

Simulation of a Battery Electric Vehicle

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Agenda

- Motivation
- Thermal Management for BEV
- Simulation Model
- Baseline Range
- Optimizations of Thermal Management System
- Preconditioning of Cabin
- Summary

Motivation

- Emission-free traveling
- Limited range
- Uncertain lifespan of battery
- Smaller waste heat
- HVAC of cabin
- Smart thermal management



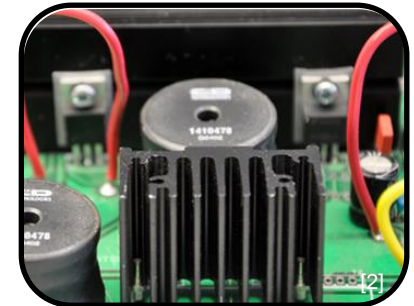
Thermal Management for BEV

Components

- Electric motor
- Inverter
- Cabin
- Battery

Requirements

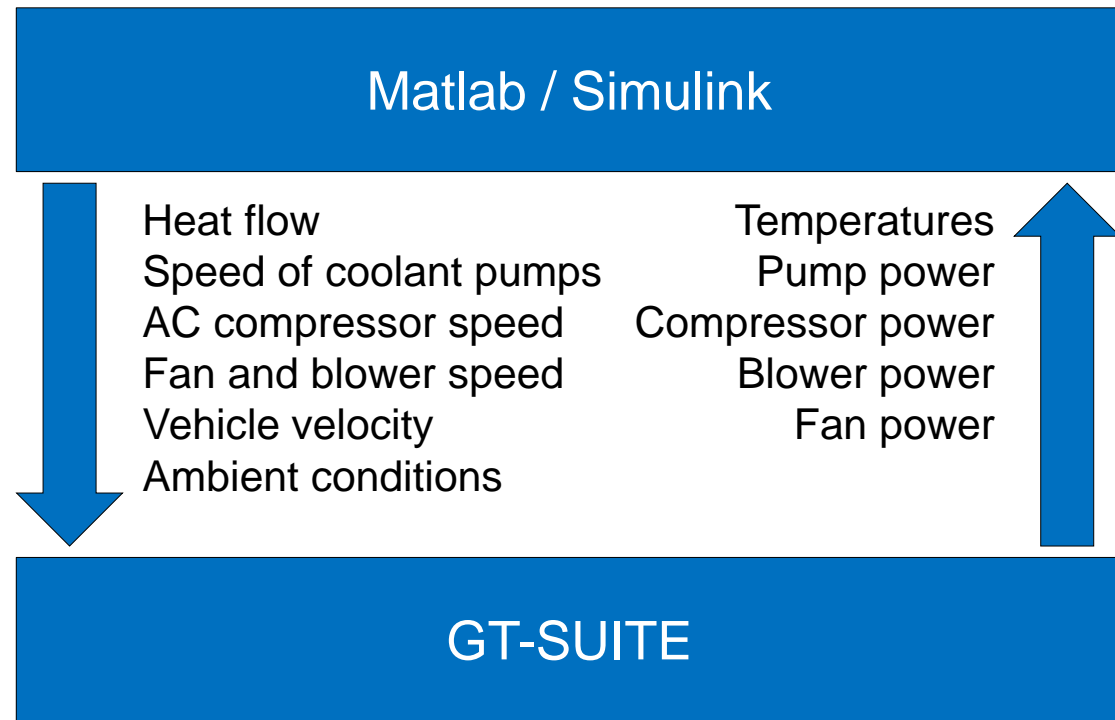
- Limit max. temperature of motor and inverter
- Satisfy need for cabin comfort
- Condition battery to operating range



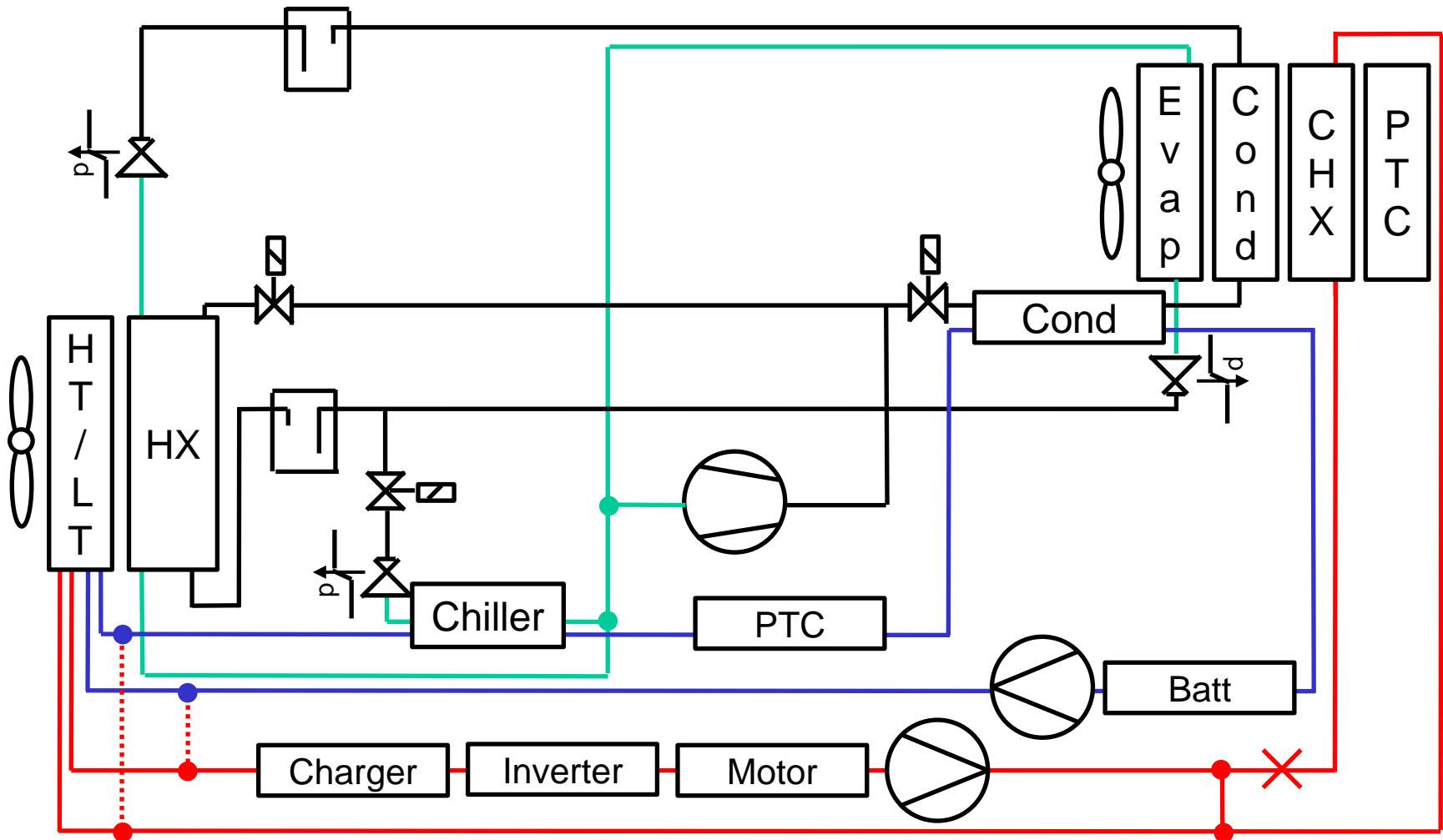
[1] fotos.autozeitung.de
 [2] eal.jku.at
 [3] gvw-fachverlage.de
 [4] autogenau.de

