

Automating meshing and thermal analysis for an EV battery pack with ANSA, TAITherm and CoTherm

Sacha Jelić, Eli Datema, Daniel Woodford



VOLT

THERMO
ANALYTICS



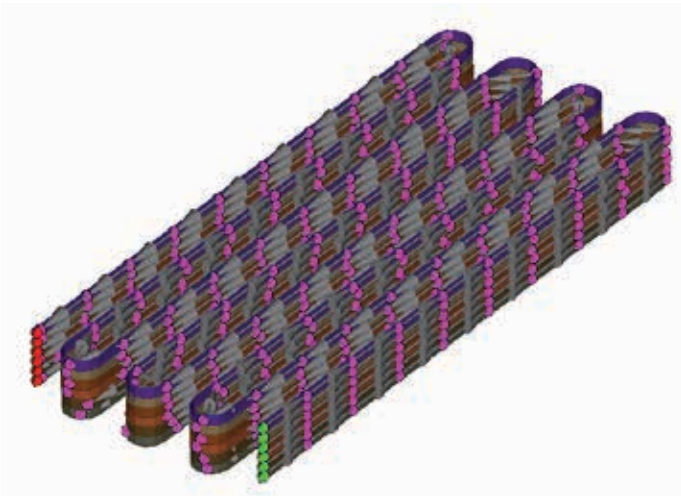
Outline

- Introduction
 - Objective
 - ThermoAnalytics 3D thermal/electrical model
 - About:Energy VOLTTE battery cell database
- Set-up
 - Geometry Automation with ANSA
 - Battery Cooling design study for 1h Drive Cycle
- Results
- Conclusions

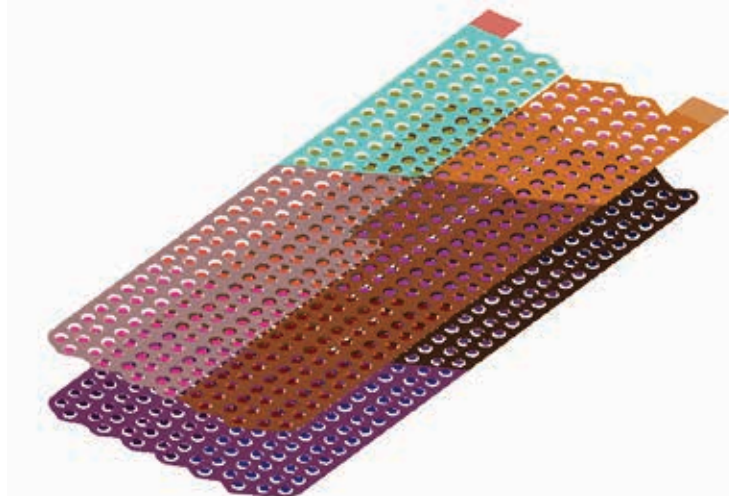
Introduction

Objective

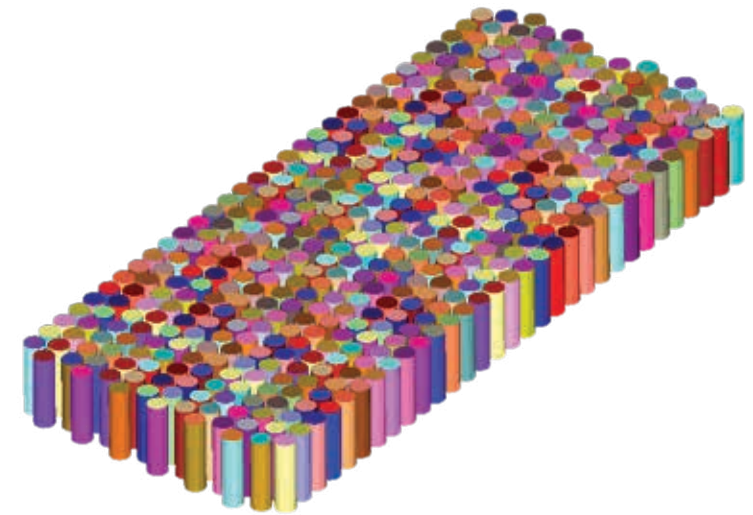
- This study shows a battery cooling design study for a 1h drive cycle, in which different battery cells will be evaluated.
- The cells are selected from the About:Energy battery database
- A geometry automation script in ANSA will help to shorten and simplify the geometry preparation process



Cooling rig with fluid streams



Joule Heating with bus bar geometry



Battery Heating with cell geometry

Introduction to ThermoAnalytics

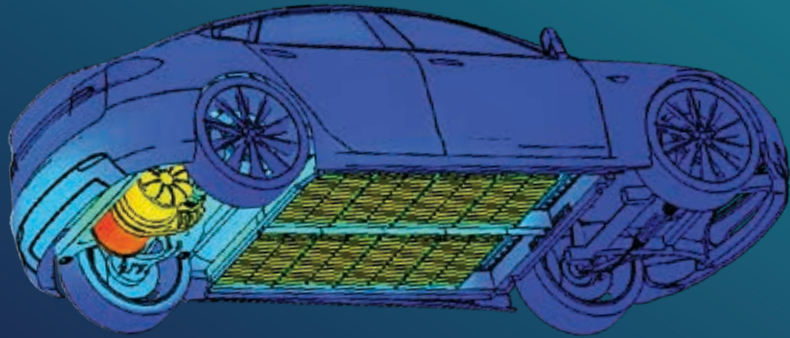


- Transient and Steady-State Analysis
- Radiation and Natural Environment
- Human Thermal Module
- Battery Analysis Module
- Integration with 1D & CFD

ThermoAnalytics ToolBox



TAI Therm

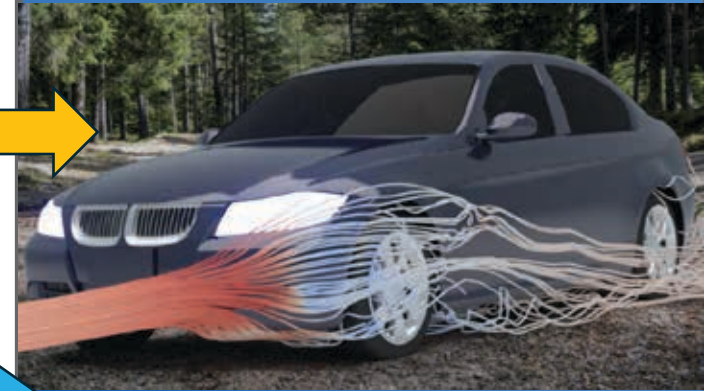


CoTherm

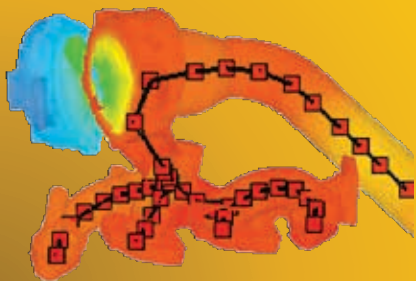


3D CFD

STAR-CCM+ ANSYS engys



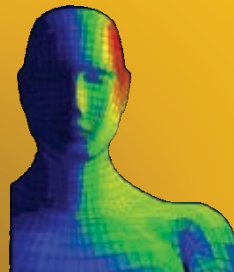
Exhaust
Extension



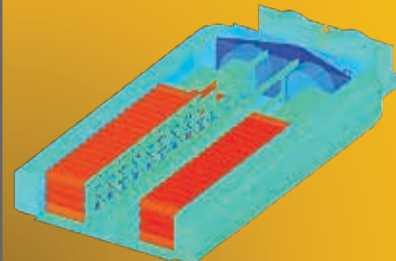
Drive Cycle
Extension



Human Comfort
Extension

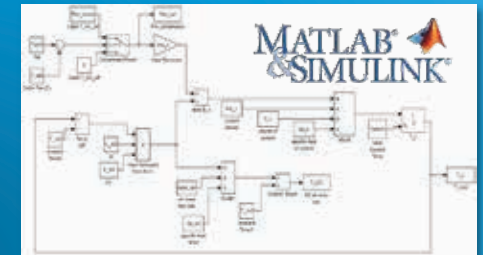


Battery
Extension



1D System Tool

GT LMS



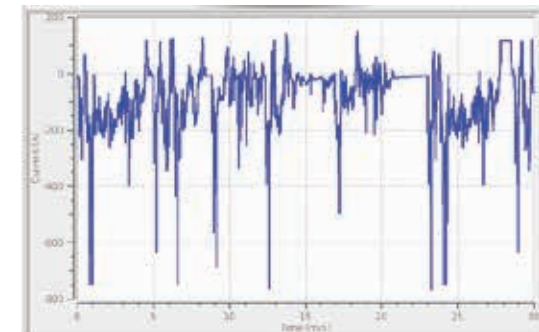
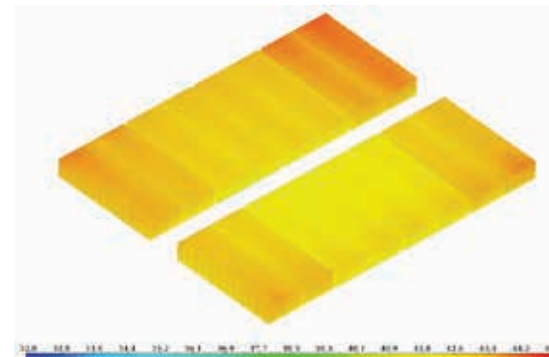
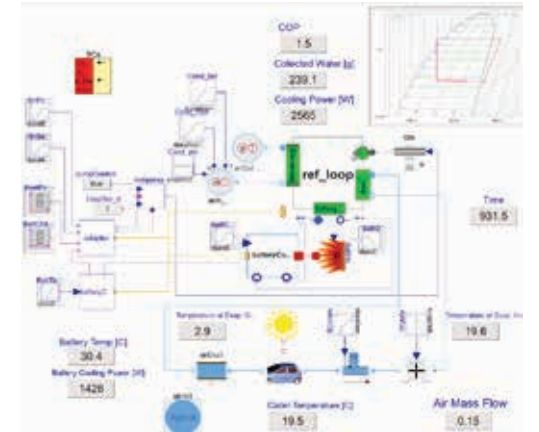
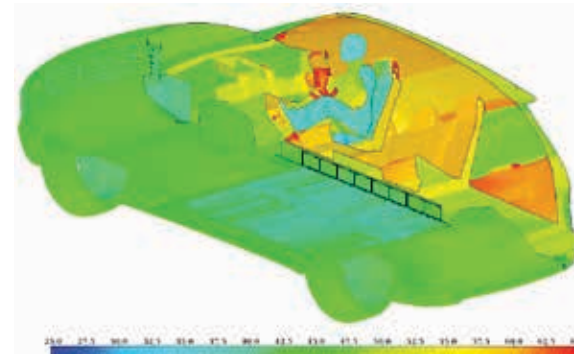
TAITherm 3D Thermal Modeling

- **3D Transient Simulation**

- TAITherm provides a fast, accurate, and easy-to-use total thermal solution
- Bridges the gap between 1-D electrical models and detailed 3-D CFD models

- **Thermal Modeling Scenarios**

- Battery packaging & vehicle integration
- Real customer drive-cycles
- Cooling System Optimization
- Load Balancing
- Hot Soak
- Fast charging
- Thermal Runaway
- Battery Lifetime
- Energy reduction

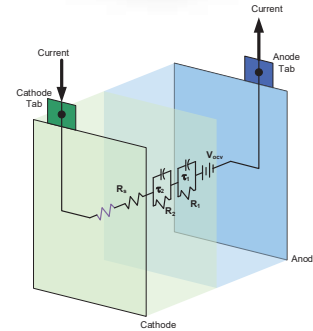


TAITherm Battery Module

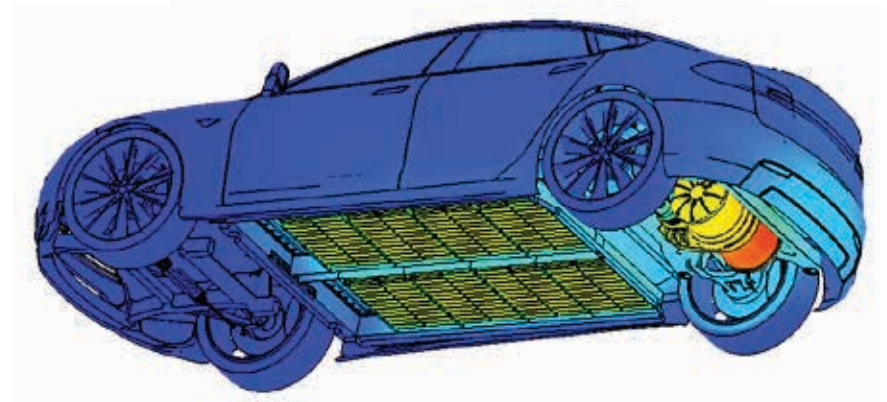
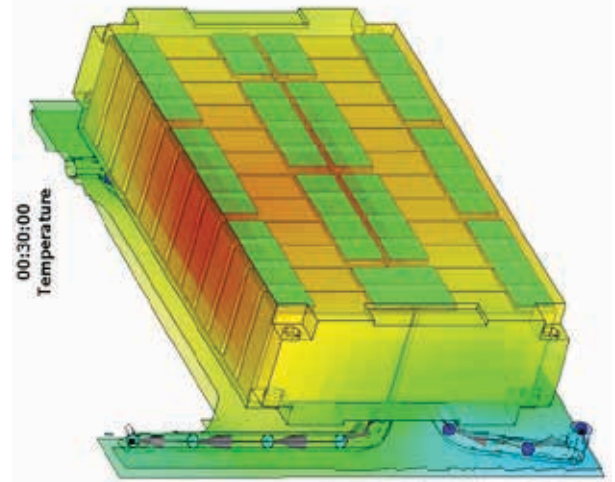
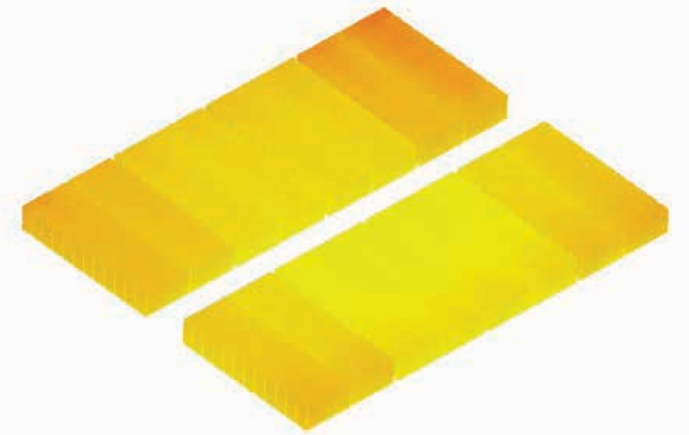
- Battery model applies to different topologies
 - Pouch
 - Prismatic
 - Cylindrical



- Any chemistry can be modeled
- Cell, Module, Pack or vehicle level
- Equivalent Circuit Model Based



- Challenges:
 - Maintain acceptable temperature range
 - Ensure uniform temperature distribution



Battery Database

500+ cells

Dimension, Material, Cost,
Origin, Capacity, Voltage, etc.



