Improving Electric Vehicle (EV) Energy Efficiency

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TECHNOLOGY OVERVIEW

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THERMAL STORAGE (HEAT BATTERIES)

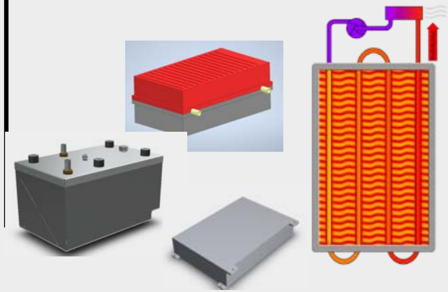
- ***Achieve range consistency in all weather conditions***
- ***Reduce thermal load on traction batteries***
- ***Extend traction battery life***
- ***Reduce time to reach optimal cabin temperature***
- ***Speed up windscreen demist or defrost***
- ***Reduce system noise***
- ***Can be integrated into PTC, Heat Pump and Refrigerated systems to improve total vehicle energy efficiency***

THERMAL STORAGE (HEAT BATTERIES)

Simple and robust battery construction

Insulated plastic or metal housing with integral heat exchanger immersed in PCM.

Sized to fit performance and vehicle packaging needs.

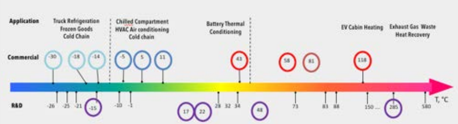


PHASE CHANGE MATERIALS (PCMs)

Use our own non toxic, non flammable phase change materials (PCMs) as the storage medium

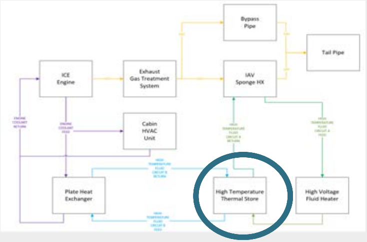
On-site chemistry department developing and producing temperature range -30ºC to +580ºC

Energy densities equal to Lithium Ion at module level



VEHICLE INTEGRATION

Simple integration to existing VTMS to absorb waste heat, store and release it when needed up to days later. Or use grid electricity to make heat and store for later use. Provide thermal loads to heat pumps



- Small EV cabin warm-up: **60% increase winter range**
- Electric truck refrigeration & heating system: **30% range increase**
- Electric bus heat pump winter operation: **Operate to -30ºC**

Product Development Programmes 2016-2020

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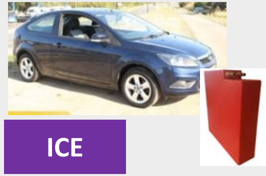
ROAD TO ELECTRIFICATiON

2016 | 2017 | 2018
2019 | 2020



ICE

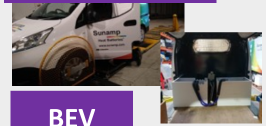
BEV

BEV

ICE

BEV

TRANSMISSIO
N



BEV

PHEV

BEV

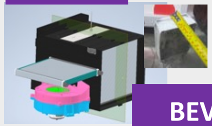
BEV

PHEV

BEV

BEV

PHEV



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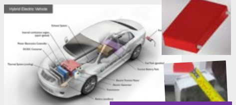

PHEV

BEV

Electric Bus, Truck & Van Cabin Heating – Gen 1

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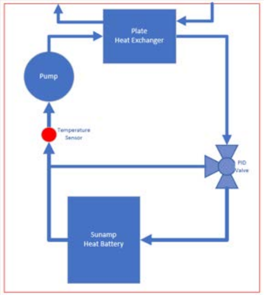

Provides fast cabin warm up & sustains cabin heating over typical duty cycle
118ºC PCM Heat Battery
7.8kWh
Electrically charged from grid
Weight 70kgs

Prototype build started, completion Q3/21
Vehicle installation and road trials Q4/21
Production intent Q1/22

Ford Transit PHEV Campervan conversion
Waste heat recovery and/or electrically charge from grid or renewables (solar/wind)

4.25T electric conversion store/door delivery truck operated by leading supermarket

7.5T Magtec Isuzu electric conversion distribution centre/stores delivery truck operated by leading supermarket

3.1T GM/Opel/Vauxhall/Peugeot/Citroen electric van operated by UK Utility companies

12M electric bus operating in sub zero conditions
Using multiple heat batteries operated by European bus integrators

Electric Passenger Car & Van Cabin Heating – Gen 2

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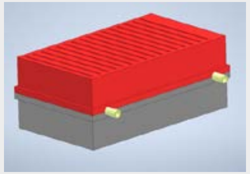
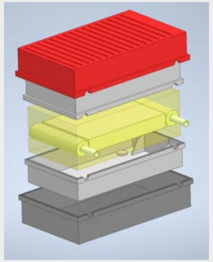




Provides fast cabin warm up and sustains cabin air heating over typical duty cycle.
285ºC PCM Compact Solid State Heat Battery 4kWh - 6.8kWh
Electrically charged from grid or exhaust gas stream (HEV)
Designed for under bonnet/seat/vehicle or to be integrated into HVAC unit

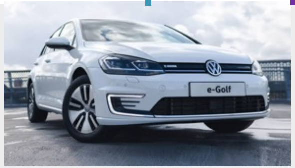
Prototype build Q3/21
Vehicle installation and road trials Q4/21
Production intent Q1/22

PHEV

BEV

Ford Transit PHEV Campervan conversion
Waste heat recovery and/or electrically charged from grid or renewables (solar/wind)

Hybrid electric passenger car with solid state PCM heater core integrated into existing HVAC unit.
Waste heat captured and stored for later use



Electric passenger car with solid state PCM heater core integrated into existing HVAC unit and electrically charged from grid or renewables (solar/wind)

3.1T GM/Opel/Vauxhall/Peugeot/Citroen electric van operated by UK Utility companies

Electric Truck & Trailer Refrigeration & Chiller Systems

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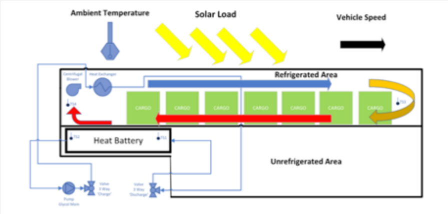
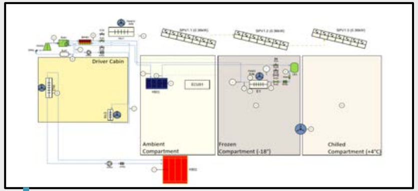
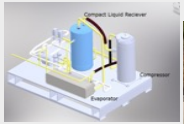


