The Battery Designer Tool

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Learning objectives for this Lecture Unit

Ansys software mentioned	• Ansys Granta EduPack™, a teaching software for materials education

Intended Learning Outcomes	
Knowledge and Understanding	Knowledge of different battery cells and how they can be combined
Skills and Abilities	Ability to select battery cells to modules for applications
Values and Attitudes	Awareness of how battery performance changes with configuration and cell types

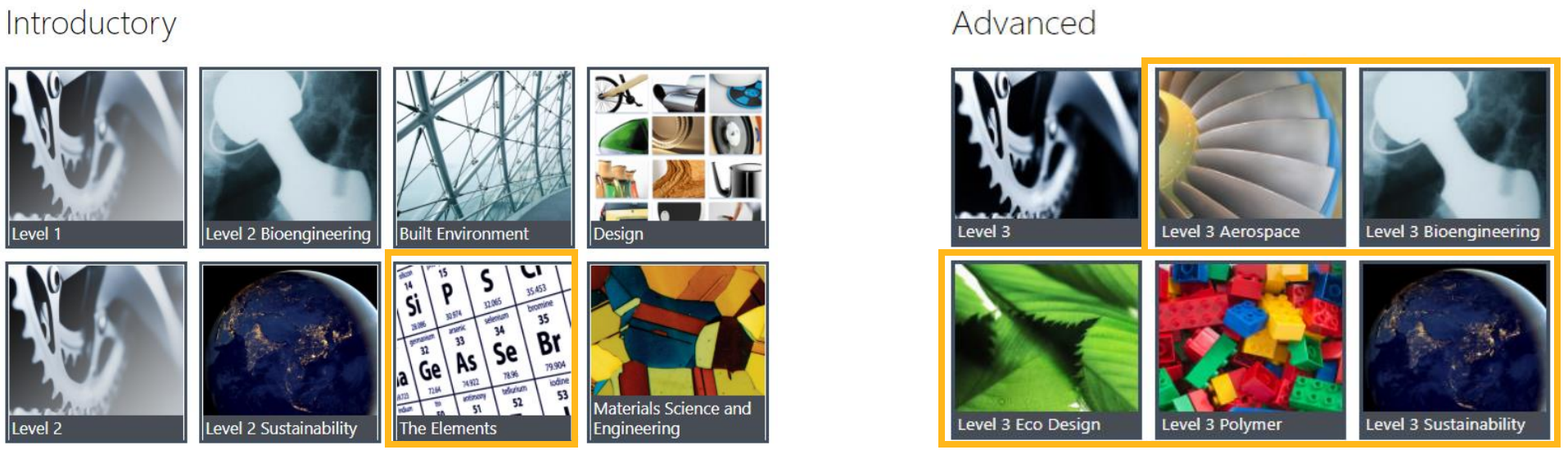
Resources

- Paper: **The Synthesizer Tool - Model Writer's Guide**
- Level 3 Industrial Case Study: Battery Designer and Materials for Transportation

Outline of lecture unit

- Background to batteries
- Relevant data
  - Power Systems-Storage
  - Battery cells
- Battery Designer synthesizer models
  - Cell to module
  - Module to pack
- Example of module design: eScooter

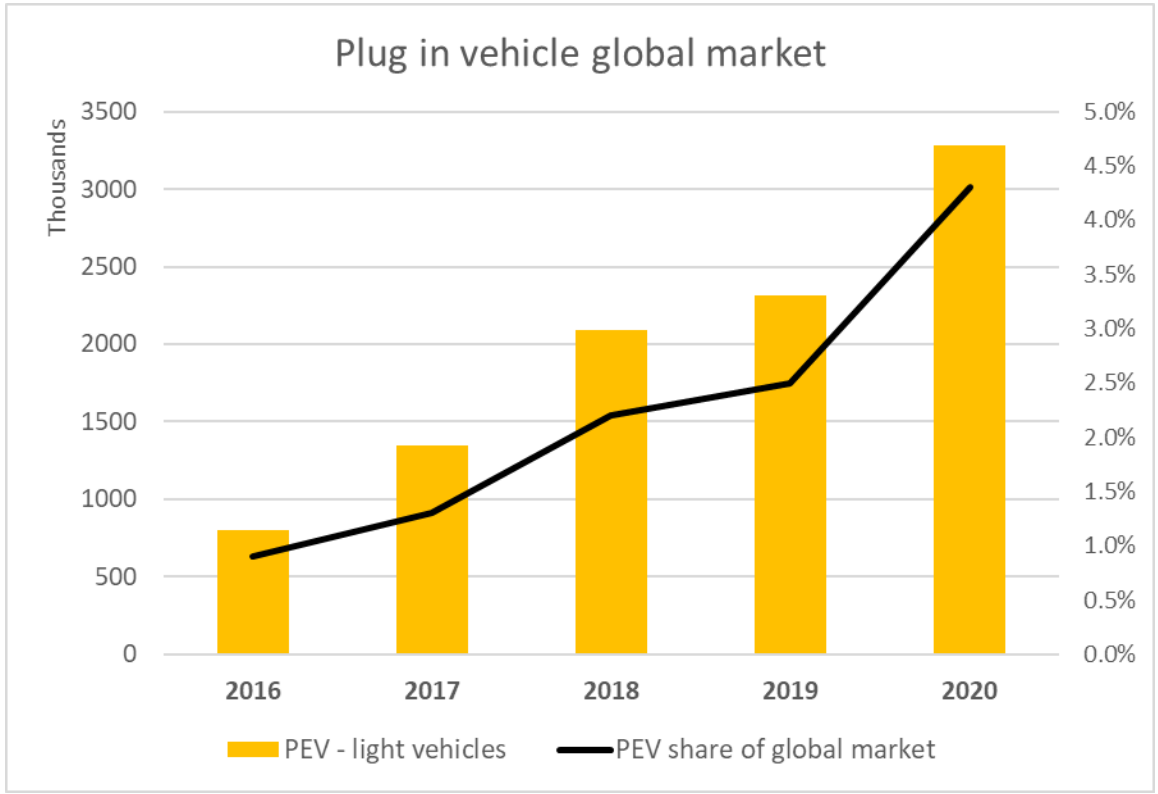
Granta EduPack databases with battery data



- The Elements database – All relevant elements for batteries
- Sustainability Level 3 – Energy Storage database
- All five Specialized Advanced databases – Battery Cells data and The Battery Designer tool

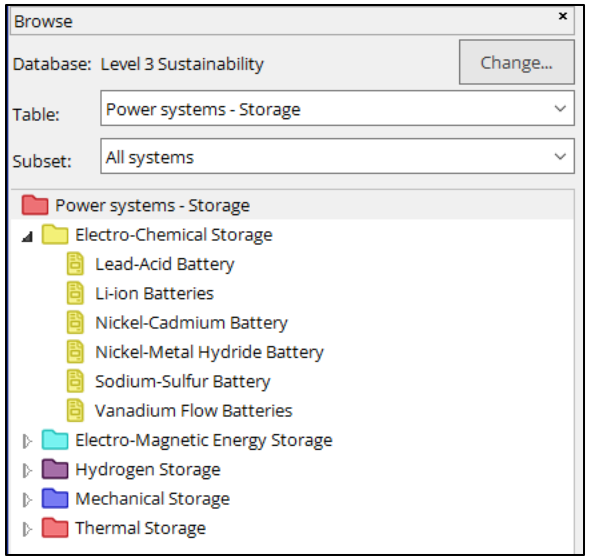
Background: materials for electrification of transport

