

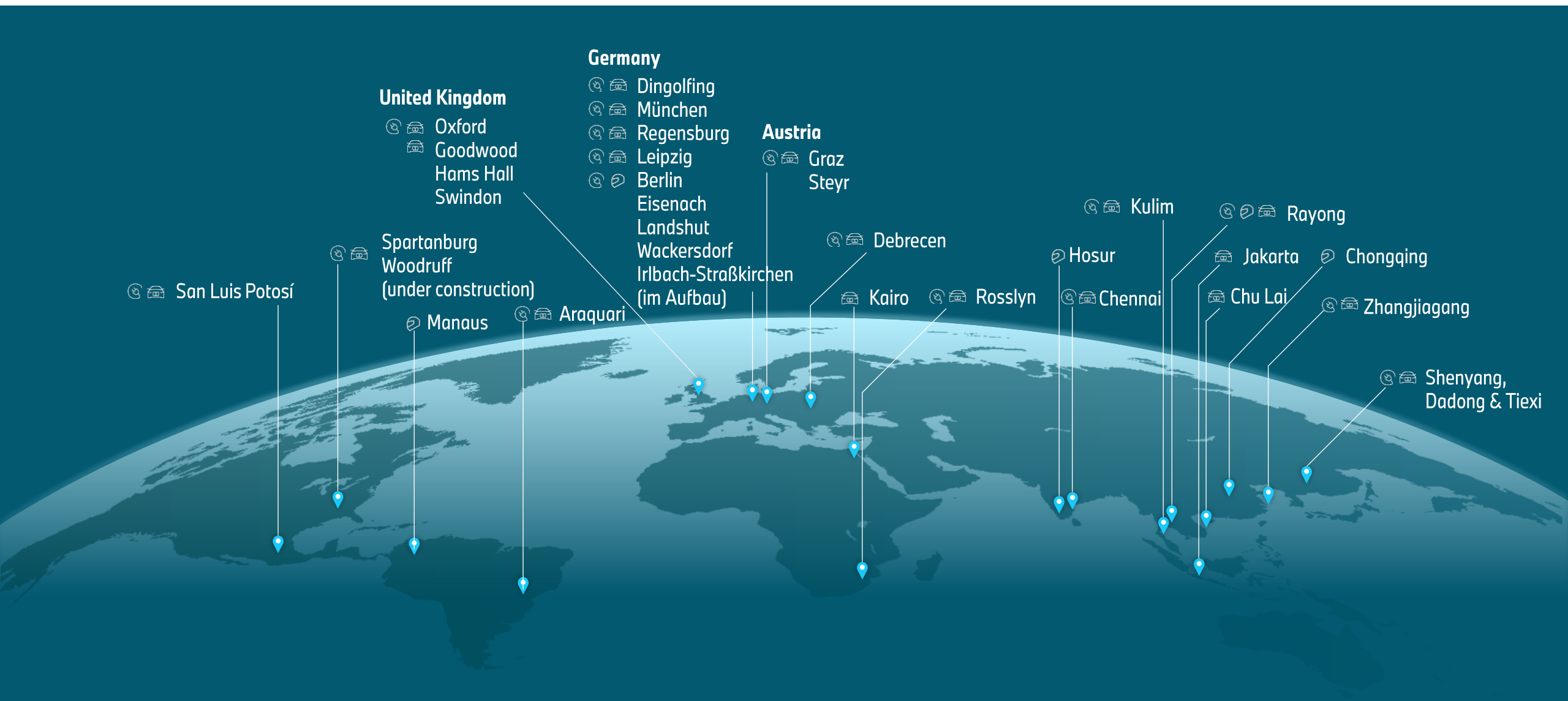


THE ROLE OF KULI ON THE WAY TO NEUE KLASSE

ECS SIMULATION CONFERENCE 2025

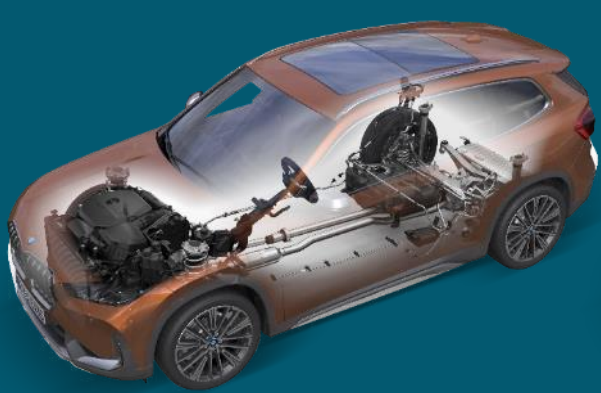
Laaber Philipp

BMW GROUP – MORE THAN 30 PLACES OF PRODUCTION WORLDWIDE



DRIVETRAIN PRODUCTION FOR MOBILITY WITH TECHNOLOGY OPENNESS

Drivetrain portfolio of BMW Group (Serial + Development)



ICE
Combustion engine



PHEV
Plug-In Hybrid



BEV
Pure electric



FCEV
Hydrogen

BEV PORTFOLIO OF BMW GROUP



Battery-
electric vehicles



MINI E



BMW ActiveE



BMW i3



BMW iX1



BMW i7



BMW iX



BMW iX3



BMW i4



BMW i5



Rolls-Royce Spectre



MINI Cooper SE



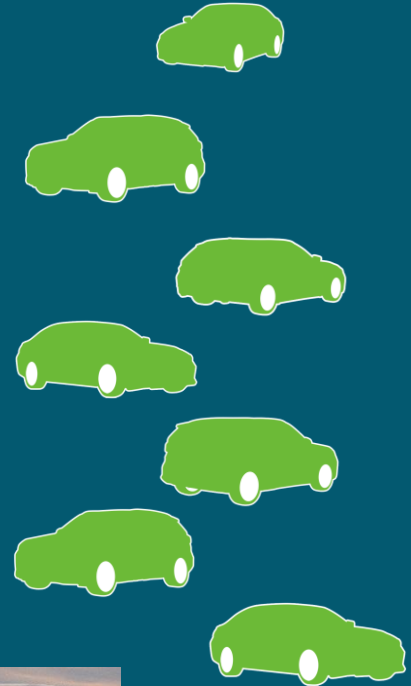
MINI Countryman
SE ALL4



MINI Cooper SE Conv.