Figure 1: Sketch of trailer

40ft Insulated Trailer Chiller/Cold Battery System

4.25T store/door delivery dlectric truck carrying frozen and chilled foods





40ft Insulated Trailers for food and other perishable goods delivery and operated by national logistic companies. Own designed chiller and
-15ºC PCM cold battery system. Prototype build started, completion Q1/21; Vehicle installation and road trials Q2/21; Production intent Q3/21

3 temperature controlled compartments using Sunamp electric refrigeration system with integrated -15ºC PCM cold battery and 118ºC PCM heat battery for cabin heating. Prototype build, vehicle installation, climatic chamber test and road trials completed October 2019. Optimisation work required to reduce weight and package size Q2/21 and Production intent Q4/21

Motivation

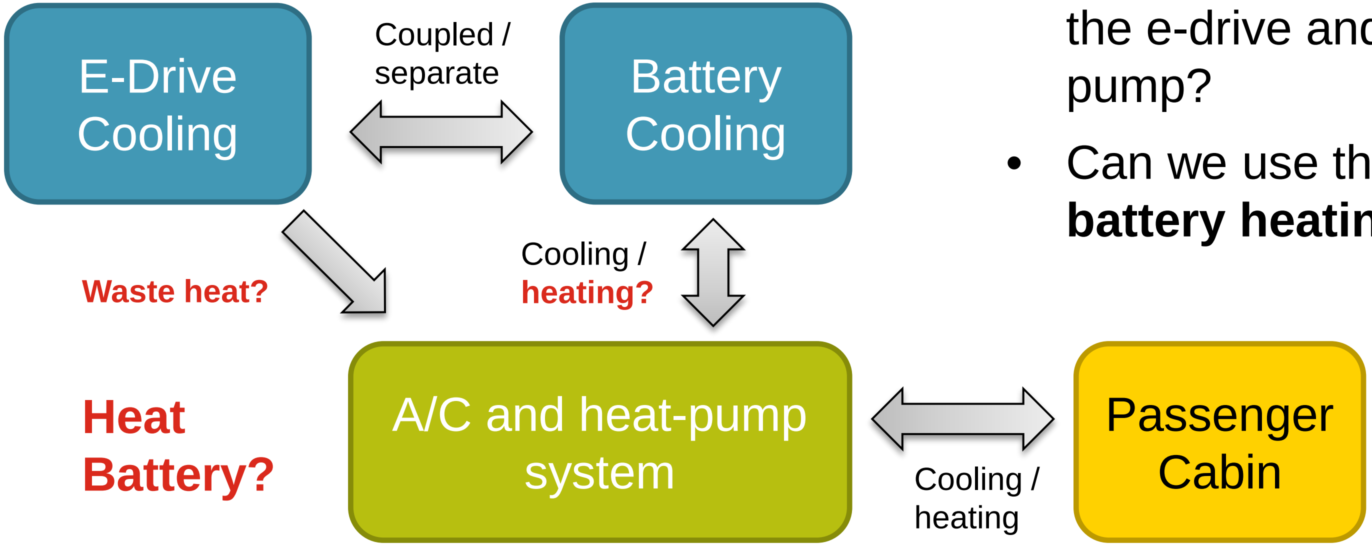
- When suppliers want to include innovative components into OEM vehicle development projects, feasibility- and benefit-studies are required.
- Last autumn Sunamp was contacted by an Asian OEM regarding PCM use in a vehicle VTM system with heat pump
- This is the story of how we supported them… and what we learned!

System architecture, simulation models and results…

For confidentiality reasons no actual OEM data was used. Shown results are generic simplifications… but show very similar effects as encountered in the actual project.

Architecture Overview

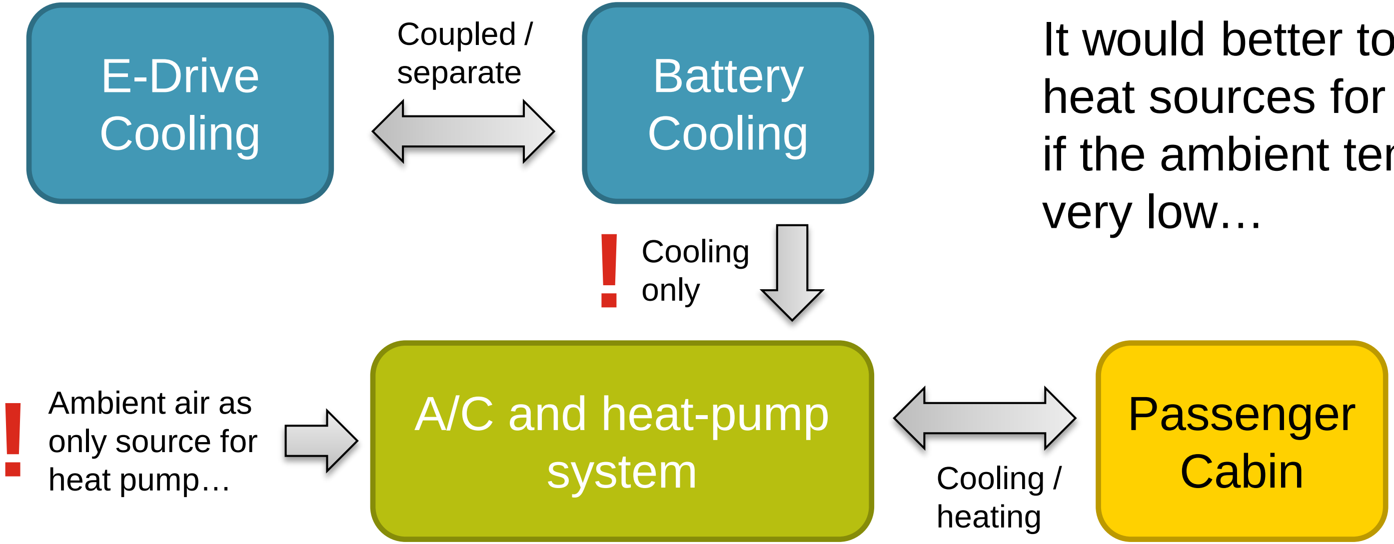
- Passenger EV, SUV segment



- **Where** to integrate the thermal battery (TB)?
- Can we use **waste heat** from the e-drive and TB for the heat pump?
- Can we use the heat pump for **battery heating**, too?