Simulation Model - TheFaMoS

- For reliable prediction a simulation tool was developed
- Co-Simulation Matlab / Simulink and GT-SUITE
- Usage of test bench results for calibration

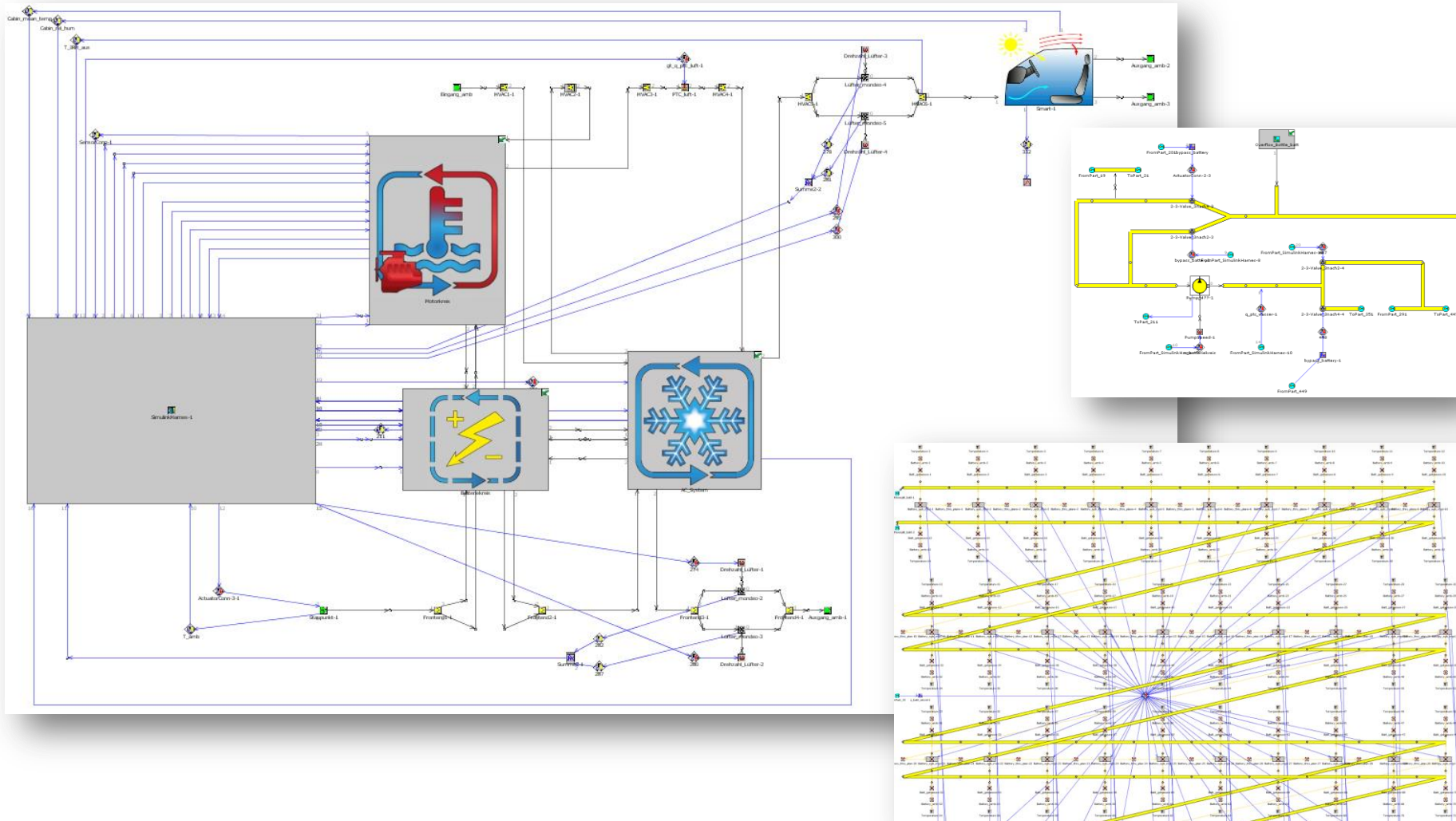


Thermal Management System



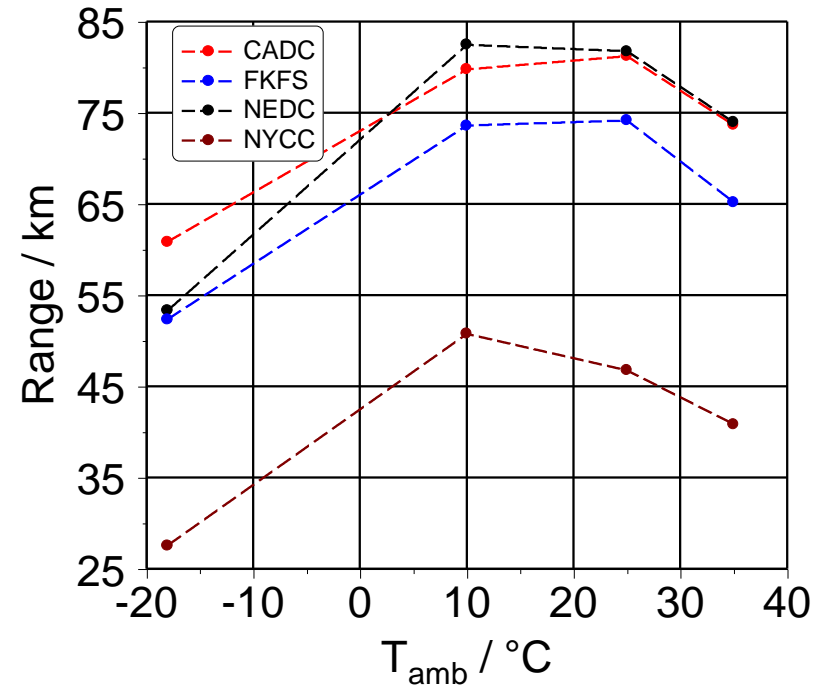
— AC HP
 — Batt.
 — AC LP
 — Motor
- - - Bypass HT-LT

GT-SUITE Model



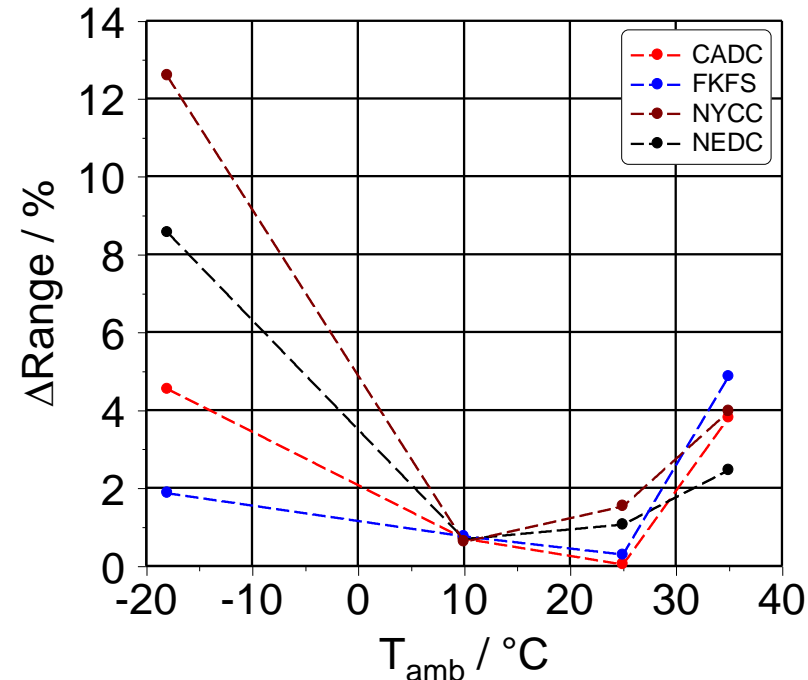
Baseline Range

- Range is determined with drive until the battery is empty
- NEDC and CADC similar ranges
