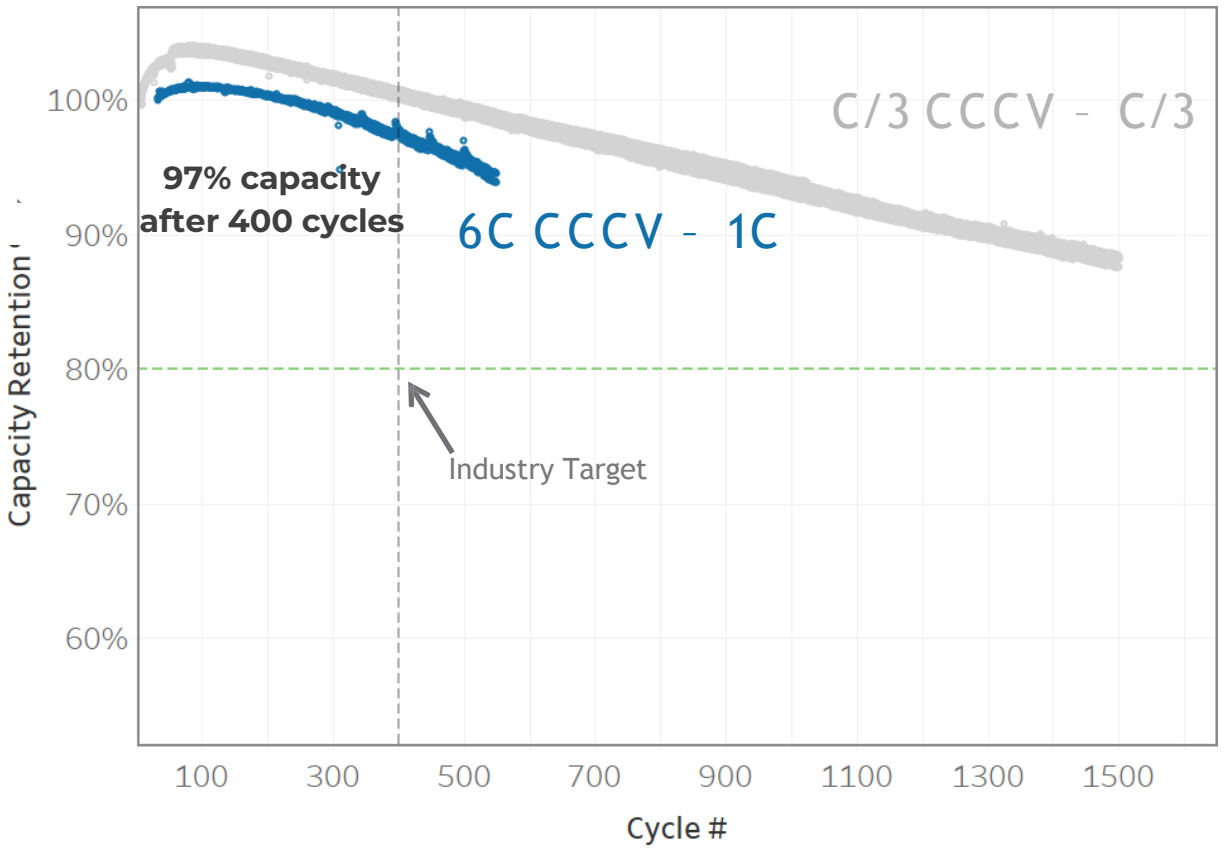
Architecture & Chemistry Built for Fast Charge

0.27 Ah EV test cells achieved 0-80% state-of-charge in 5.2 minutes



Charge Rate	0→80% SOC (min)	0→90% SOC (min)	0→99% SOC (min)
6C	8.6	9.9	14.9



NMC-622 CELL DATA
267 mAh (29 mm x 17 mm x 3.4 mm)
541 Wh/l packaged energy density (889 Wh/l core)
695 Wh/l modeled packaged energy density for 55Ah cell
4.2 – 2.5V Cell Voltage @ 30 deg. C
6C CCCV Charge – 1C Discharge with periodic multi-rate diagnostic discharge steps