Problems of the original architecture…

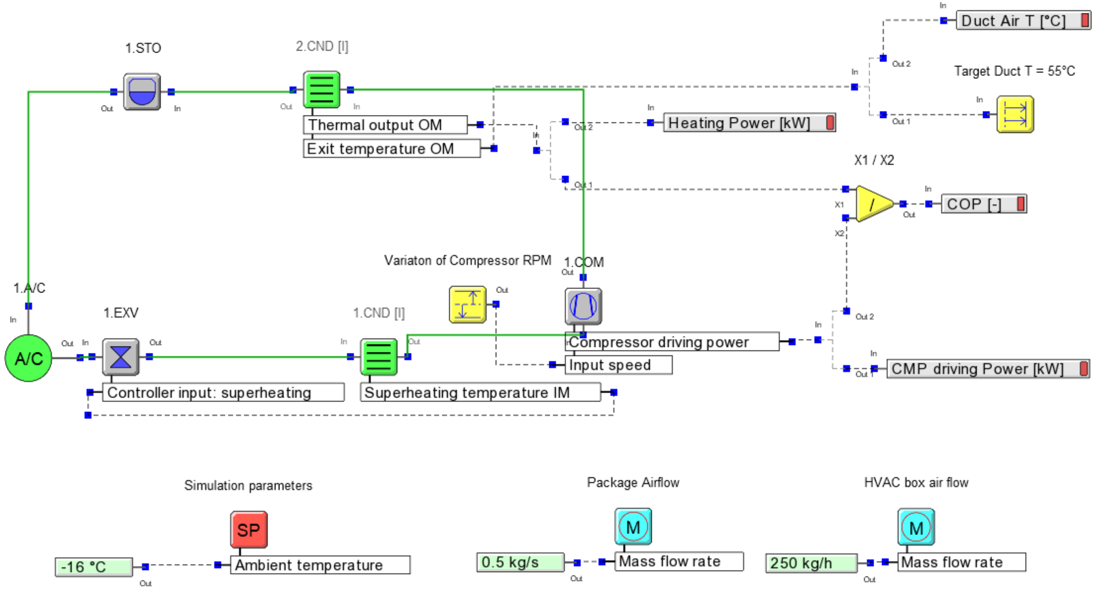
- Air sourced (R134a, R1234yf) heat pumps have performance problems in very low ambient temperature conditions (high pressure ratio, low efficiency)
- Battery heating with a PTC heater is inefficient as well (and requires a PTC heater component)

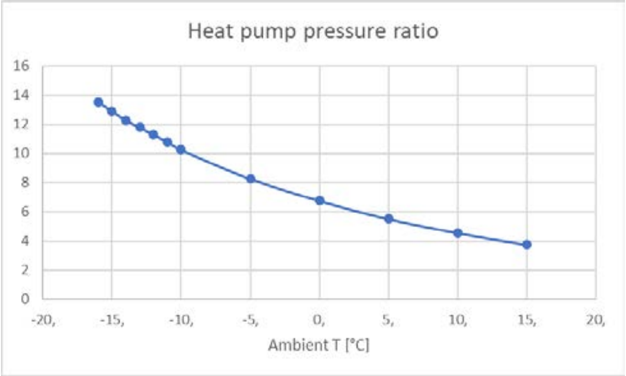


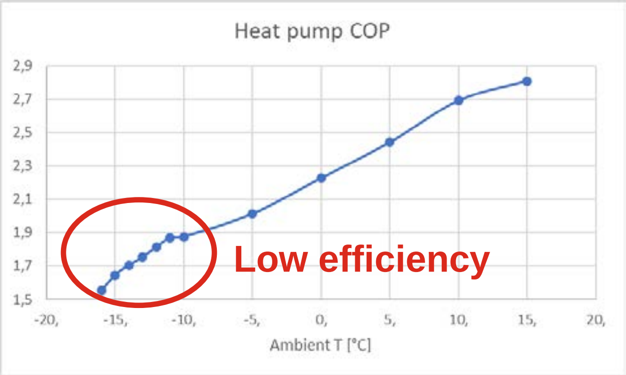
It would better to find alternative heat sources for the heat pump, if the ambient temperature is very low…

A simple simulation model of an air sourced heat pump system

At different ambient temperatures we vary the compressor RPM to reach 55°C air duct T for cabin heating…

