

Saving Energy in Public Transport Vehicle Pools by Continuous Operation Data Analysis

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Linz AG Linien: Transport network

Length of routes: 206,06 km
Passengers: 85,43 Mio.
Service area: 120 km² / ~ 240.000 inhabitants

Average distance between stops: 426 m
Cruising speed: 20 km/h
Average journey: 4,1 km



Linz AG Linien: Fleet

- Street trams
 - 33 trams „Cityrunner 1“ (2002-2009)
 - 29 trams „Cityrunner 2“ (2011-2016)
- Historic mountain tram
 - 4 trams
- Busses
 - 12 busses hybrid 12m
 - 76 busses hybrid 18m
 - 20 trolley busses



VanHool Equi.City 24 Trolleybus



- Technical Specifications
 - Length: 24.6m
 - Width: 2.55m
 - Curb weight: ca. 24.000 kg
 - Max. total weight: 36.500 kg
 - Doors: 4
 - Axles / Tyres: 4 / 12
 - Total capacity: 180

Boundary Conditions / Targets

- 1.250.000km annual distance driven by LINZ AG trolley-bus fleet
- Related electric energy consumption: 3.975.000 kWh



This means significant costs and equivalent CO2 emissions

Target: 15% reduction of energy consumption

Project Mission

Reduce energy consumption and emissions
in public transportation



Steps

Collect data

Analyse

Derive
improvements



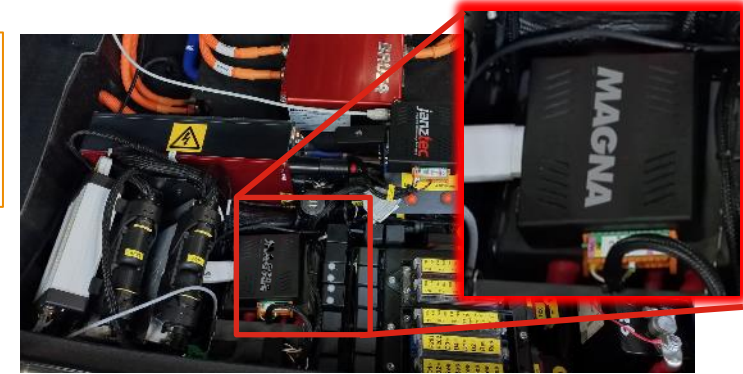
Collect Data

Magna DriveInsights

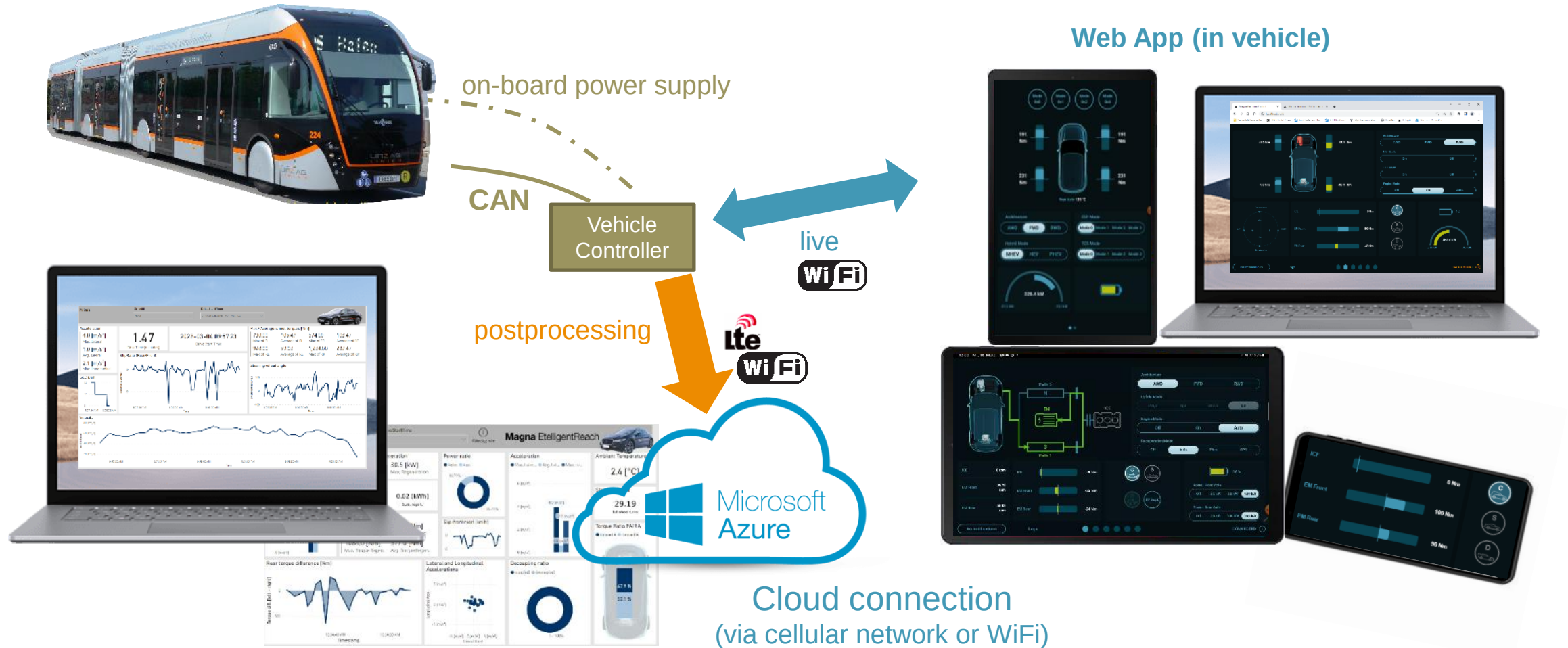


**Highly customizable and flexible IoT system
providing deep insights into any vehicle**

- Super small and flexible IoT device to access CAN bus
- In-vehicle HMI for controlling vehicle parameters and real-time visualization of vehicle states
- Log CAN data of any vehicle type to the cloud
- Comprehensive online dashboard to analyze collected data and trips
- Rollout to new vehicle types within minutes
- Over-the-air-update capable