Enovix Architecture

High Energy Density

High Cycle and Calendar Life

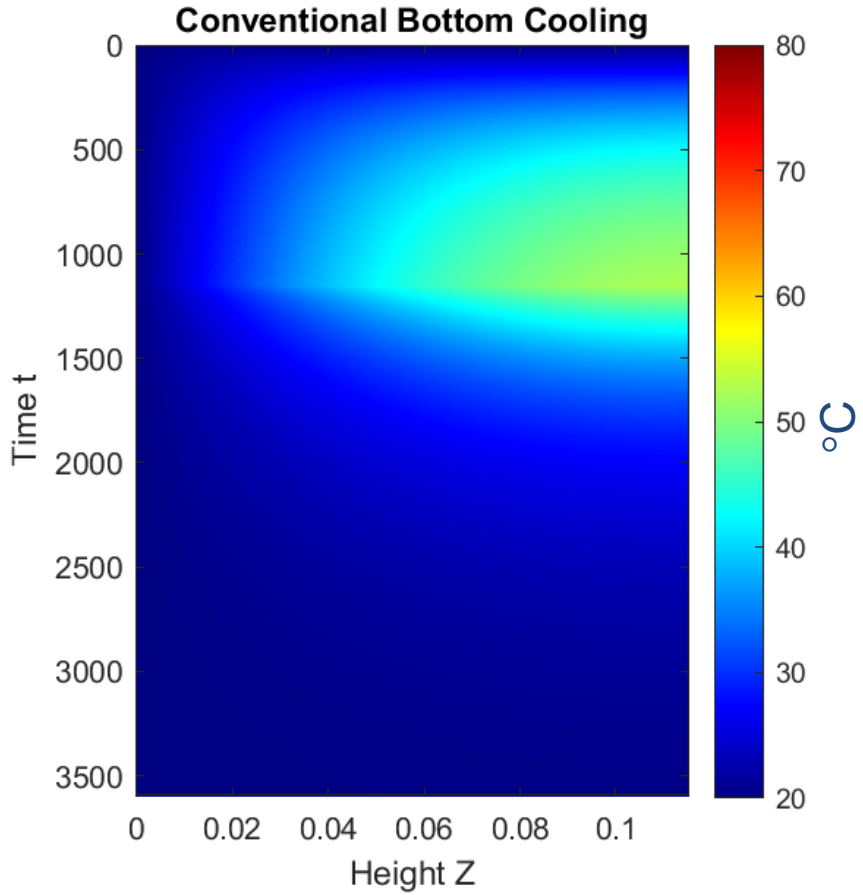
Fast Charge

Excellent Thermal Performance

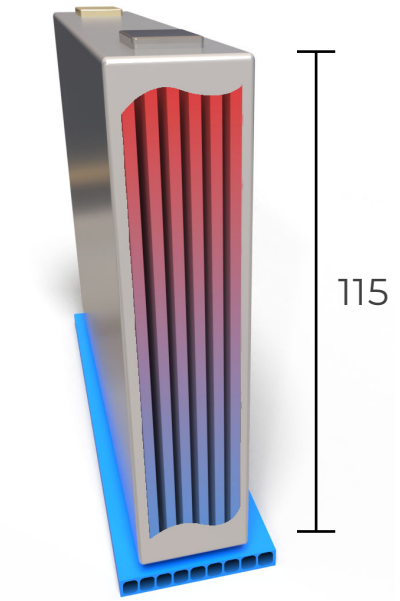
Reoriented Electrodes Designed to Deliver Excellent Thermal Performance