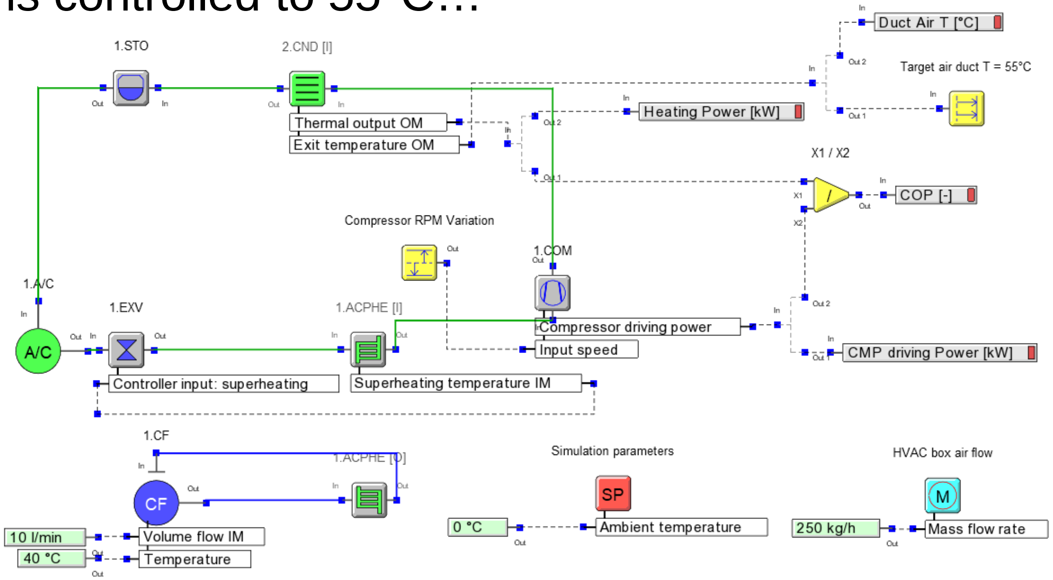




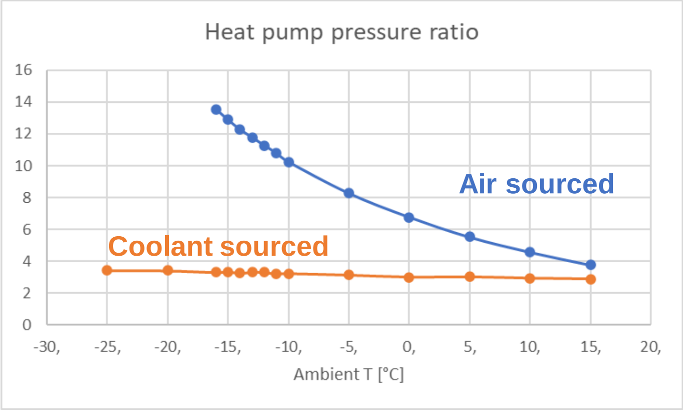


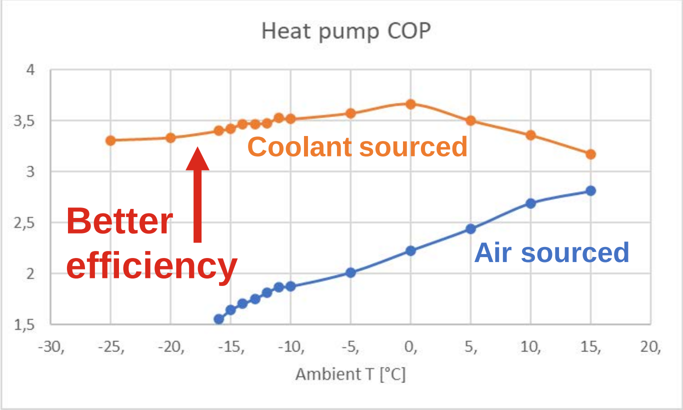
A heat pump using waste heat from the electric powertrain (warmed-up powertrain scenario)

Similar model, but now the heat comes from 40°C powertrain coolant via a chiller. Air duct T again is controlled to 55°C…

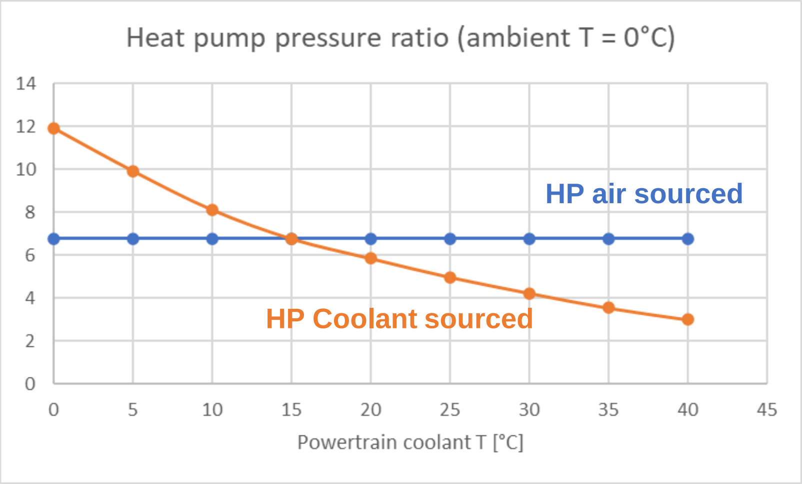


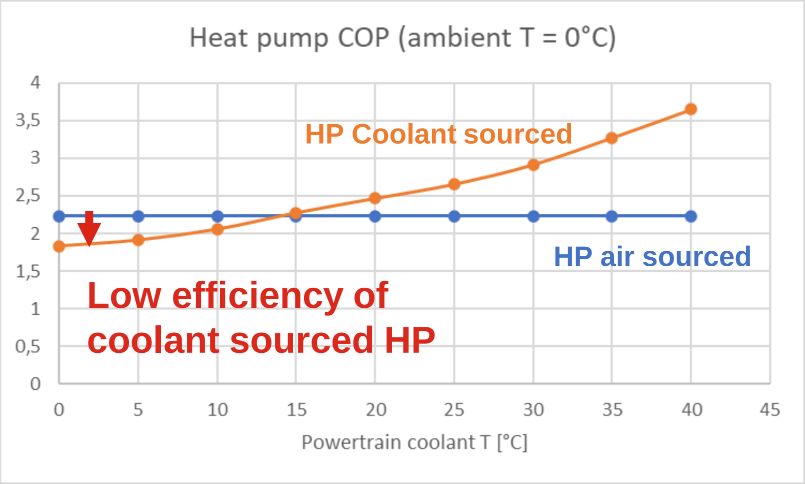
But what happens, if the powertrain is still cold?





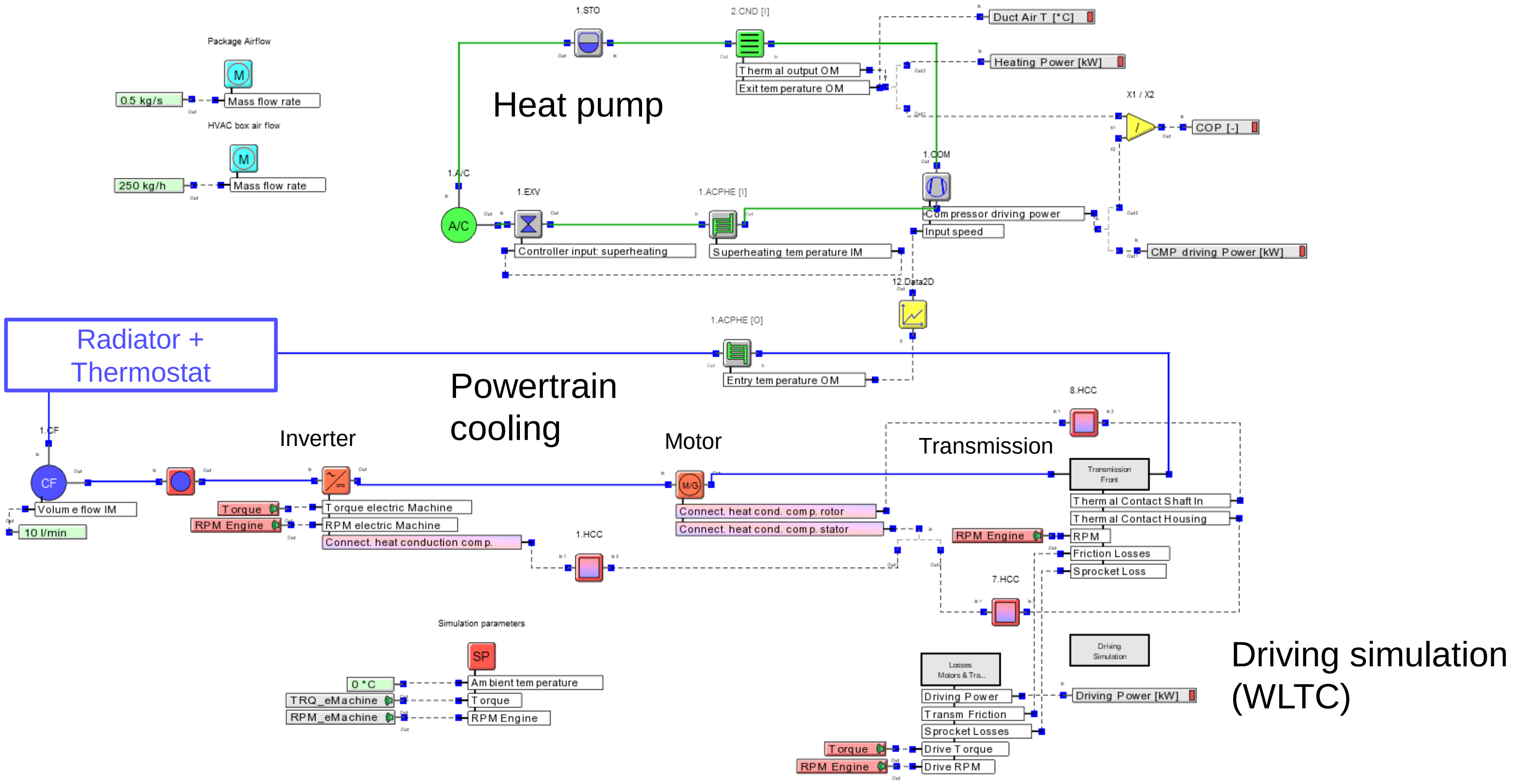
Simulation results for a cold-soaked powertrain (ambient temperature 0°C)