- Range in FKFS cycle is slightly lower
- In very slow NYCC ($V_{ave}=11,4$ km/h) the range is low due to HVAC consumption
- Trends of the range depending on temperature are similar for all cycles



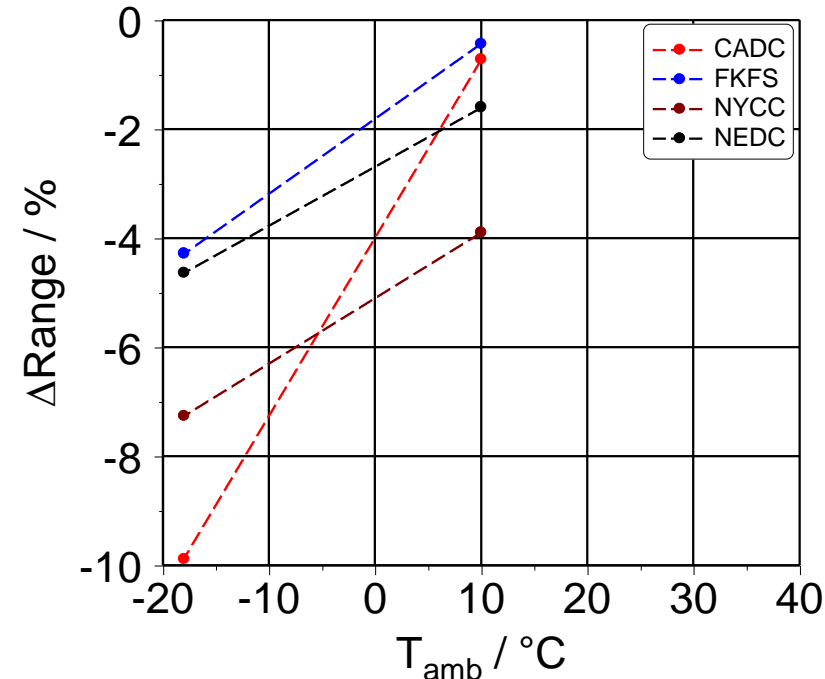
Circulating Air Quota (50%)

- Speed control of the blower is not changed
- Usage of a mixer which is set to approximately 50% recirculating air
- At -18°C and 35°C, the benefits of recirculating air are clearly visible
- At 10°C and 25°C, the effect is negligible