VOLT

Battery Database

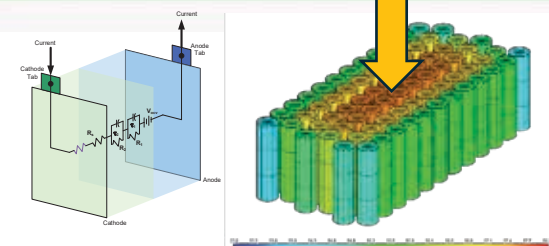
| Manufacturer | Model | Available data | Verified | Form factor | Capacity / Ah |
|--------------|----------------|----------------|----------|-------------------|---------------|
| About:Energy | Gen1 Demo | ↑ | ✓ | Cylindrical 21700 | 5 |
| LG Chem | INR21700-M50 | ↔ | ✓ | Cylindrical 21700 | 4.85 |
| Samsung | INR21700-40T | ↑ | ✓ | Cylindrical 21700 | 4 |
| LG Chem | INR21700-M50LT | ↑ | ✓ | Cylindrical 21700 | 4.9 |
| Murata | US21700VTC6A | ↑ | ✓ | Cylindrical 21700 | 4.1 |
| Samsung | INR18650-30Q | ↑ | ✓ | Cylindrical 18650 | 2.95 |
| Tesla | Tesla Model Y | ↑ | ✓ | Cylindrical 4680 | 23.7 |
| Panasonic | Tesla Model 3 | ↑ | ✓ | Cylindrical 21700 | 4.8 |
| Lishen | LR2170SD | ↑ | ✓ | Cylindrical 21700 | 5 |
| Sony | US18650VTC6 | ↑ | ✓ | Cylindrical 18650 | 3.12 |

Equivalent Circuit
Data collected for

35+ cells

THERMO
ANALYTICS 

Download



Set-up

Geometry Automation in ANSA

Geometry: Objective

Starting Point:

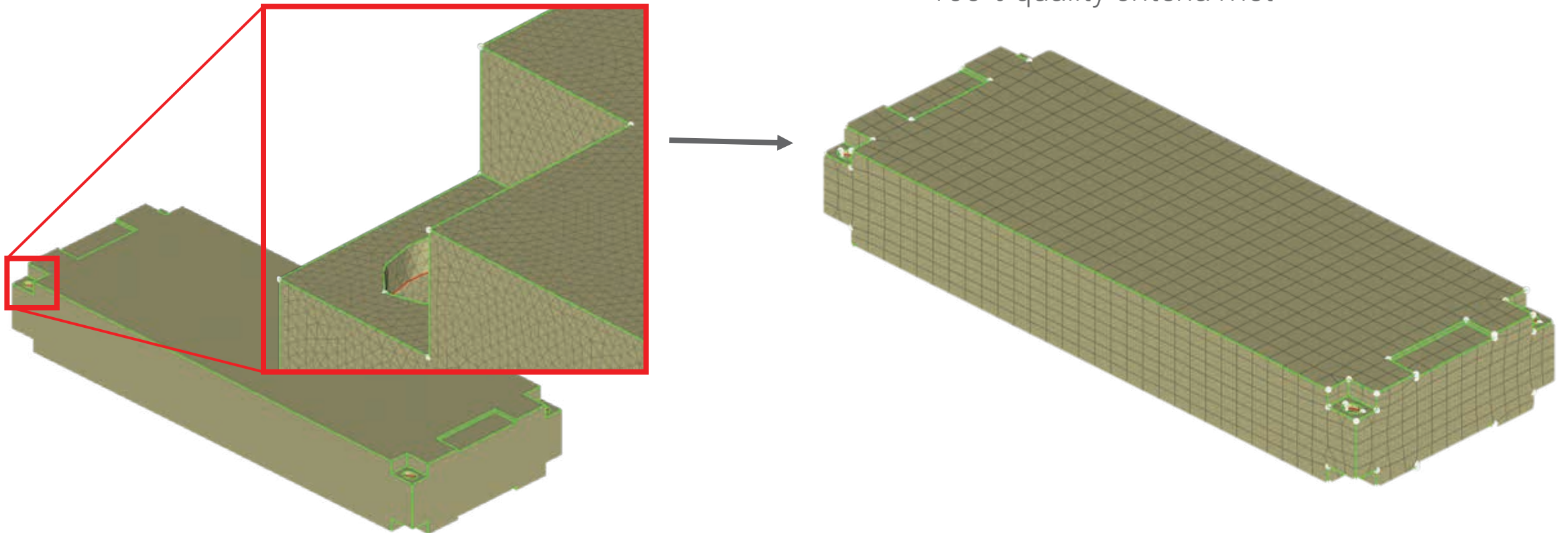
Fine CFD Mesh (or other mesh):

- 500,730 elements
- All trias
- A fine 2mm size mesh

Objective:

Quad Dominant Coarser Thermal Mesh:

- 100,000 – 150,000 elements
- Quad dominated
- 10-20 mm size mesh
- 100% quality criteria met



Geometry: ANSA BATCHMESHING

```
batch_surf_scen = batchmesh.GetNewMeshingScenario('Thermal Mesh', 'PIDS')
```

```
### Create Meshing Scenario ###
```

ANSA

PRE PROCESSOR

Auto-fix:
Define Quality Criteria



```
qualityCriteriaDictionary = {  
'min angle quads':[True, 'IDEAS', 40],  
'max angle quads':[True, 'IDEAS', 140],  
'min angle trias':[True, 'IDEAS', 25],  
'max angle trias':[True, 'IDEAS', 125],  
'aspect ratio':[True, 'NASTRAN', 15],  
'skewness':[True, 'PATRAN', 65],  
'warping':[True, 'IDEAS', 15]  
}  
  
for key, val in qualityCriteriaDictionary.items():  
    base.FillShellsOptionsSet(key, val[0], val[1], val[2])
```

SYNOPSIS:

ansa.batchmesh.GetNewMeshingScenario(name, search_for) Named Arguments

DESCRIPTION:

The function creates a new meshing scenario.

ARGUMENTS:

* name : string (optional)

Define a name for the scenario, or create an untitled one by leaving the argument blank.

* search_for : string (optional)

Change the type of entities to add to the scenario.
Accepted values are: "PARTS", "GROUPS" or "PIDS".

RETURN TYPE:

object

RETURN VALUE:

Returns a reference to the newly created meshing scenario.

EXAMPLE:

```
import ansa  
from ansa import batchmesh
```

```
def main():  
    mesh_scen = batchmesh.GetNewMeshingScenario('Meshing_Scenario')
```

#OR to create an untitled one:

```
def main():  
    mesh_scen = batchmesh.GetNewMeshingScenario()
```

#OR to add PIDS to a scenario:

```
def main():  
    mesh_scen = batchmesh.GetNewMeshingScenario('Meshing_Scenario', 'PIDS')
```

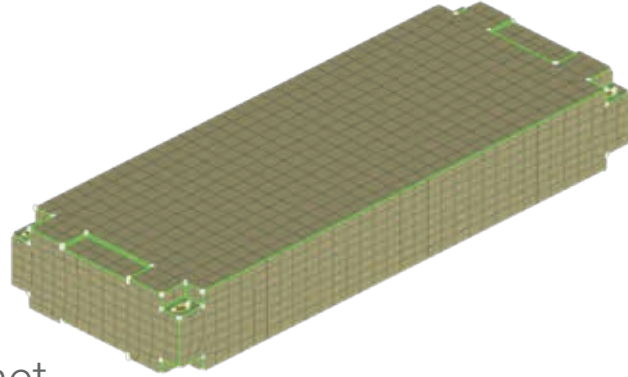
Remeshing:
Define Target Element Size per Part

```
sessionsParamsDictionary = {  
'cell':['7mm', 5, 2],  
'chiller':['10mm', 8, 2],  
'fin':['10mm', 10, 8],  
'module':['15mm', 20, 2],  
'plate':['2.5mm', 3, 2],  
'tabs':['3mm', 3, 2],  
'terminal':['2mm', 3, 1],  
}
```

Geometry: Mesh Comparison

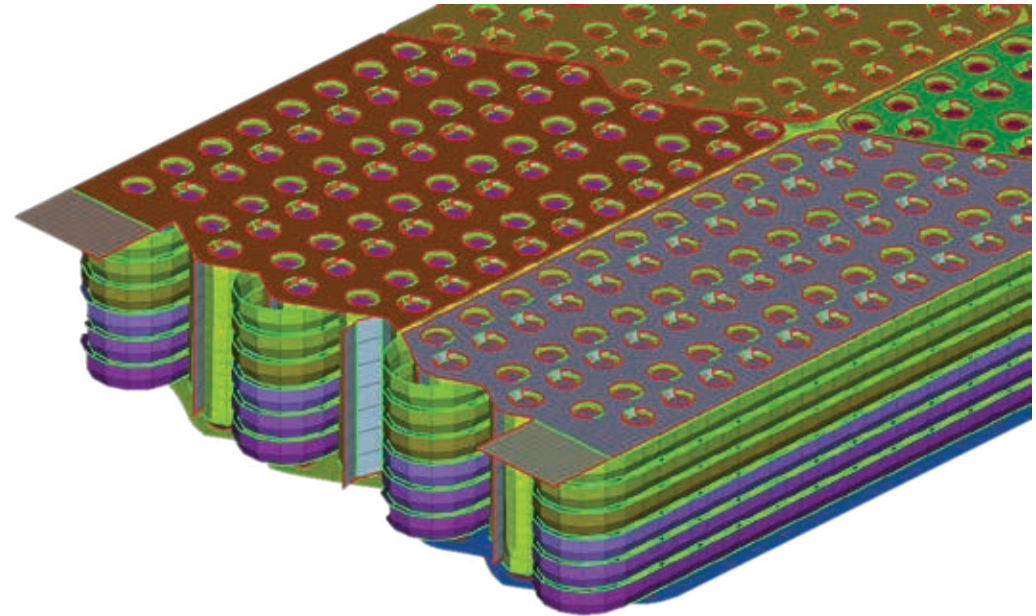
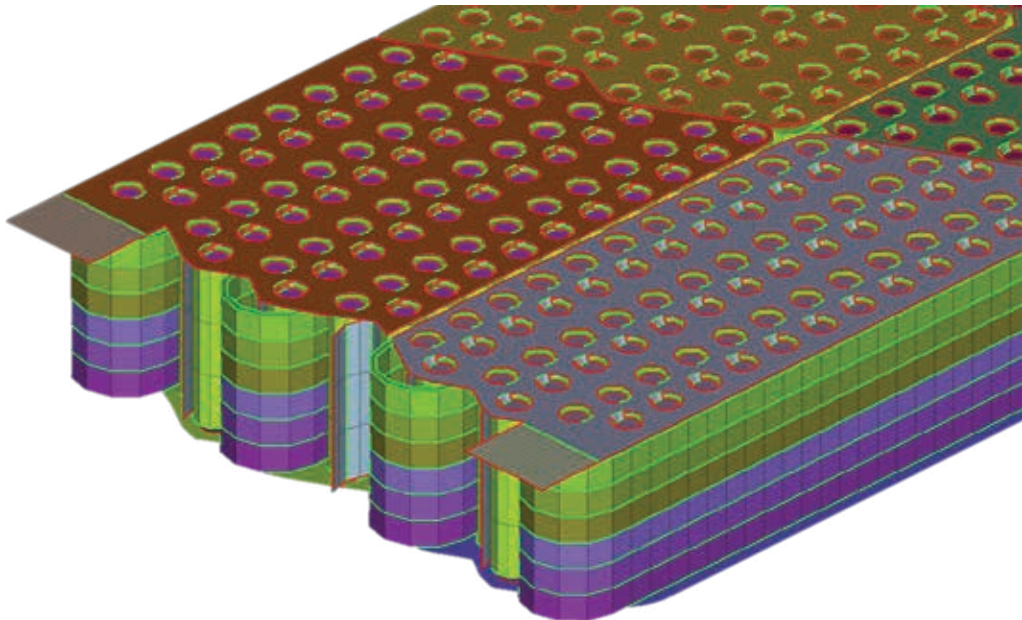
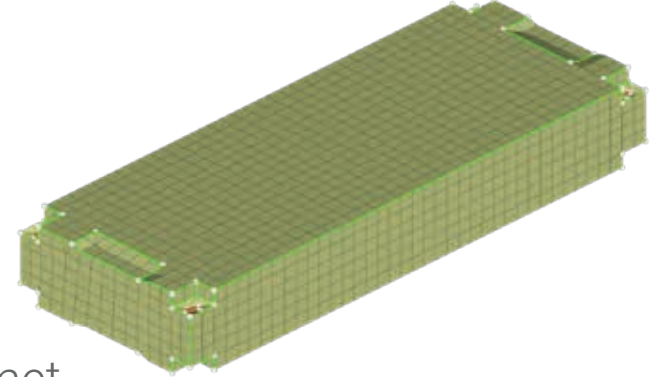
Manually
Created Mesh:

- 109,153 elements
- Quad dominated
- 10-20 mm size mesh
- 100% quality criteria met
- 4h Manual effort