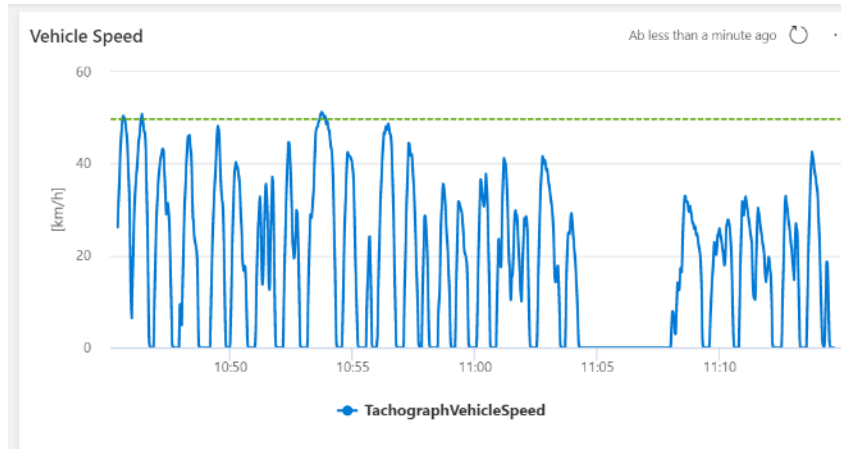
Magna DriveInsights



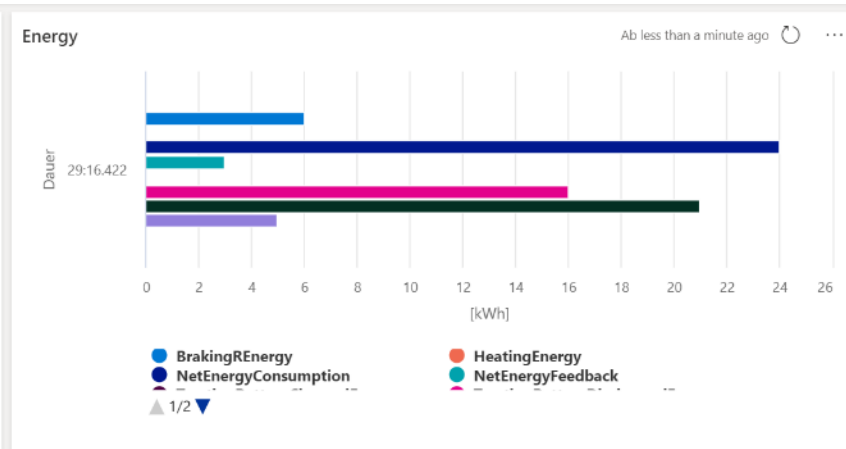
Sample Data of Trolley Bus



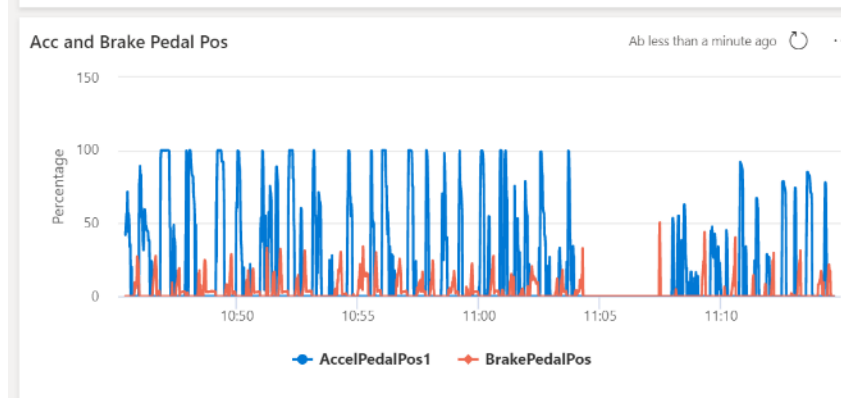
Vehicle speed