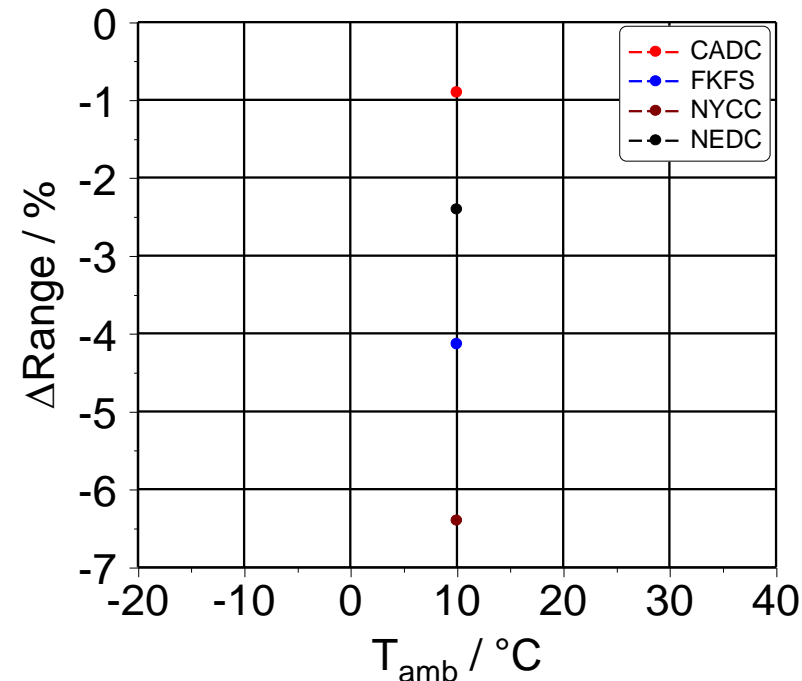
Usage of Waste Heat to Heat the Cabin

- The baseline uses a cabin heat exchanger to use waste heat from the motor circuit
- If this usage is suppressed and the heat deficit compensated by the PTC and the heat pump, the range drops significantly
- If a synchronous motor is used, the effect is smaller since the efficiency is higher



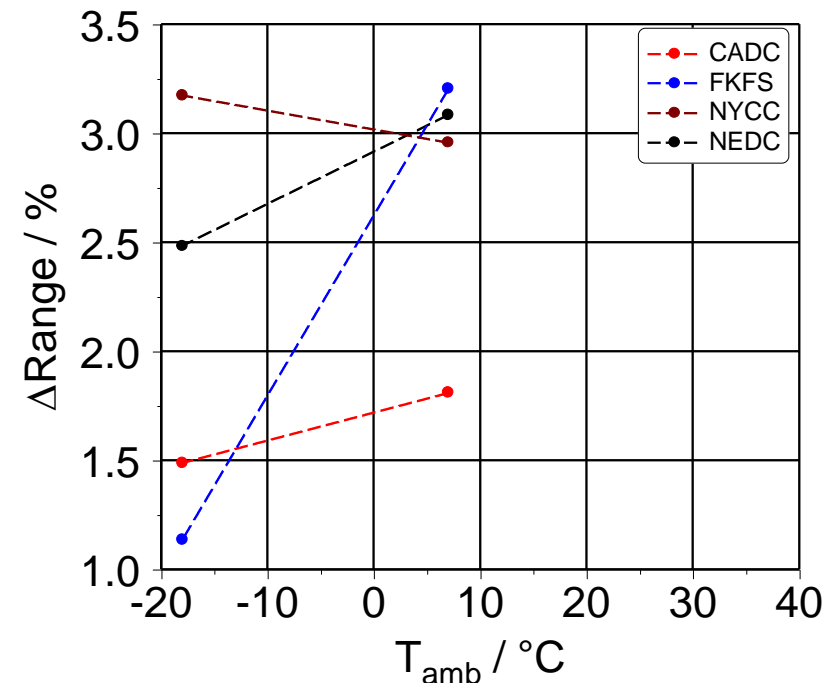
Heat Pump

- The baseline uses a heat pump for the heating of the cabin
- If the heat pump is turned off and the heat deficit is compensated by the cabin heat exchanger and the PTC, the range decreases
- The elimination of the heat pump is more drastic than the elimination of the cabin heat exchanger