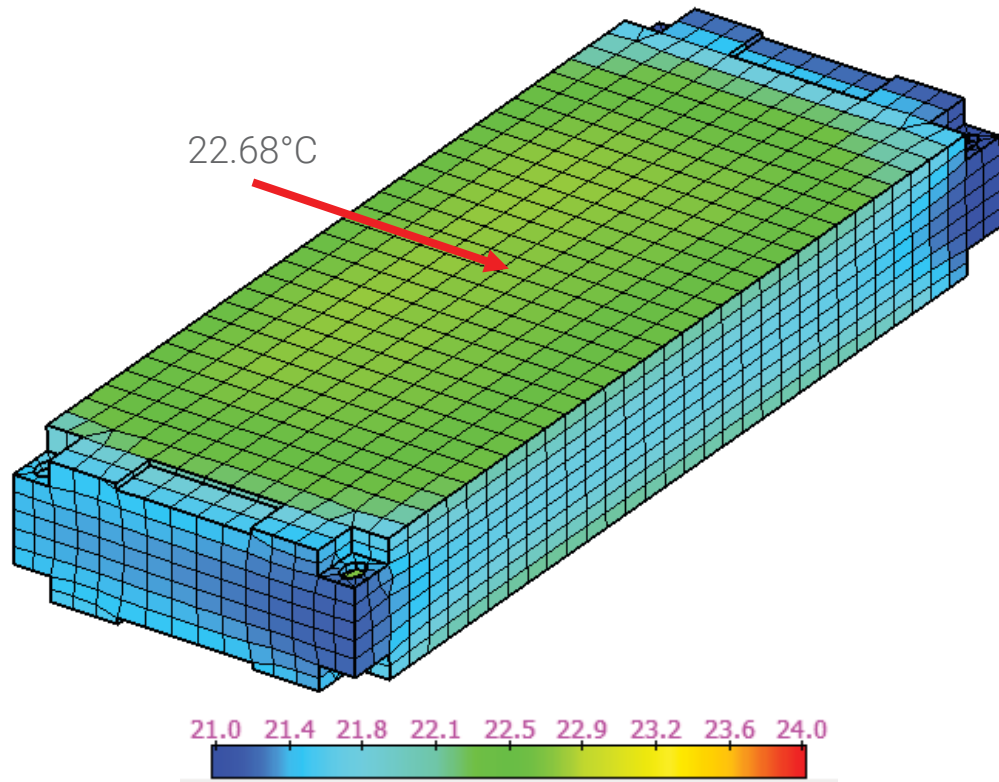
Automated Mesh:

- 123,180 elements
- Quad dominated
- 10-20 mm size mesh
- 100% quality criteria met
- 5 min machine effort

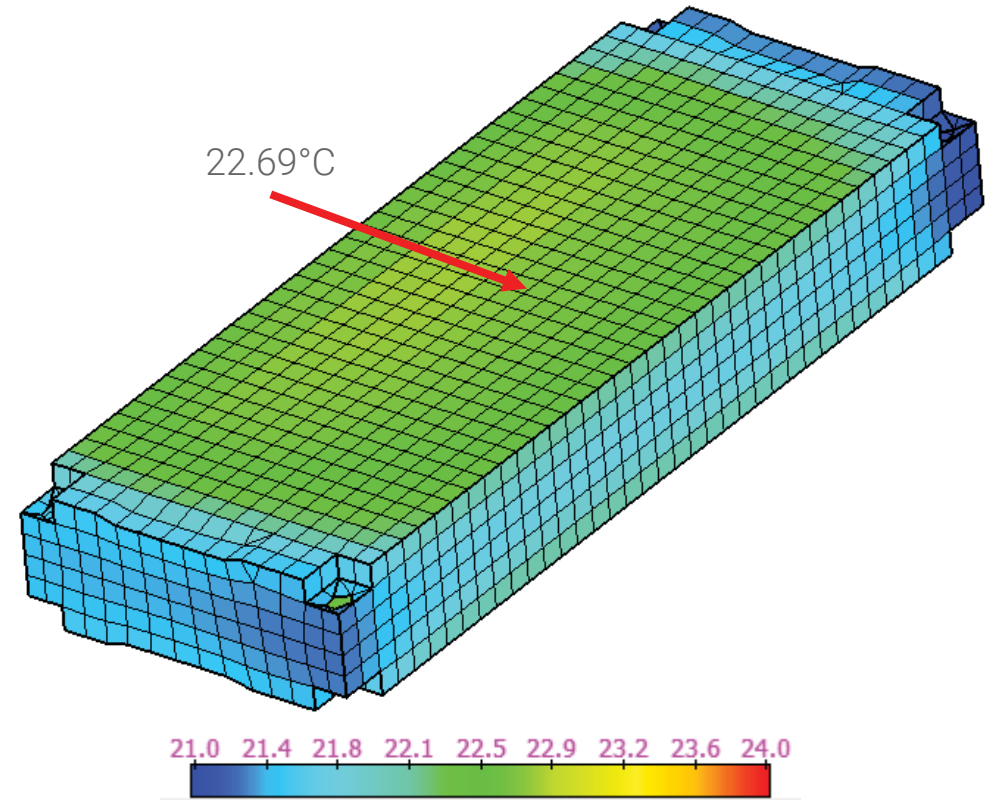


Geometry: Results Comparison

Manually Created Mesh



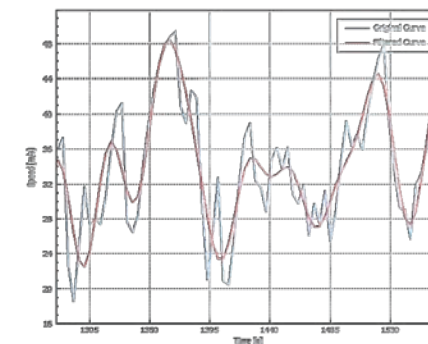
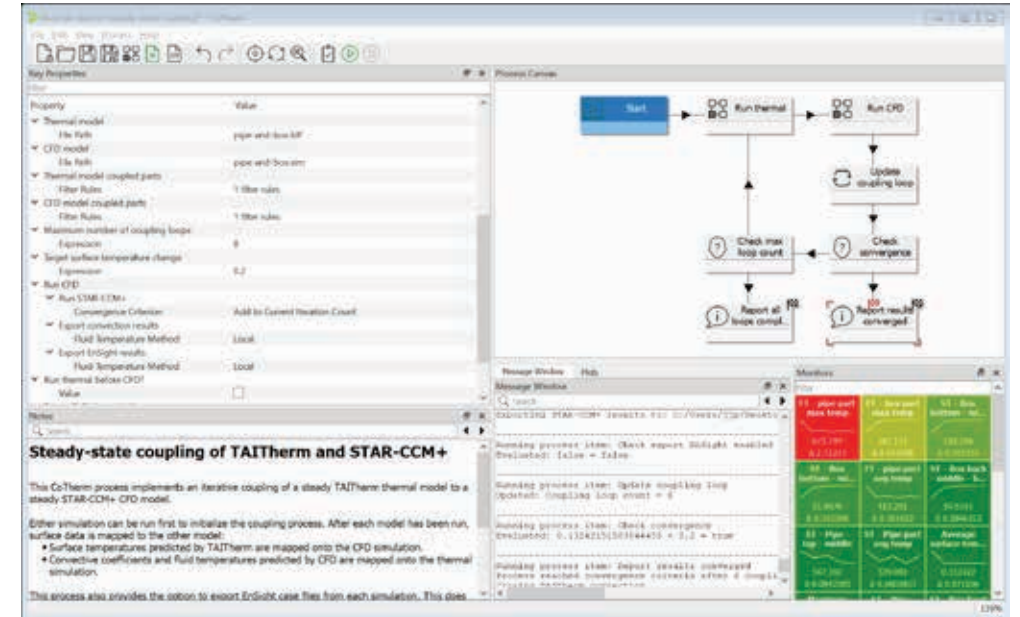
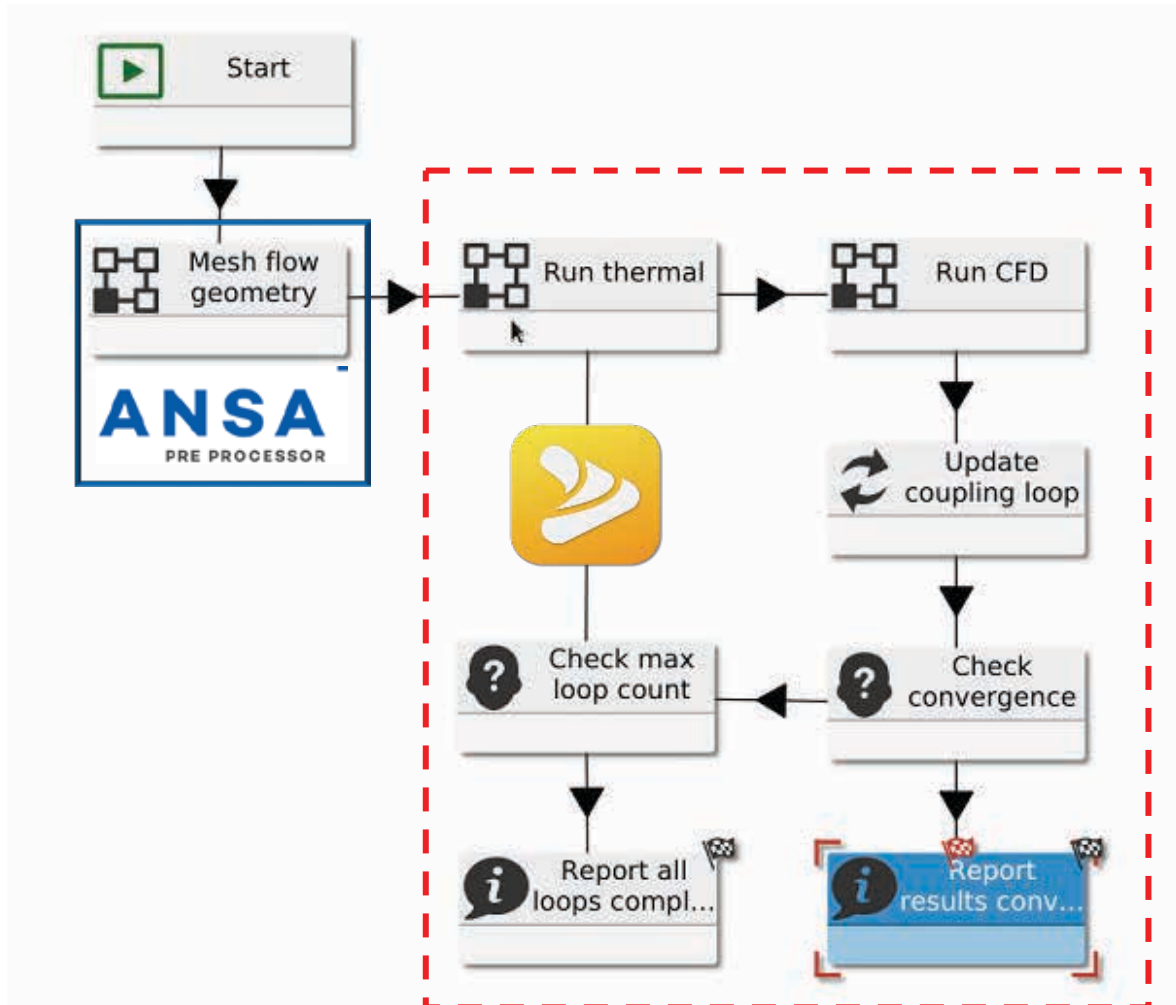
Automated Mesh



CoTherm Process Automation



CoTherm



Transient coupling / Drive-cycle

Set-up

Battery Cooling Design study for 1h Drive Cycle

Objective

Given a five unique battery types from the v  VOLTT determine the difference in performance using simulation.

Battery Names

LG M50L

Samsung50S

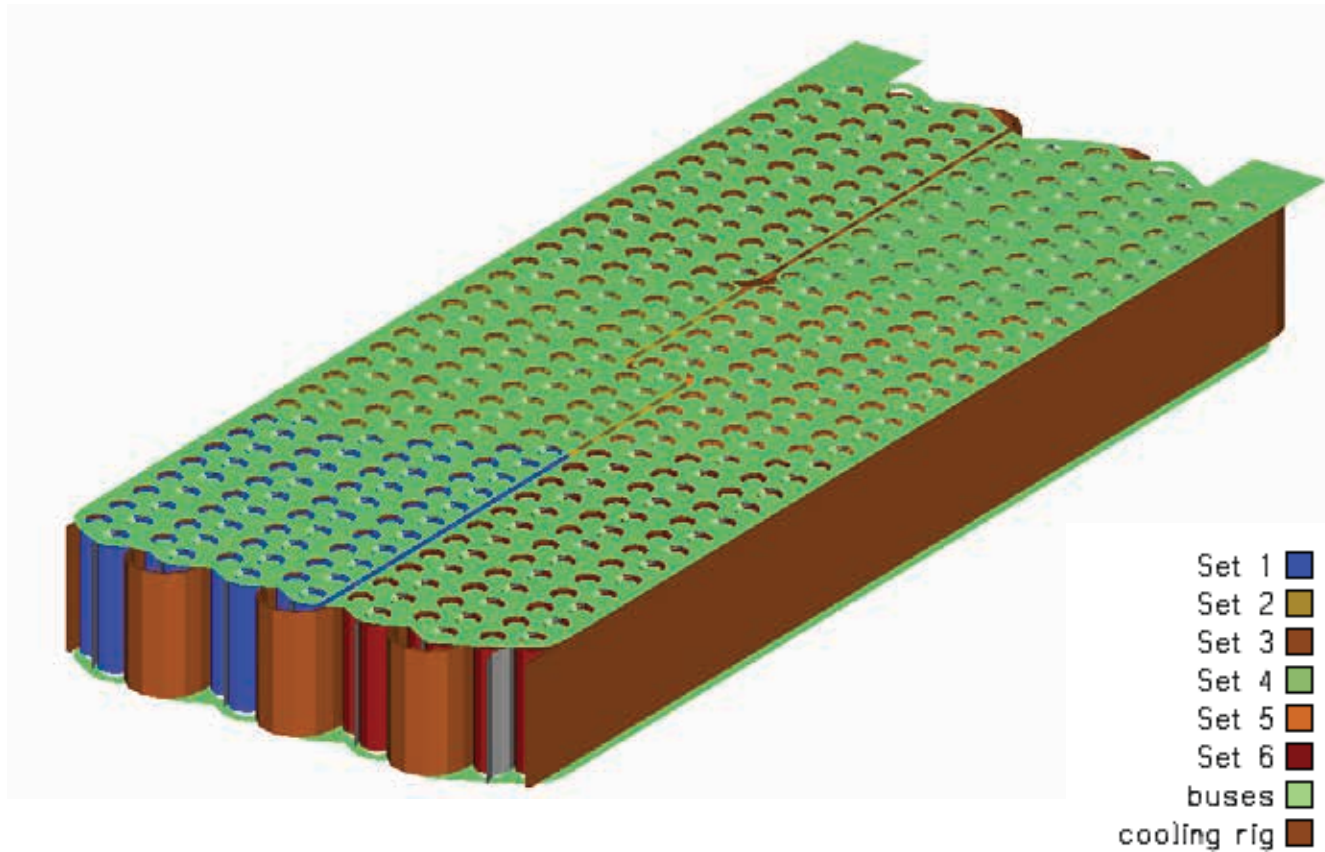
Samsung50E

Samsung48X

Lishen LR21700SF

- Operating scenarios
 - Constant current discharge (nominal 1C)
 - Drive cycle (IEEE EV Example)
- Heat sources
 - Battery cells
 - Bus bars
- Heat Exchanger
 - Input temperature taken from measurement (IEEE EV Example)