- Huge growth of electric and hybrid vehicles
- Many battery types contain toxic elements:
  - **Lead,**
  - **Cadmium**
  - **Mercury**
- Some contain critical elements:
  - **Lithium**
  - **Cobalt**
- Most electric motors contain magnets
- These have rare earth elements:
  - **Neodymium**
  - **Samarium**
  - **Dysprosium**



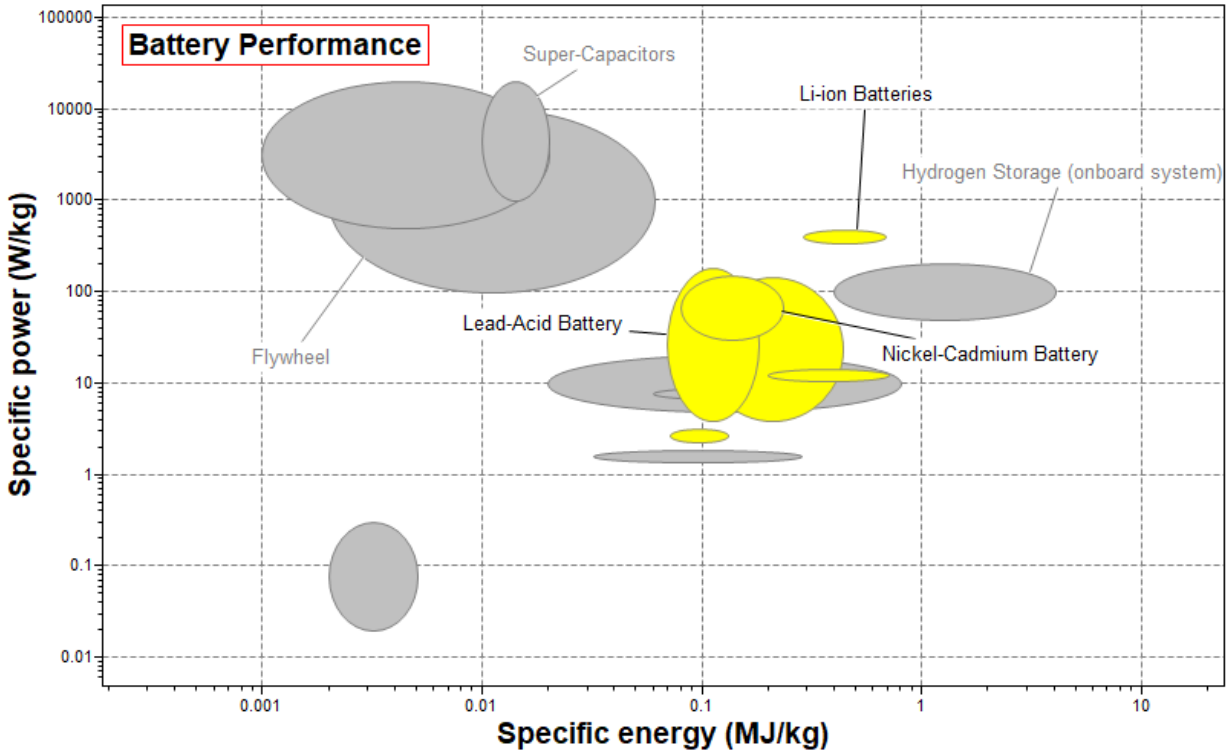
Top 5 Countries: China, Germany, USA, France, UK

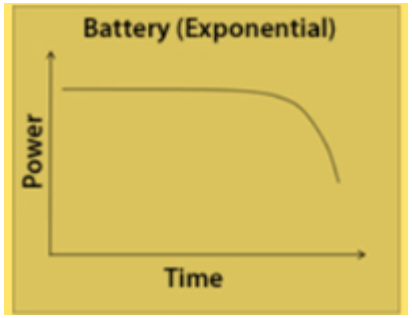
The Power Systems-Storage datatable



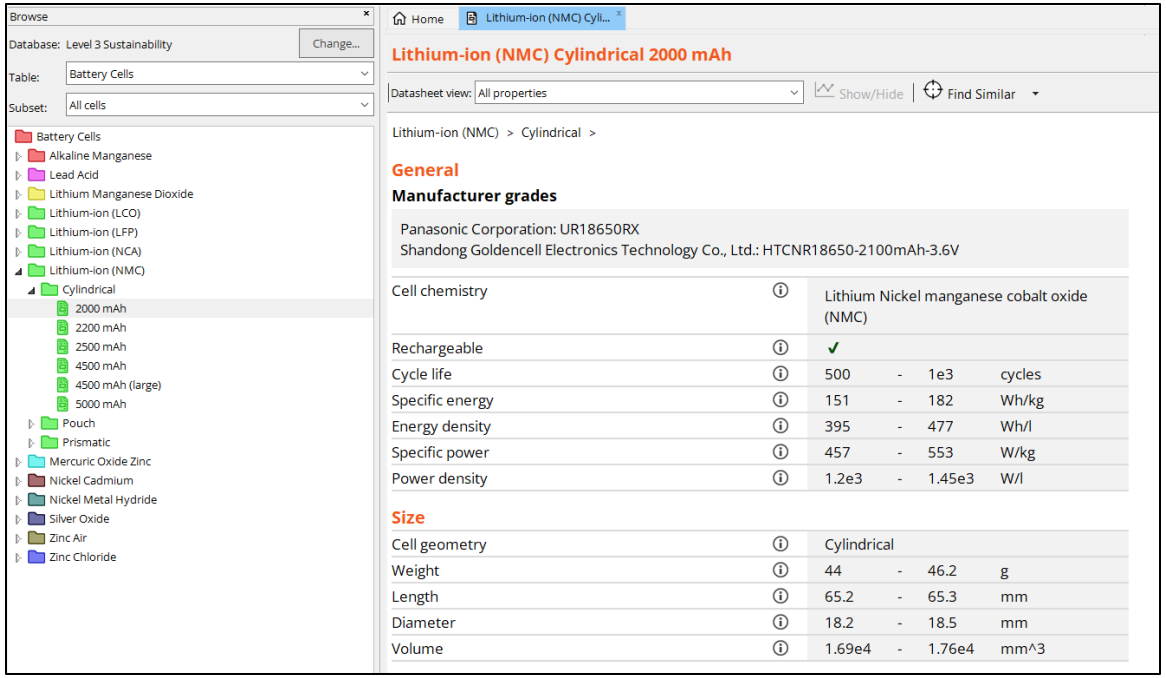
Specific power = power per mass, promotes acceleration
Specific energy = stored energy per mass, promotes range

Li-ion batteries perform better than others, but without the need for lead or cadmium





The Battery cells datatable



Cylindrical cell

- Generally lower cost
- High mechanical stability
- Most commonly available
- Used in EVs