BMW iX2



NEUE KLASSE

Pilot fleet

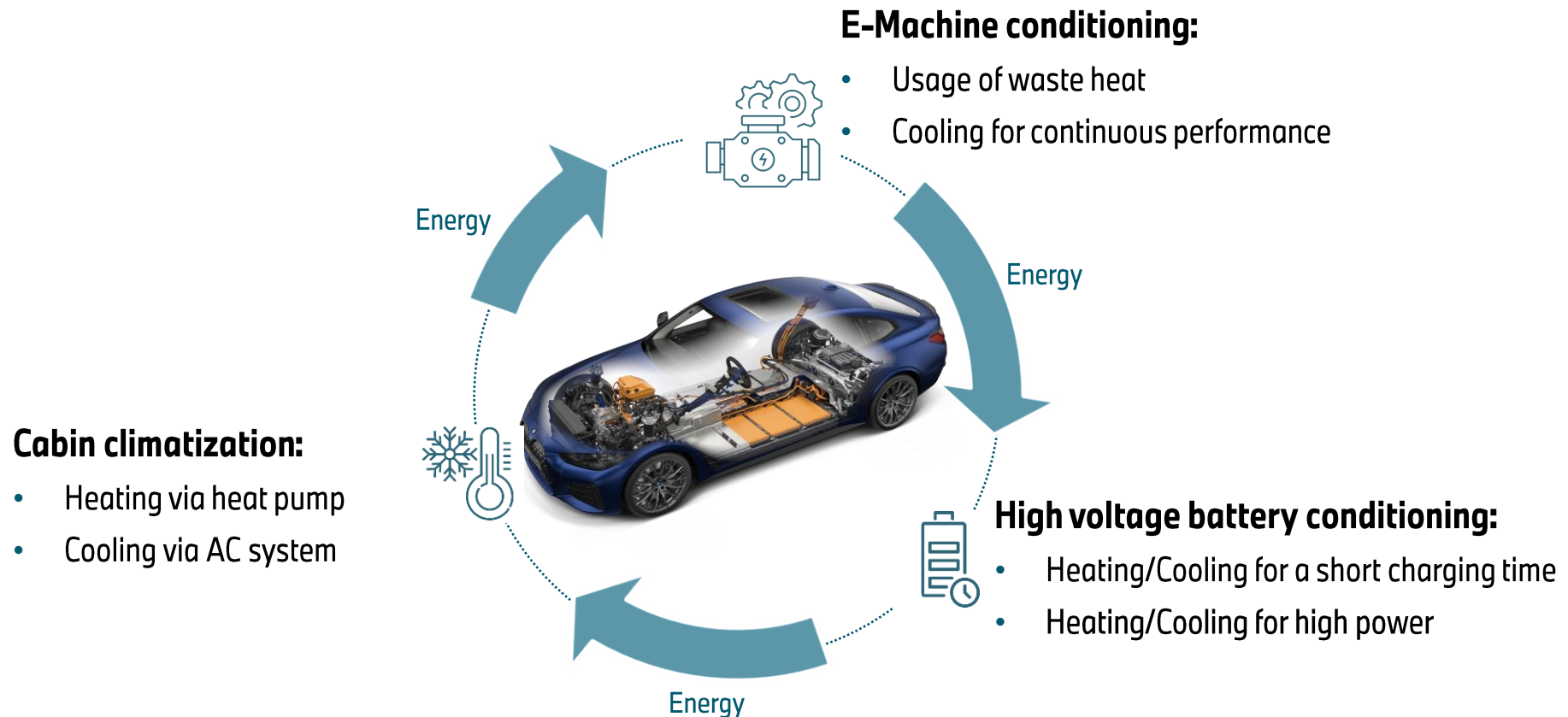
1st model

Rollout

Future

BEV THERMAL MANAGEMENT – WHAT IS IT?

Heat flux within BEV



Heat

=



Energy

=



Electric range

Intelligent BEV Thermal management connects interacting Subsystems with the goal to provide noticeable car properties as efficient as possible.

BEV THERMAL MANAGEMENT – WHAT IS HAPPENING AT OUR CUSTOMERS?

We start with a road trip

Relaxing highway driving



Operating mode
Cooling the e-drive

Dynamic up-hill driving



Operating mode
Cooling the e-drive and the high voltage battery including the AC system

Countryside driving with passing maneuvers



Operating mode
Cooling the e-drive and the high voltage battery

Moderate driving with low ambient temperature



Operating mode
Heating up the cabin



Heat

=



Energy

=



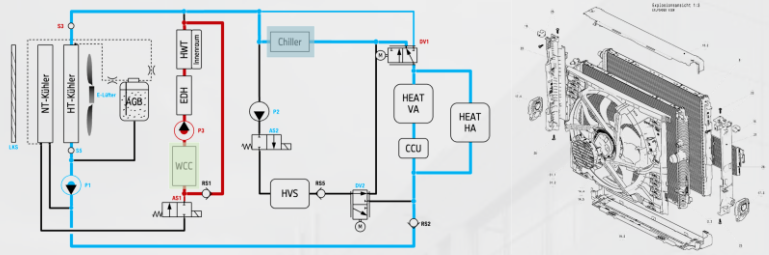
Electric range

Intelligent BEV Thermal Management activates in each Customer- and Driving situation the right operating mode to reach an overall energetic optimum.

BEV THERMAL MANAGEMENT – WHAT IS DONE IN STEYR?

The adding value of our development center in Steyr

Topology - & Component development

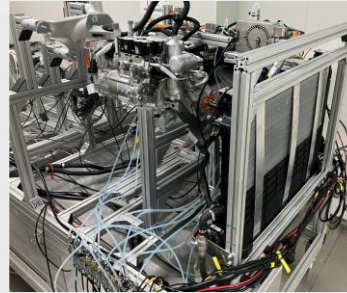


Software engineering

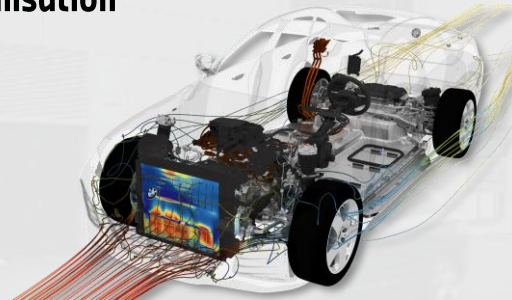
- ❖ Programming
- ❖ Implementation
- ❖ Testing
- ❖ Validation