Thermal model setup



TAITherm model contains 444 cells split into 6 sets

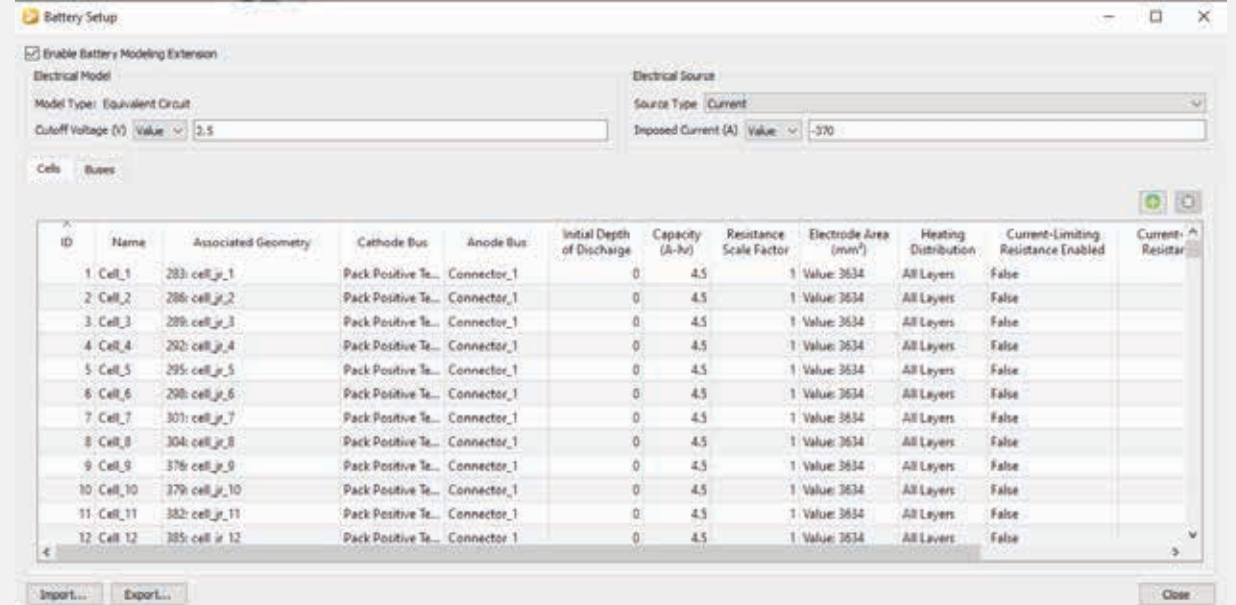
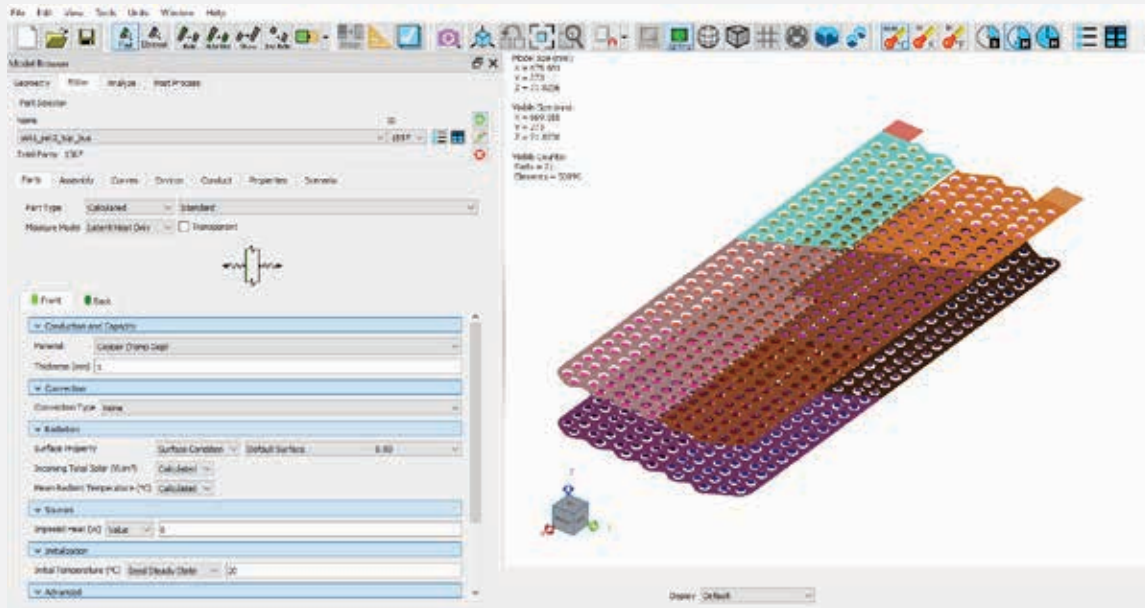
Fluid streams are used to model cooling of the pack

Joule heating is applied to the bus geometry

Joule Heating Setup

Thermal Model

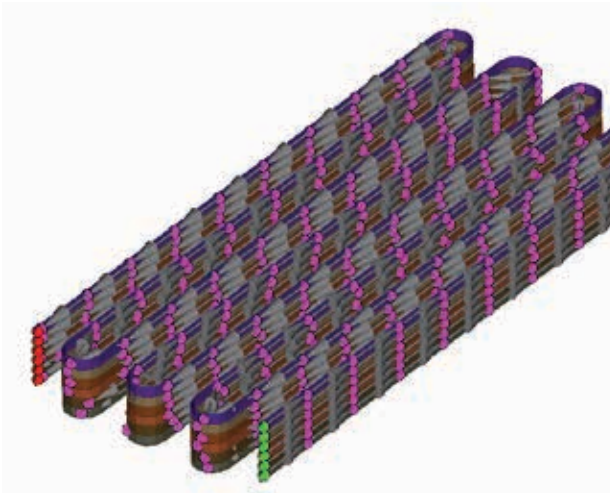
- Continuous geometry
- Thermal boundary conditions
- Initial conditions
- Some electrical parameters, such as curves



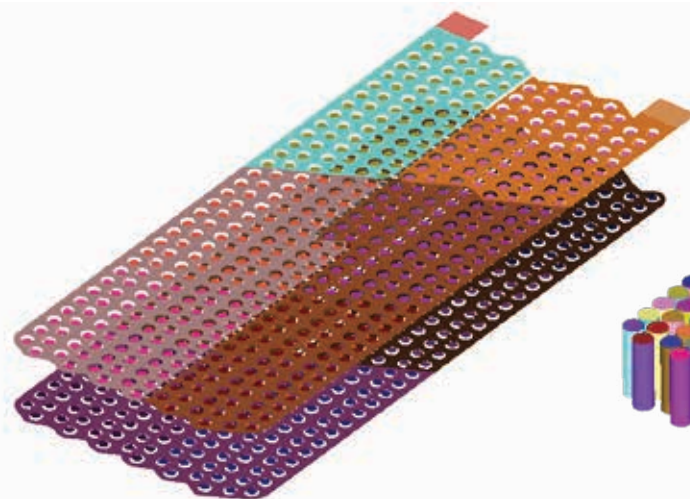
Constant current models

| Imposed Current Pack | Initial Depth of Discharge | Cutoff Voltage |
|----------------------|----------------------------|----------------|
| -370 A | 0 | 2.5 V |

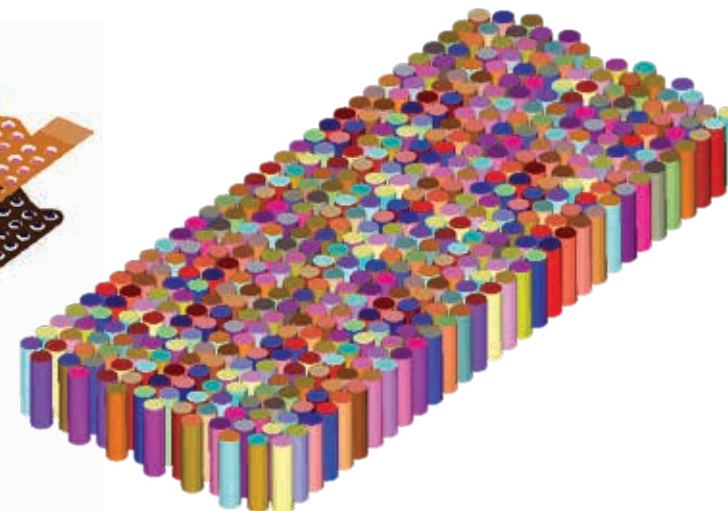
Models run until the cutoff voltage is reached.