33X Higher* thermal conductivity to large face of prismatic cell

2.5C Fast Charging Temperature Profile



Cell Dimensions: 173 x 115 x 32 mm



Conventional Stack Cell Bottom-Cooled

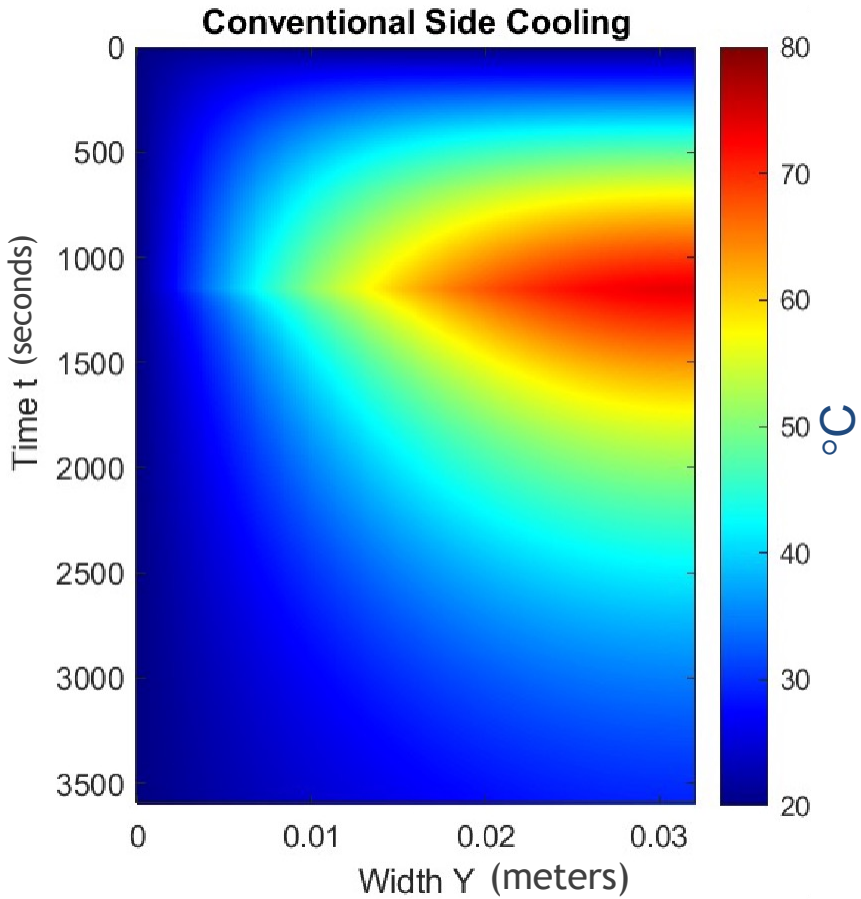
$\Delta T_{max} = 31.9^{\circ}C$

*Assumptions: 2.5C charging 0-80% SOC, 27.6 W/mK in-plane conductivity, 0.82 W/mK thru-plane conductivity, 1046 J/kg heat capacity, 2.4g/cc density, 25 ohm cm2 constant ASI, 4 mAh/cm2 electrode loading, 336 uM wave pair thickness, 1-dimensional heat transfer constrained to electrodes

Reoriented Electrodes Designed to Deliver Excellent Thermal Performance

33X Higher* thermal conductivity to large face of prismatic cell

2.5C Fast Charging Temperature Profile



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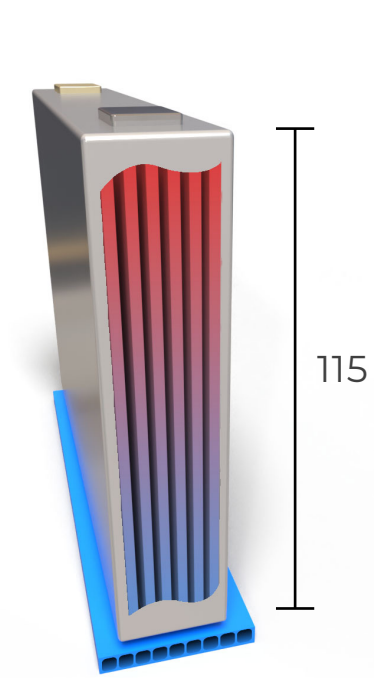
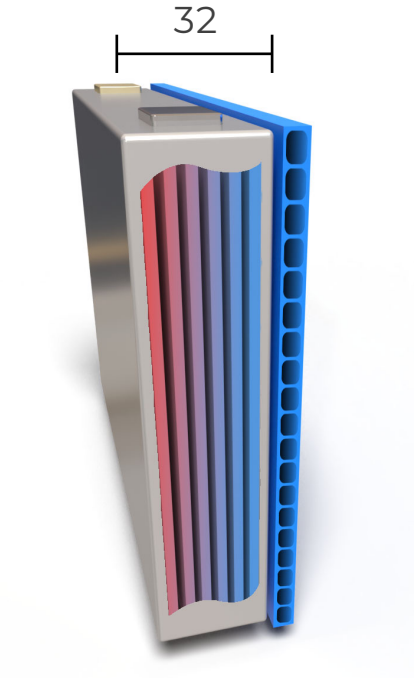