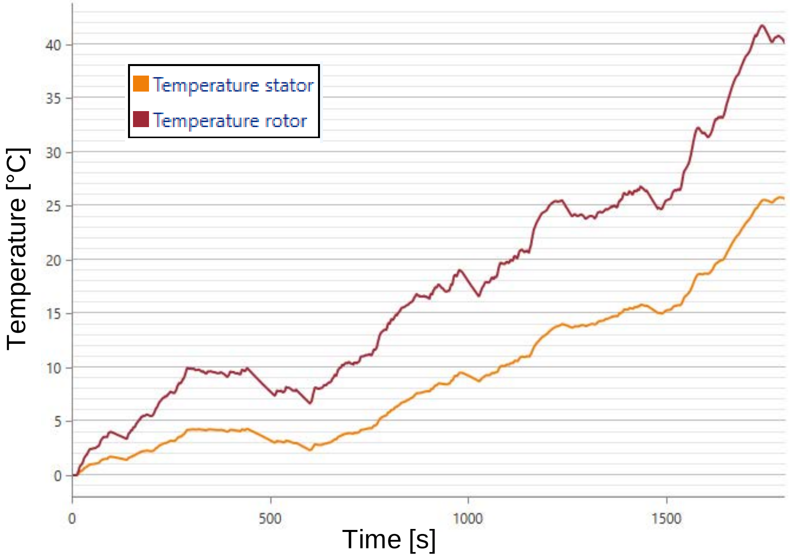
- In cold-start conditions the coolant sourced HP performs even worse than the air sourced HP (due to the small chiller size)
- How does this impact the performance in a vehicle (considering typical powertrain warm-up times)?

A simplified vehicle simulation model

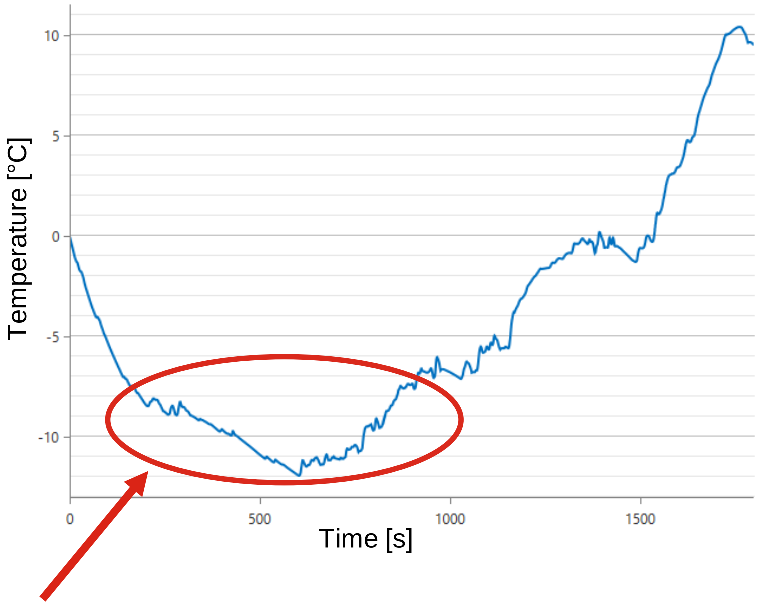


Temperature levels for cold-soaked WLTC at 0°C (coolant sourced heat pump active)

E-Motor temperatures



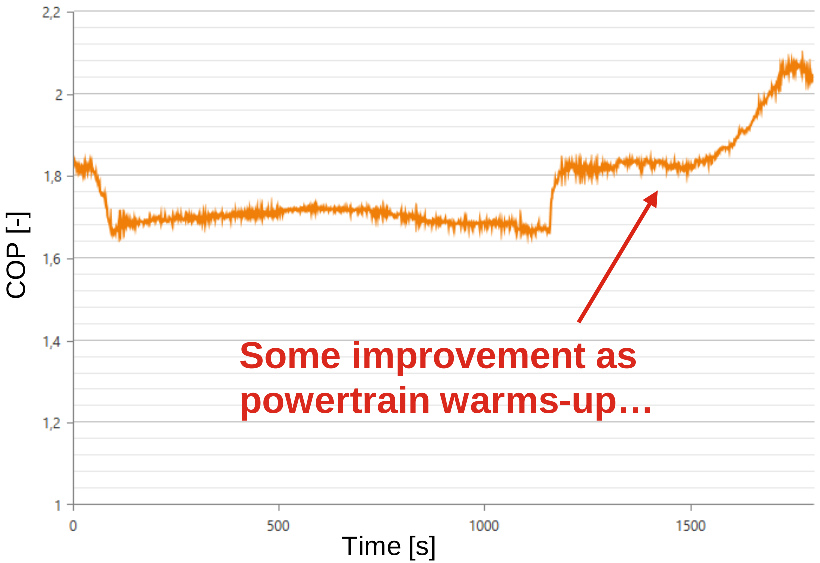
Coolant T at Chiller



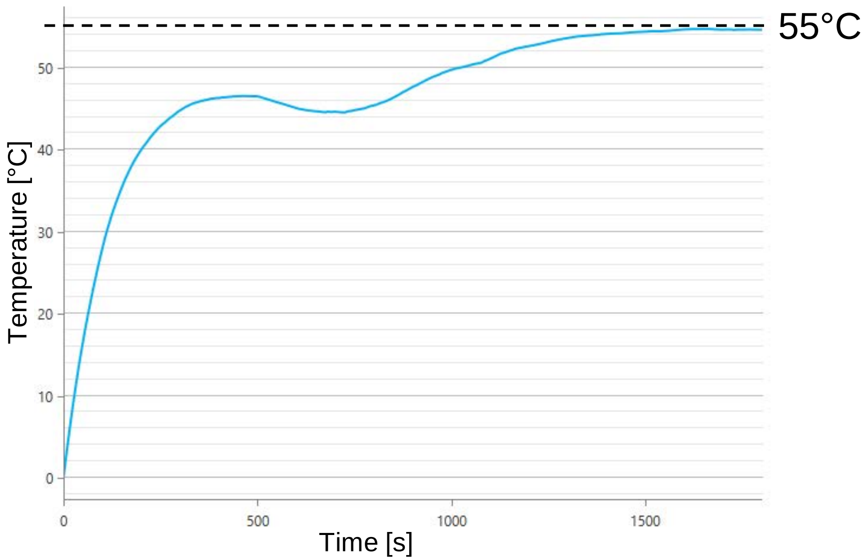
The chiller cools down the coolant too much (too little heat available from powertrain)
This is not a good idea…