Component-, System- and Vehicle testing



Virtualisation



Engineering @ Steyr

Control strategy



Software



Hardware



Heat

=



Energy

=



Electric range

THE ROLE OF SIMULATION IN THERMAL MANAGEMENT

ICE Thermal Management = Cooling of components to prevent overheating



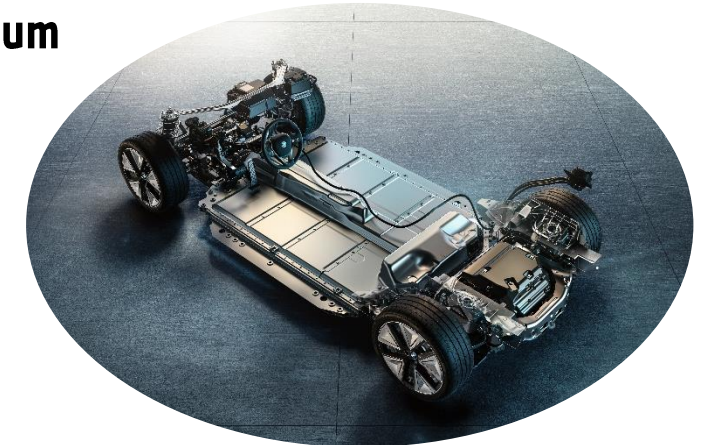
- To prevent overheating, simulations on component level can be done
- Minor presence of simulation in early phase
- Weak coupling to subsystems like AC sufficient
- **Simulations are driven by component development**



BEV Thermal management = Intelligent distribution of heat to reach an energetic optimum

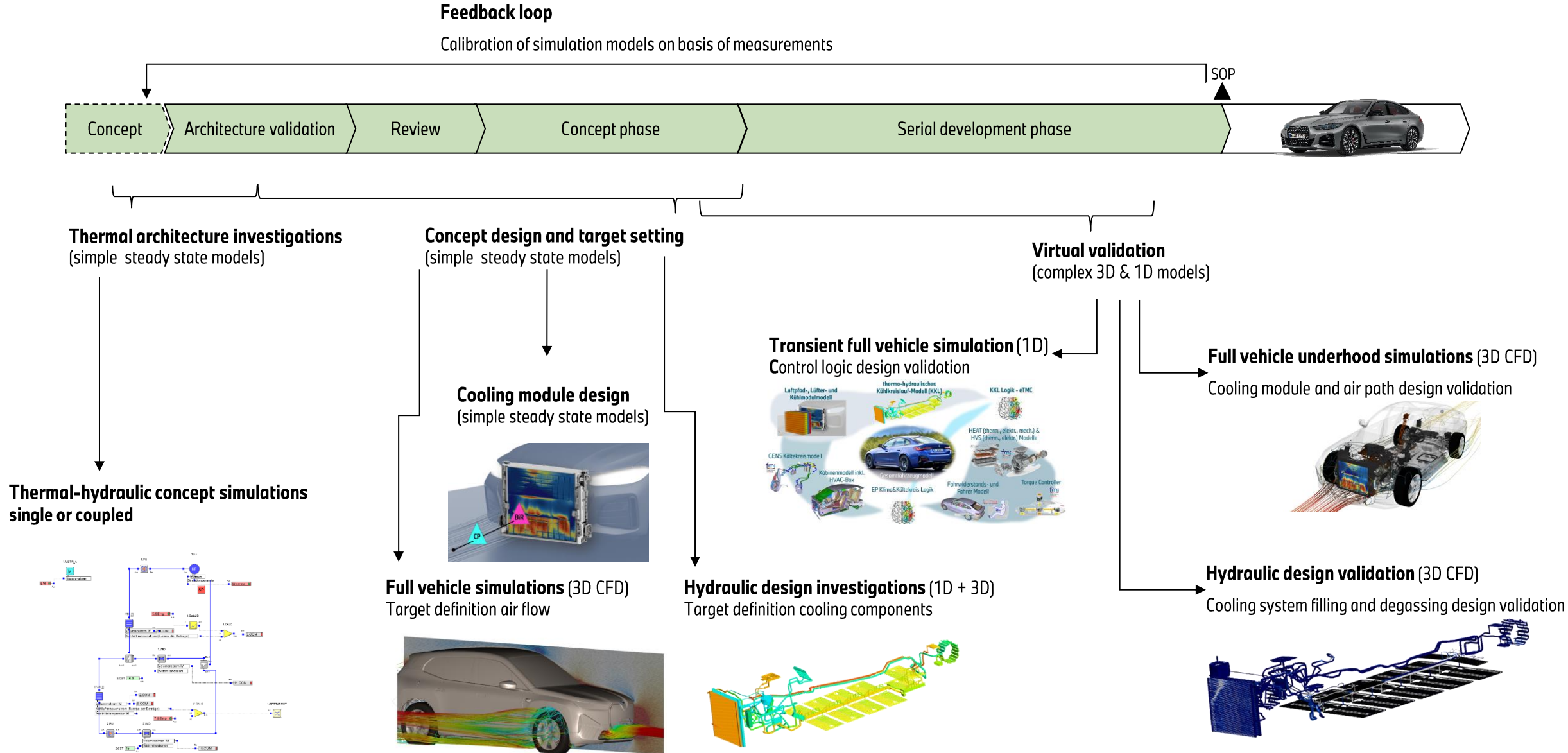


- To reach an energetic optimum, virtual iterations on system level are needed
- Simulation as the key player in the early phase development
- Strong coupling to subsystems like AC necessary
- **Simulations are driven by system engineering**