Conventional Stack Cell Bottom-Cooled

$\Delta T_{max} = 31.9^{\circ}C$



Conventional Stack Cell Side Cooled

$\Delta T_{max} = 53.8^{\circ}C$

*Assumptions: 2.5C charging 0-80% SOC, 27.6 W/mK in-plane conductivity, 0.82 W/mK thru-plane conductivity, 1046 J/kg heat capacity, 2.4g/cc density, 25 ohm cm2 constant ASI, 4 mAh/cm2 electrode loading, 336 uM wave pair thickness, 1-dimensional heat transfer constrained to electrodes

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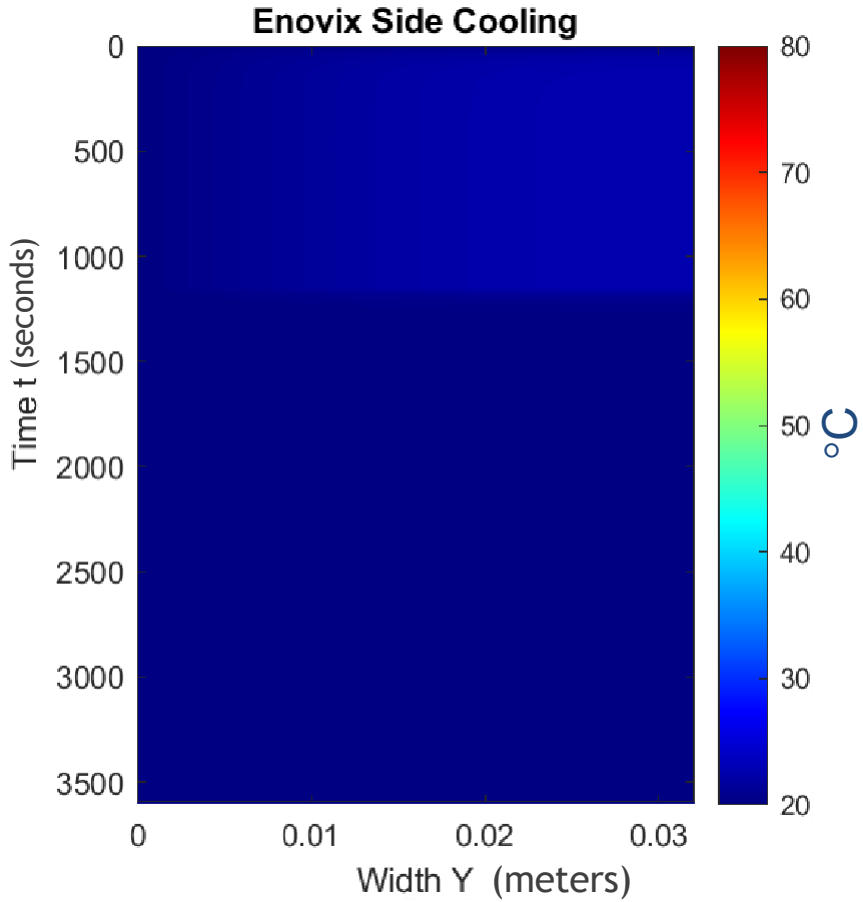

