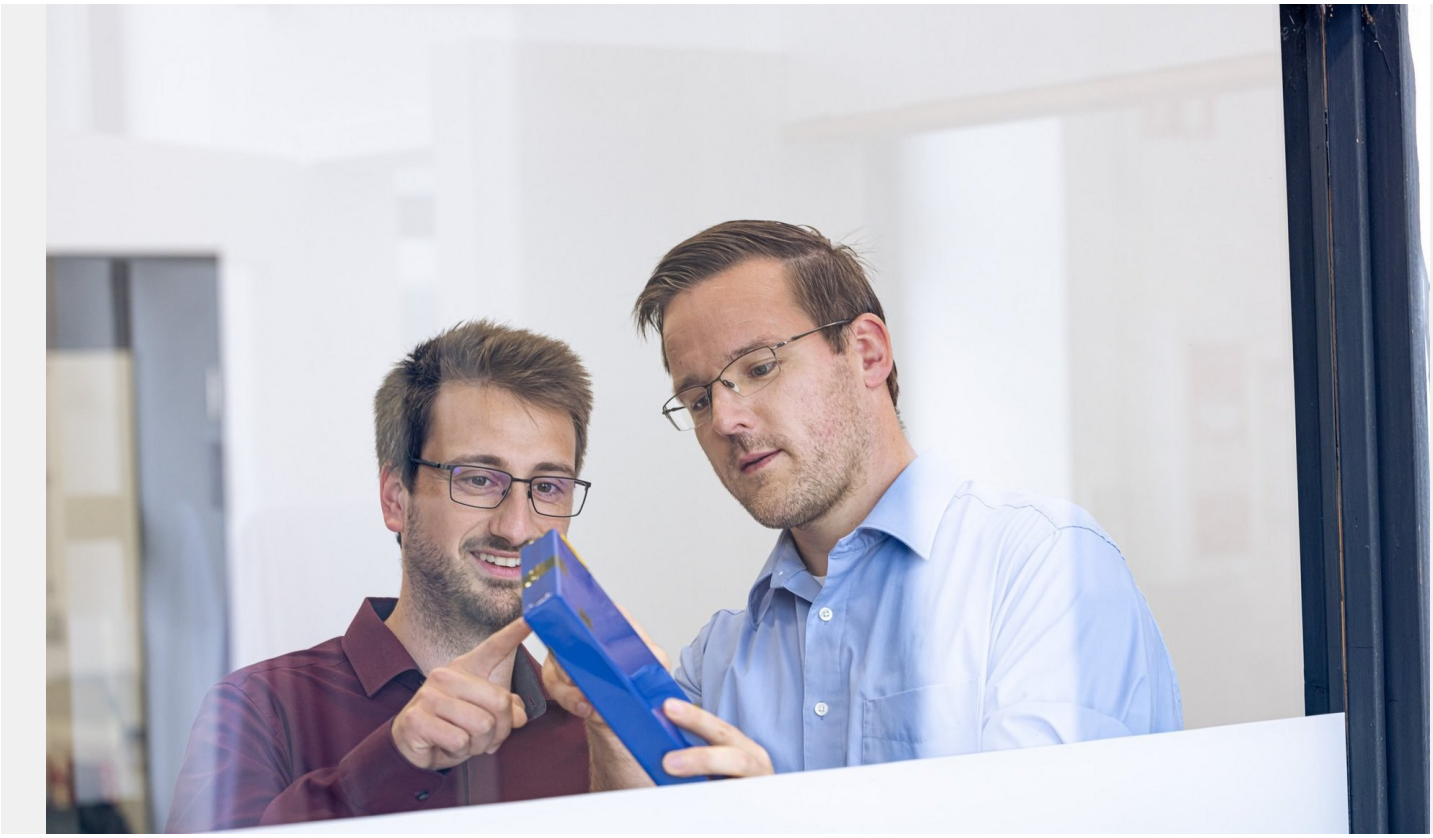
TIL Add-On Battery
Battery Thermal Management & Safety



Modeling and Simulation of Battery Thermal Management & Safety

The TIL Add-On Battery provides a comprehensive model library for the **comparison, evaluation, and optimization of battery system topologies and operating strategies** for battery thermal management systems (BTMS). It enables model-based design, performance analysis and the assessment of safety-relevant phenomena. The add-on incorporates more than ten years of experience from modeling activities and customer projects.