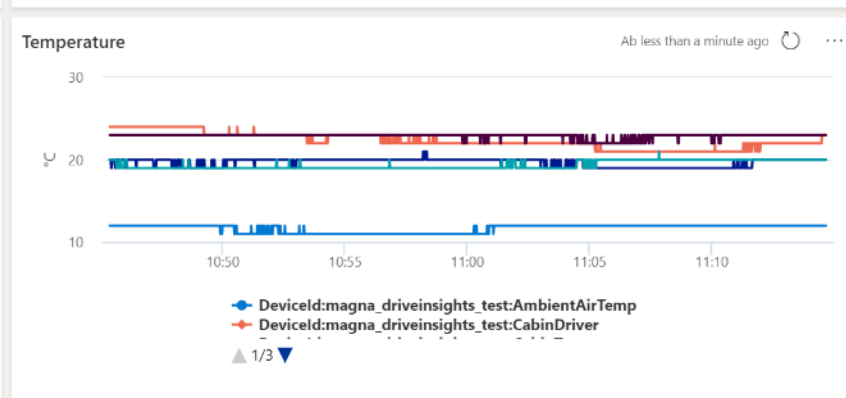
Energy consumption



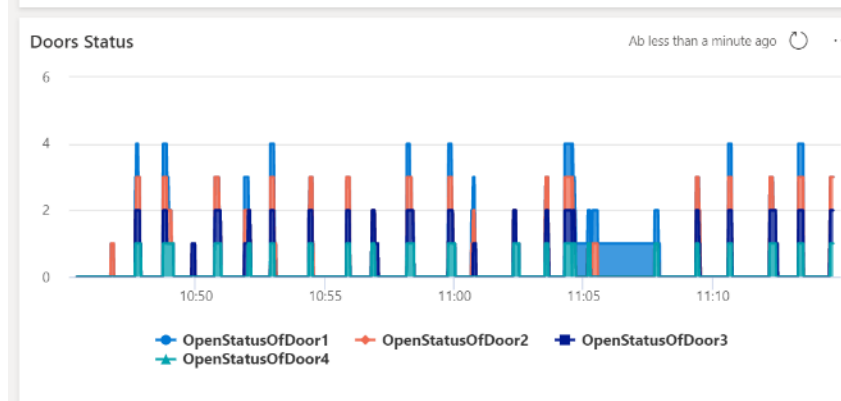
Accelerator and brake pedal position



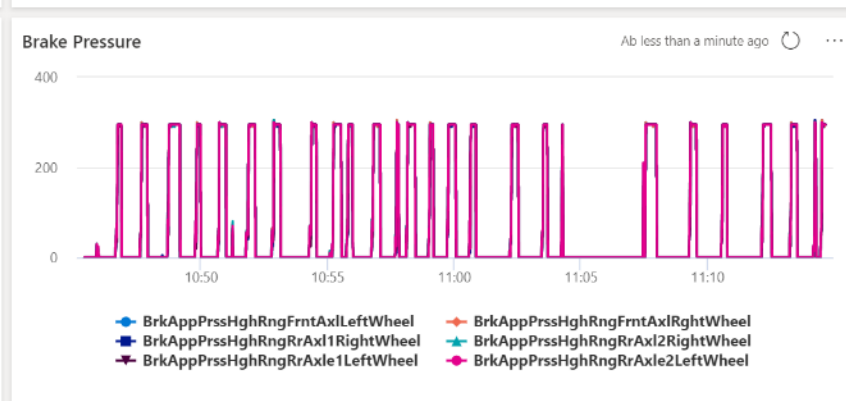