Prismatic cell

- High mechanical stability
- High packing density
- Used in phones

Pouch cell

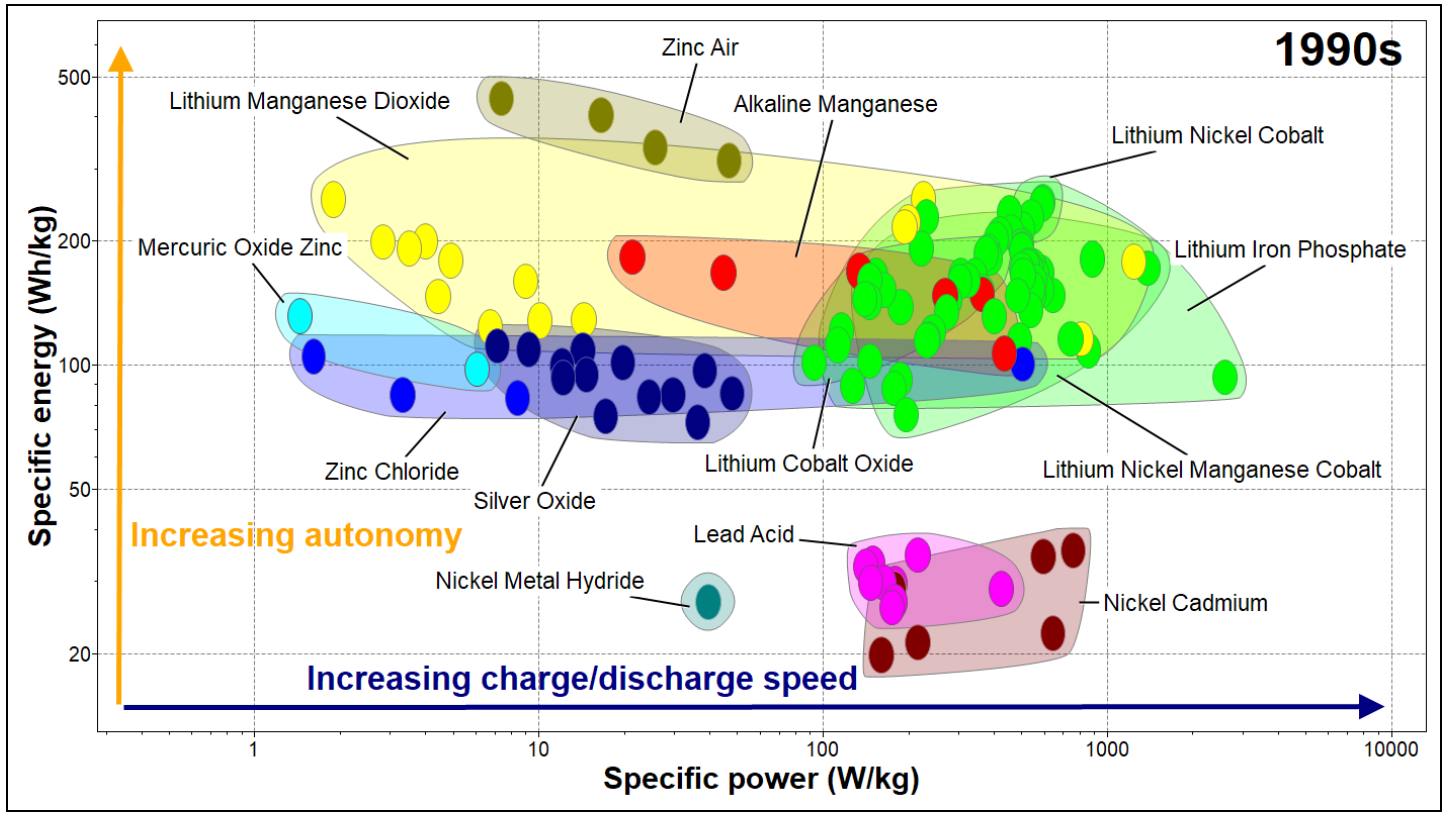
- Low mechanical stability
- High packing density
- Used in drones and R/C

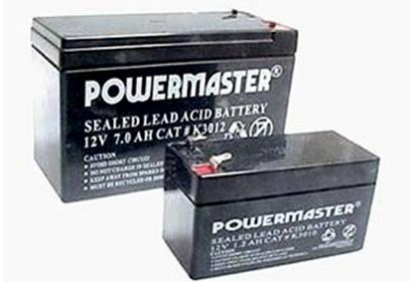
Coin cell

- Small
- Inexpensive
- Used in small appliances

Battery cell technology – 200 years of development

The Ragone plot is suitable for comparing performance of energy-storage devices, as well as energy devices such as engines, gas turbines, and fuel cells. The vertical axis describes how much energy is available per unit mass, while the horizontal axis shows how quickly that energy can be delivered, the power per unit mass.