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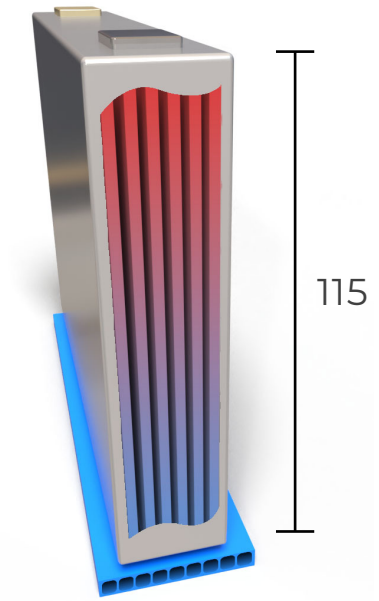
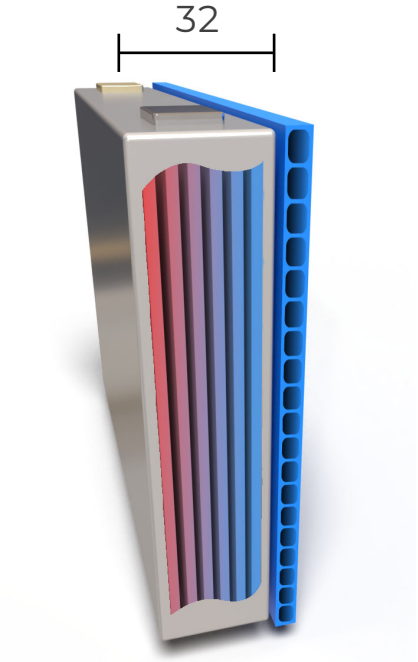


