

# Modeling and Simulation of Thermal Systems with the TIL Suite and Dymola

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founded  
2015

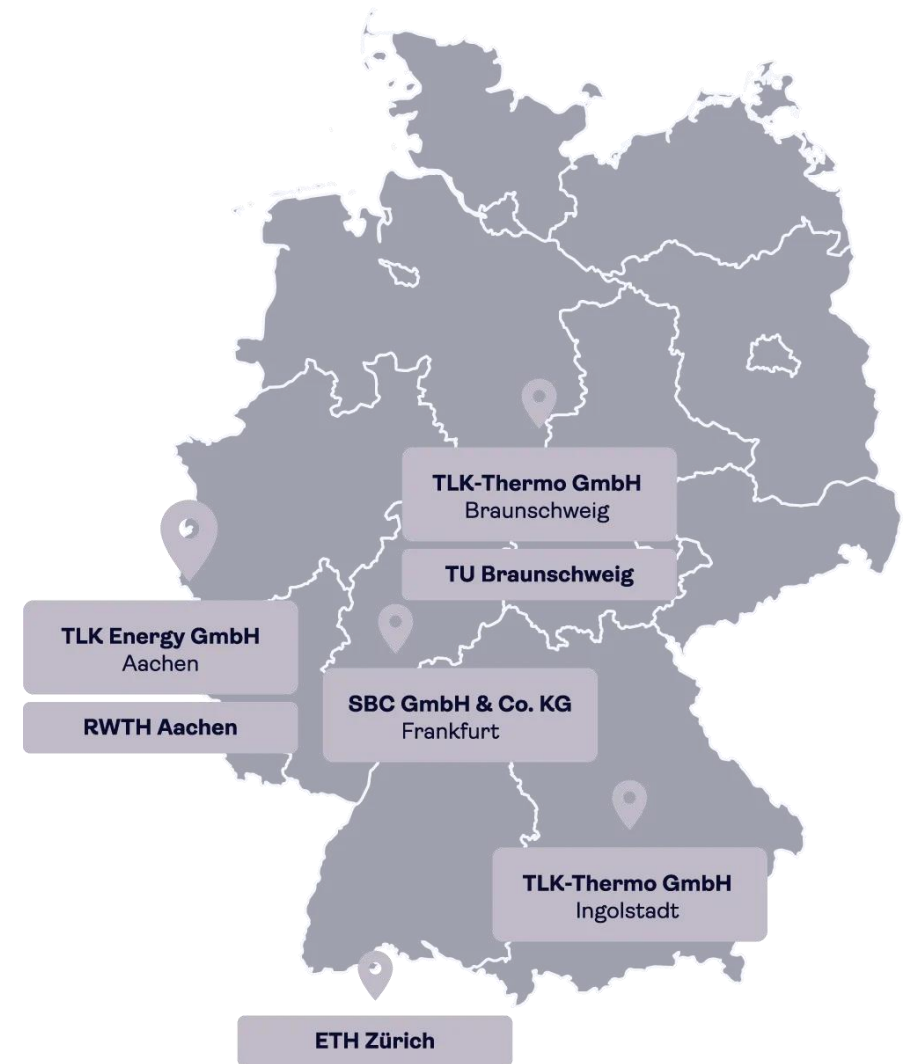
in  
Aachen, Germany

Partner of  
TLK-Thermo

Joint venture with  
SBC GmbH & Co. KG

Employees TLK  
90

## Our Services



*We are a consulting and service company for thermodynamics, process engineering and dynamic modeling.*

# AGENDA

**1** Dymola and Modelica

**2** Model Libraries

**3** Example Projects

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## Dymola Software

- Modeling and simulation environment by Dassault Systèmes
- Based on the **Modelica** language
- Powerful solvers for large, complex systems
- Create models in text form (coding) or by graphical interface (drag-and-drop)



## Modelica Language

- Free and open modeling language
  - Maintained by non-profit organisation Modelica Association
- Object-oriented & Equation-based
- Suitable for mathematical description of multi-physical systems
  - Electrical, thermal, mechanical, hydraulic, ...



Modeling Language:



Software:



Libraries:

- ModelicaStandardLibrary
- VehicleInterfaces
- Modelica-Compliance
- Modelica\_LinearSystems2
- Buildings
- BuildingSystems
- BuildingControlLib
- ExternalMedia
- IDEAS
- Modelica\_DeviceDrivers
- Modelica\_Requirements
- Modelica\_StateGraph2
- ModelicaTutorials
- Modelica-GNU\_ScientificLibrary,
- modelica-ibpsa
- ElectricalEnergyStorage
- HeatTransferComponents
- HelmholtzMedia
- OpenIPSL
- OpenModelica\_Microgrid
- OpenHydraulics
- EMOTH
- PNlib
- ...