Cooling rig with fluid streams



Joule Heating with bus bar geometry

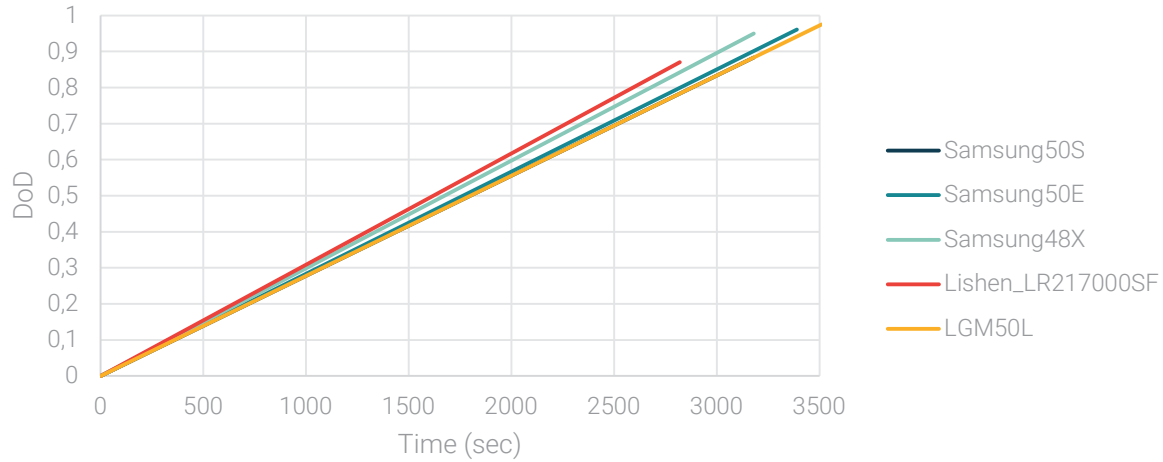


Battery Heating with cell geometry

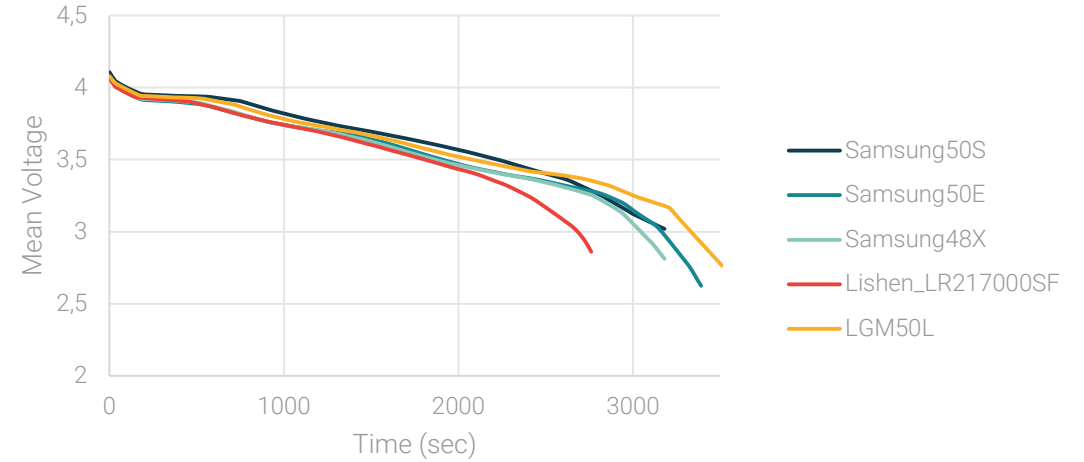
Results

Constant Current Results

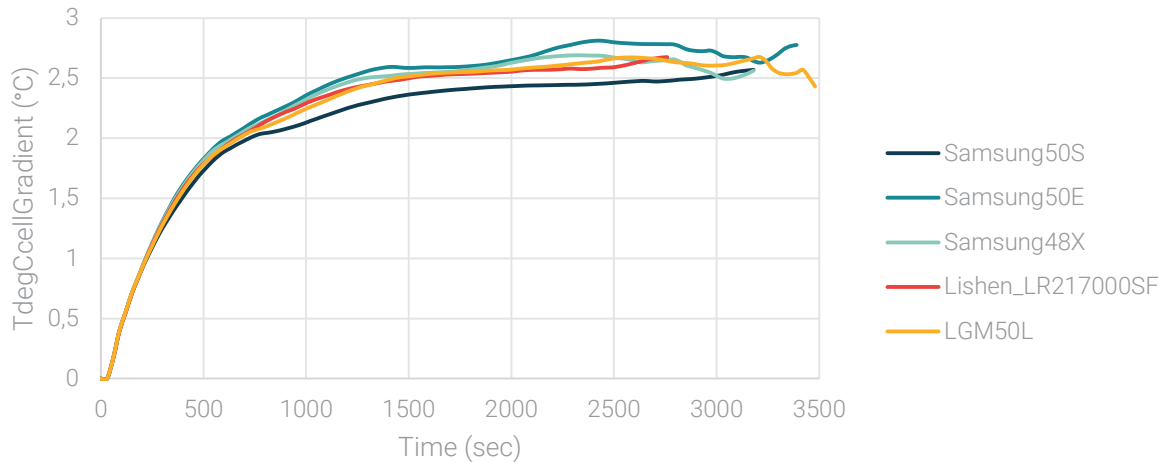
Depth of Discharge



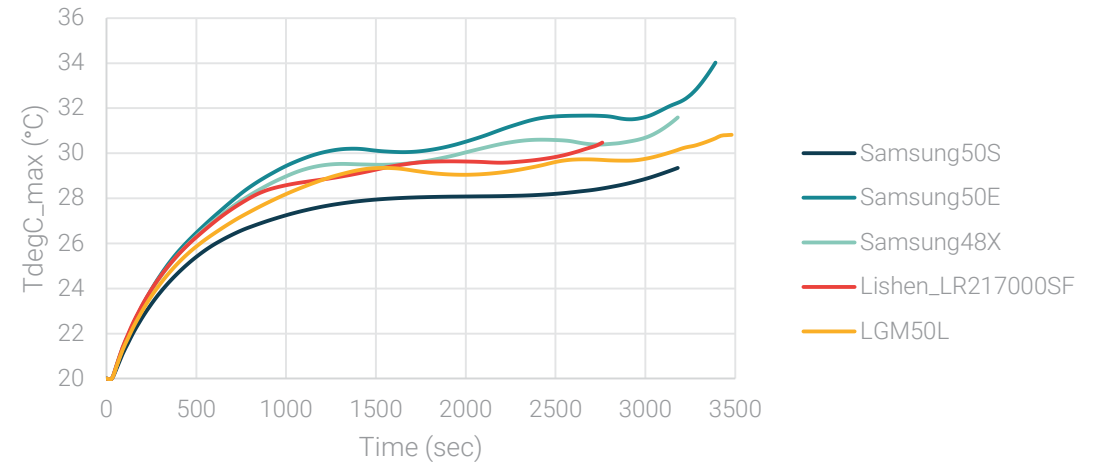
Mean Voltage

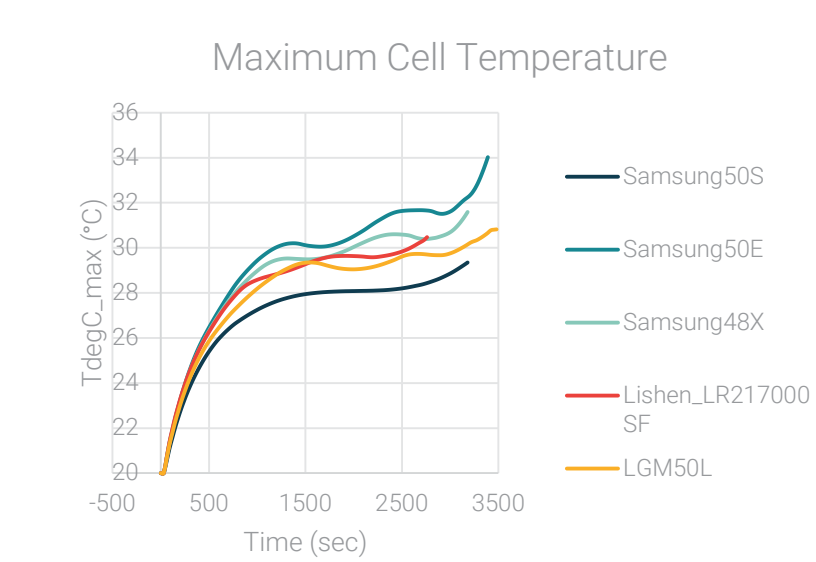
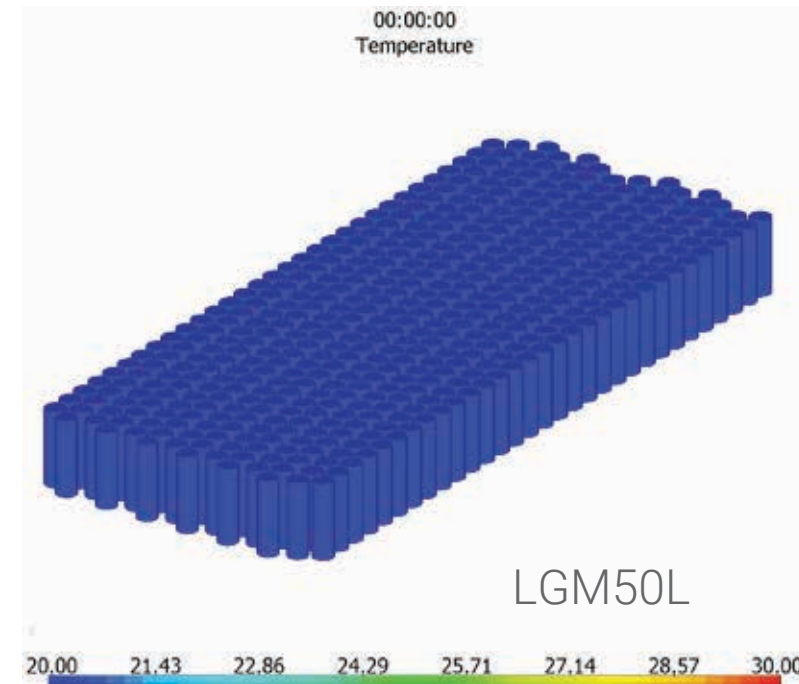
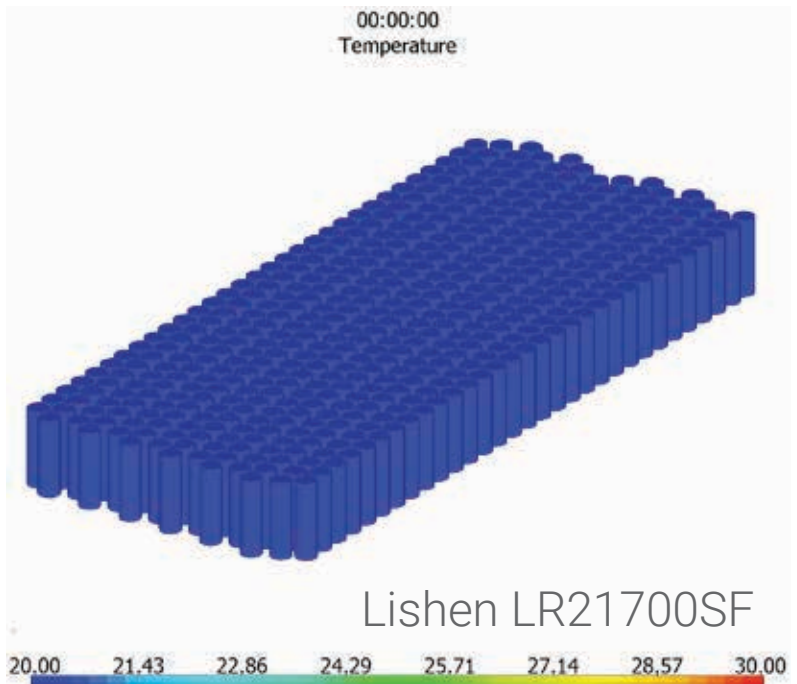
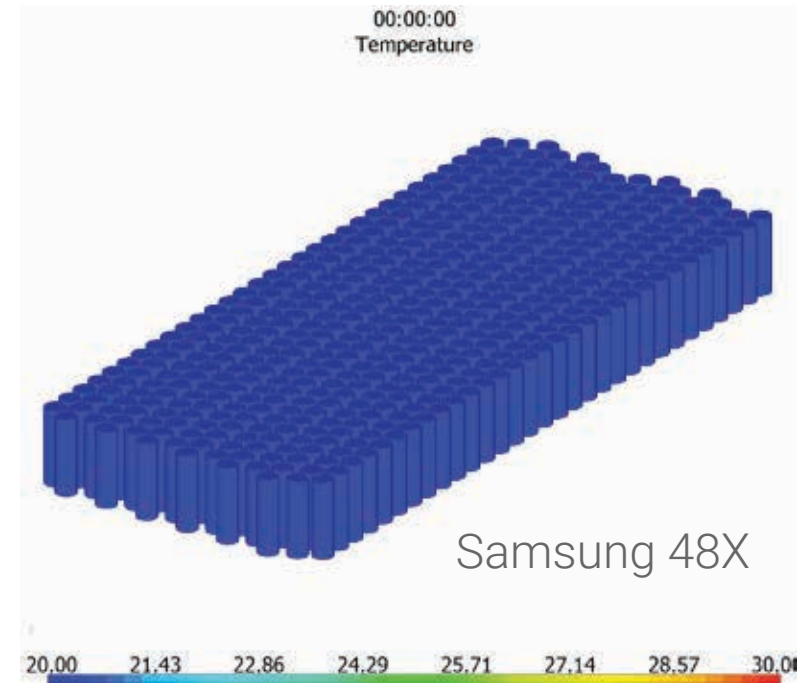
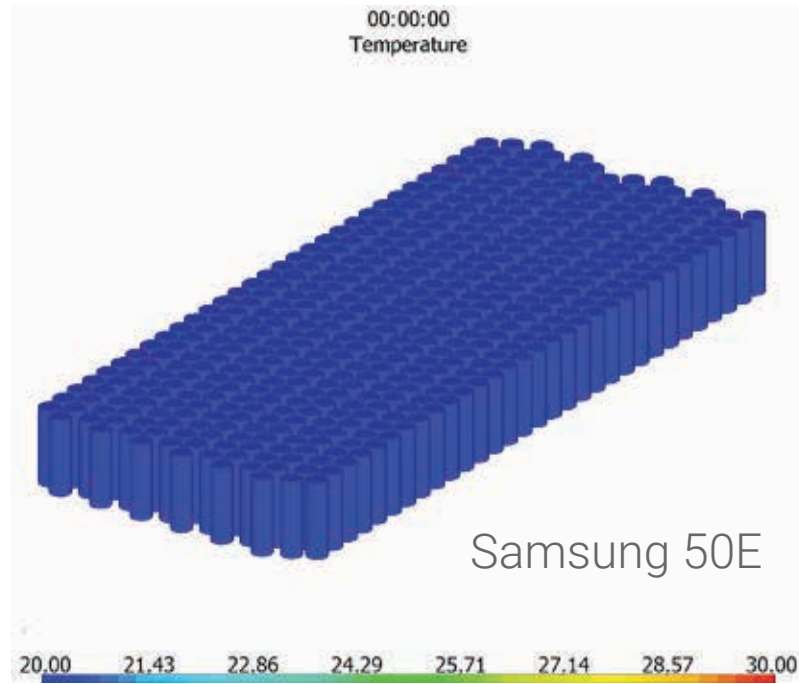
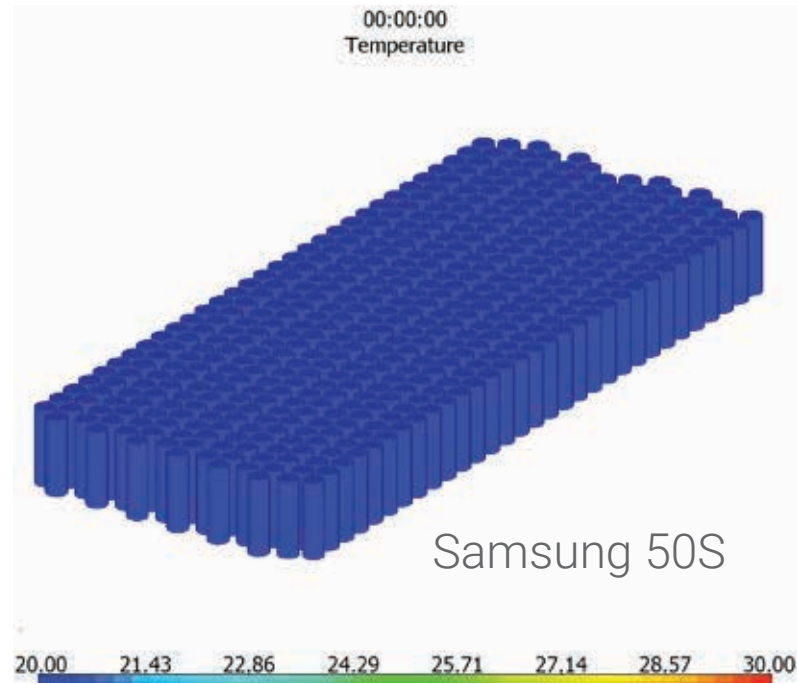