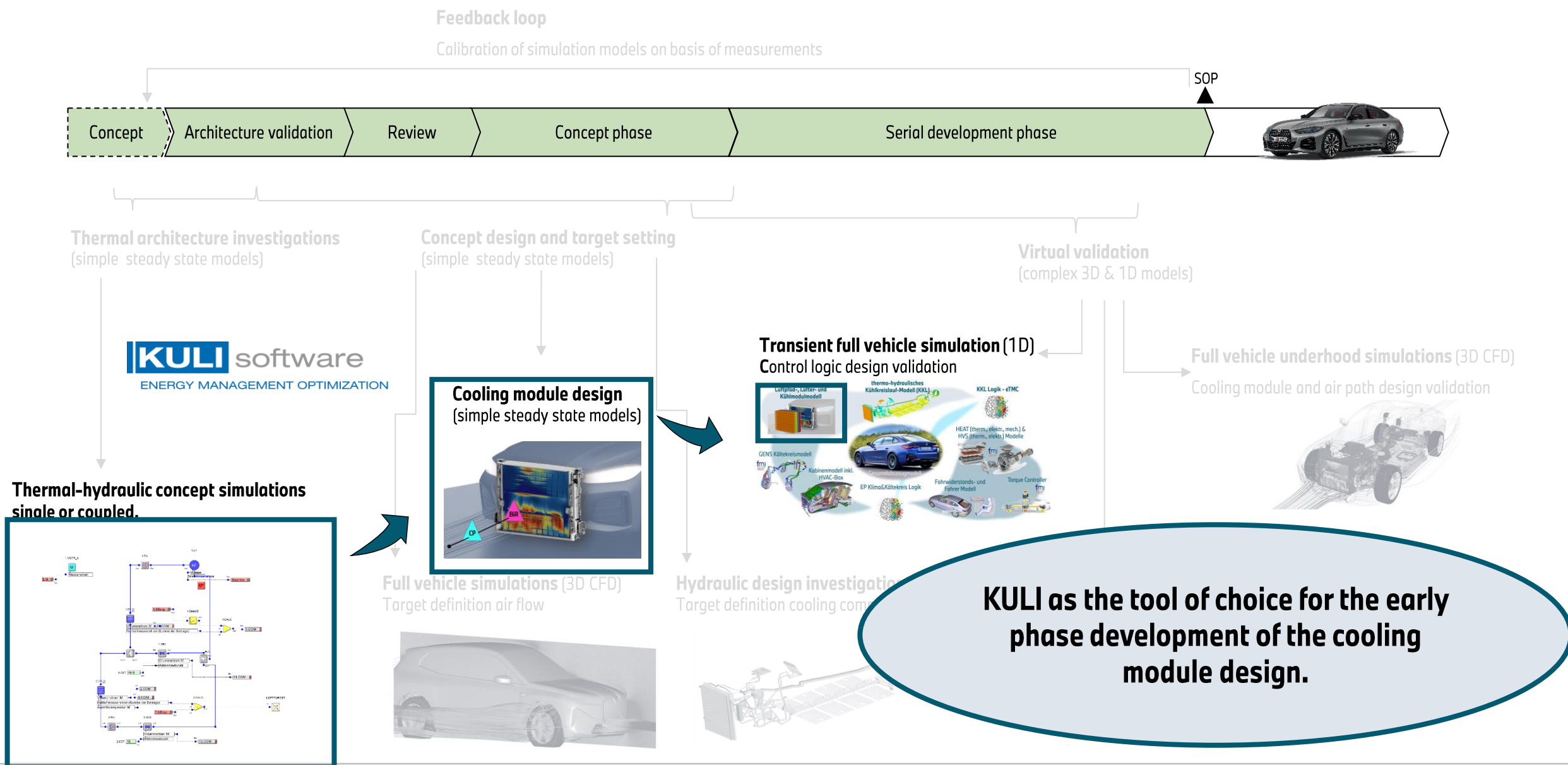


Thermal simulation within BEV Thermal Management development gets a much higher priority than in the past.

WHERE THERMAL SIMULATION COMES INTO THE GAME?



WHERE THERMAL SIMULATION COMES INTO THE GAME?

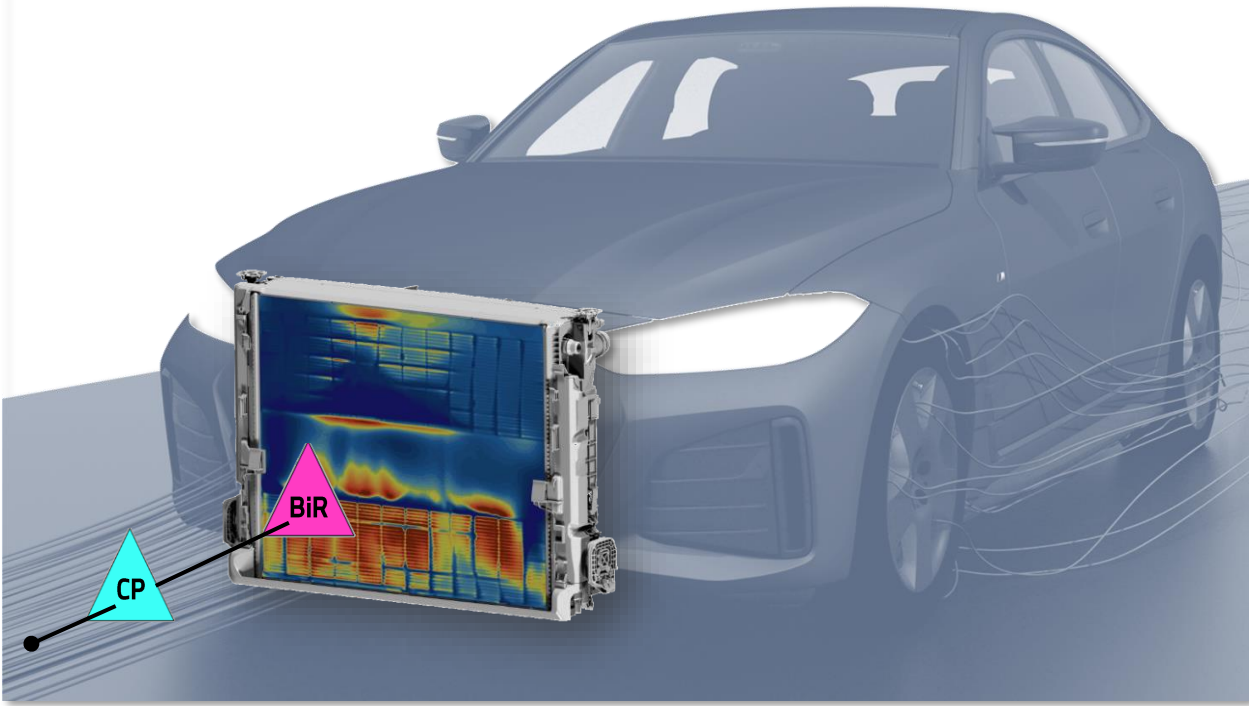


WHY KULI IN EARLY PHASE DEVELOPMENT?

Early phase development requires fast and reliable results for a multitude of different designs and architectures.

We use KULI because of....