- TIL
- TILMedia
- Process Systems Library
- Aircraft Dynamics Library
- Vehicle Dynamics Library
- Engine Dynamics Library
- ClaRa+ Library
- Electrification Library
- Battery Library
- Smart Electric Drives Library
- HumanComfort Library
- HVAC Library
- Air Conditioning Library
- Thermal Power Library
- Fuel Cell Library
- Fuel Systems Library
- Environmental Control Library
- Hydro Power Library
- Hydrogen Library
- EDrives Library
- Power Train Library
- Flexible Bodies Library
- Fluid Power
- ...

<https://modelica.org/libraries/>

# MODELICA FEATURES

- **Equation based modeling**

→ Allows natural and flexible description of physical systems

- **Graphical representation**

→ Provides a easier unders

- **Exchangeability and Extensibility**

Various interfaces for C, Pyt

Supports [FMI standard](#)

→ Models can be easily exc

(Embed models in your o

## Object orientation

→ Enables hierarchical and structured modeling



The Modelica logo features a stylized grey 'm' with a red dot above the 'i', followed by the word 'Modelica' in a bold, black, sans-serif font.

LIVE-DEMO

Functional  
Mock-up  
Interface



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**1** Dymola and Modelica

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**2.1** Modelica Standard Library

**2.2** TIL - Suite

**2.3** Process System Library

**3** Example Projects



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**2** Model Libraries

**2.1** Modelica Standard Library

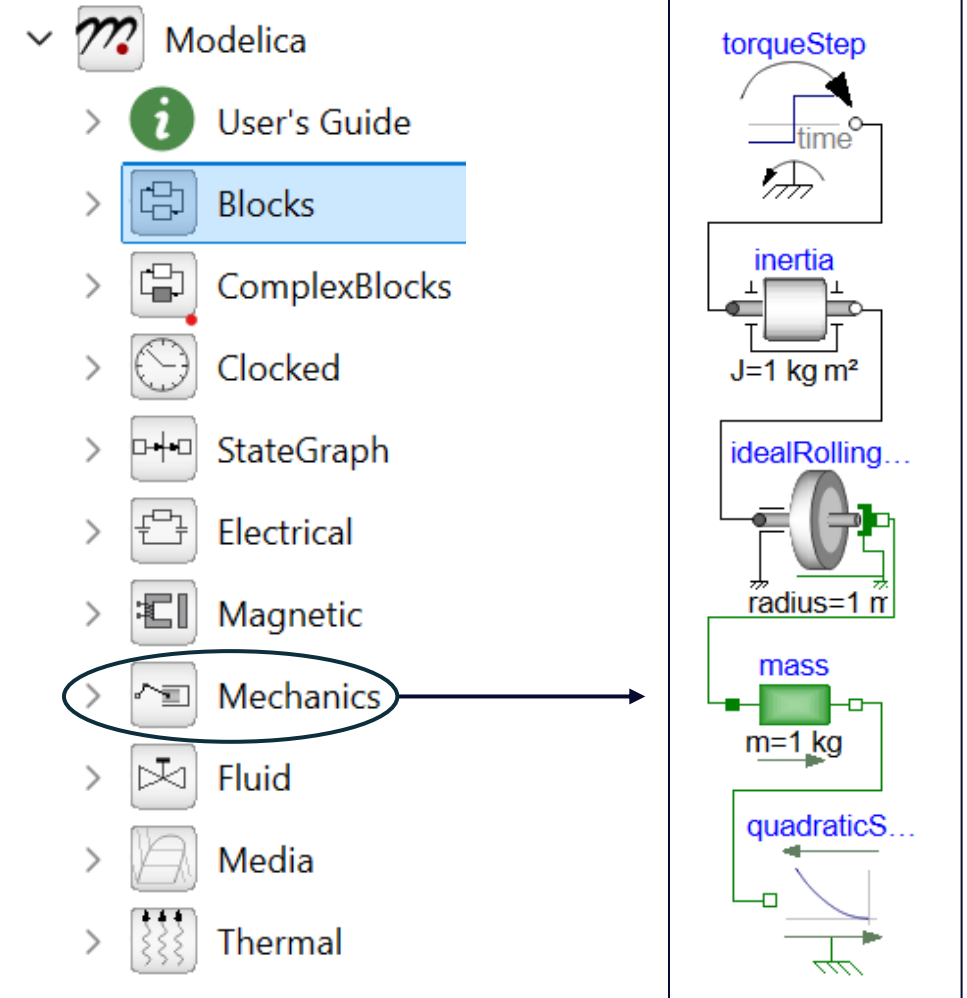
**2.2** TIL - Suite

**2.3** Process System Library

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# MODELICA STANDARD LIBRARY (MSL)