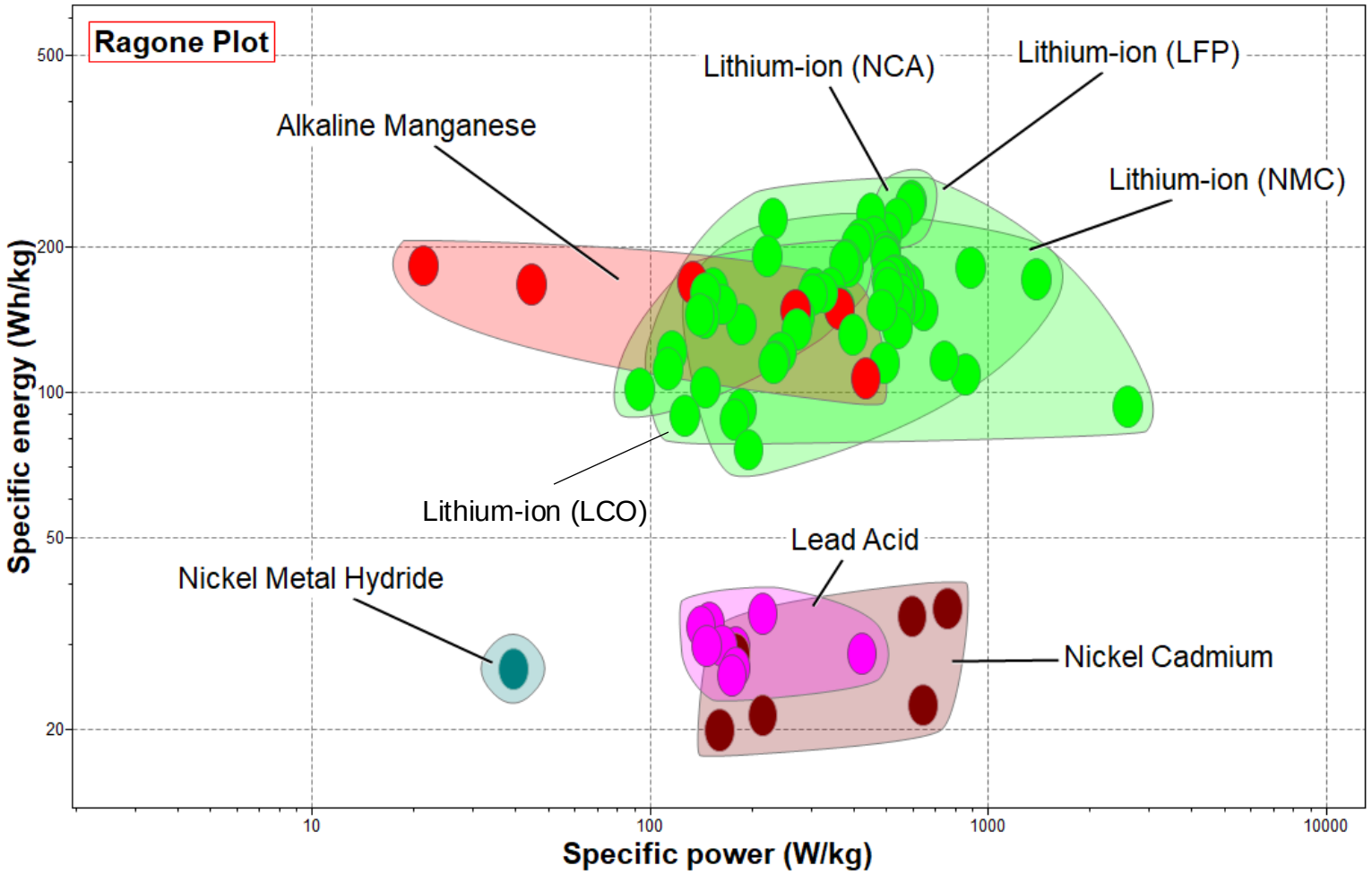




18650 - 18 mm diameter, 65 mm long

Images from Ansys Granta EduPack software

Ragone plots for rechargeable batteries

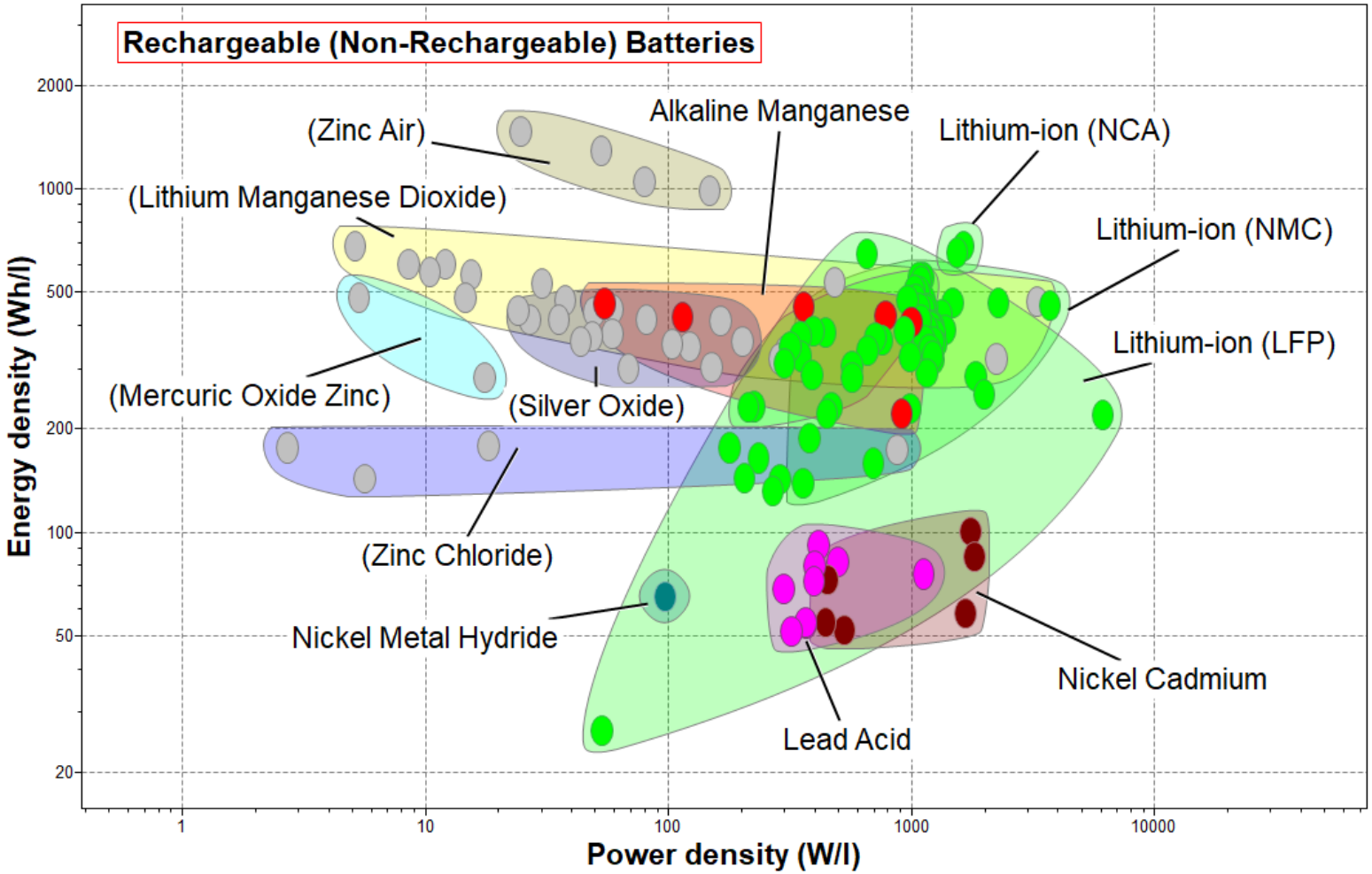


LCO=Lithium Cobalt Oxide
LFP=Lithium Iron Phosphate
NCA=Nickel Cobalt Aluminum Oxide
NMC=Nickel Manganese Cobalt

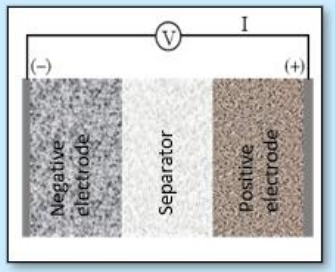
Lithium-ion type batteries are superior in both energy and power performance.

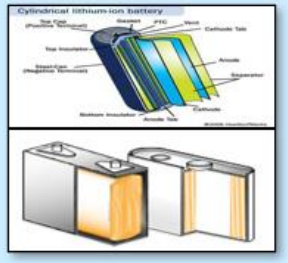
Heavy metal batteries have considerably less energy storage capacity per weight.

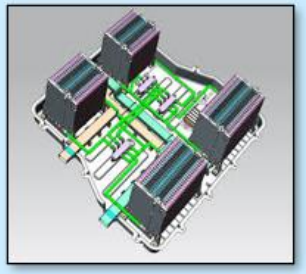
Energy density and Power density for rechargeable batteries



Battery Designer models and building blocks for transportation







Electrode

A cell consist of negative electrode, separator, positive electrode and current collector

Cell

The layers are wound to create Cylindrical, Prismatic or Pouch cell

Battery Module

The cells are grouped to form a battery module

Battery Pack

The module are connected to form a battery pack.