COP and air duct T for cold-soaked WLTC at 0°C (coolant sourced heat pump active)

Heat pump COP



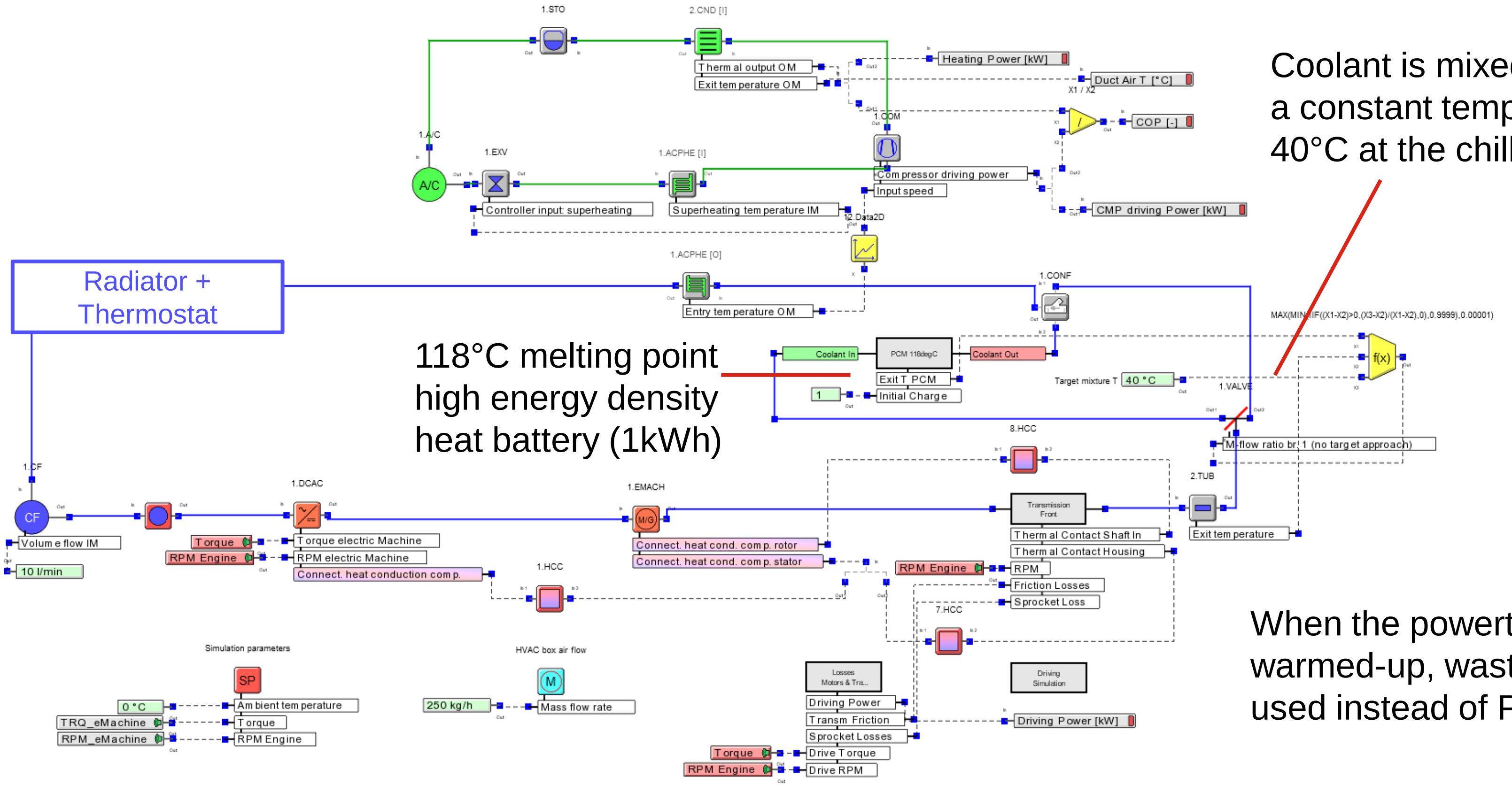
Air duct temperature



For the cold powertrain the COP is not good and the heat pump has problems to reach the target air duct temperature

A different heat source is needed!

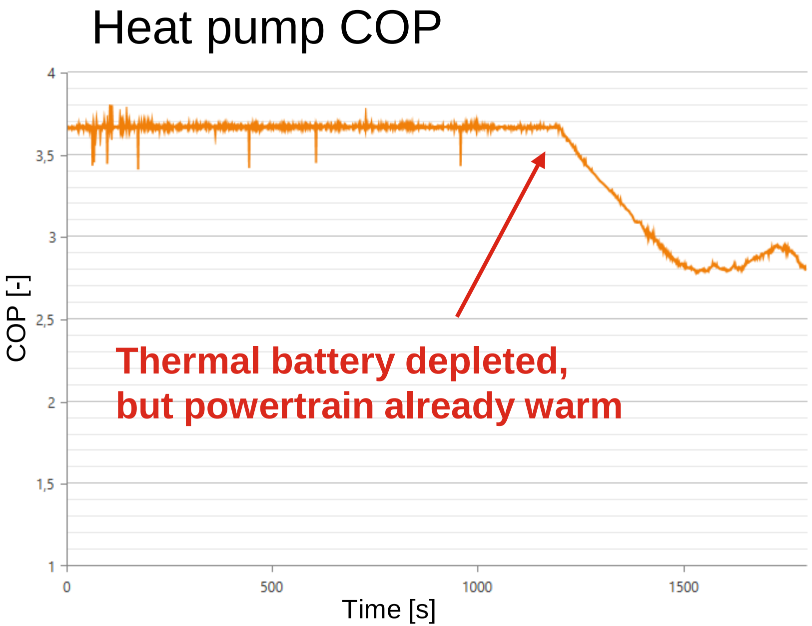
Using a thermal battery to improve the system performance…