- Free library from the Modelica Association
- Integrated into Dymola by default
- Includes basic models and interfaces for
  - Mechanics
  - Electrics, electronics
  - Thermodynamics, Fluid Mechanics
  - Control systems, discrete modelling, Math



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## TIL SUITE – Software for Thermodynamic Systems

 **TIL** – Thermal components and systems (two-phase flow)

 **TILMedia** - Thermophysical properties (own solvers)

**+** Add-Ons

(Some) Customers



**BOSCH**



**Vaillant**



**VIESMANN**

*Danfoss*



**AIRBUS**

## TIL Standard Components

### Heat Exchangers

Fin and Fin

Fin and Tube

Multi-Port Extruded Tubes

Tube and Tube Plate

Shell and Tube

All Heat Exchangers using finite volume approach (FV). Various Moving Boundary models available.

### VLEFluid Components

Boundary	inl.Bound.	Compressor	Recipr.	Scroll	Ejector	Expander	Pump
Valve	3 W Valve	TXV	TXV-Block	CapillaryTube	Hyd. Resist.	Pr. State	
Separator	Tube	Volume	Junction	Sensor	StatePoint	Fill Station	Adapter

### Gas Components

Boundary	Fan	Hyd. Resist.	Valve
Volume	Tube	Junction	Inductor
Sensor	StatePoint	Adapter	

### Liquid Components

Boundary	inl.Bound.	Pump	Sensor	Inductor
Exp. Tank	Tube	Volume	Junction	Adapter
Valve	3 W. Valve	Hyd. Resist.	Bend	

### Top Level

- System Information Manager
- Various Examples

### Other Components

Heat Bdy.	Heat Cap.	Heat Res.	Sensor	Controller
Mech. Bdy.	Sensor	StepSource	Smo. Step	Watchdog
TimeSwitch	Smo. Switch	Dis. Smooth.		

## TIL ADD-ONS

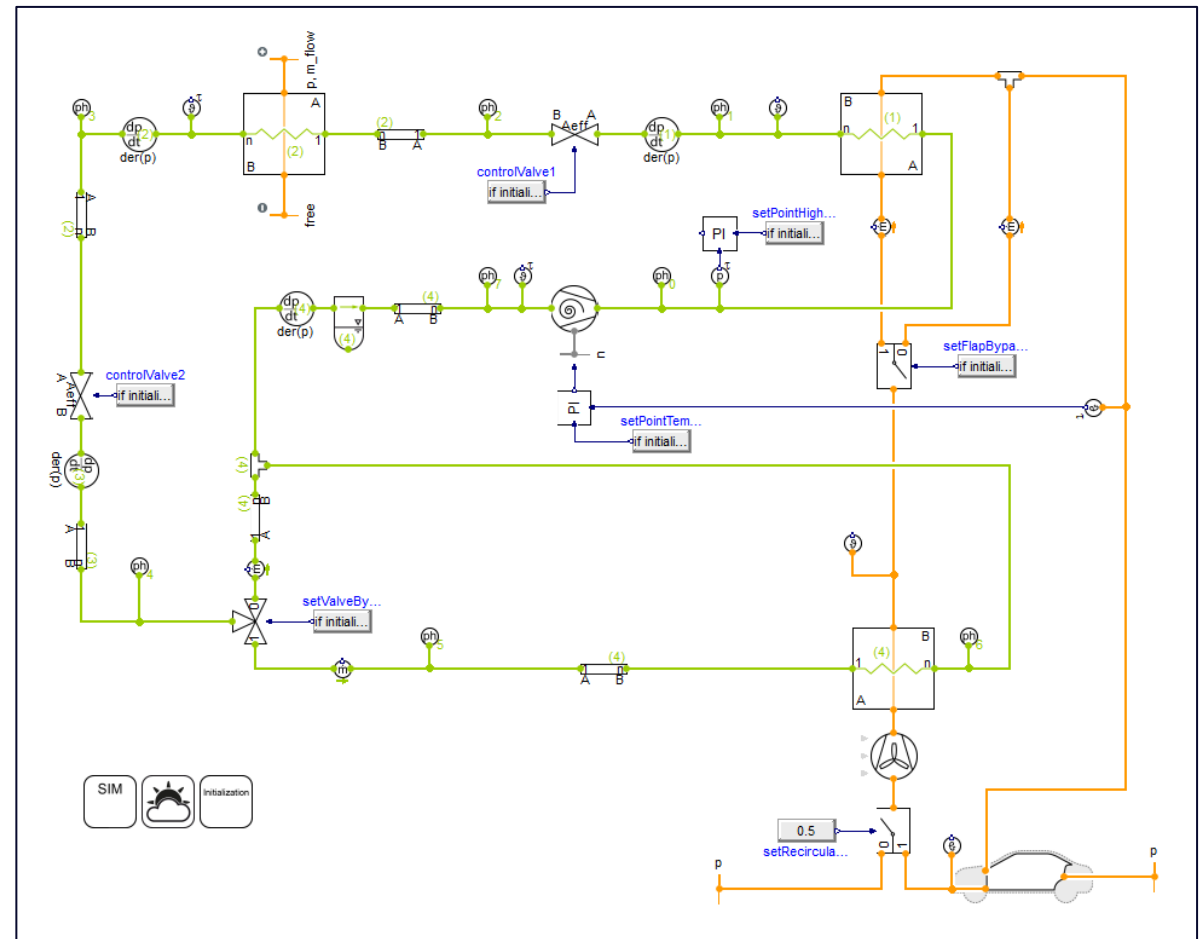
- ✓ Automotive – HVAC and battery thermal management
- ✓ Hydrogen – fuel cells, electrolysis, liquefaction, refueling stations
- ✓ PCM Storages – phase change thermal storages
- ✓ Heat Storage – stratified water tanks
- ✓ Adsorption – gas purification, drying, Direct Air Capture (DAC)