- Variety of car configurations for the same cooling module
- Cooling module investigations in a standardized manner
- Evaluations in automated form in a short cycle time
- Simple air path modelling and calibration to CFD results
- Easy coupling to subsystems via Python controller



KULI software
ENERGY MANAGEMENT OPTIMIZATION

Bearbeiter: Laa
Abteilung: EA-441
Datum: 01.01.2025
Kommentar: Auslegung NCAR

Include Sheets

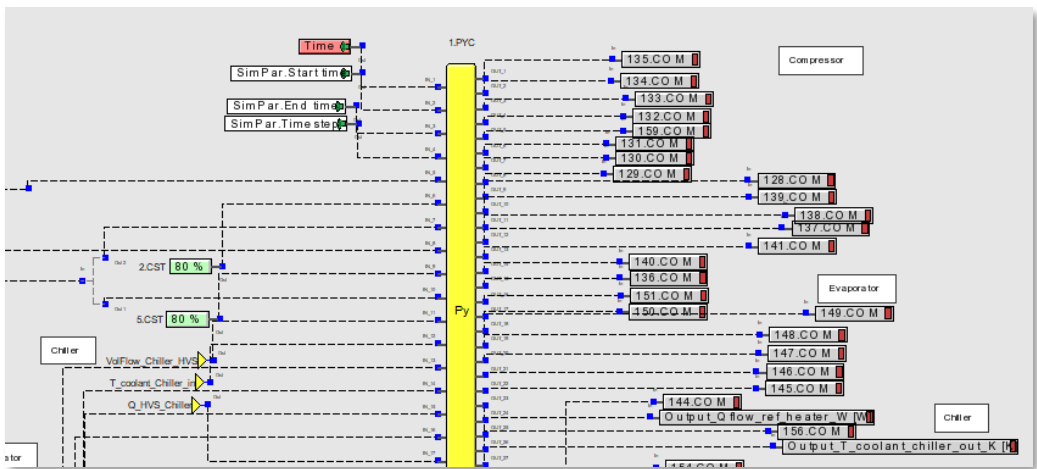
Select Components

Statistics

Open KULI

Calculation Finished!

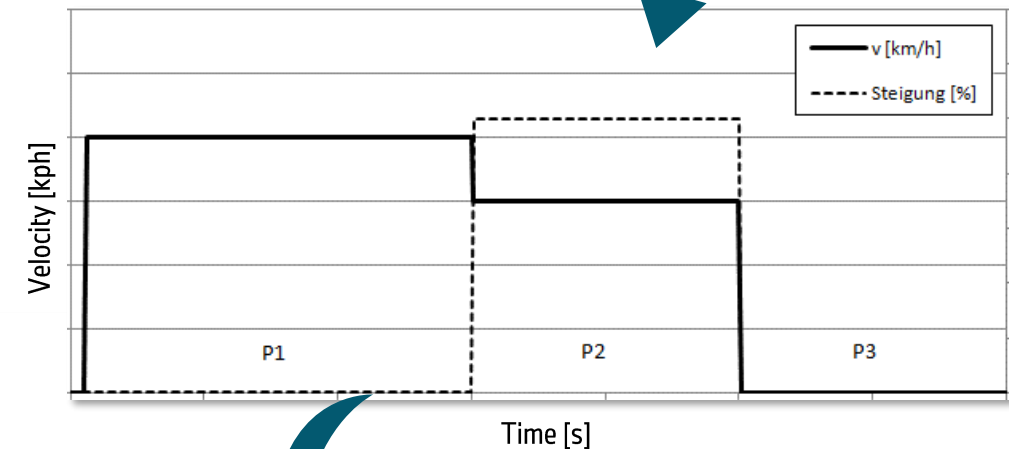
ID	ADB Bezeichnung	Fahrzeug	Cluster	Motor	Einsatz	Race Track	SULEV	Hybrid	SCS-File	Error
1	Lieferant 1 v1	NB5	NCAR	XB	ECE	-	-	Nein	AirpathL1_SE1_CFD.scs	OK
2	Lieferant 1 v2	NB5	NCAR	XB	ECE	-	-	Nein	AirpathL1_SE1_CFD.scs	!!
3	Lieferant 1 v5 PowC	NB5	NCAR	XB	ECE	-	-	Nein	AirpathL1_SE1_CFD_FanPowC.scs	OK
4	Lieferant 2 v1	NB5	NCAR	XB	ECE	-	-	Nein	AirpathL2_SE1_CFD.scs	OK
5	Lieferant 2 v1 HL	NB5	NCAR	XB	HL	-	-	Nein	AirpathL2_SE1_CFD.scs	OK
6	Lieferant 2 v1 Fan2 HL	NB5	NCAR	XB	HL	-	-	Nein	AirpathL2_SE1_CFD.scs	!!
7	Lieferant 1 v1 Fan2 ECE	NB5	NCAR	XB	ECE	-	-	Nein	AirpathL1_SE1_CFD.scs	OK
8	Lieferant 1 v1 Fan2 HL	NB5	NCAR	XB	HL	-	-	Nein	AirpathL1_SE1_CFD.scs	OK
9	Lieferant 3 v1 Fan2 ECE	NB5	NCAR	XB	ECE	-	-	Nein	AirpathL3_SE1_CFD.scs	OK
10	Lieferant 3 v1 Fan2 HL	NB5	NCAR	XB	HL	-	-	Nein	AirpathL3_SE1_CFD.scs	OK



BEV MODEL FOR THERMAL MANAGEMENT

Thermal simulation workflow for BEVs enhanced during Gen5 development

- Steady state points representing transient cycles
- BEV specific operating points respecting all components
- Extension of ambient temperature range
- Component and system degradation to be considered
- More cases to be considered than for an ICE