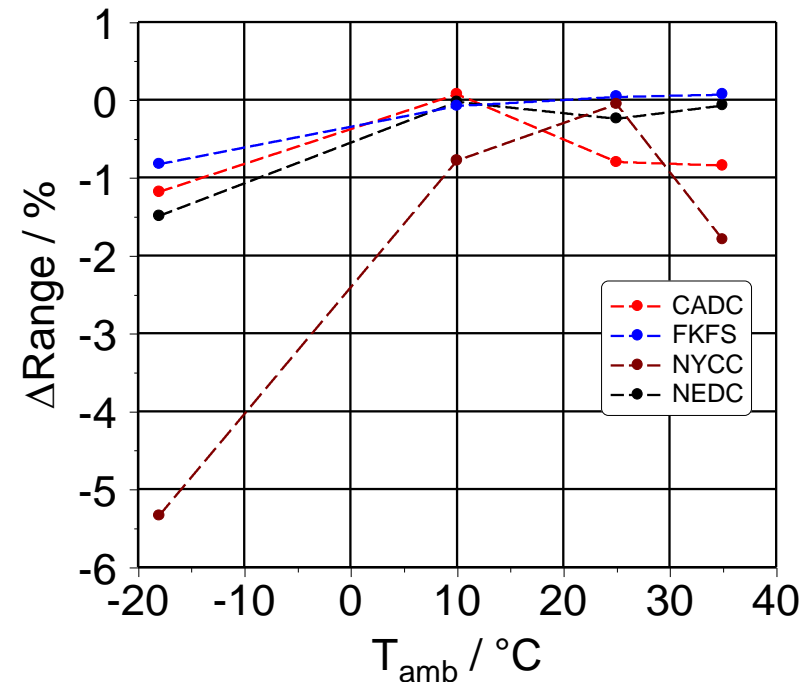
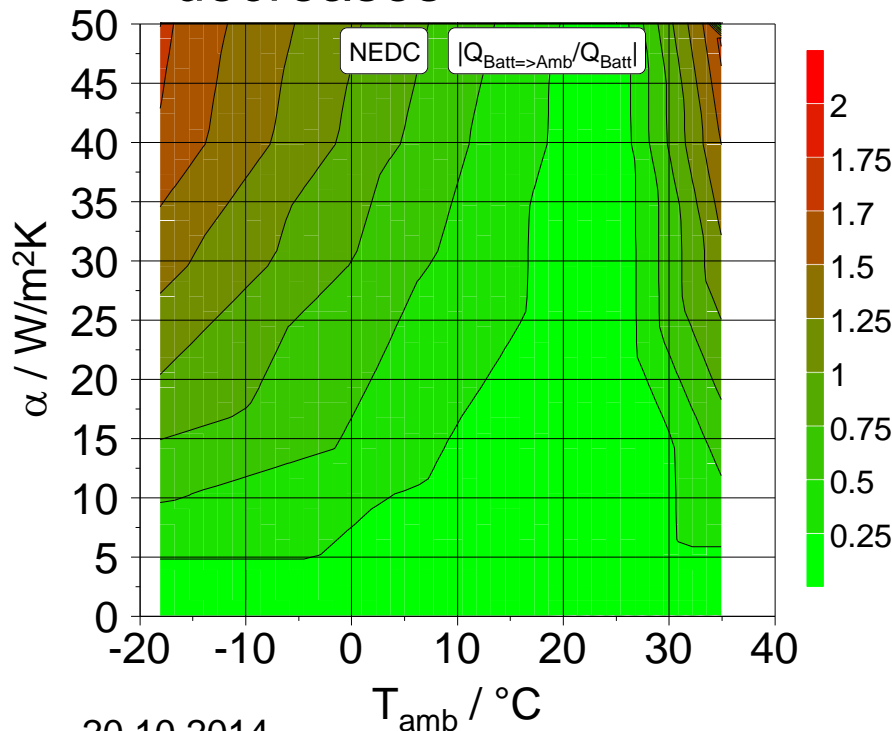
Waste Heat Usage for Heating of Battery

- In the baseline the PTC is below 10°C used to keep the battery at operating temperature
- If waste heat is used instead, the range is increased
- Range is on average increased by about 2.5%



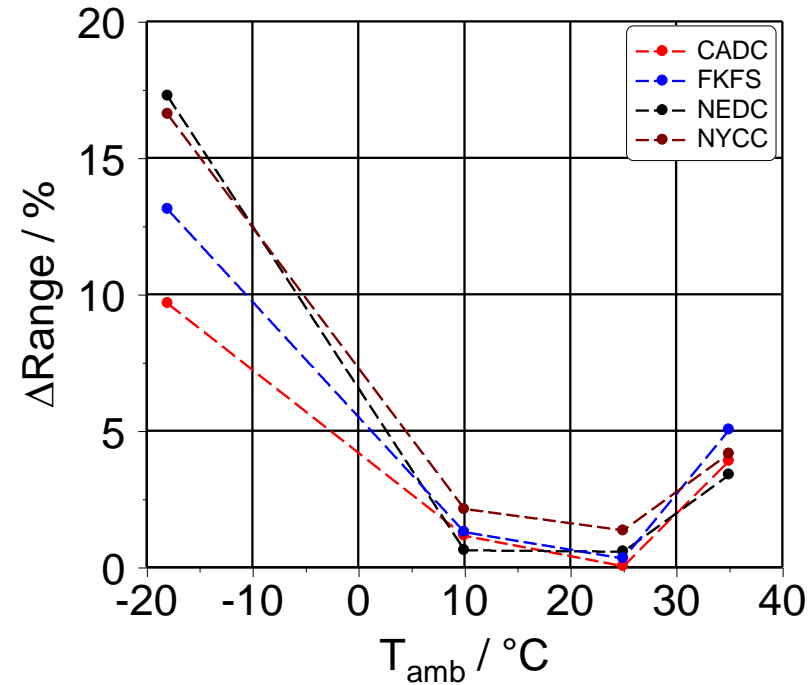
Insulation of Battery

- The battery loses / gets a lot of heat from the environment, if it is not insulated
- If α is increased from 0 W/m²K to 10 W/m²K, the range decreases