## TIL ADD-ON Automotive

### Use Cases

- Essential for the design of a vehicle ventilation system
- Cooling of battery or motor
- Efficient heating of the cabin

### Example: Automotive Heat Pump and AC-Cycle

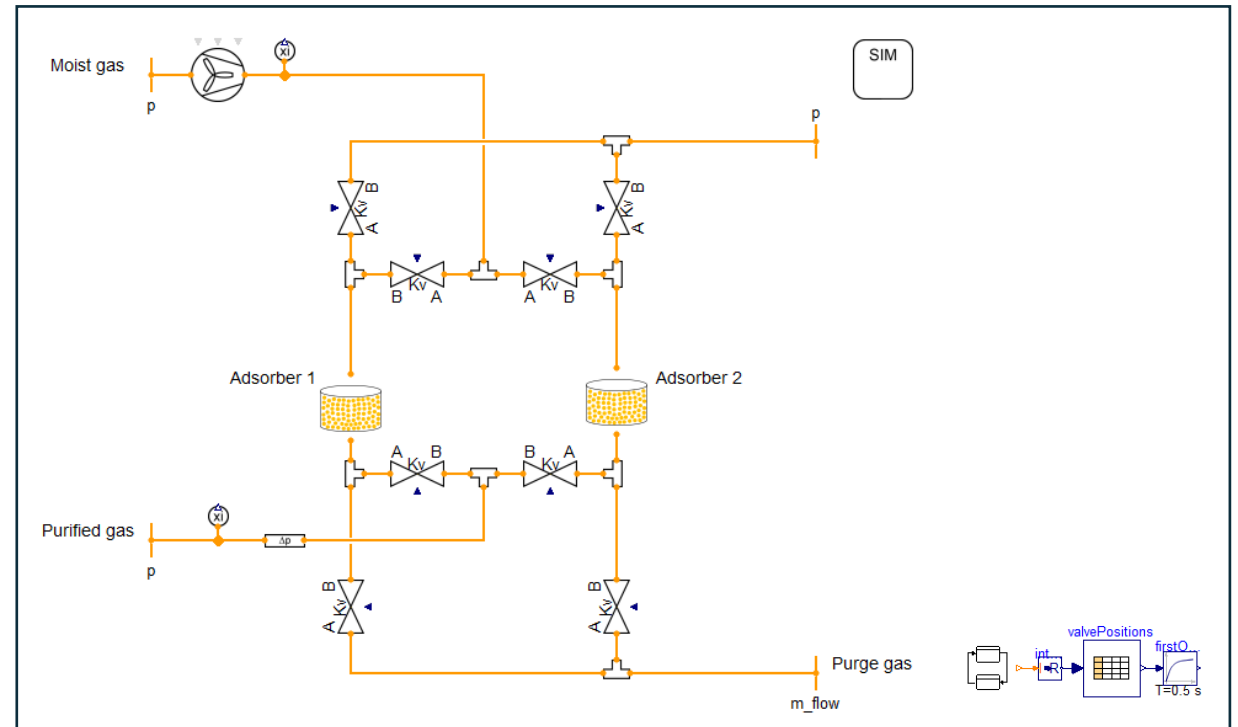
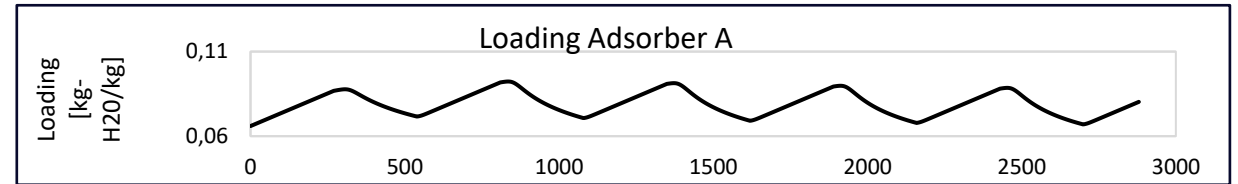