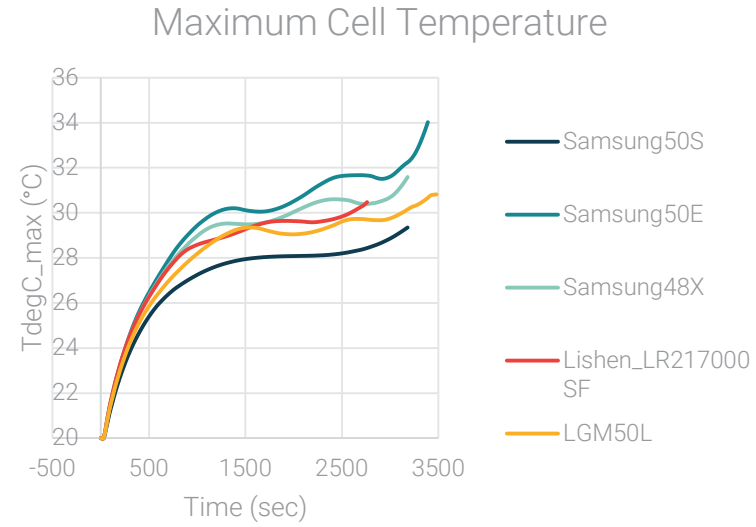
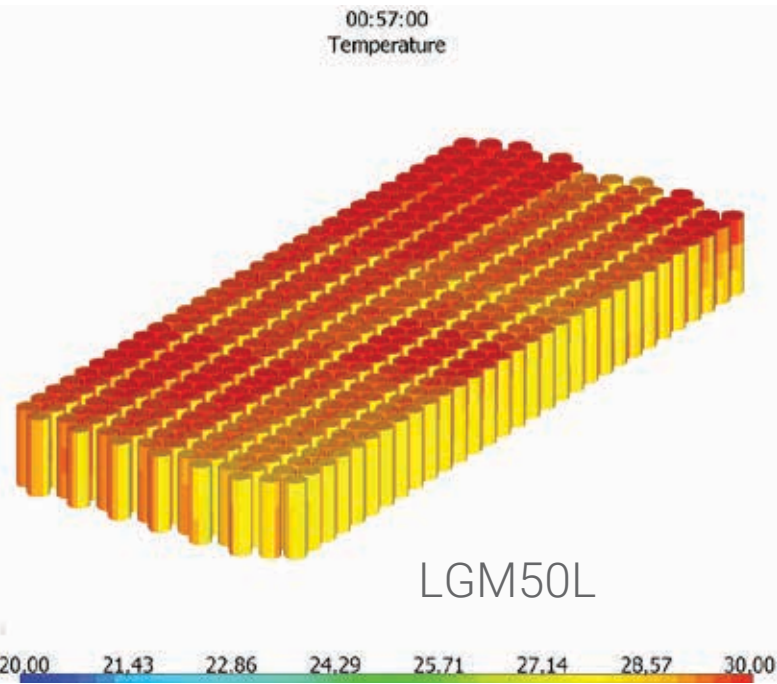
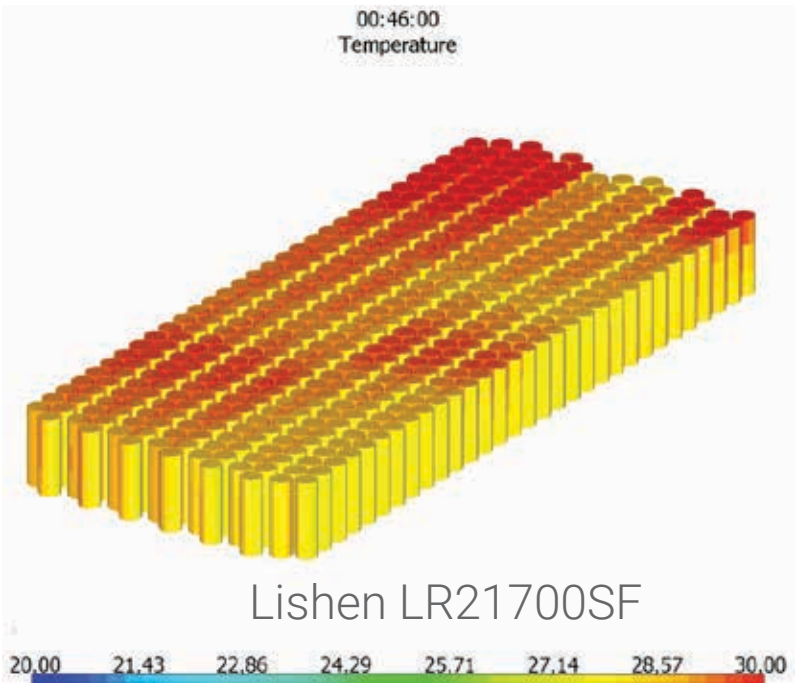
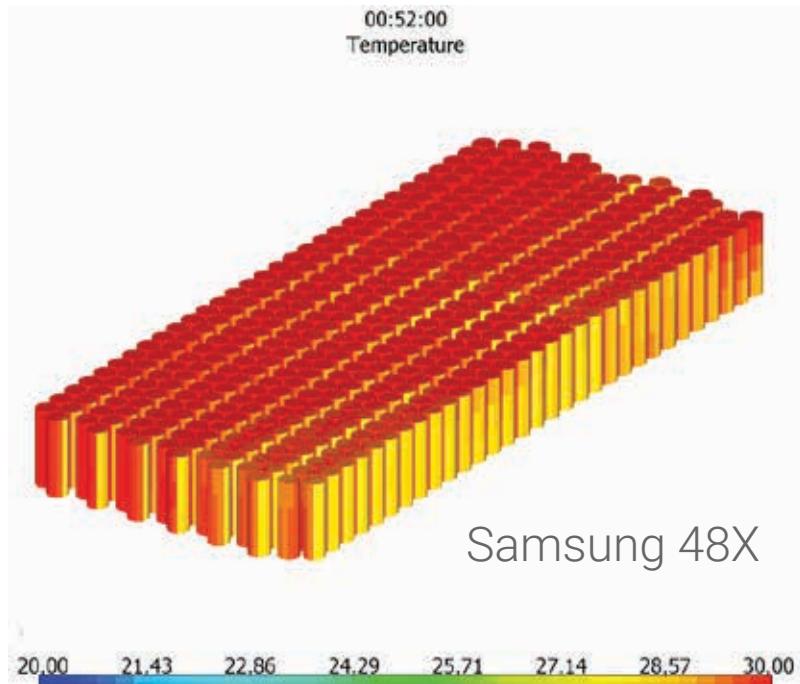
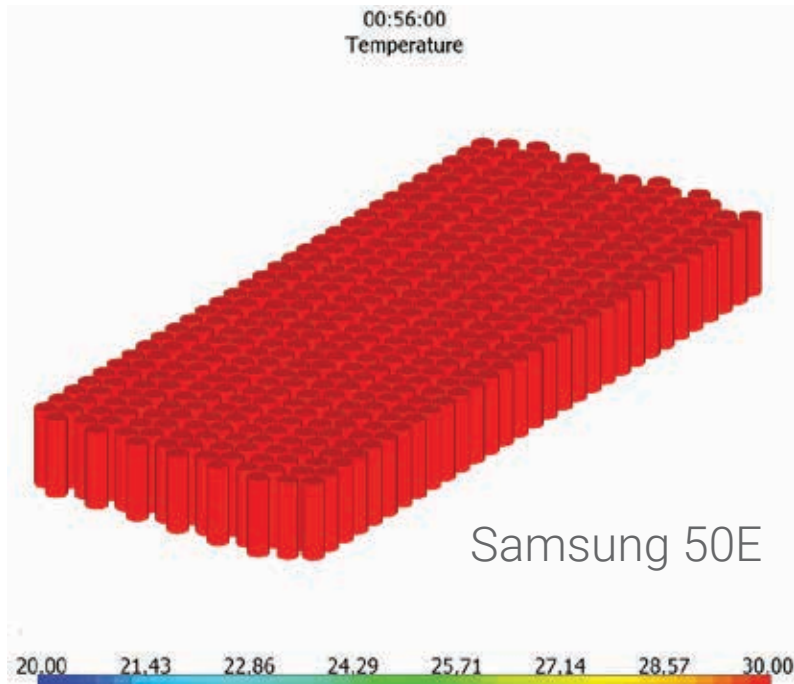
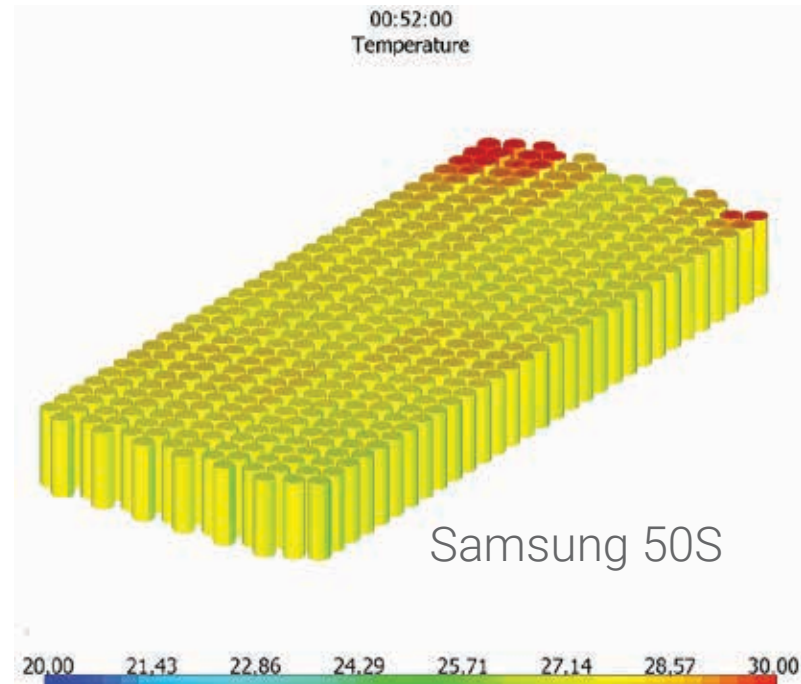
Cell Temperature Gradient



Maximum Cell Temperature

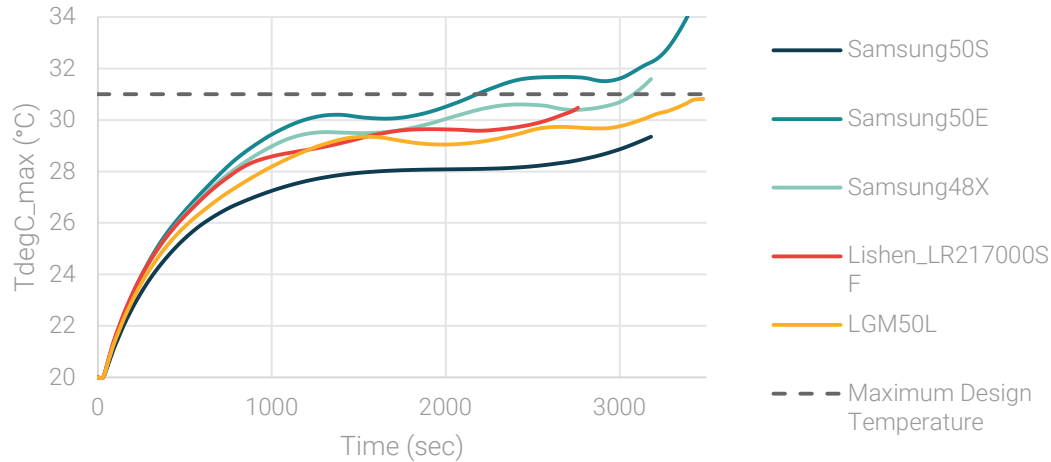






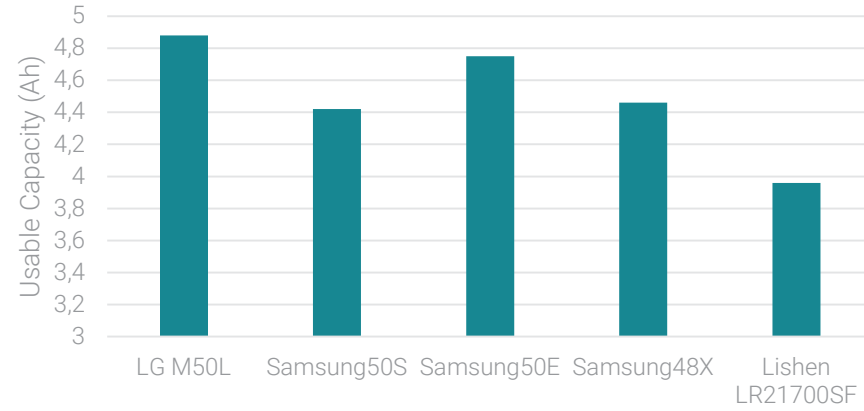
Cell Selection

Maximum Cell Temperature



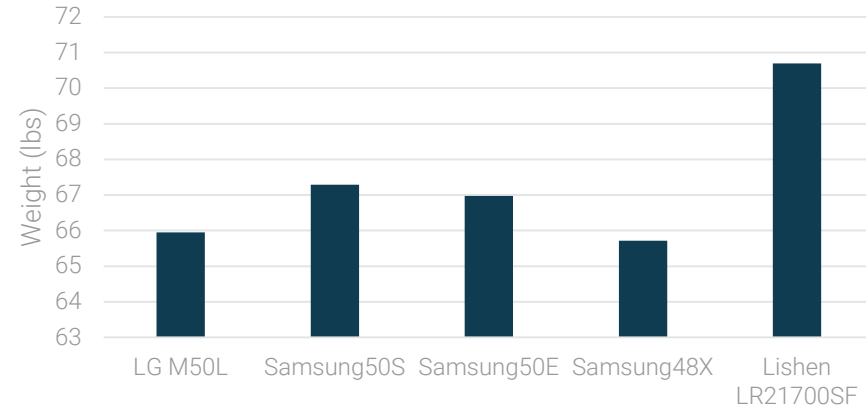
Best Temperature: Samsung 50S

Usable Capacity Comparison



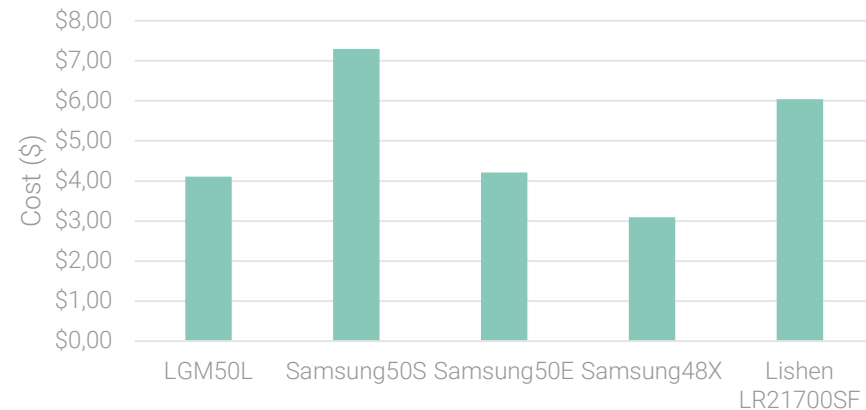
Best Capacity: LGM50L

Pack Weight (444 cells)