Ambient and interior temperatures



Doors status



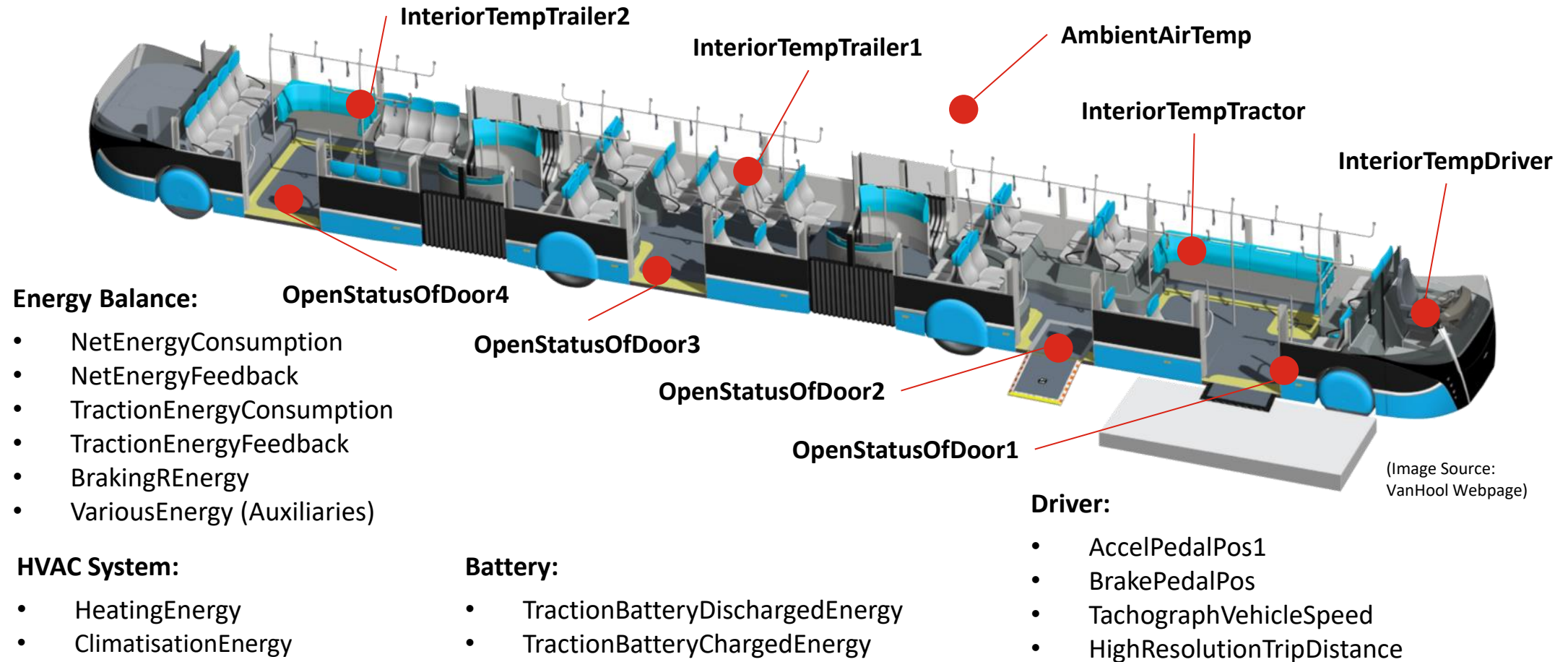
Brake pressure





Analyze & Derive Improvements

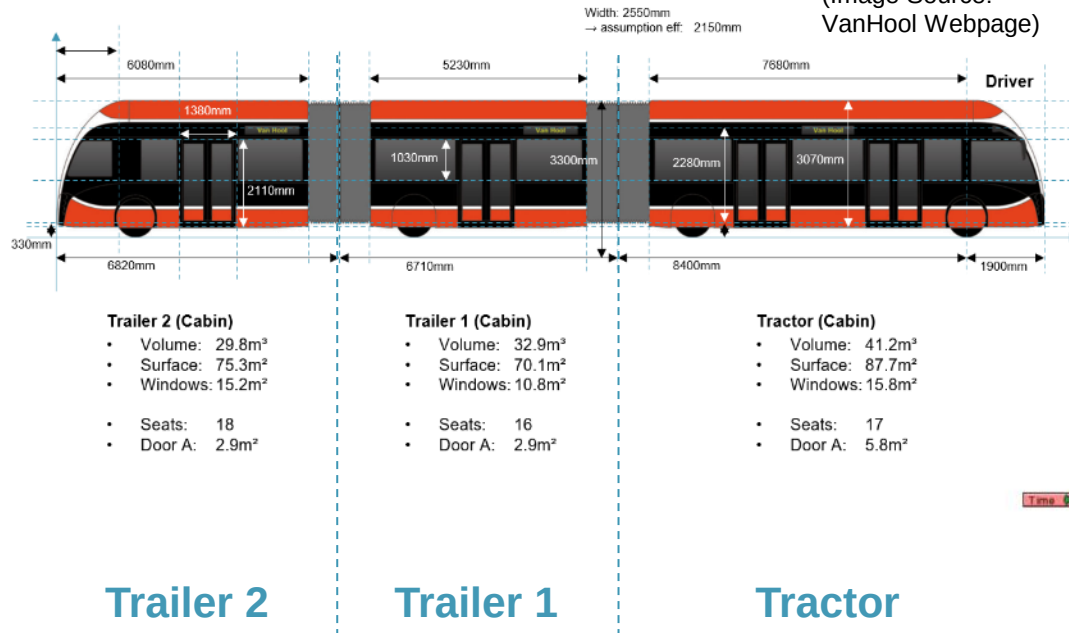