## TIL ADD-ON Adsorption

### Use Cases

- Gas separation
  - CO2 capture
  - Hydrogen purification
  - Moist air drying
- Industrial Drying
  - Paper production
  - Battery coils

### Example: Thermal Swing Adsorption (TSA) System





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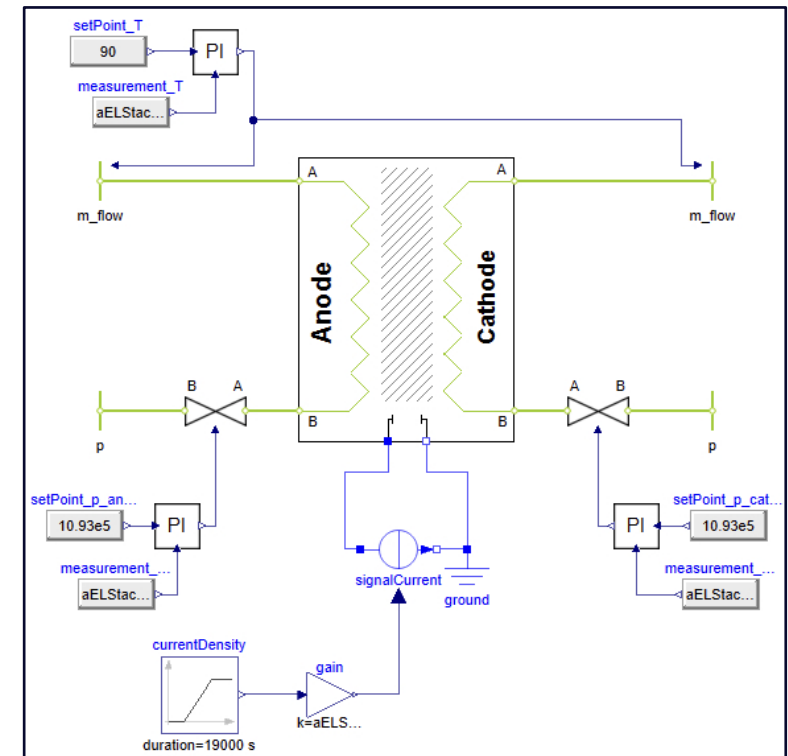
## Process Systems Library (PSL)

- Dynamic simulation for two-phase mixtures
- Both phases have variable compositions
- Enables reactions and thermal separation processes

### Use Cases

- Hydrogen production (PEM and alkaline electrolysis)
- New chemical processes (PtX)
- Carbon capture (amine based)

### Example: Alkaline Electrolysis



# AGENDA

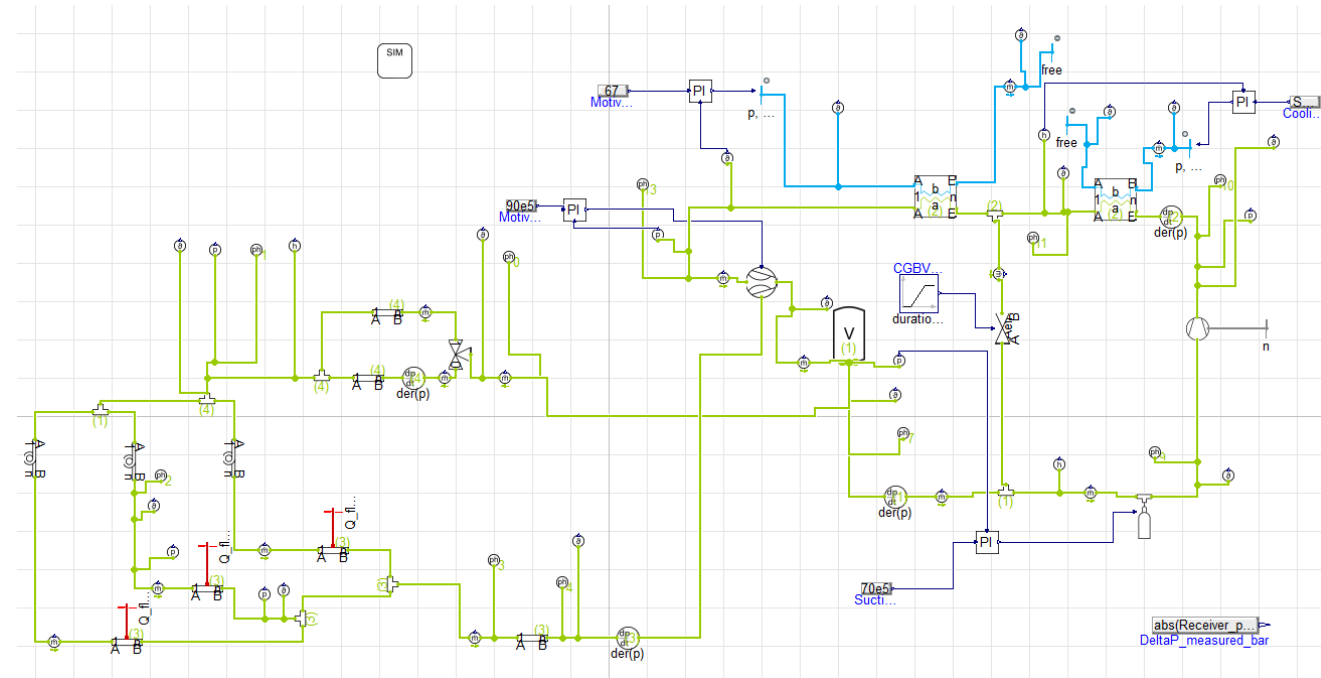
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## Xenon-refrigerant silicon detector cooling