Best Weight: Samsung 48X

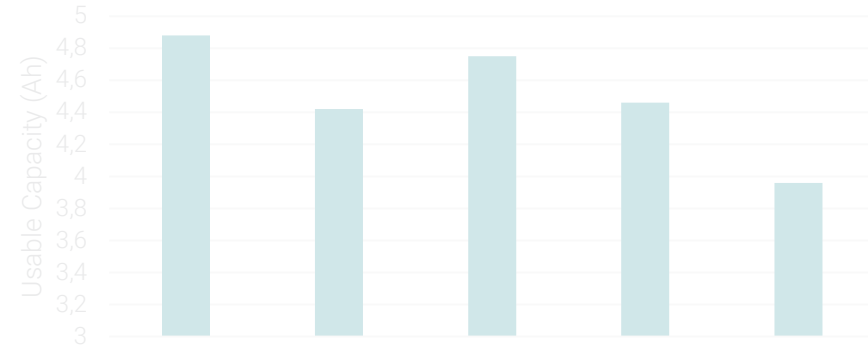
Cost per cell (with 400 purchased)



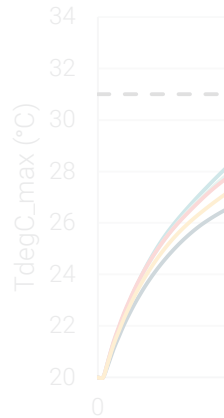
Best \$: Samsung 48X

Cell Selection

Usable Capacity Comparison



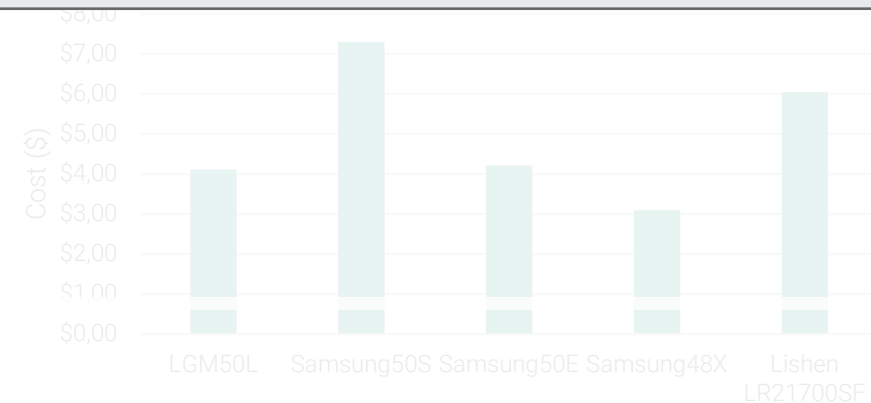
Best Capacity:
LGM50L



| | Weight | LGM50L | Samsung 50S | Samsung 50E | Samsung 48X | Lishen LR21700SF |
|-----------------|--------|--------|-------------|-------------|-------------|------------------|
| Max cell temp | 7 | 5 | 9 | 1 | 3 | 6 |
| Usable Capacity | 9 | 9 | 5 | 8 | 5 | 3 |
| Weight | 4 | 8 | 5 | 6 | 9 | 1 |
| Cost | 4 | 7 | 2 | 7 | 9 | 3 |
| | | 176 | 136 | 131 | 138 | 85 |

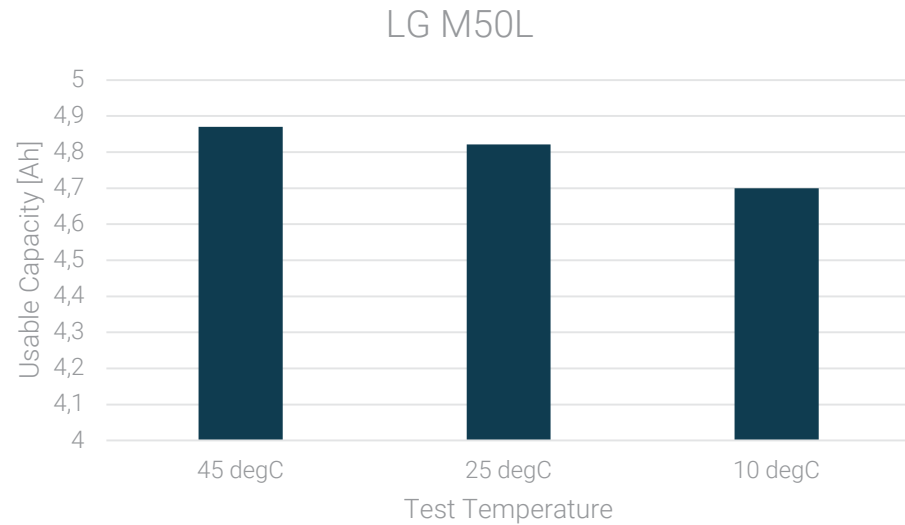
Best Temperature: Samsung 50S

Best Weight:
Samsung 48X



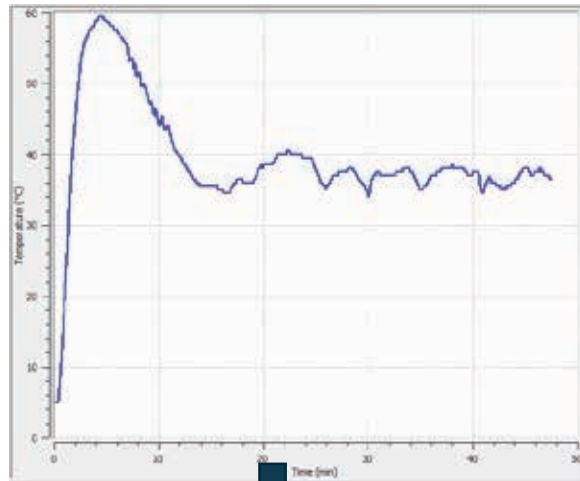
Best \$:
Samsung 48X

Battery Performance – Varying Temperature and Current

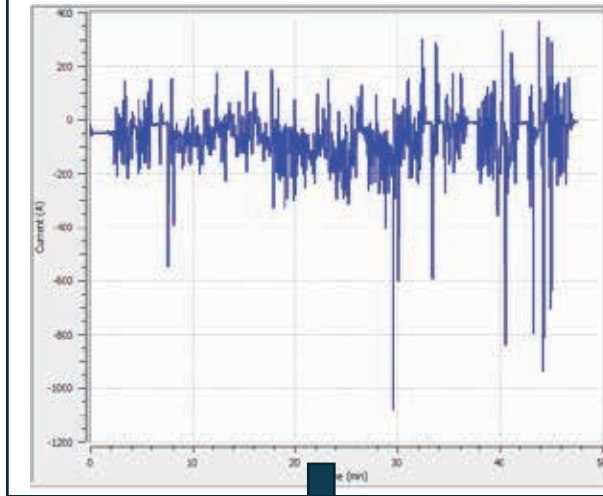


Model Drive Cycles

Heat Exchanger Temperature (°C)

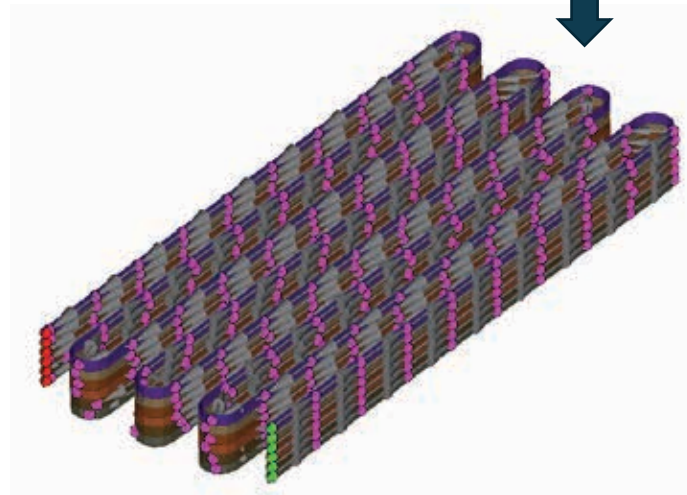


Current (A)