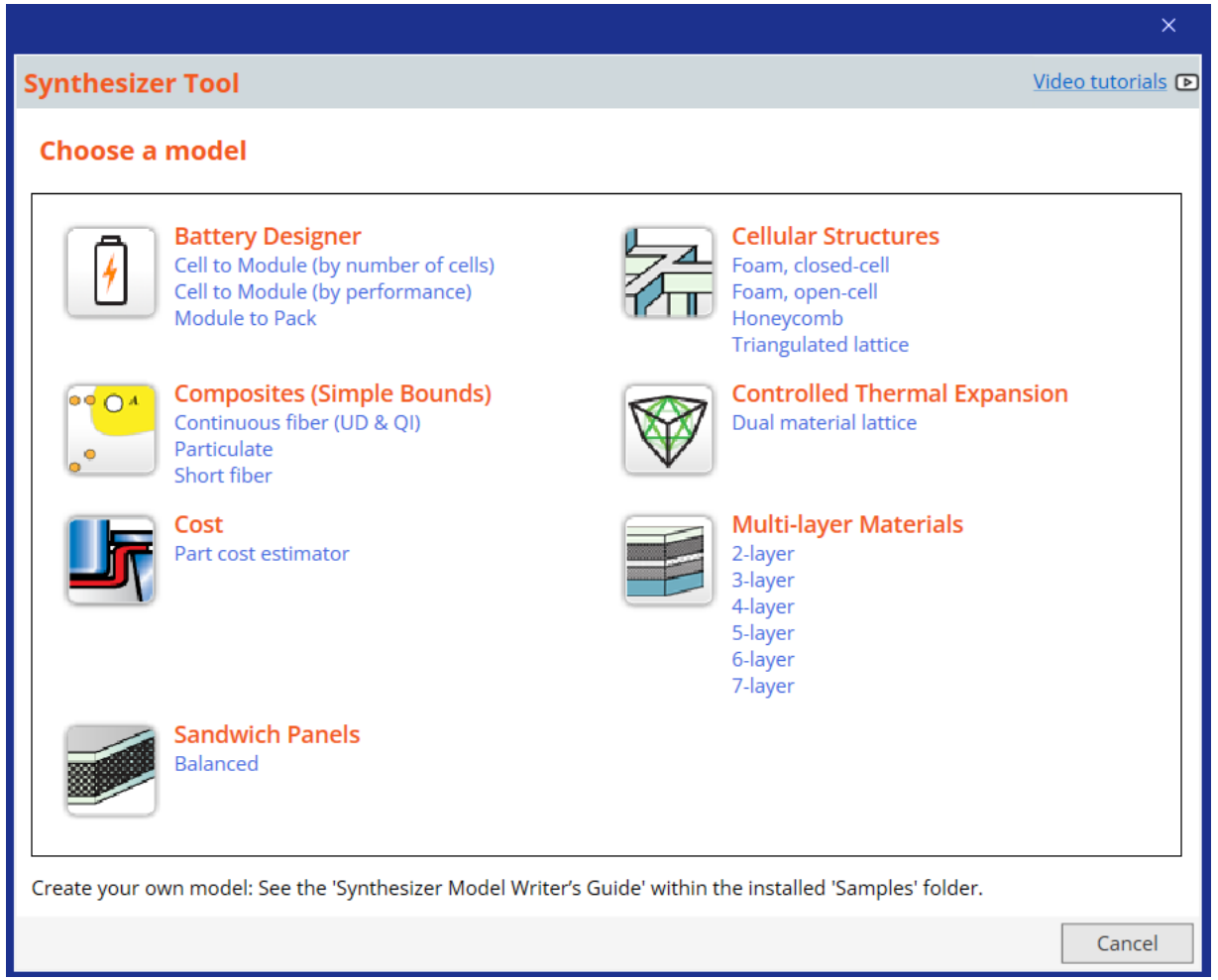
Transport System

The pack is integrated with other components (Power electronics, motors, etc) in EV power train

What is the Synthesizer tool?

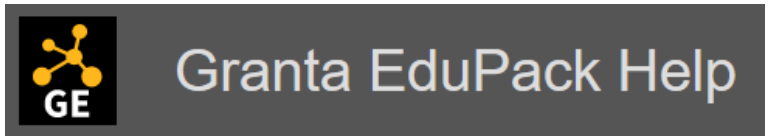
Click on **Synthesizer** on the main toolbar and under **Battery Designer**, click on the required model type:

- Cell to Module (specified by number of cells)
- Cell to Module (specified by performance)
- Module to Pack



Battery Designer: Assumptions and calculations

> Tools > Synthesizer Tool > Synthesizer Reference > Battery Designer: Assumptions and calculations



The models in the Battery Designer are heavily simplified and designed to allow rapid comparison between different cells, configurations and thermal management systems.

The equations used by the Synthesizer tool's Battery Designer, and full details of the assumptions the models make.

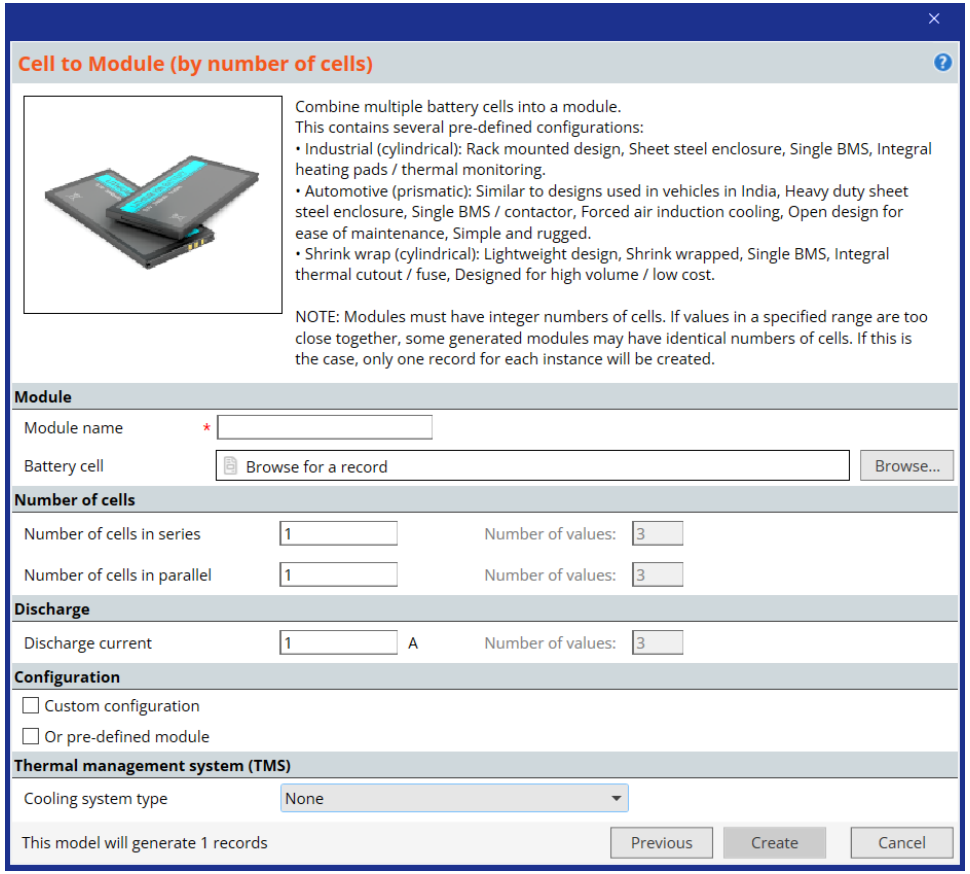
Assumptions used by model
- Energy and Power calculations
- Thermal Management model