Currently Available Sensor Data



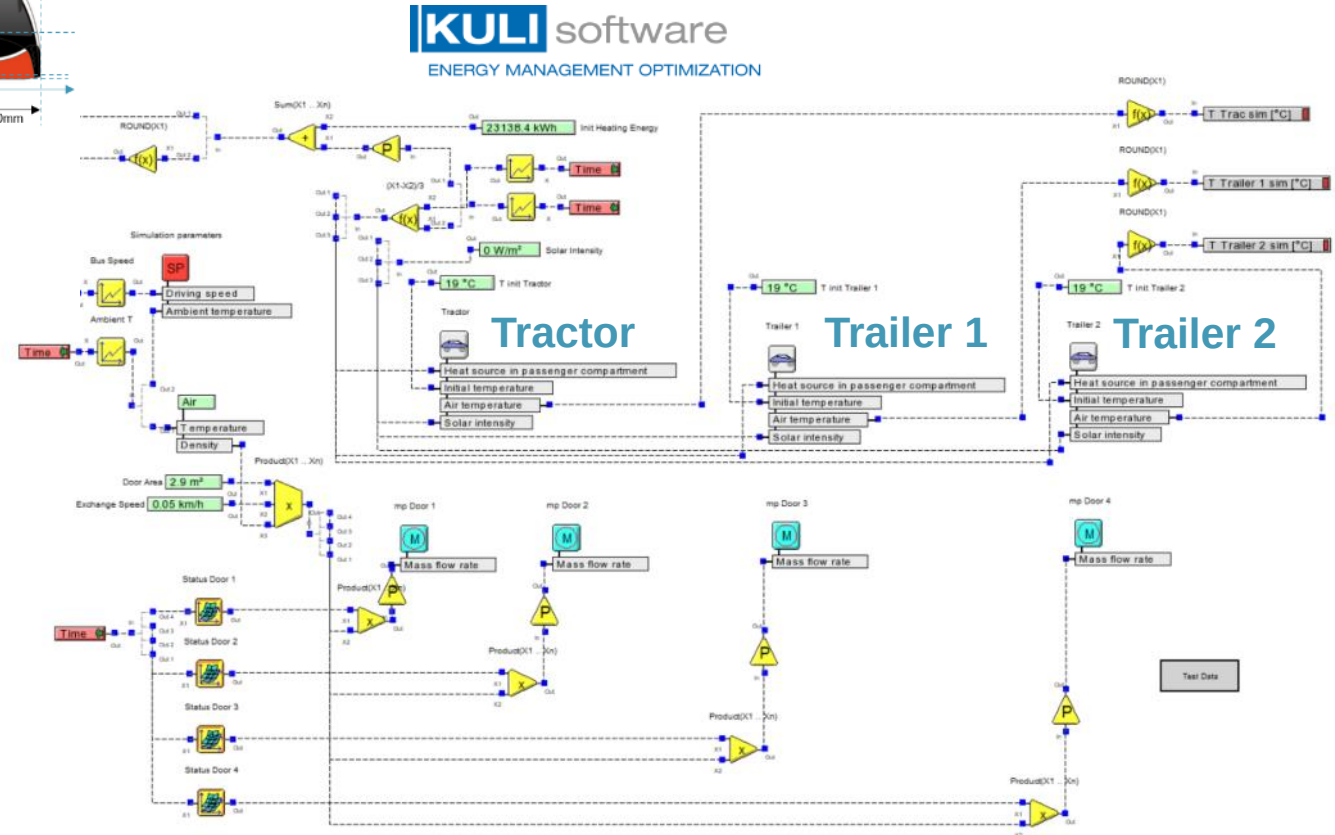
Thermal Modelling Approach

Technical Data

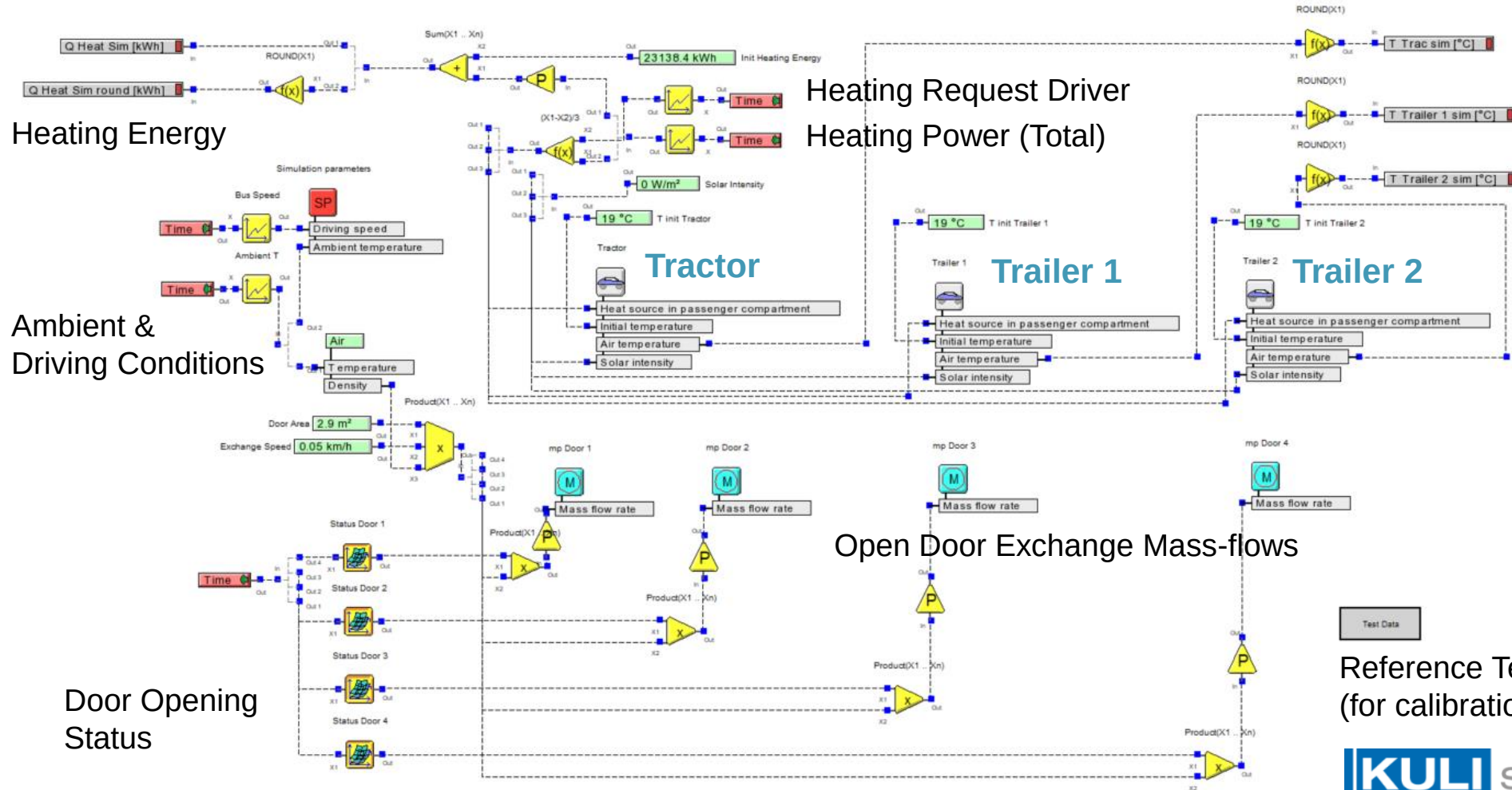
(Image Source:
VanHool Webpage)