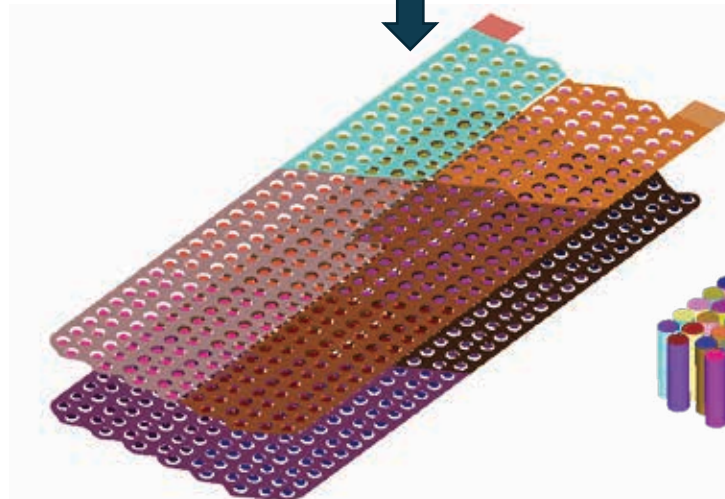


Initial Depth of Discharge

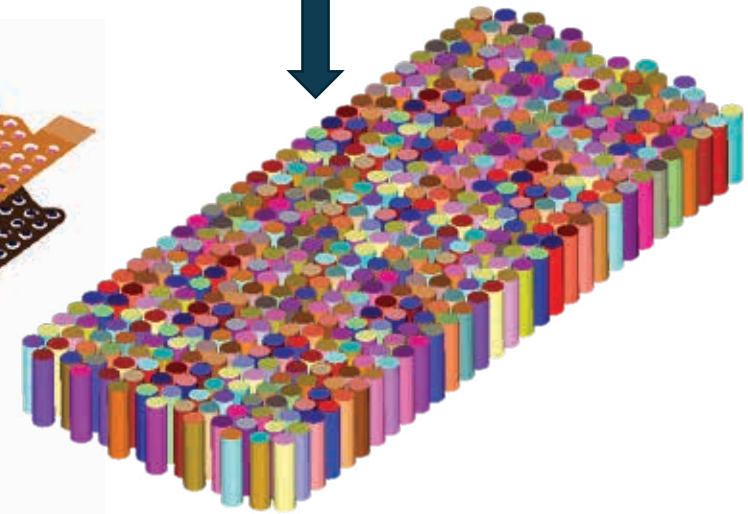
0.29



Cooling rig with fluid streams

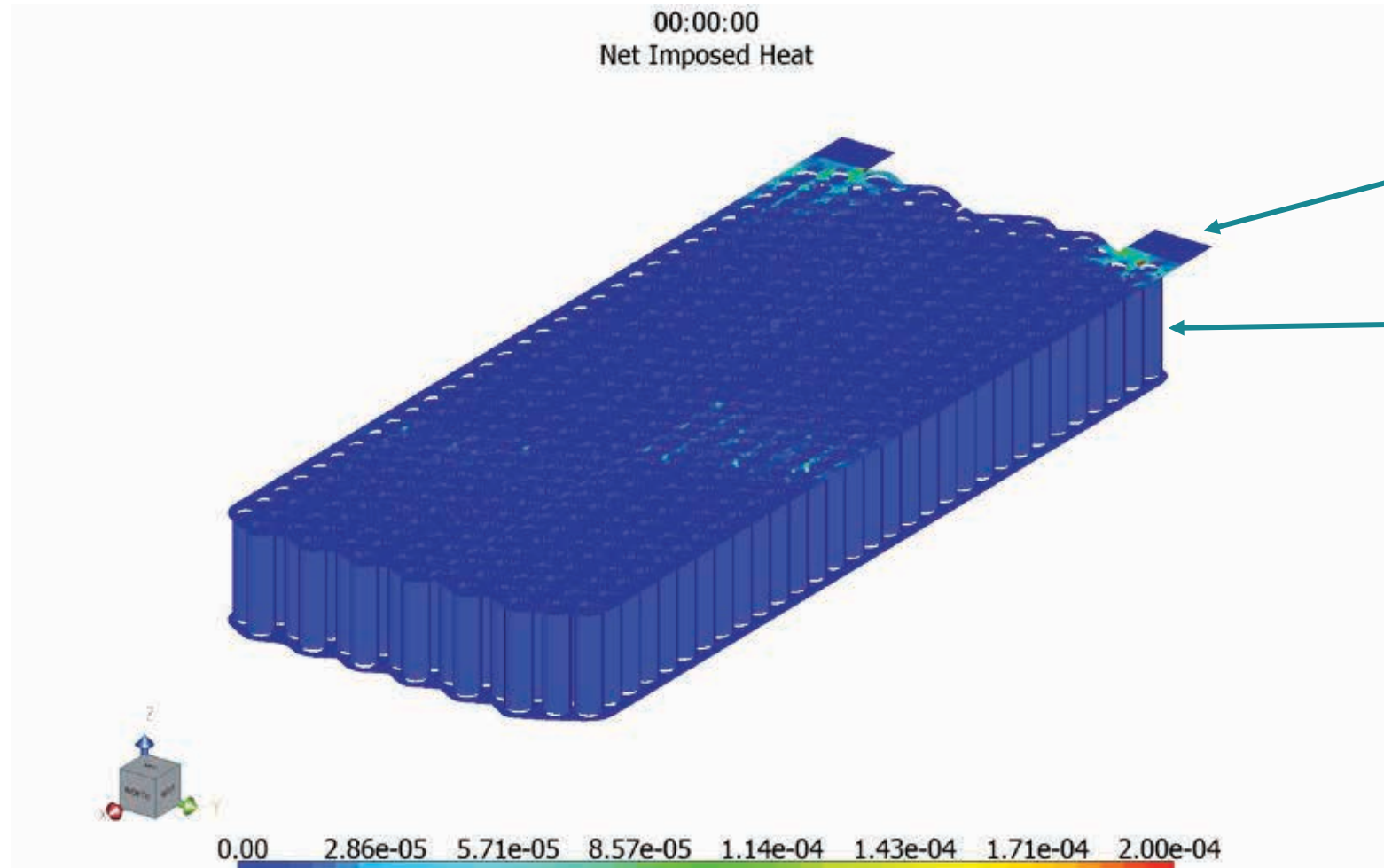


Joule Heating with bus bar geometry



Battery Heating with cell geometry

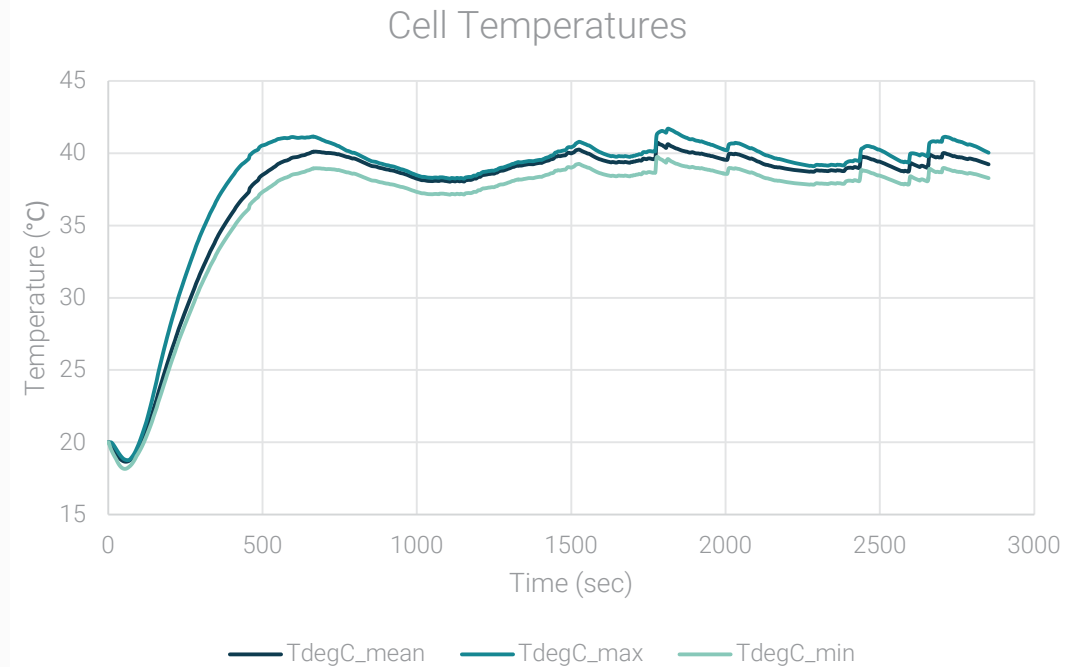
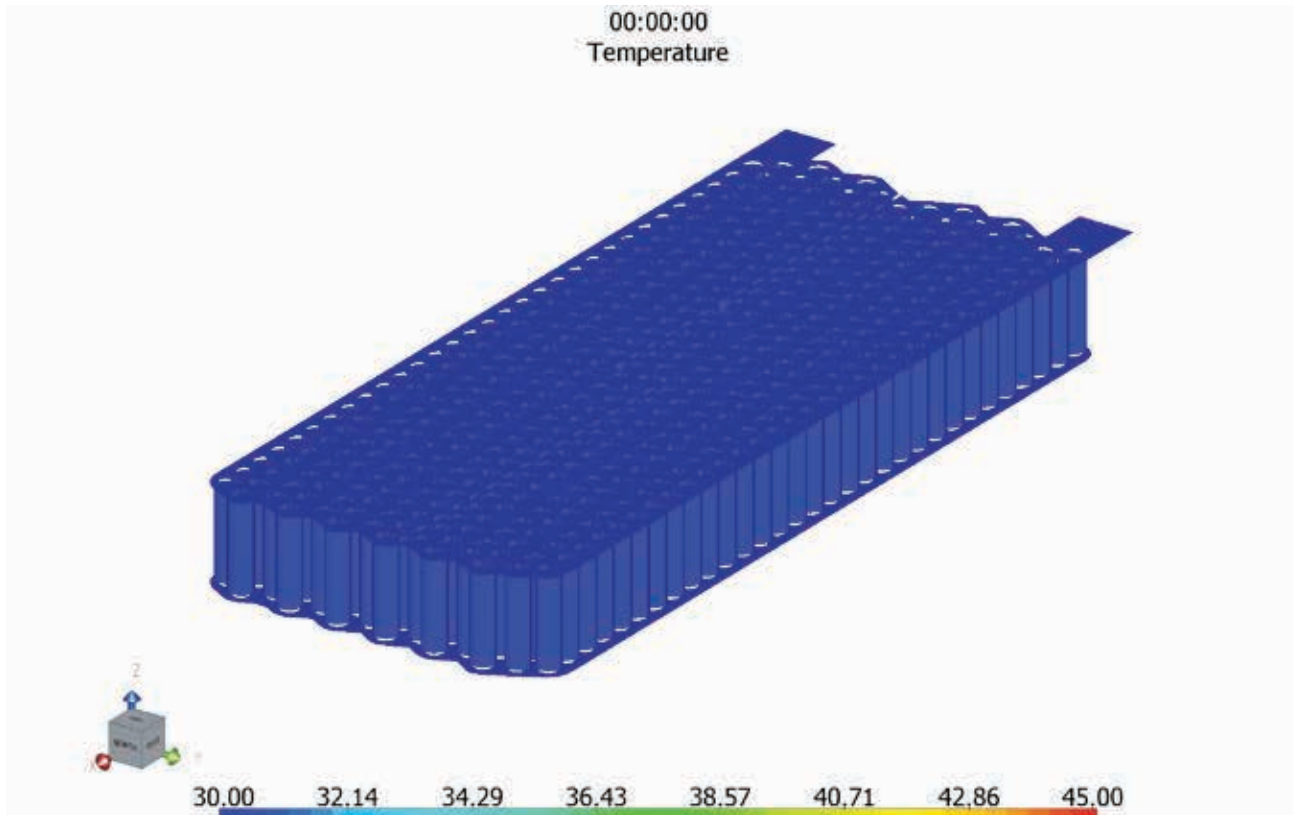
LGM50L Drive Cycle Results



Imposed heat from joule heating on the bus geometry

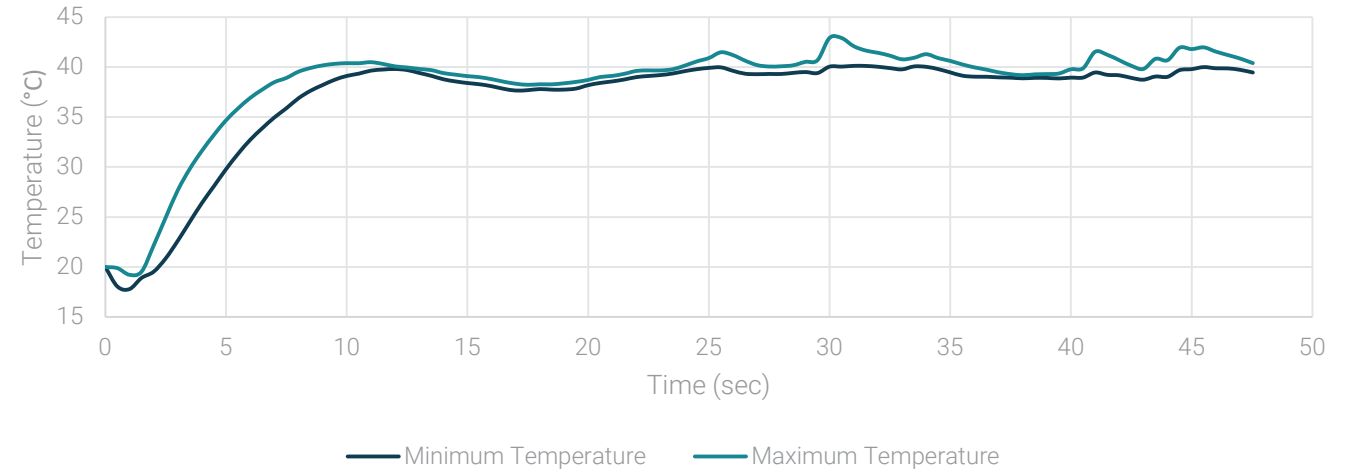
Imposed heat from battery heating on the cell geometry

LGM50L Drive Cycle Results

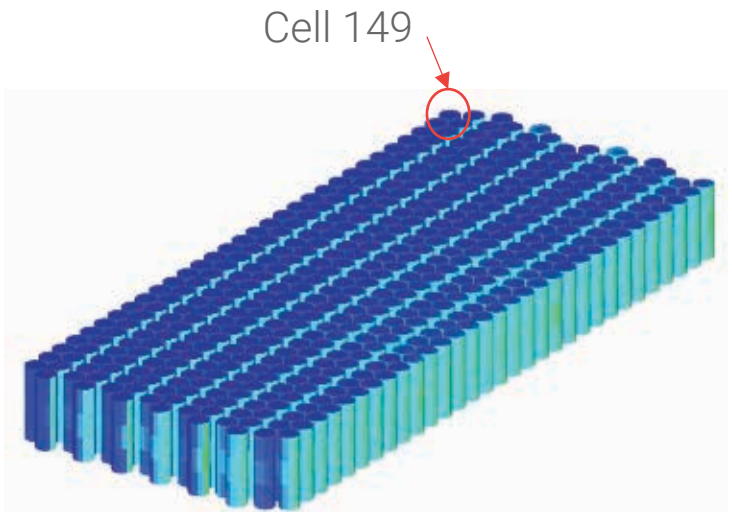
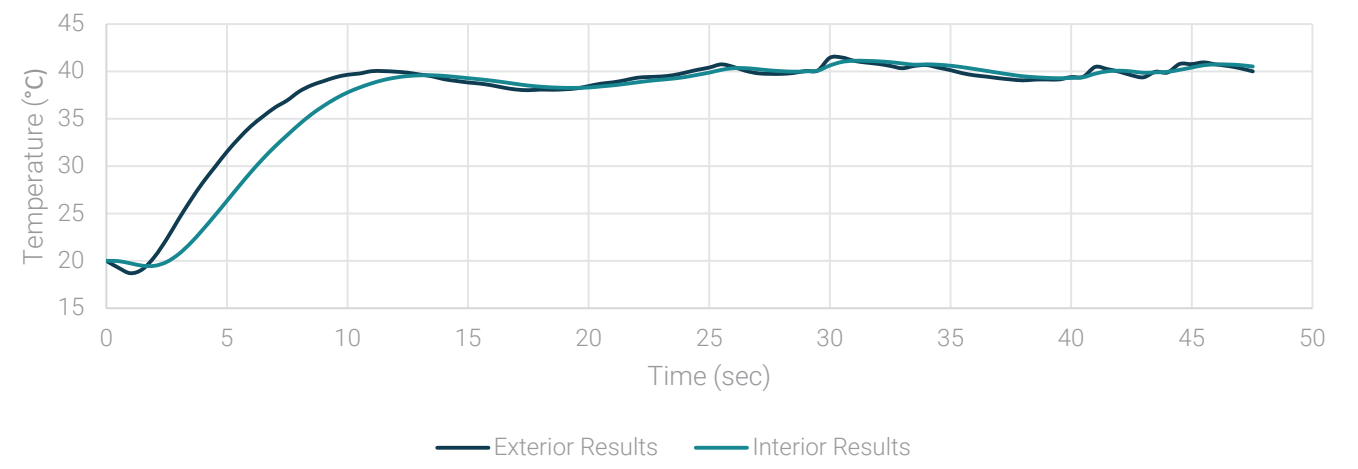


LGM50L Drive Cycle Results


Cell 149 Exterior Temperature Results



Cell 149 Exterior and Interior Temperature Results



Conclusions

- About:Energy's  VOLT database can be used with TAITherm to aid in the selection of battery cells from over 500 commercially available alternatives
- A 3D thermal/electric battery pack model aids in the selection of cells, cooling design, Joule heating in bus bars and cell balancing in the electrical equations
- The LG M50L was chosen as the cell of choice for this application, due to the highest usable capacity, moderate weight, and reasonable price
- The BETA CAE batch meshing script can support the geometry process



VOLT

Battery Database



www.aboutenergy.io



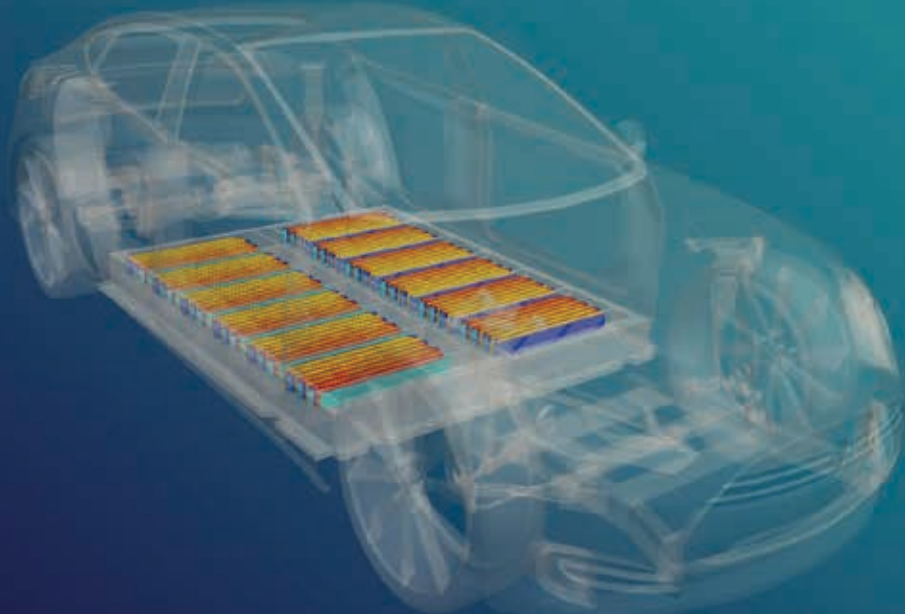
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Thank you

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