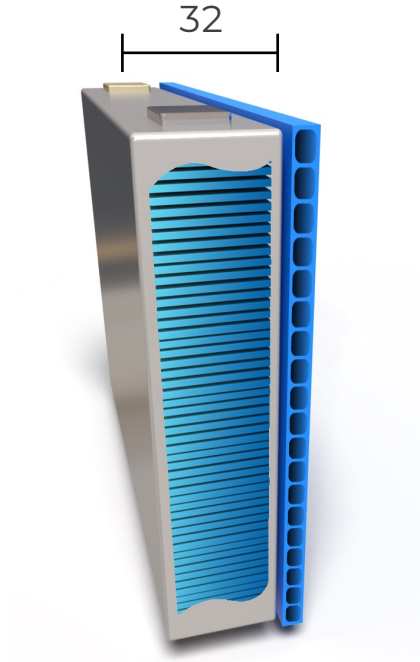
Conventional Stack Cell Bottom-Cooled

ΔT_{max} = 31.9˚C



Conventional Stack Cell Side Cooled

ΔT_{max} = 53.8˚C



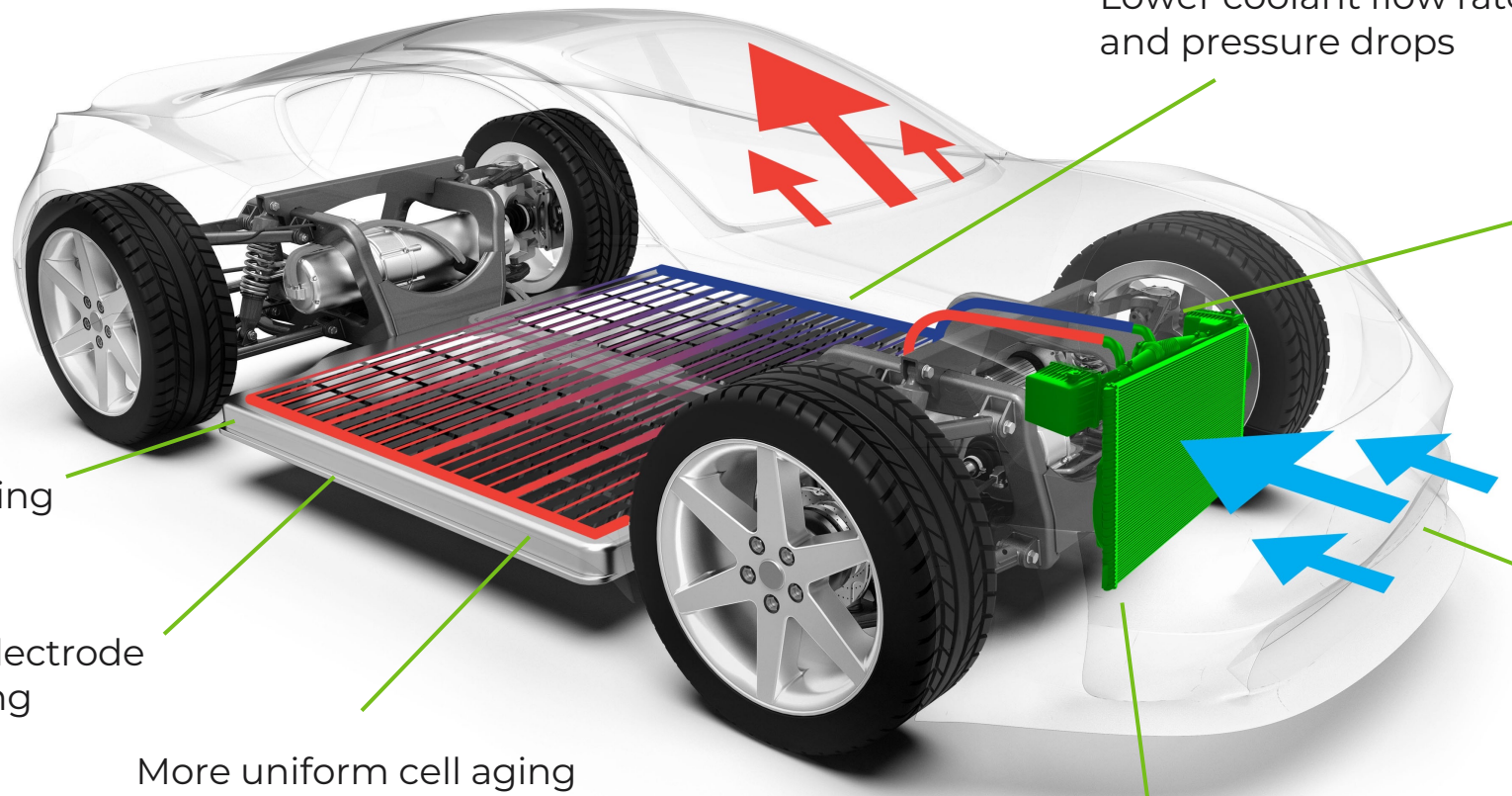
Enovix Stack Side Cooled

ΔT_{max} = 2.8˚C

*Assumptions: 2.5C charging 0-80% SOC, 27.6 W/mK in-plane conductivity, 0.82 W/mK thru-plane conductivity, 1046 J/kg heat capacity, 2.4g/cc density, 25 ohm cm2 constant ASI, 4 mAh/cm2 electrode loading, 336 uM wave pair thickness, 1-dimensional heat transfer constrained to electrodes

Cell Thermal Design Key to System Performance

Significant opportunities to reduce system cost, improve performance



Lower coolant flow rate and pressure drops

Reduced compressor size, weight and power

Faster charging

Increased electrode loading

More uniform cell aging

Enables warmer coolant and greater heat rejection

Smaller radiator

Enovix Cell Architecture Well-Suited to EVs

Thermal Advantages Enable Fast Charge; Cycle Life and Calendar Life Demonstrated

Advantaged vs. Conventional Cells[1]

~10x Improvement in Cell Internal Temperature Gradient

0-80% Charge in 5.2 Minutes Demonstrated

1,500 Cycles, Projected 10+ Year Calendar Life, Achieved 88% Capacity Retained

Architecture validated in consumer electronics space with global leaders

Pursuing Industry Partner Strategy

Actively Working with Industry Leading OEMs – Focus on JV/Licensing

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Mobility@Enovix.com

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[1]Company estimates based on internal test data shown in Appendix slides 20-22
[2]The New Oil: Investment Implications of the Global Battery Economy - Morgan Stanley Research, Nov. 15, 2021

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Thank You

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