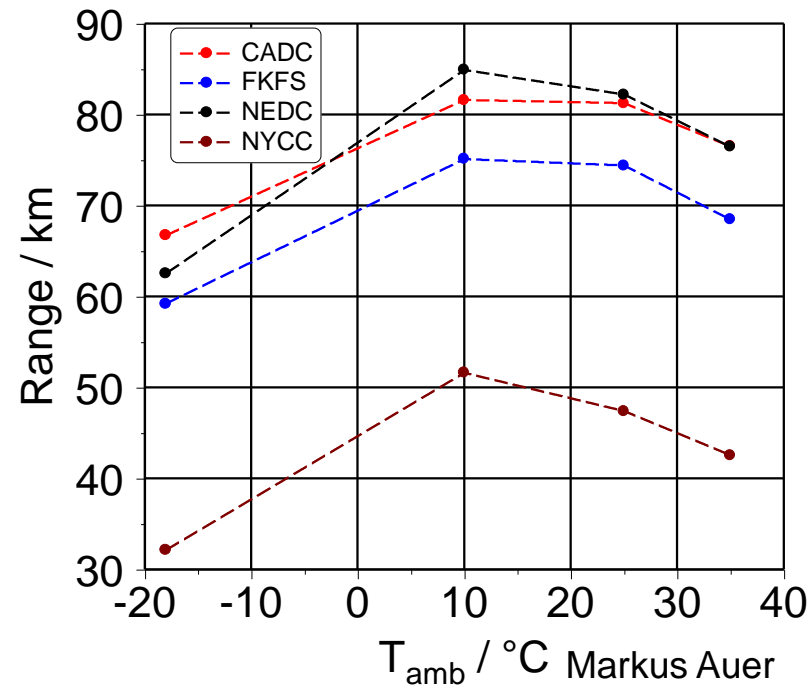
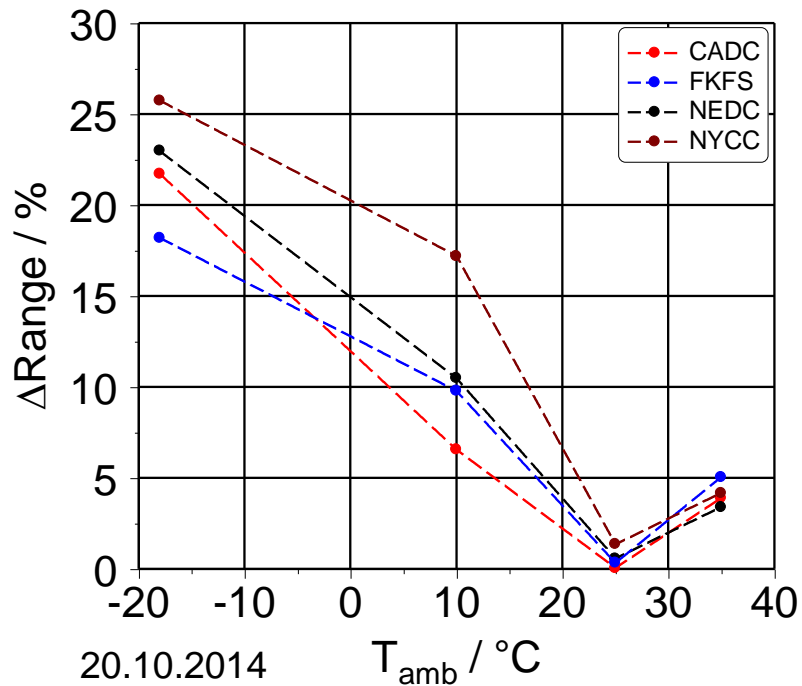
Combination of Single Optimizations

- Relative to baseline
- Recirculating air 50%
- Lightened motor
- Adapted cabin mean temperature with compensation of heat deficit
- Usage of waste heat to heat the battery



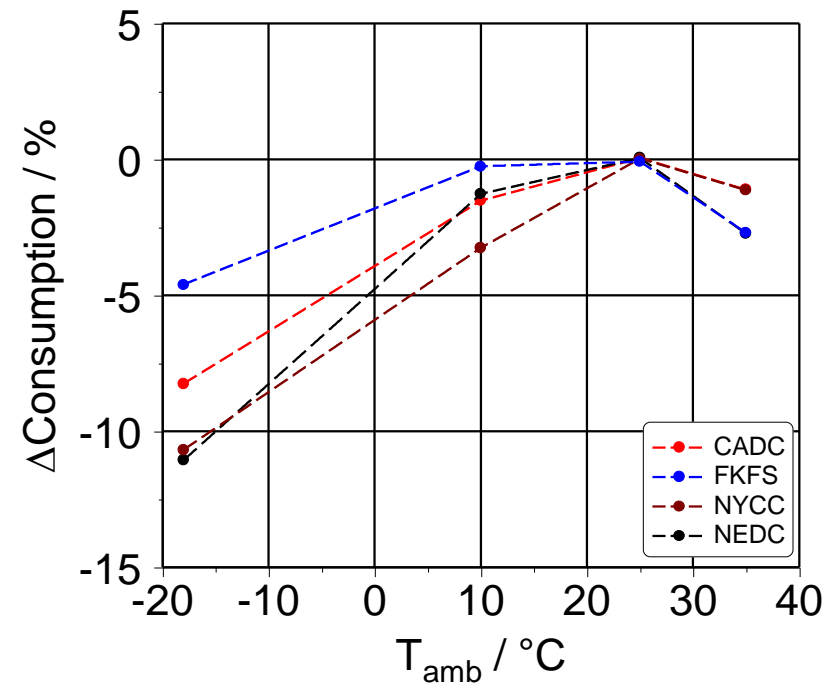
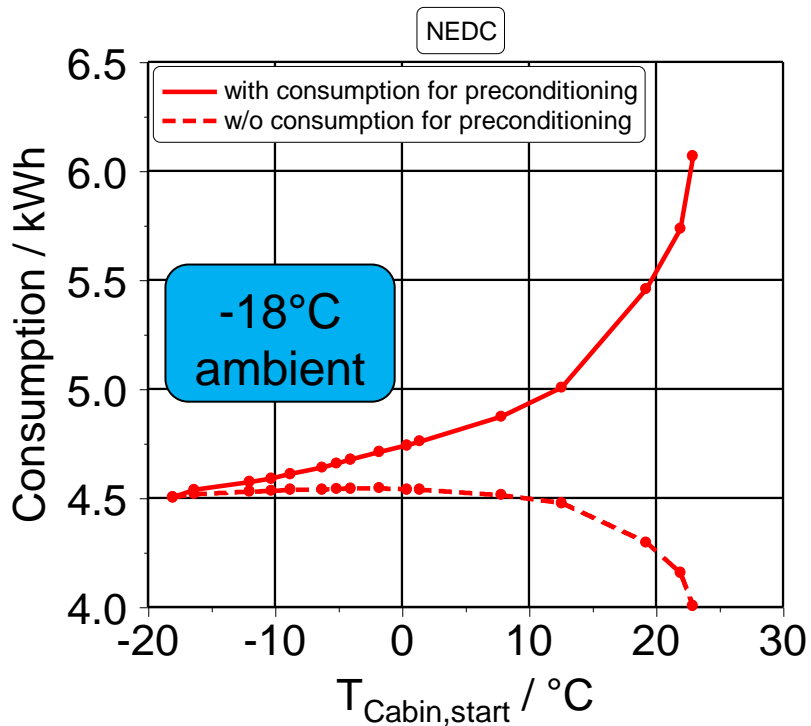
Combination of Single Optimizations

- As before, only with respect to baseline without cabin heat exchanger and heat pump
- Significant advantages can be seen at low temperatures



Preconditioning of Cabin

- Total energy consumption increases with preconditioning
- With preconditioning at low temperatures, the consumption can be significantly reduced