Auslegungsdatenblatt Kühlung V3.0

Erstellt von: Philipp Laaber

Erstellt am: 01.01.2025

Abteilung: EA-441

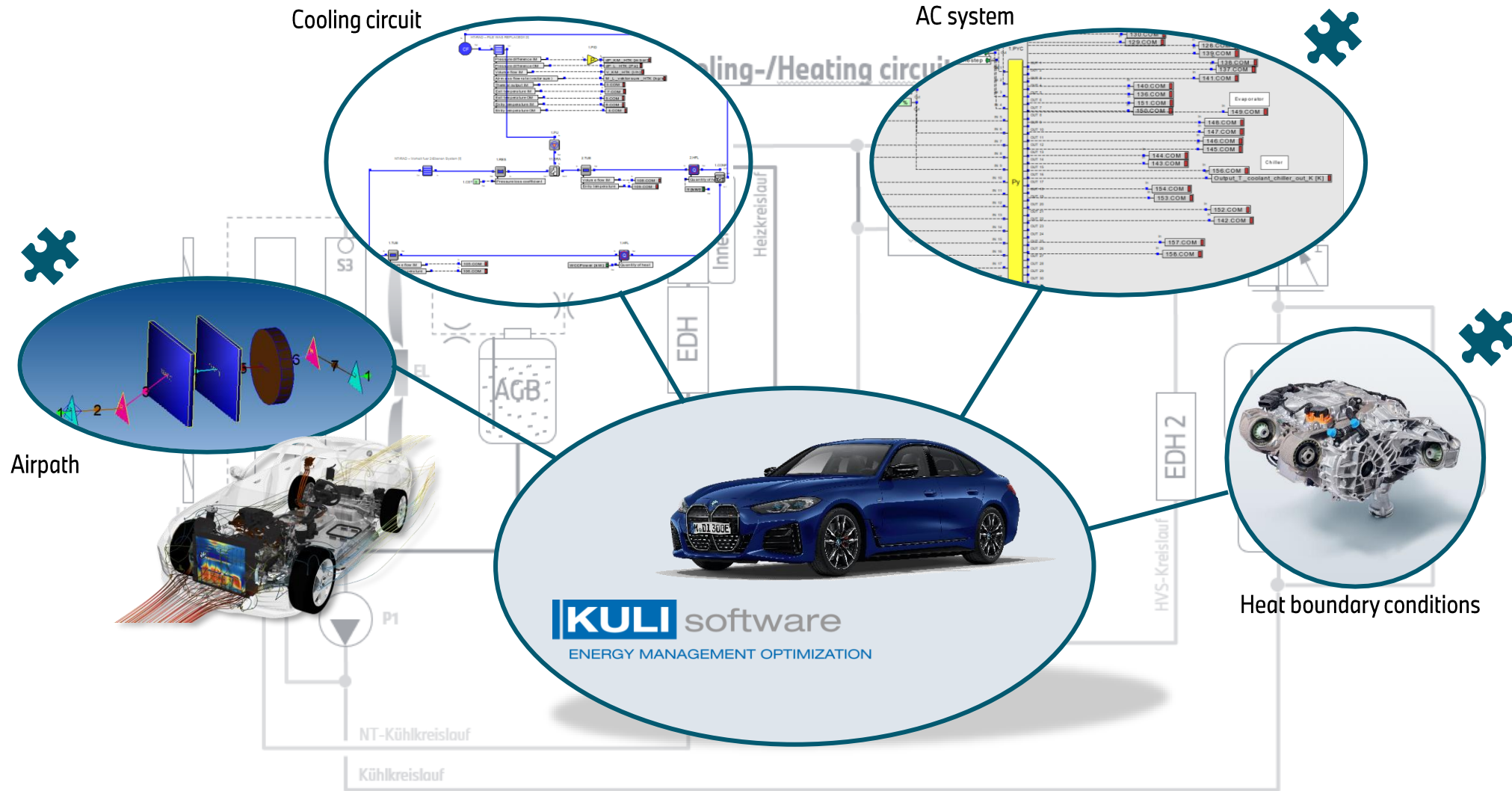
Typ: BEV

Kommentar (optional)

Betriebspunkte	(Stationär)	Einheit	OP 1	OP 2	OP 3	OP 4	OP 5	OP 6	OP 7	OP 8	OP 9	OP 10	OP 11	OP 12	OP 13	OP 14
Umgebungs- randbeding- ung	Fahrzeuggeschwindigkeit	[km/h]														
	Aufwaermtemperatur (HLW)	[K]														
	Motordrehzahl	[U/min]														
	Umgebungstemperatur	[°C]														
	Umgebungsdruck	[bar]														
	Wärmestrom KMHT Kreis	[kW]														
	Wärmestrom KMNT Kreis	[kW]														

In BEV cooling module development the complexity shifts from the module hardware to the boundary conditions!

KULI BEV MODEL

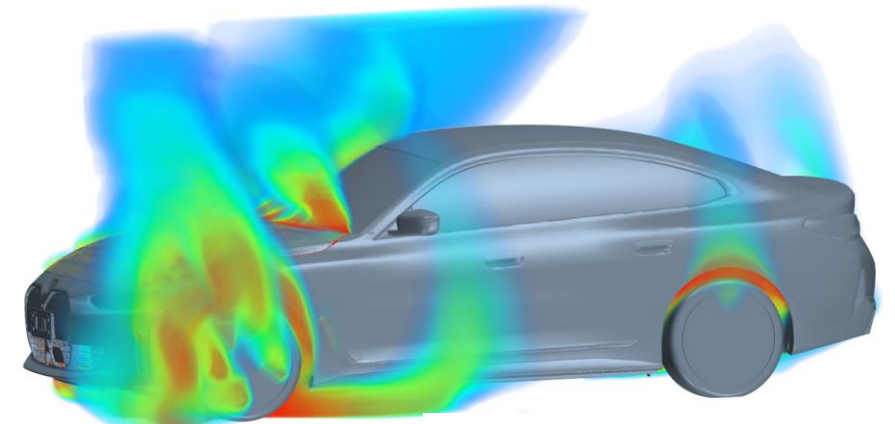


Setup of KULI model can be done easily but getting the correct input data is the challenge!

CHALLENGES IN AIRPATH MODELLING

In order to model the airpath in KULI one need to solve the following challenges with 3D CFD first:

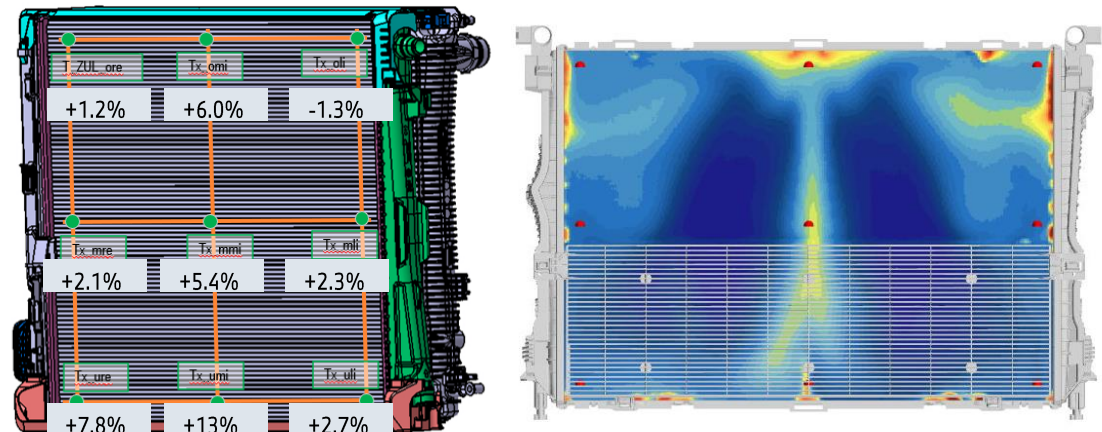
- ❧ Definition of worst case configuration for air path modelling
- ❧ Accurate geometry preparation to adress leakage flows
- ❧ Ambient temperature modelling
- ❧ Deformation of CAD geometry due to wind speed
- ❧ Creation of CFD results for air mass flows with high accuracy



The biggest challenge in modelling the airpath is to fully understand it!