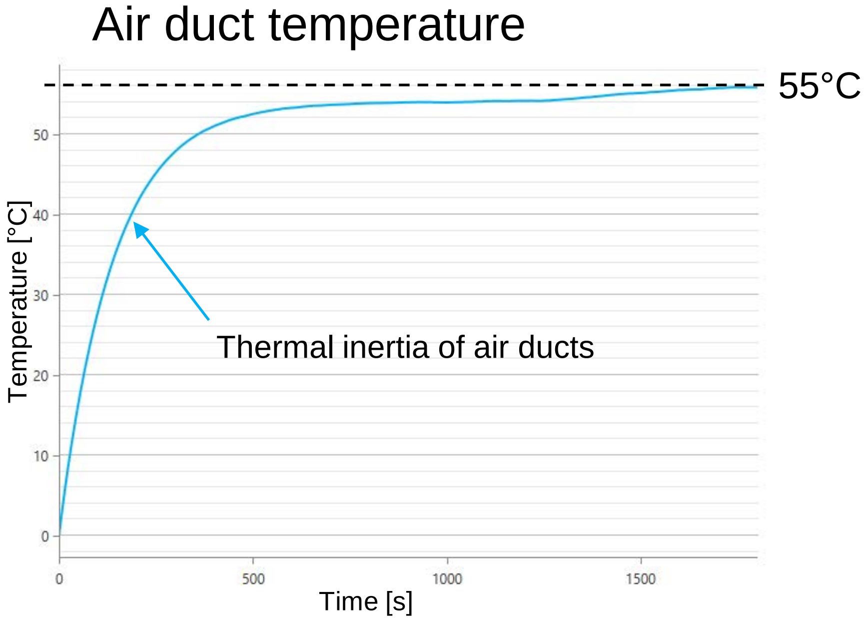


Coolant is mixed to achieve a constant temperature of 40°C at the chiller inlet

When the powertrain is warmed-up, waste heat is used instead of PCM heat…

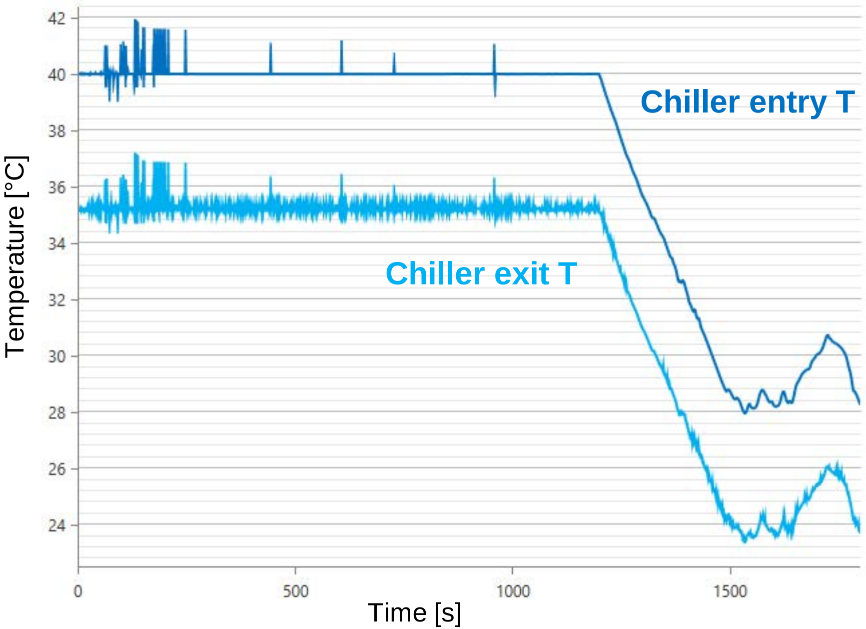
COP and air duct T for cold-soaked WLTC at 0°C (combined PCM / waste-heat usage)





COP is significantly better now, also the air duct target temperature is reached much more quickly… and when the thermal battery is discharged, the warmed-up powertrain can take over.

Chiller coolant T for cold-soaked WLTC at 0°C (combined PCM / waste-heat usage)



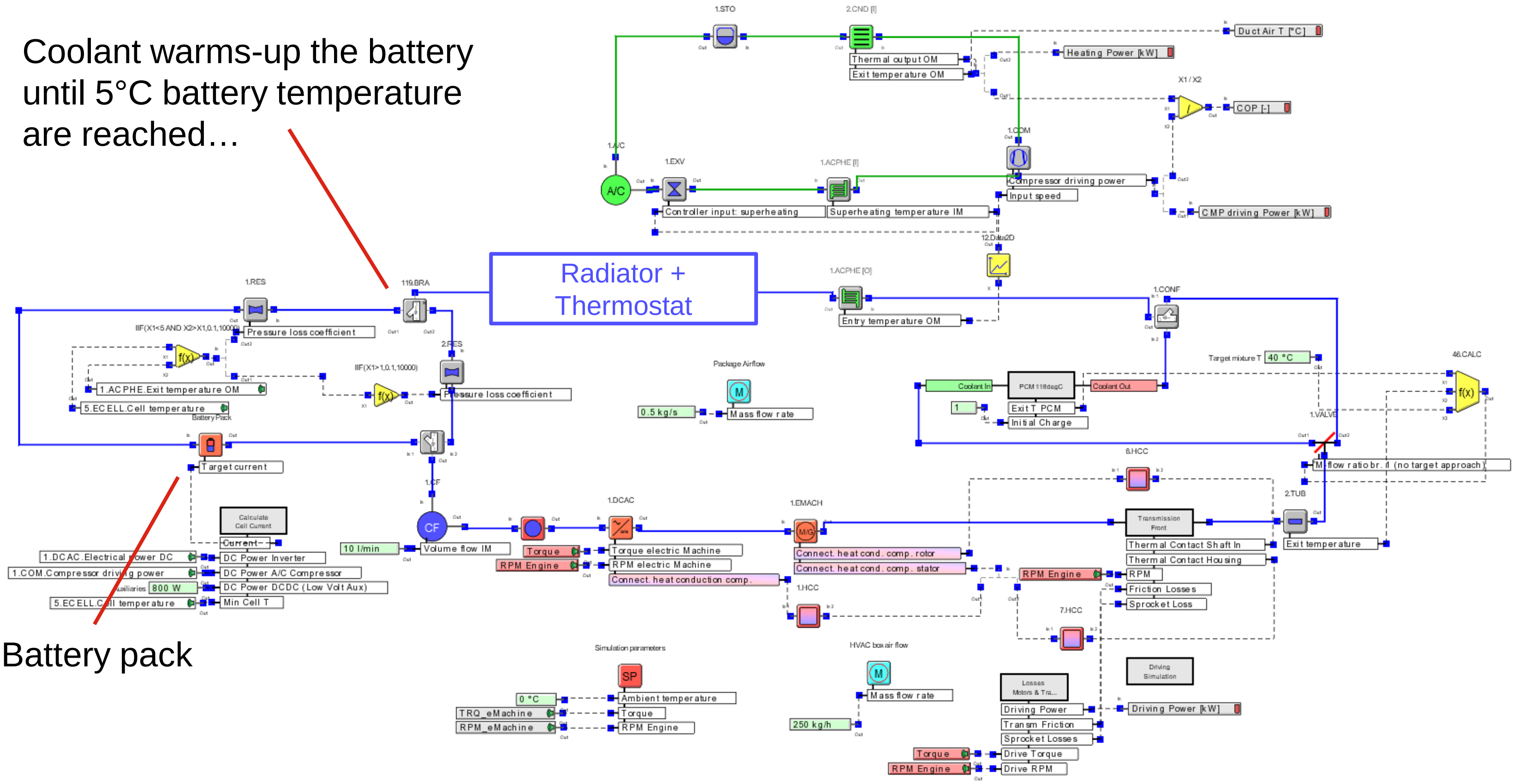
As long as the heat battery is charged, the target chiller temperature of 40°C is maintained nicely