- Adaptation of a  $CO_2$  based refrigeration cycle to Xenon
- Very good agreement of simulation data with lab prototype measurements
- Contiero et al (2023), “A prototype with Xenon to simulate the future advance refrigeration unit for cooling of silicon detector trackers”, 26th International Congress of Refrigeration, DOI: 10.18462/iir.icr.2023.0347



➡ Evaluate qualitative design studies for cooling concept

➡ Compare with lab experiment quantitatively

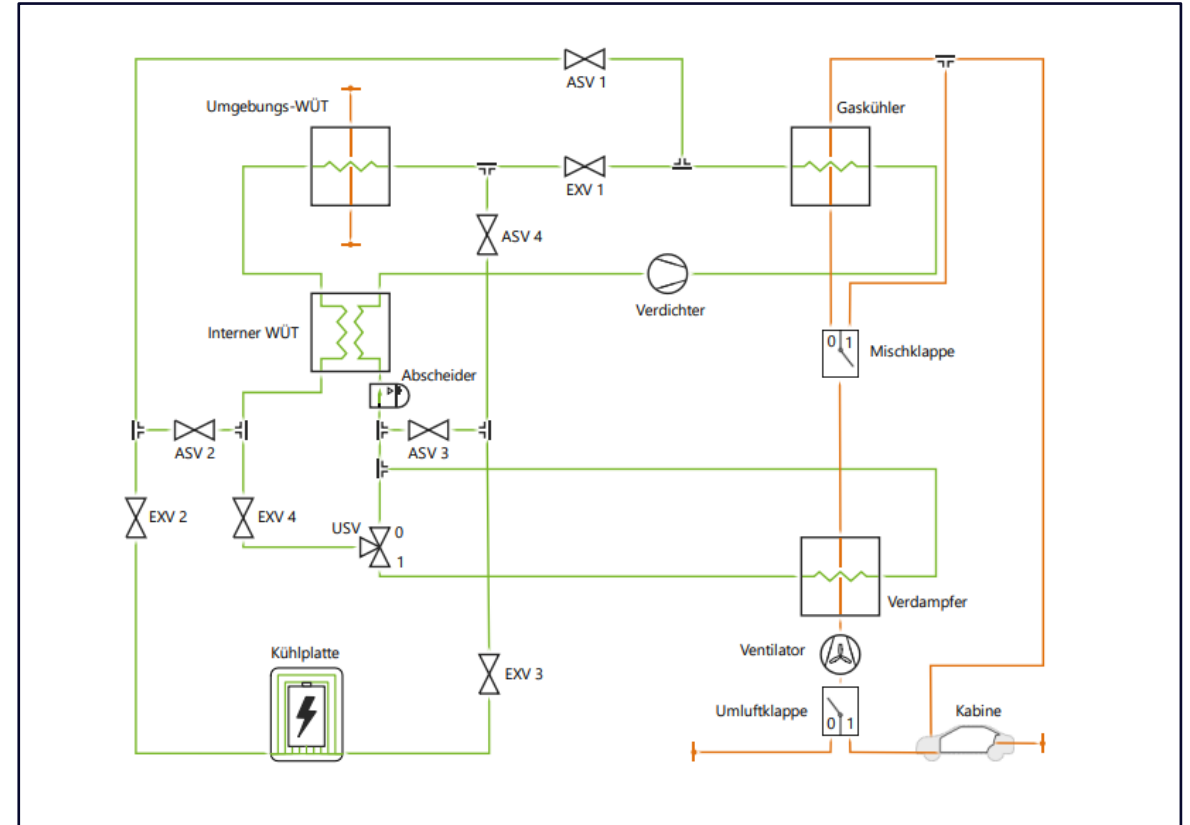


EP-DT  
Detector Technologies



## Reversible CO<sub>2</sub> heat pump

- Direct (refrigerant) temperature control of the battery
- Increased efficiency, weight and cost savings
- Model bases design of:
  - System layout
  - Control concept