Summary

- Simulation model of a battery electric vehicle
- Thermal management system with AC and heat pump
- Baseline range
- Potential for single optimizations
- Potential of combination of single optimizations
- Effect of preconditioning of cabin on consumption

Acknowledgement

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- Members of the working group

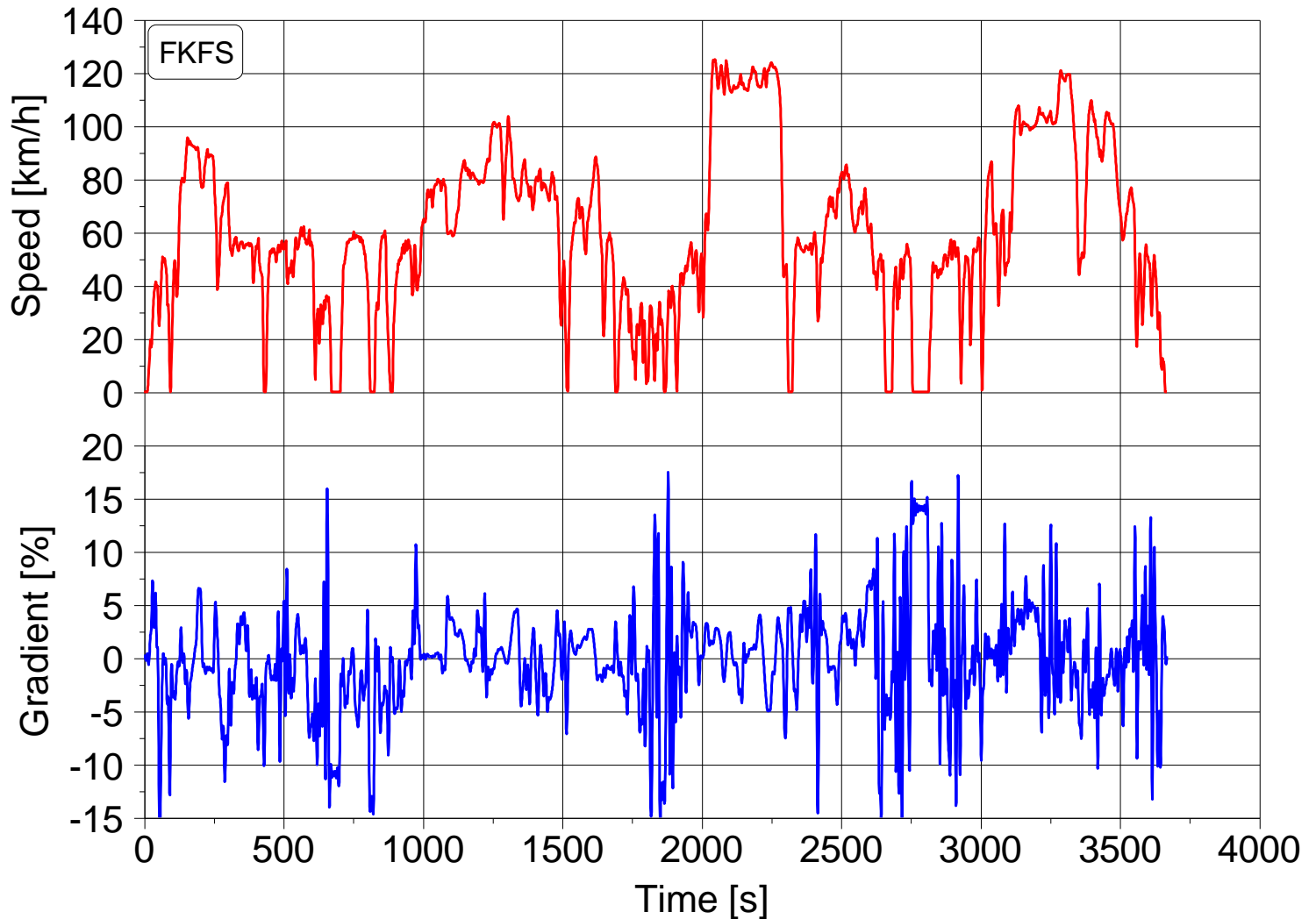


Thank you for your kind attention!