Calculations used by model
- Cell to Module calculations
  - Discharge, Energy and Power
  - Thermal Management
- Module to Pack calculations

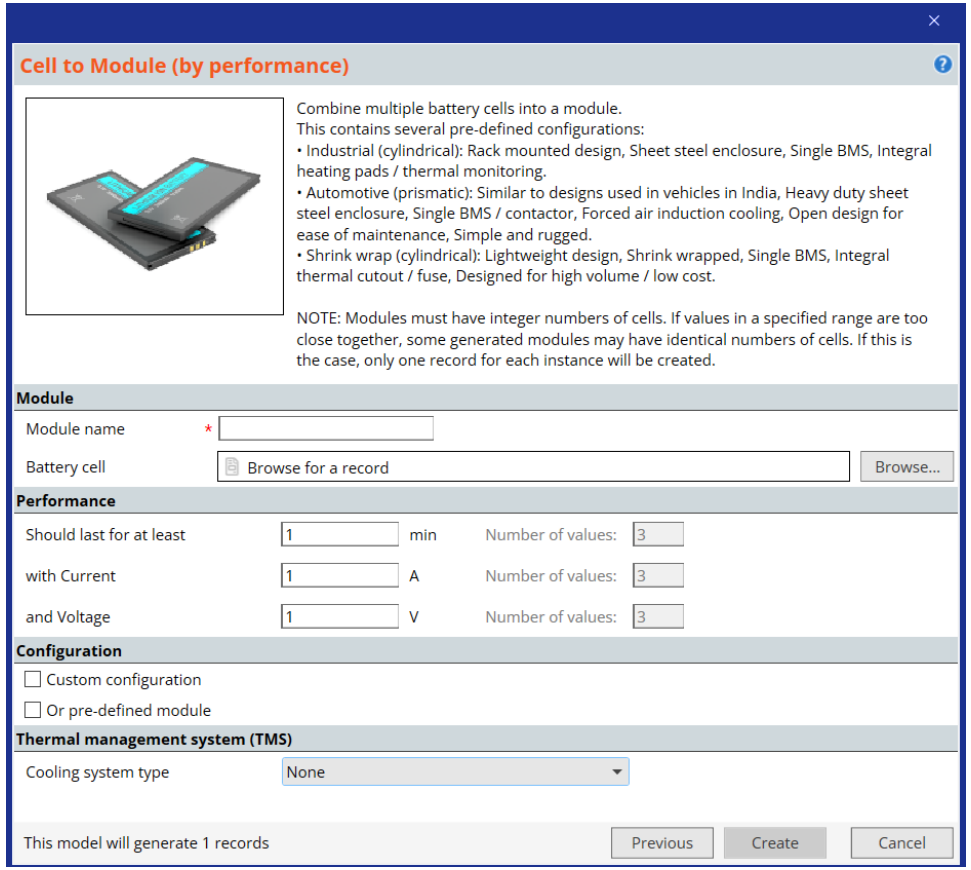
Summary of data and inputs required
- Cell to Module (by number of cells)
- Cell to Module (by performance)
- Module to Pack (by number of modules)
- Module to Pack (by performance)

Synthesizer model: Cell to module options

① By number of cells



② By performance



Synthesizer model: Cell to module specifications

Specify your required module properties, then click Create to synthesize the Module record(s).
The records will be added to the Battery Cells table under My Records > Synthesized > Modules.
Click Previous to go back and choose a different model.

Module
Enter a Module name; this is used to name the synthesized records.
Click Browse... to select a Battery cell from the Batteries datatable.

1. Cell to Module (by number of cells)
Enter the required Number of cells in parallel and Number of cells in series
Discharge
Enter the target Discharge current for the module.
You can enter a single value or a range (e.g. 0.1-0.2 A).

2. Cell to Module (by performance)
Enter the target Discharge time, Current and Voltage for the module. You can enter a single value or a range (e.g 12-20 V).

> Modules must have integer numbers of cells. If the target ranges are too close together, some generated modules may have identical numbers of cells. If this is the case, only one record for each instance will be created.

Synthesizer model: Cell to module configurations

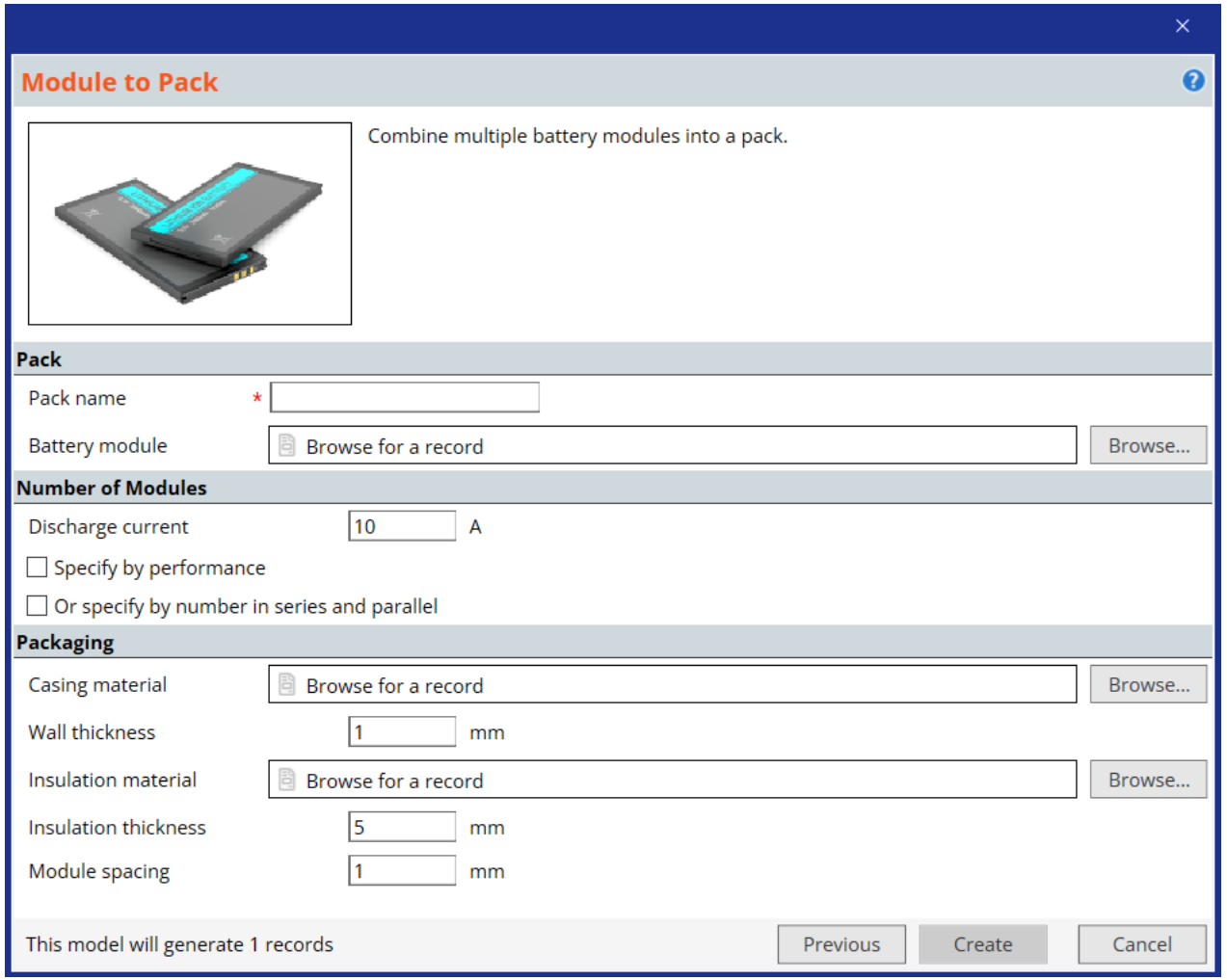
Configuration
Select the Pre-defined module checkbox to select one of the pre-defined configurations: Industrial, Automotive, or Shrink wrap.