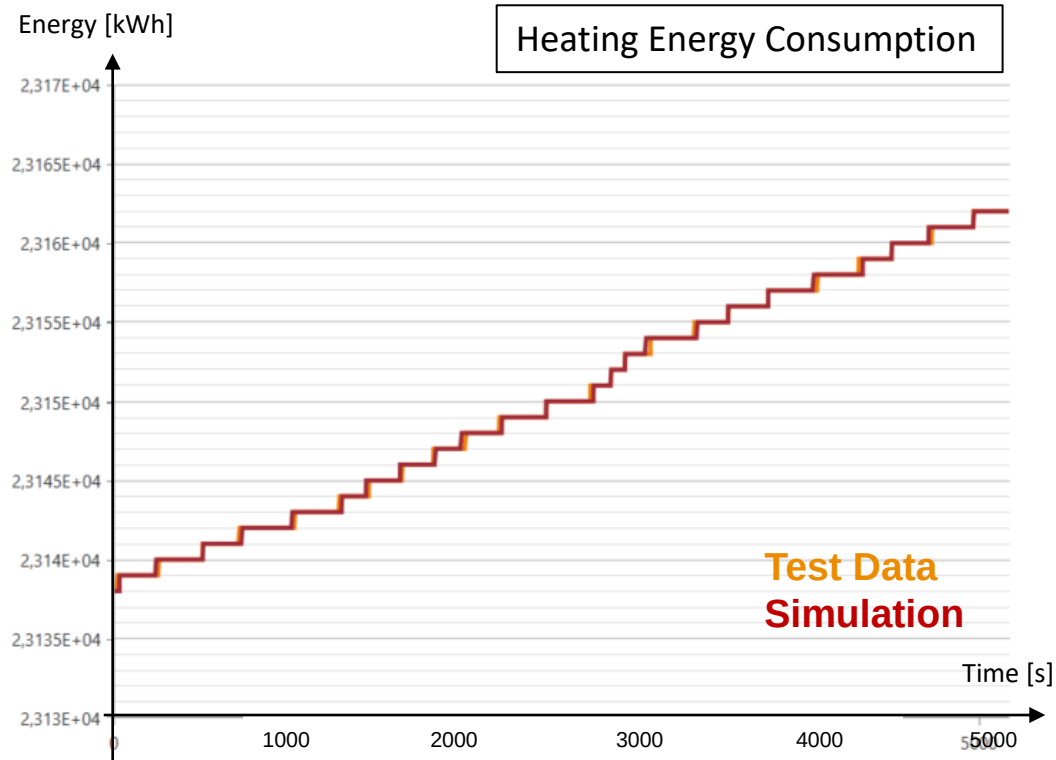
3x KULI simple
cabin model



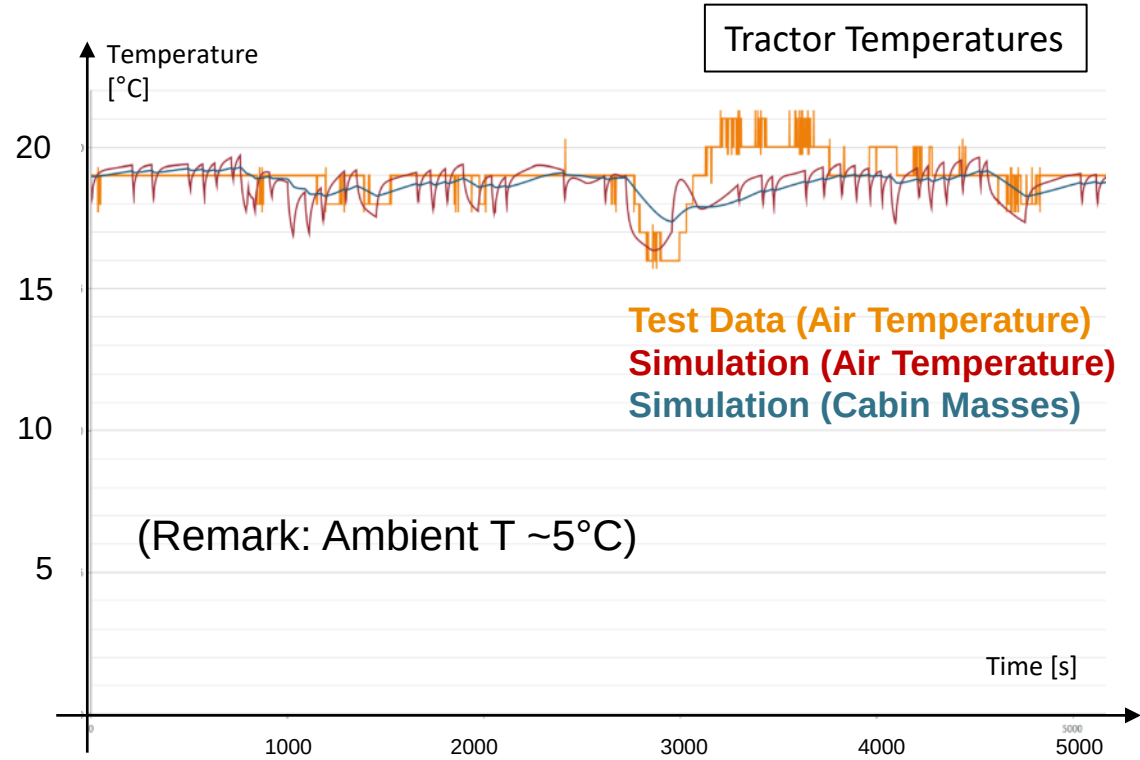
Thermal Model (Details)