But even when the heat battery is depleted, the warm powertrain can maintain coolant temperatures above 24°C

There should be some potential for using the warm coolant after the chiller for battery heating as well (thus eliminating the need for a battery PTC heater)…

Modified architecture for battery heating capability

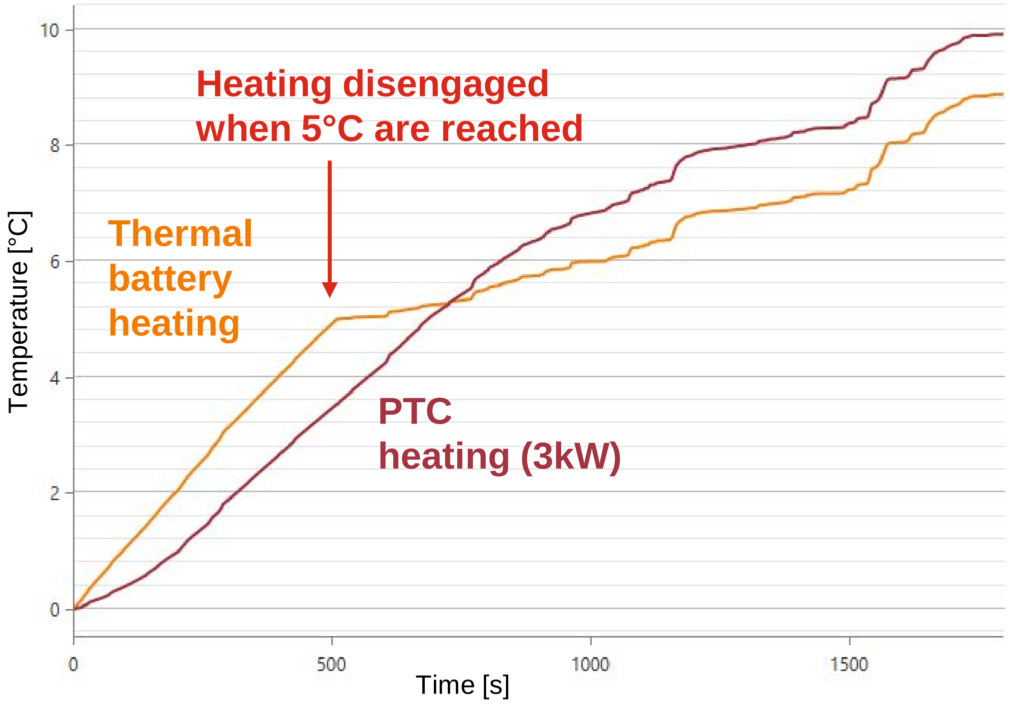
Coolant warms-up the battery until 5°C battery temperature are reached…



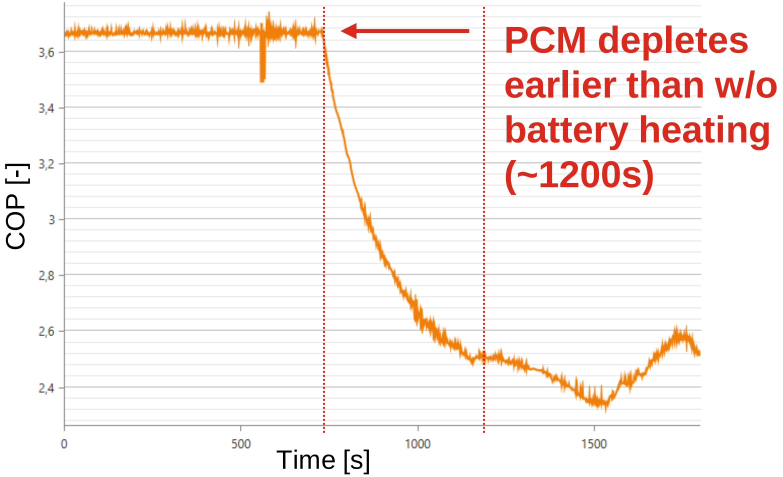
Battery pack

Simulation results (WLTC at 0°C) including battery heating

Battery average cell temperatures



Heat pump COP



PCM can heat both cabin an battery… but depletes more quickly.

COP of HP is still very good, though

Energy consumption comparison (0°C WLTC)

- How much energy is needed for heating the cabin and the EV battery?
  - Base vehicle (air sourced): **1.49kWh**
  - Heat battery for cabin, PTC for battery: **1.04kWh (-30%)**
  - Heat battery used for all heating efforts: **0.65kWh (-56%)**
- Using residual heat after the chiller for battery heating also reduces thermal losses from powertrain to air (lower temperature gradient)
- The heat battery can significantly improve the efficiency of the overall cooling system!

Summary

Summary

- Air sourced heat pumps perform badly in very cold conditions and waste heat from the powertrain is only available after a significant warm-up phase.
- A thermal battery can bridge this gap by providing high energy density storage.
- Phase change materials thus can significantly improve vehicle efficiency in cold winter conditions, if
  - … a suitable VTM system architecture is chosen
  - … the control strategy is adapted to thermal battery use
  - … the chiller is large enough to transfer sufficient heat to the heat pump and
  - … thermal losses over the powertrain can be controlled

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INSPIRING **INNOVATION.**