Select the Custom configuration checkbox to specify module properties in the Packaging section. If both checkboxes are selected, the Pre-defined configuration will be applied. If neither checkbox is selected, the Custom configuration will be applied.

Packaging
Click Browse... to select a Casing material and Insulation material, and enter the corresponding Wall thickness or Insulation thickness. Specify the Cell spacing within the module.

Thermal management system (TMS)
Select a cooling system from the list:
- None
- Passive air cooling
- Active air cooling
- Liquid cooling
- Dielectric cooling

Synthesizer model: Module to pack



A Module consists of multiple connected cells in a casing with insulation and optional cooling system.

A Pack consists of multiple connected modules in a casing with insulation and optional cooling system.

Synthesizer model: Module to pack model

Specify your pack requirements, then click Create to synthesize Pack record(s).
The records will be added to the Battery Cells table under My Records > Synthesized > Packs.
Click Previous to to go back and choose a different model.

Pack
Enter a Pack name (this will be used to name the synthesized records), and click Browse... to select a Module from the browse tree. You can use a cell record from the data-table, or your own synthesized Module record.

Number of Modules
To calculate number of modules from performance requirements:
1.Select the Specify by performance checkbox
2.Edit the target Voltage window, Discharge time and Discharge current as a single value or a range (e.g. 3.3-3.7 V)

To calculate pack performance from number of modules:
1.Select the Specify by number in series or parallel checkbox
2.Edit the Number of modules in series and Number of modules in parallel

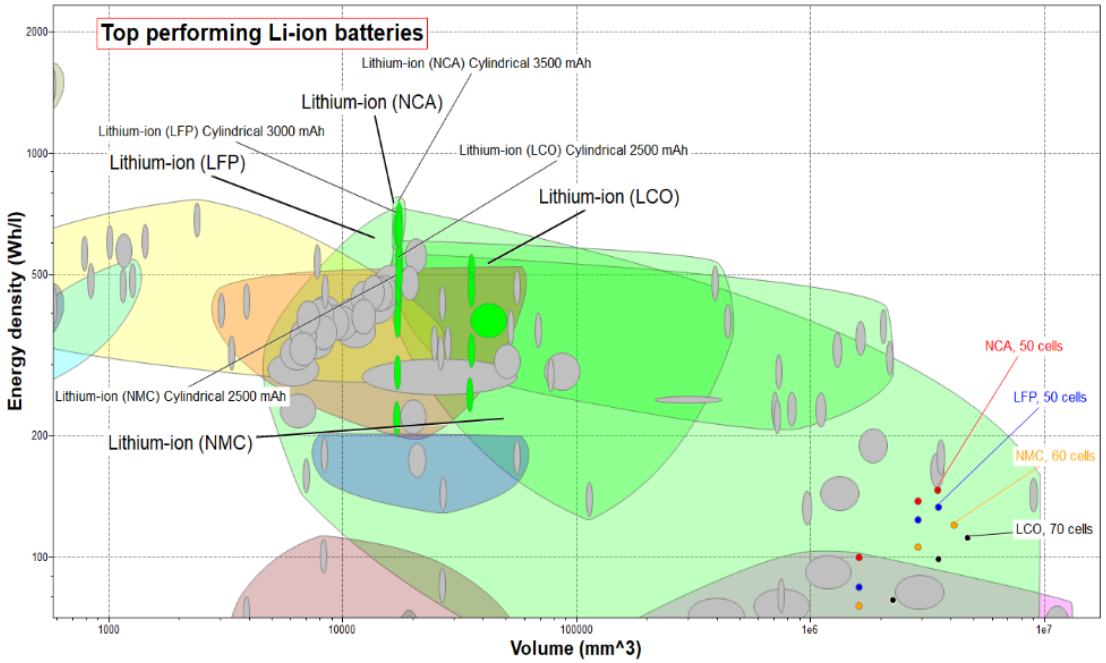
> If both checkboxes are selected, the synthesized records will be specified **by performance**. If neither checkbox is selected, the synthesized records will be specified **by the number of modules in series or parallel**.