VALIDATION OF SIMULATION MODELS

... and compare with measurements

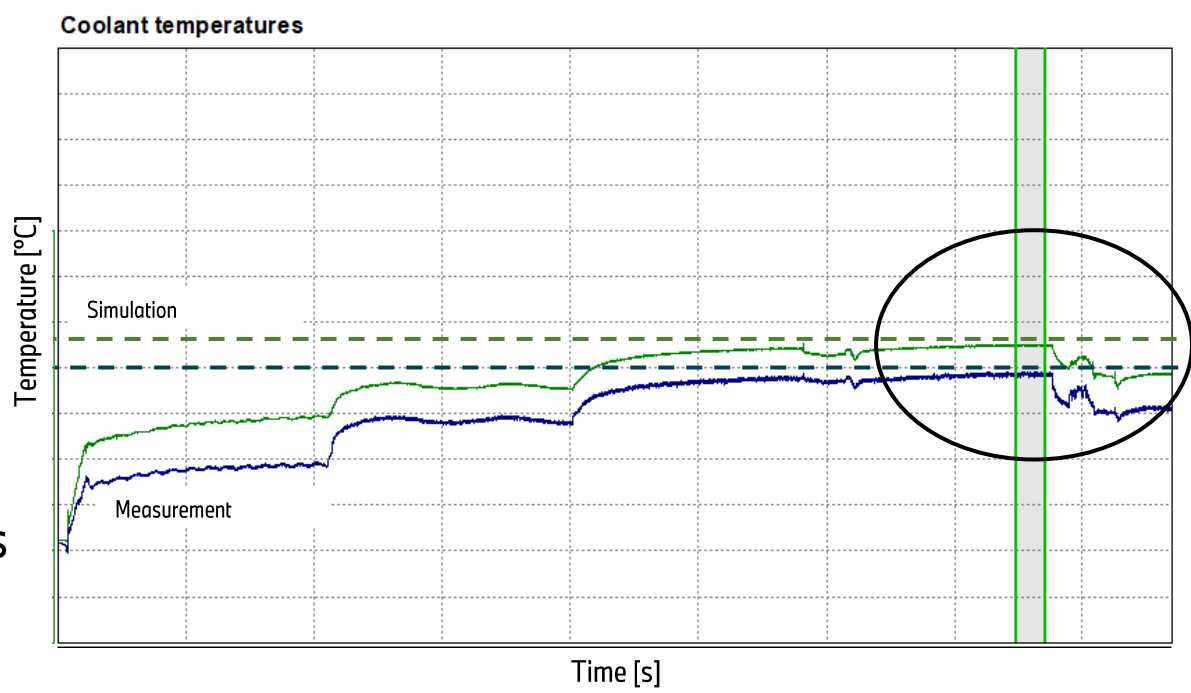


Validation results show that

- Air path can be well captured by CFD
- KULI modelling is appropriate to predict coolant temperatures
- Heat exchanger components are well modeled

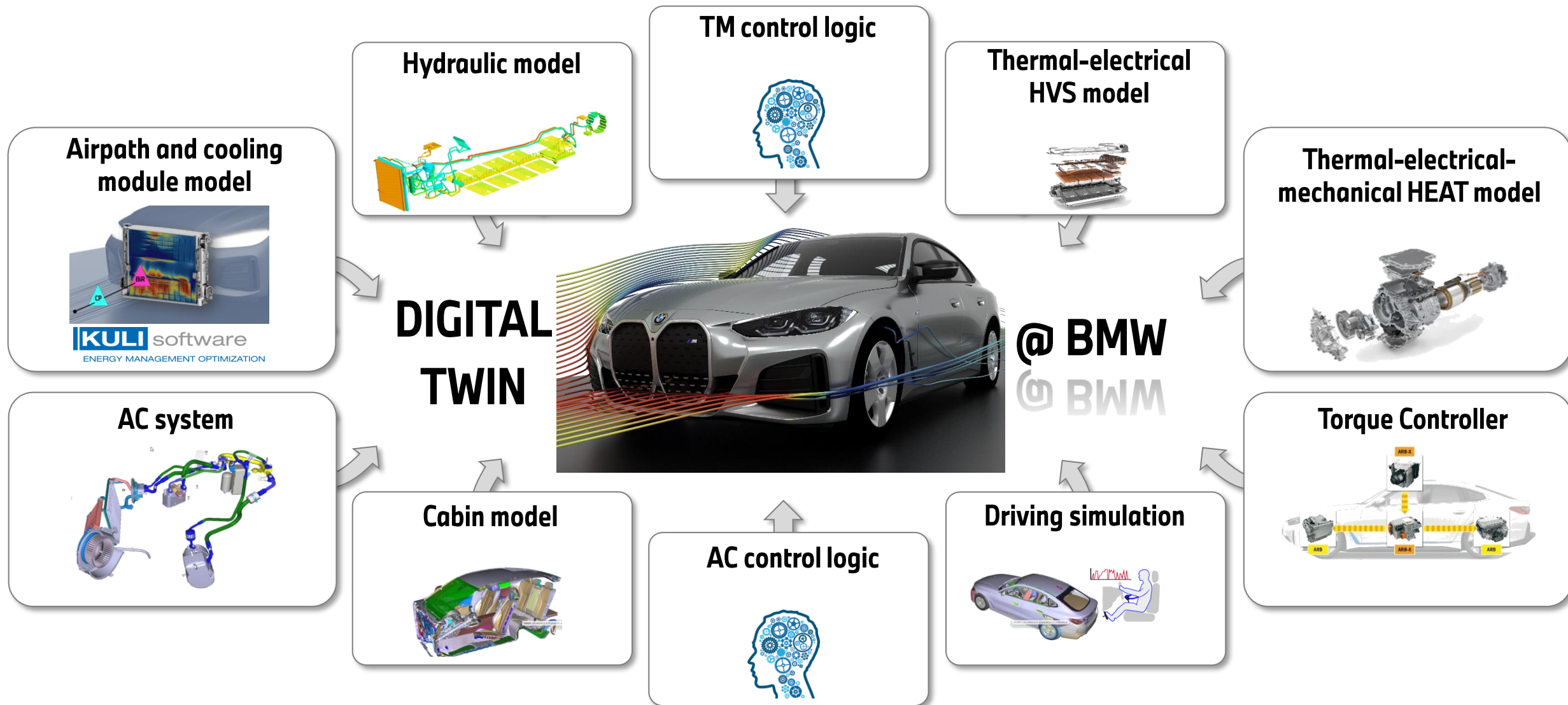
KULI software
ENERGY MANAGEMENT OPTIMIZATION