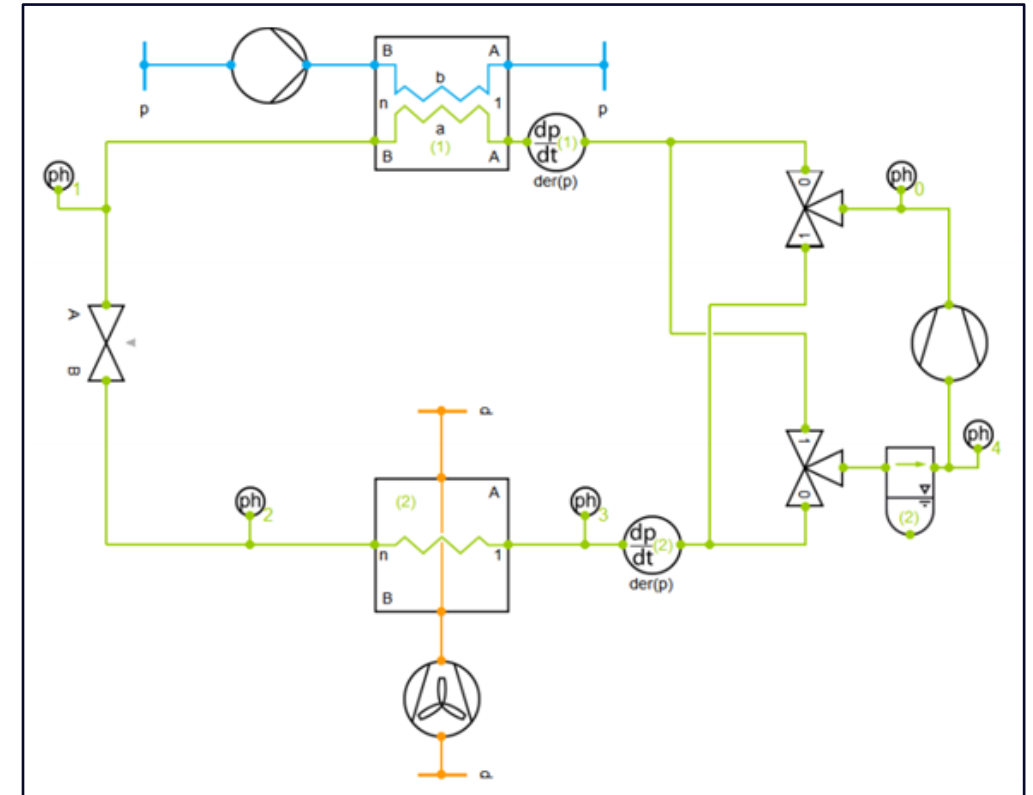


➔ Test different ideas before building real prototypes



## Real Time Models for HiL Tests

- Real controllers tested with virtual heat pumps
- Robust and fast heat pump models developed with TIL
- Exported to dSPACE platform



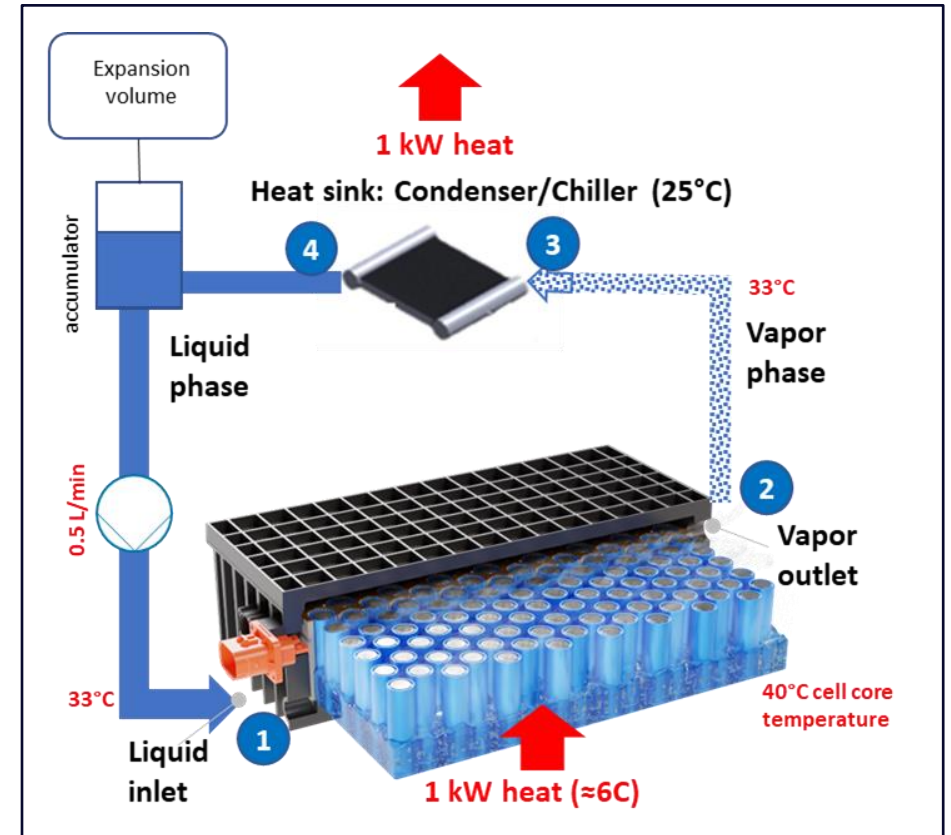
➡ Identify control issues at an early stage