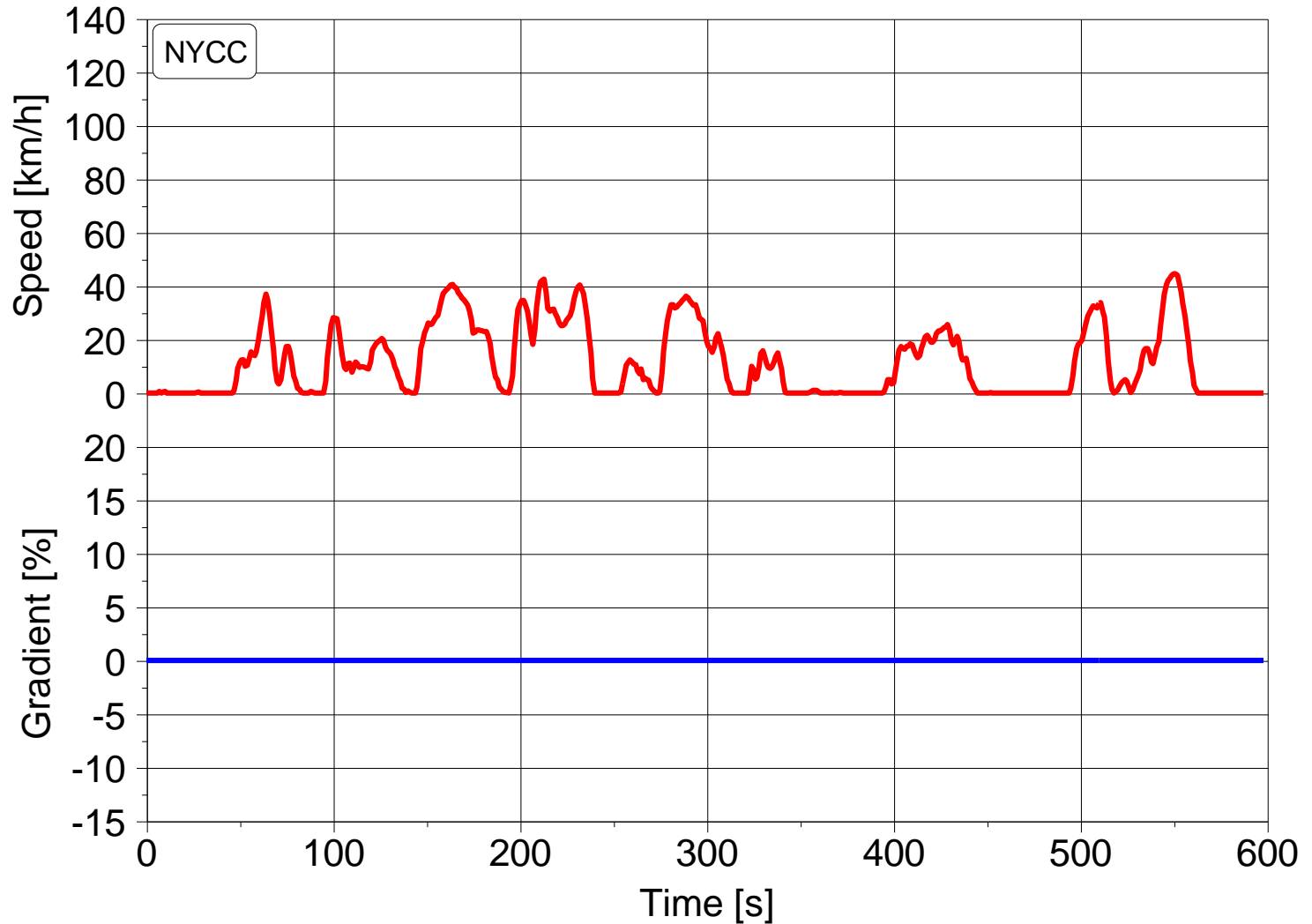
Questions?

Backup

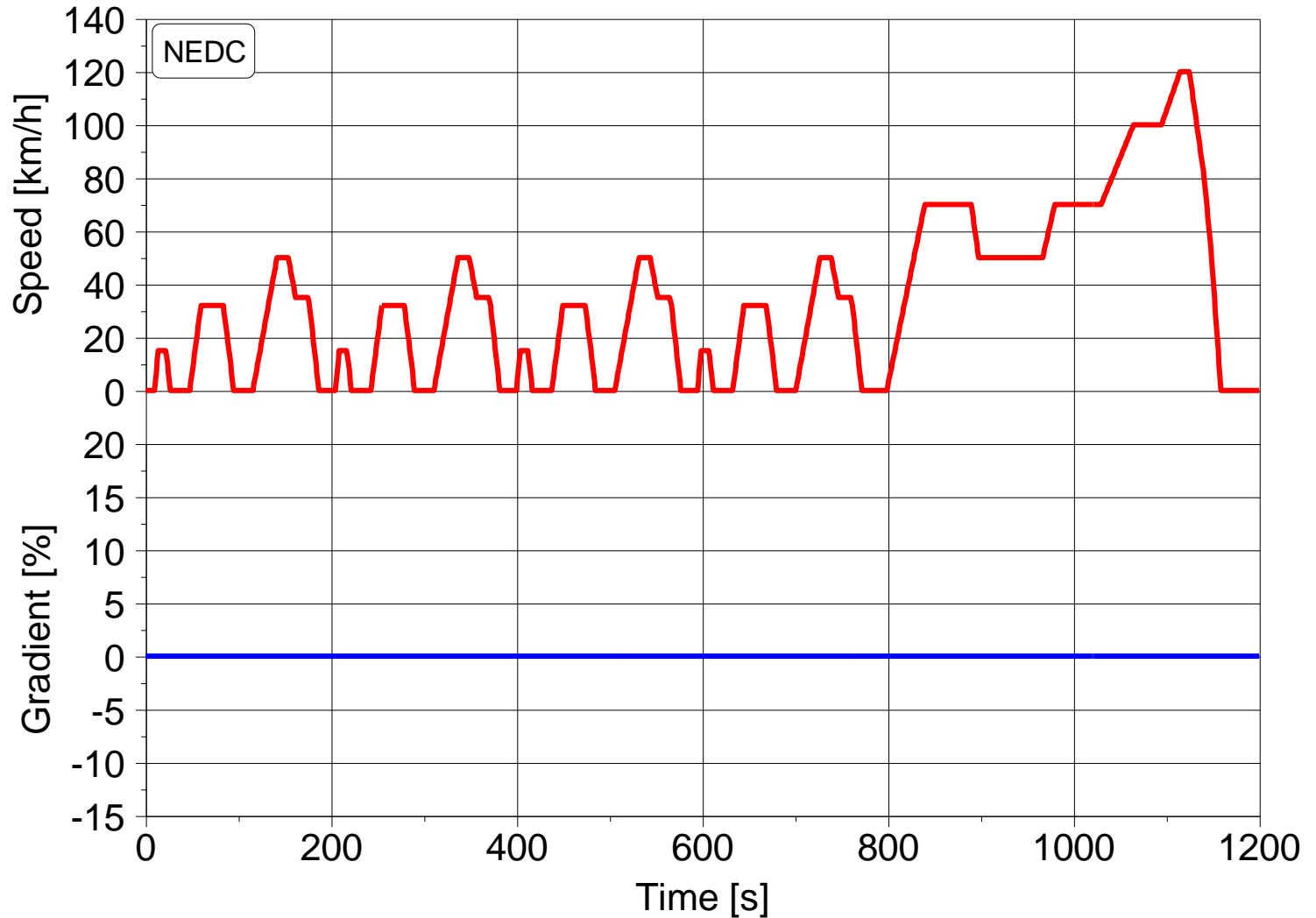
FKFS Lap (Stuttgart, Germany)



NYCC



NEDC



CADC