Calibration Results (Live Cycle Data)

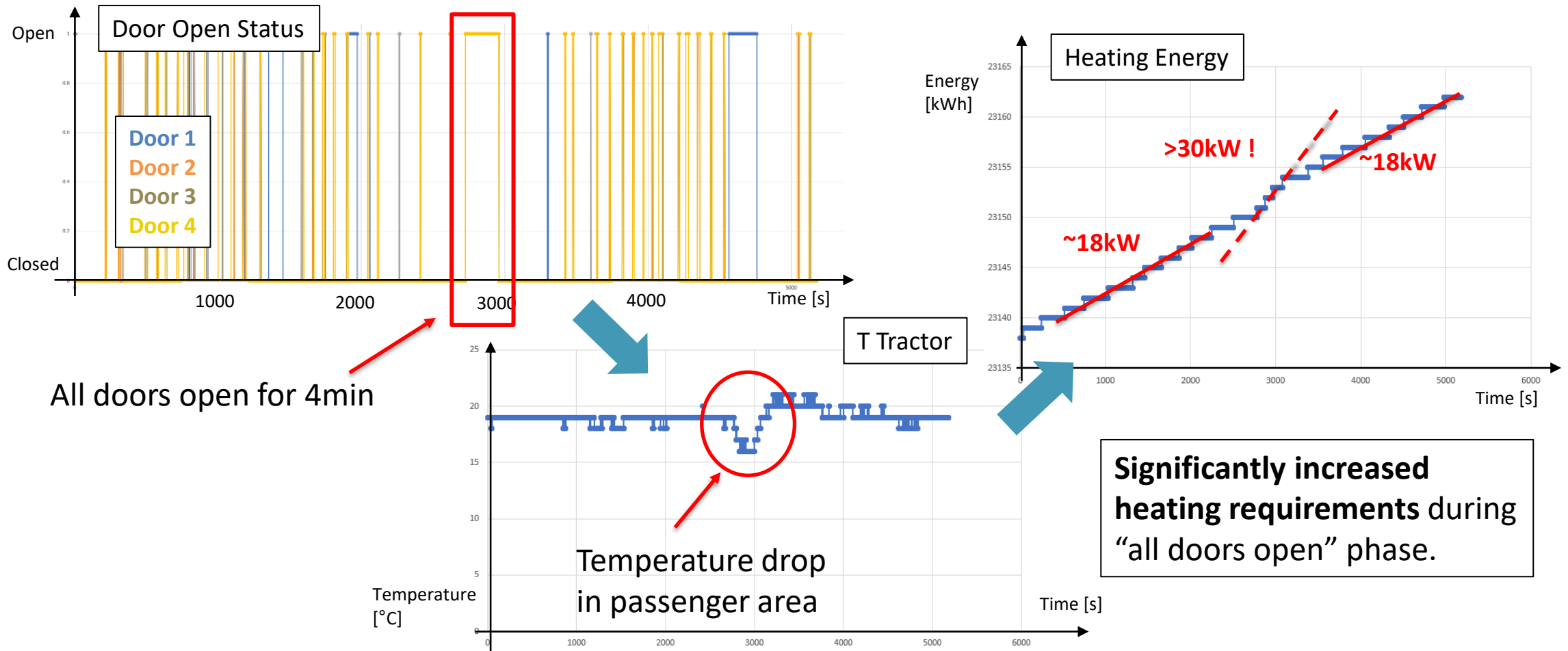


- Good match of heating power
- Challenge: Low resolution sensor data

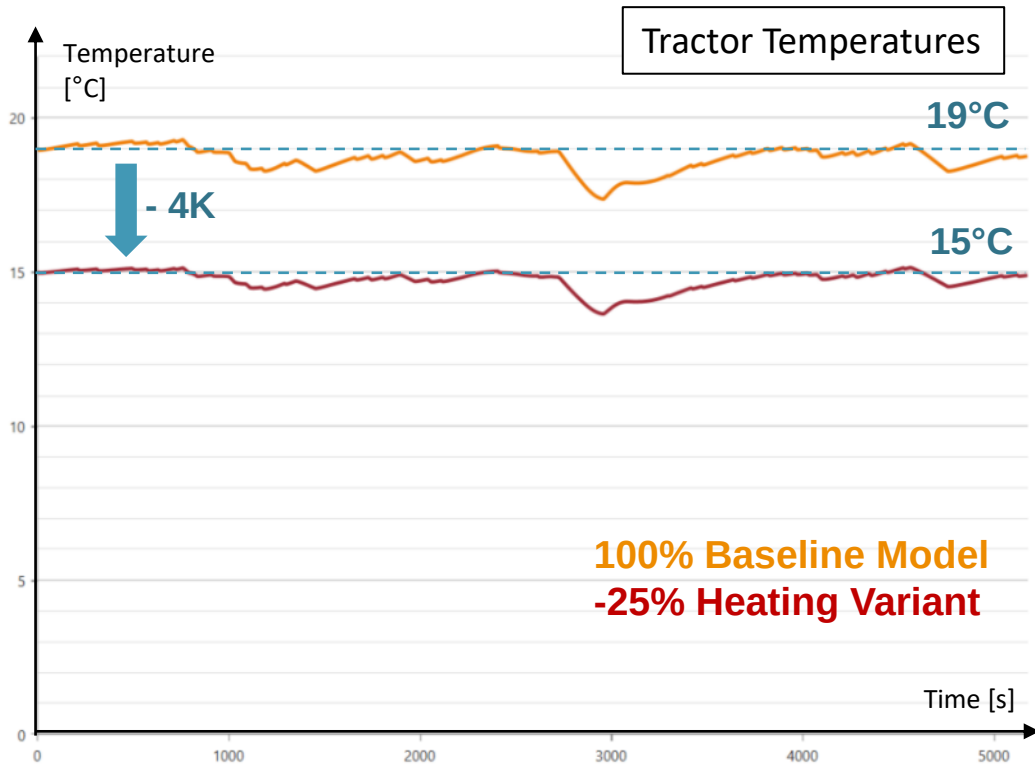


- Good match of temperature levels