➡ Reduce number of lab experiments



## Two-phase Immersion Cooling of Batteries

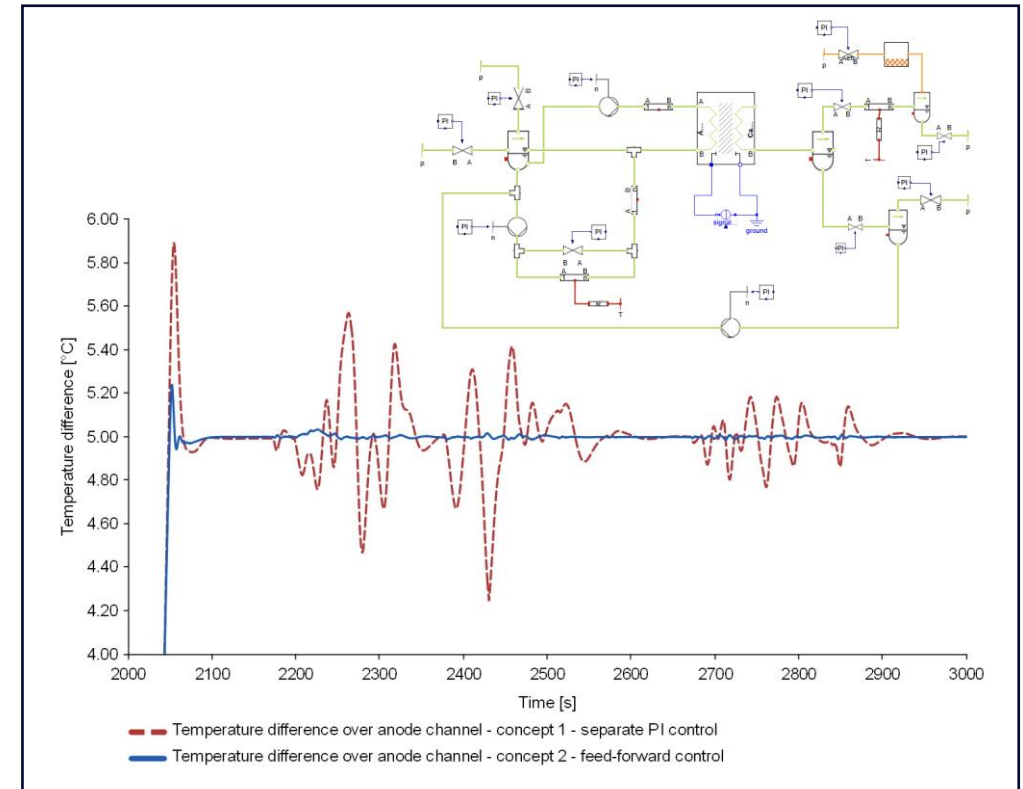
- Model based system design and component sizing
- Analysis of customer benefits including the overall thermal management system



➔ Convincing customers (automotive OEMs)

## Stack Cooling for PEM Electrolyzers

- Waste heat needs to be dissipated
- Constant temperature difference is good for stack lifetime
- Transient load profile (e.g. coupled to wind turbine)
- Model based control design



➔ **Greatly improved control performance**



NEUMAN&ESSER



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# PRODUCT AND TRAININGS

Book **TRAININGS** to become proficient with Dymola and gain a deep understanding of the libraries.

## TRAININGS



**Experienced trainers**



**Optimized concept**



**Standard or customized**



**Online and On-site**

### Modelica/Dymola Training

 Jan 27 - Jan 29, 2025

 9:00 am - 6:00 pm CET

 Online (flextime)



### Customized training


 Your choice


 Your choice

 Your choice

### TIL Suite Training

 Jan 30 – Jan 31, 2025

 9:00 am - 6:00 pm CET

 Online (flextime)



<https://tlk-energy.de/en/modelica-training>

# Contact



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**THANK YOU FOR  
YOUR ATTENTION**

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