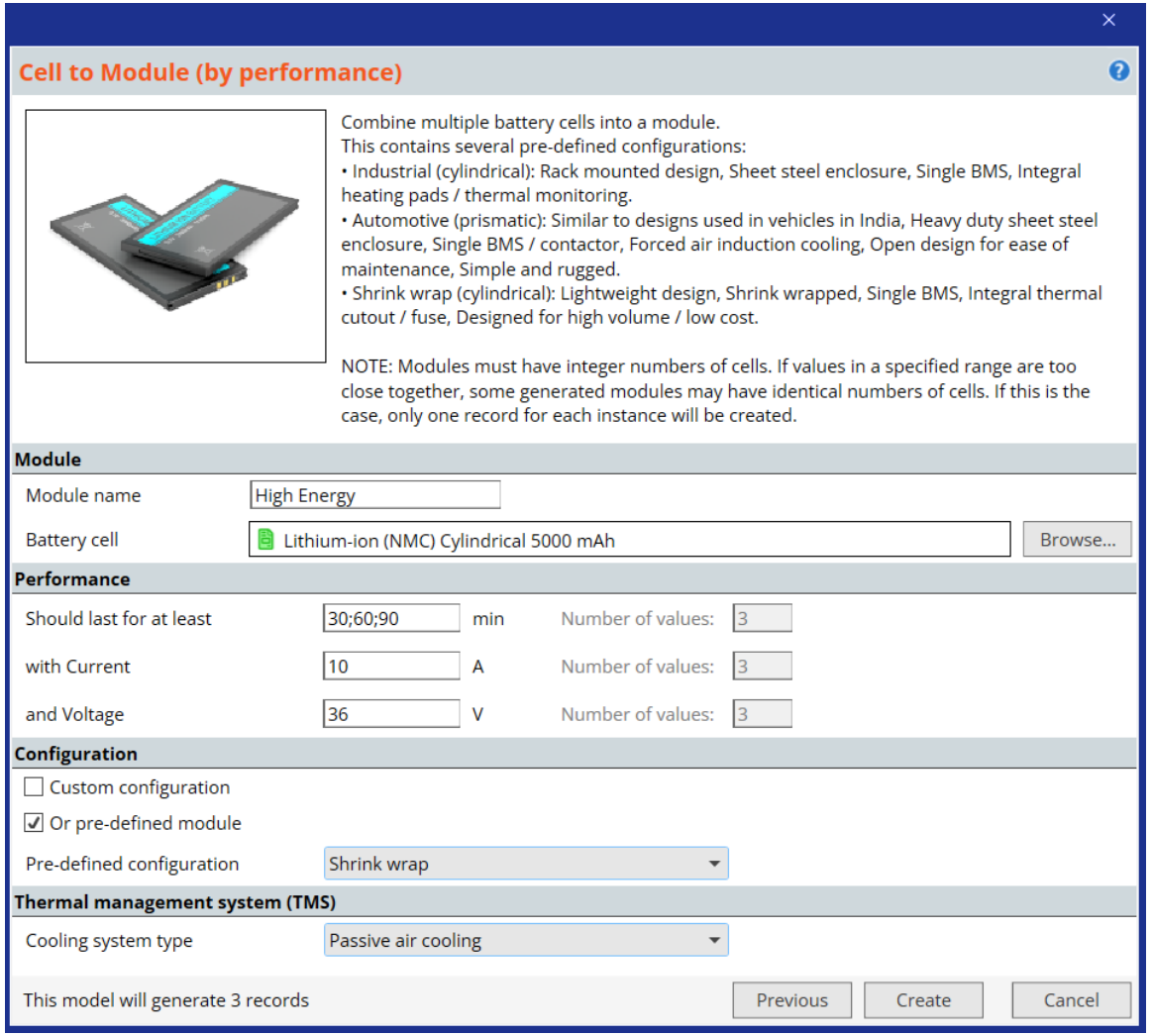
Example – Battery module for e-scooters

Objective: Maximize energy density, limited volume

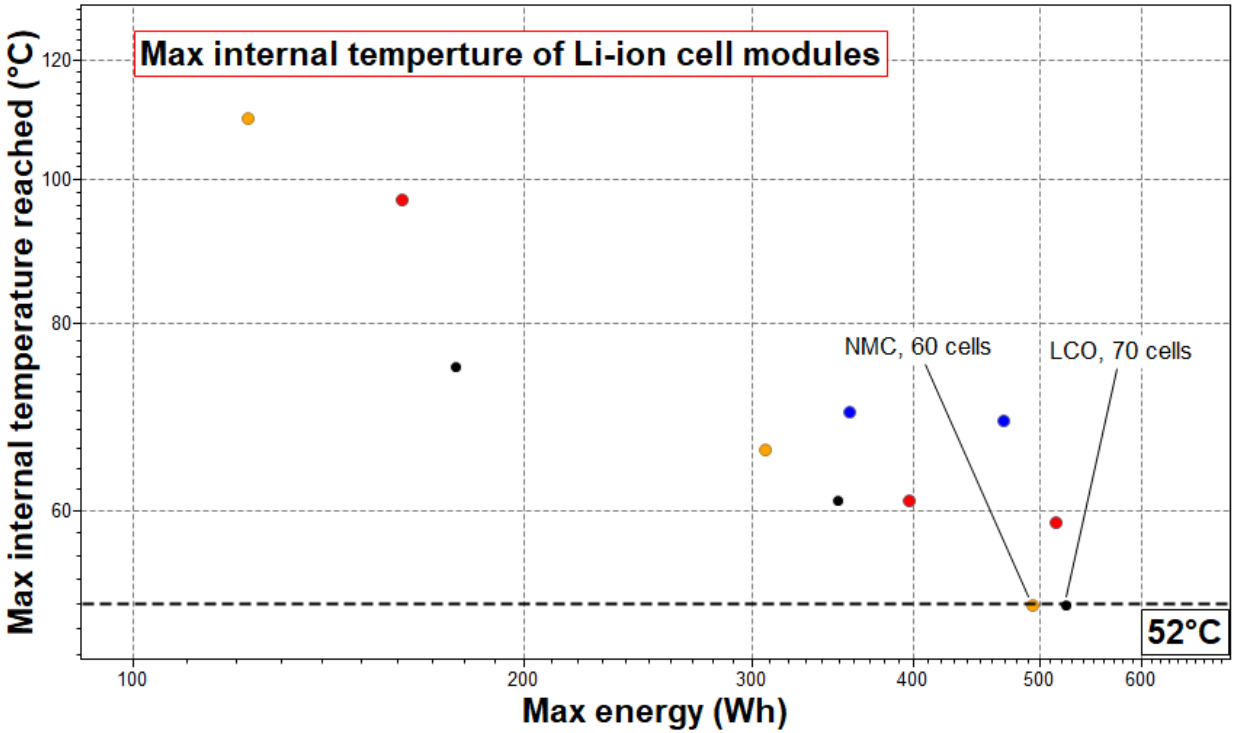
Requirements:

- Li chemistry cells, Geometry: Cylindrical
- 1000 cycles, 3yr life span (every day usage)
- Supplies 36 V, 10 A
- 30-90 minutes use

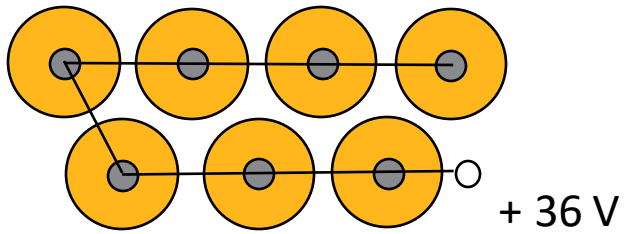




Example – Battery module for e-scooters



7 x 10-stack Li-ion



Summary

- The Battery Designer is an early-stage battery pack design tool for initial comparisons across different module and pack configurations.
- It uses simplified models and selection data from commercially available cell types to estimate key performance metrics, taking choice of cell, configuration, casing and insulation materials, and thermal management system into account.
- A database of products, such as the battery cell one, will evolve with time and results will depend on which systems are available. It is also fundamentally different in selection than selection of materials based on material properties. Ashby charts and a performance index technique can still be used.
- Additional materials considerations could be explored with the Ansys Granta EduPack software:
  - Material selection for lighweight of the structural casing
  - Quick Eco Audit of e-transport systems *vs* conventional power
  - Critical materials/supply chain risks of battery elements and their substitutes

The initial versions of Battery Designer and the Batteries data-table were developed as part of the MAT2BAT collaborative R&D project (Innovate UK, Faraday Challenge competition, Project no 133723), and subsequently further developed and integrated by Granta Design Limited, an ANSYS Inc. subsidiary.

Thanks to Dr Billy Wu, Dr Samuel Cooper and Nathasha Gjerløv Fiig of Imperial College London for their contributions to the tool and data table schema.

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