	Cycle 1	Cycle 2
Driving Speed [kph]	0 kph	210 kph
ΔT Coolant (Measurement – Sim) [K]	< 1K	< 1K



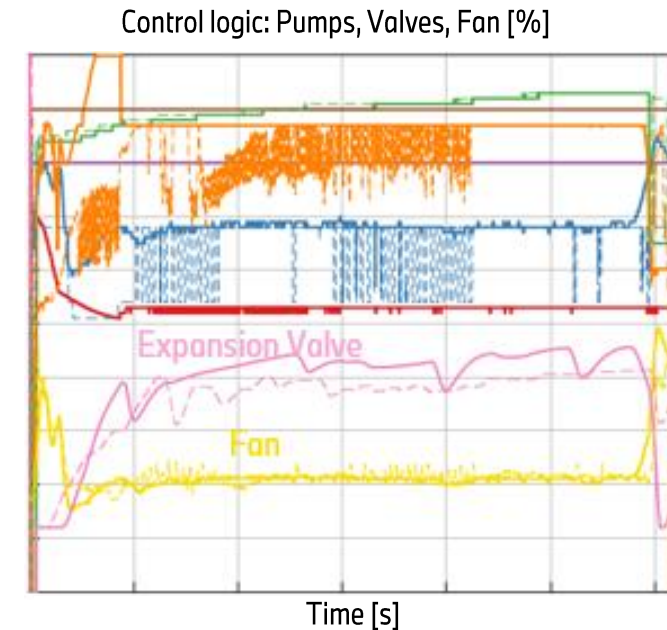
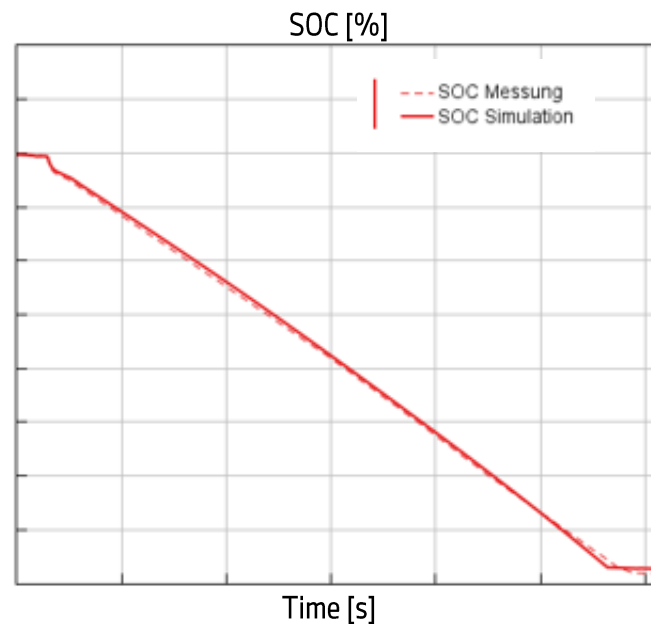
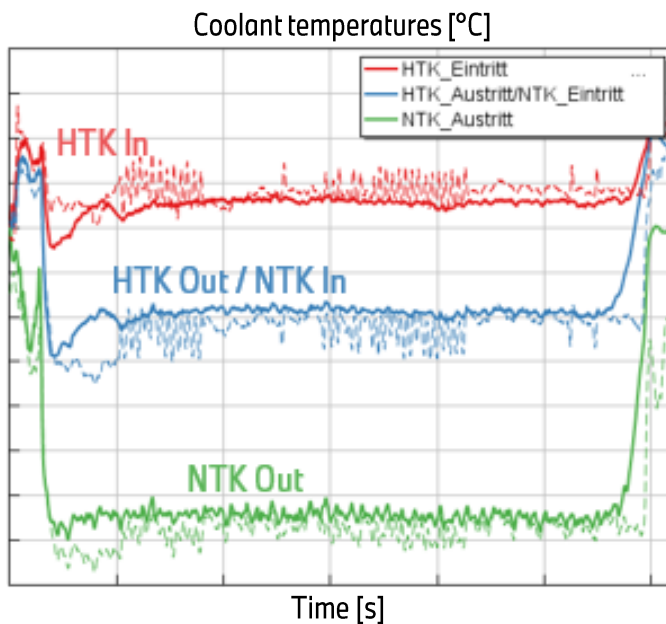
With KULI and CFD the coolant temperatures can be well predicted!

GOING INTO THE FULL VEHICLE SIMULATION MODEL



VALIDATION OF FULL VEHICLE SIMULATION

- High speed cycle validation by prescribing ambient temperature and driving speed
- Very good fit for key values
- Minor discrepancies in valve logic



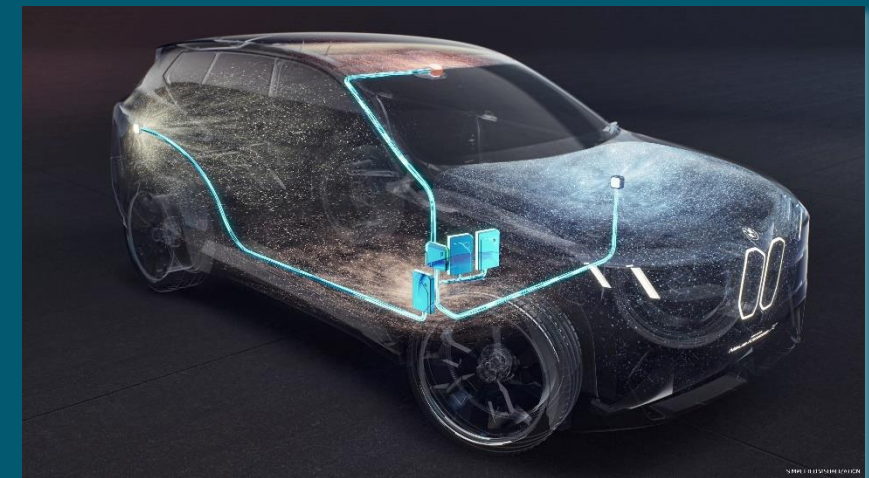
— Simulation
--- Measurement

The simulation tool chain in BMW's development cycle is well prepared for future developments

THE ROAD TO NEUE KLASSE

Challenges for simulation are solved....
...but they are still there on a higher flight altitude.

- ❧ More than 40 car models until 2027
- ❧ New software architecture with 4 superbrains for driving dynamics, autonomous driving, panoramic idrive as well as basic functions
- ❧ New high voltage battery concept based on round cells and 800V technology for 30% higher charging speed and same for electric range
- ❧ New model kit based electric drivetrain Gen6
- ❧ New factory for Neue Klasse SOP





Thank you for your attention !