The TIL Add-On Battery supports the design and optimization of battery systems and corresponding BTMS for three key application areas:

- Simulation of temperatures, voltages, state of charge (SOC), and heat dissipation of stacks and systems for integration into cooling and refrigeration circuits
- Design, evaluation, and topology studies for battery thermal-management systems
- Simulation of thermal runaway and thermal propagation for evaluating safety aspects

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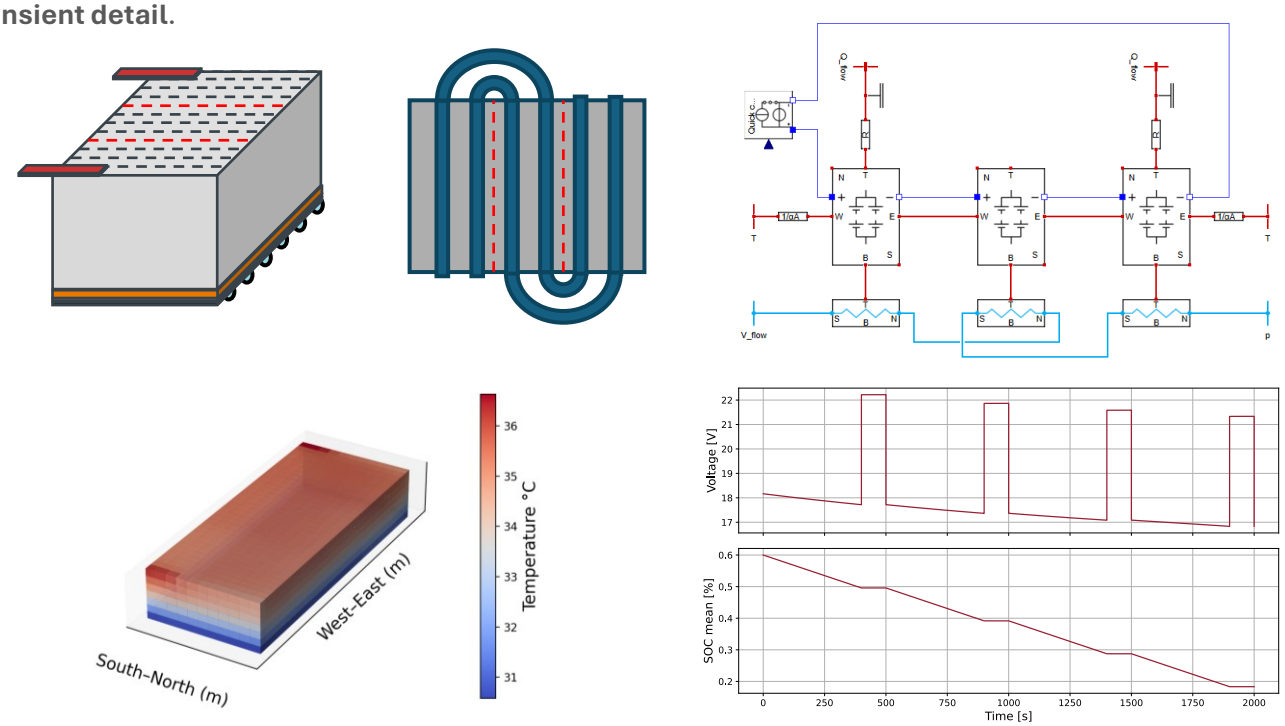
TIL Add-On Battery
Battery Thermal Management

Battery Thermal Management Systems

Easy-to-configure stack models with suitable cooling-plate models calculate the transient behavior of temperatures, voltages, currents and SOCs of stacks and full battery systems. They support different cooling concepts, including gas, liquid and two-phase cooling. With simulation times of under 5 minutes per battery system, various battery and BTMS topologies can be evaluated rapidly in full **three-dimensional transient detail**.

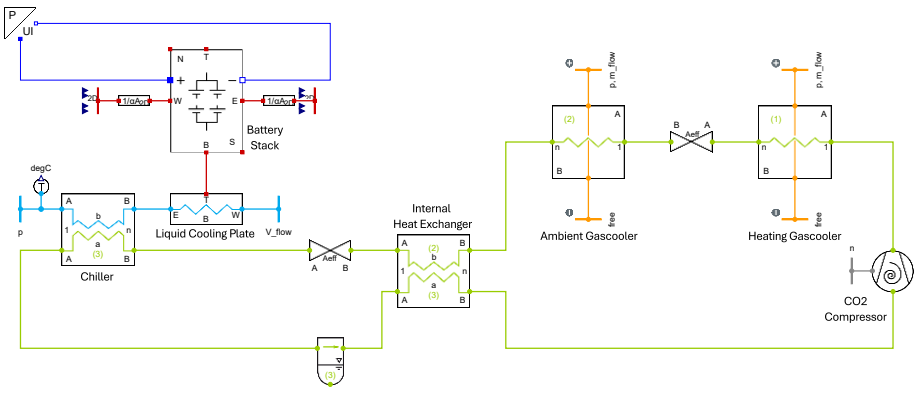


Battery stack with S-type liquid cooling configuration and high voltage connectors (top), including resulting temperatures after charging as well as voltage and SoC during discharging

Integration into Overall Thermal Management Systems

Battery cell, battery stack and cooling plate models can be coupled with TIL Suite and other TIL Add-on models to **integrate battery simulations into** the evaluation and optimization of **thermal systems across application domains**, e.g.

- Automotive air-conditioning or heat pumps
- Hybrid fuel cell battery systems
- Stationary Energy Storage



Battery stack model integrated in an automotive thermal management system

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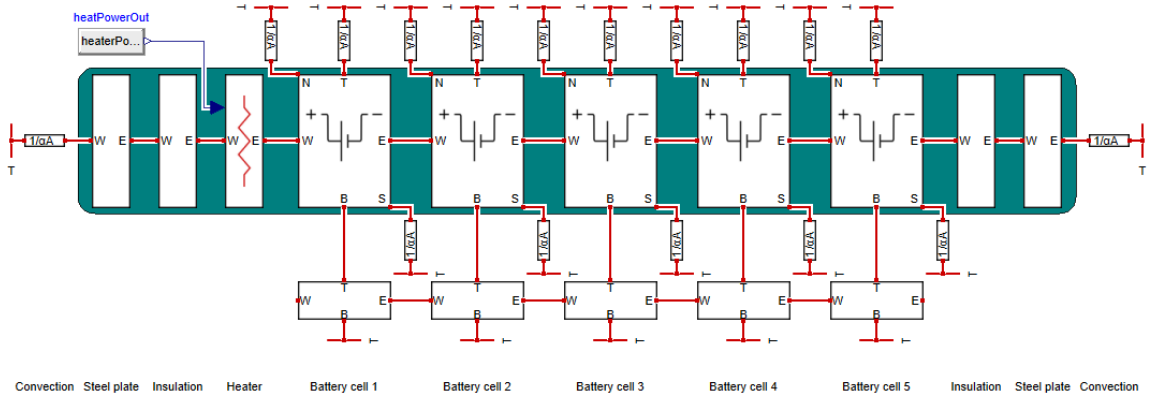
TIL Add-On Battery
Battery Safety

Complex Cell Model

The complex cell model consists of discretized **electro-thermal models combined with reaction models** to represent abuse behavior. Users can either choose from existing reaction models to simulate the thermal runaway of a battery cell or create custom models based on experimental data, such as Differential Scanning Calorimetry (DSC) data.



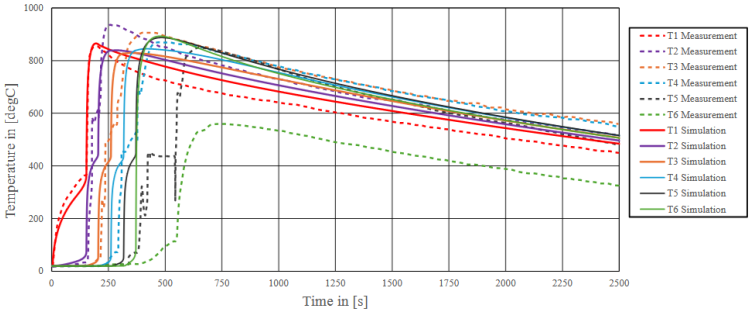
Stack configuration for a thermal propagation experiment, consisting of five complex battery cell models, insulation materials and a heating foil

Thermal Runaway & Propagation

The cell model enables simulation of both **normal and abuse operation of individual cells and cell stacks**, including transitions between these operation modes. The Add-on Battery empowers the user to develop safe battery systems by considering their thermal behavior under demanding conditions, such as fast charging.

Using the (system-)models, the following analyses, among others, can be performed:

- Simulation of thermal propagation in a cell stack
- Analysis of materials and thickness of intermediate layers



Comparison of measurement propagation experiment from Schöberl et. al. and simulation

Your Key Benefits

- ✓ **Easy 3D discretized modeling**
- ✓ **Fast and easy-to-configure stack models**
- ✓ **Complex cell models for detailed analysis of electrical, thermal and safety behavior**
- ✓ **Seamless integration in TIL Suite**

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