- Challenge: Low resolution sensor data
- Challenge: Sensor position leads to **latency**
- Challenge: Impact of **passengers**

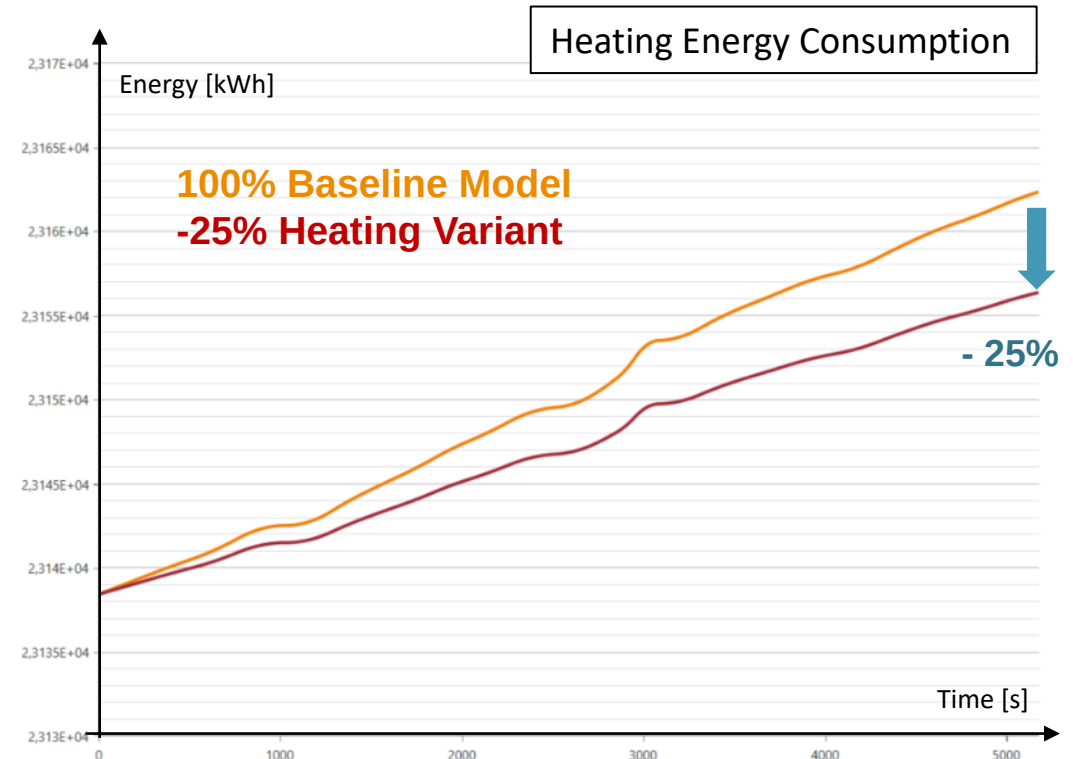
Analysis: Door-Opening Effects



Improvements: Energy Saving Potentials



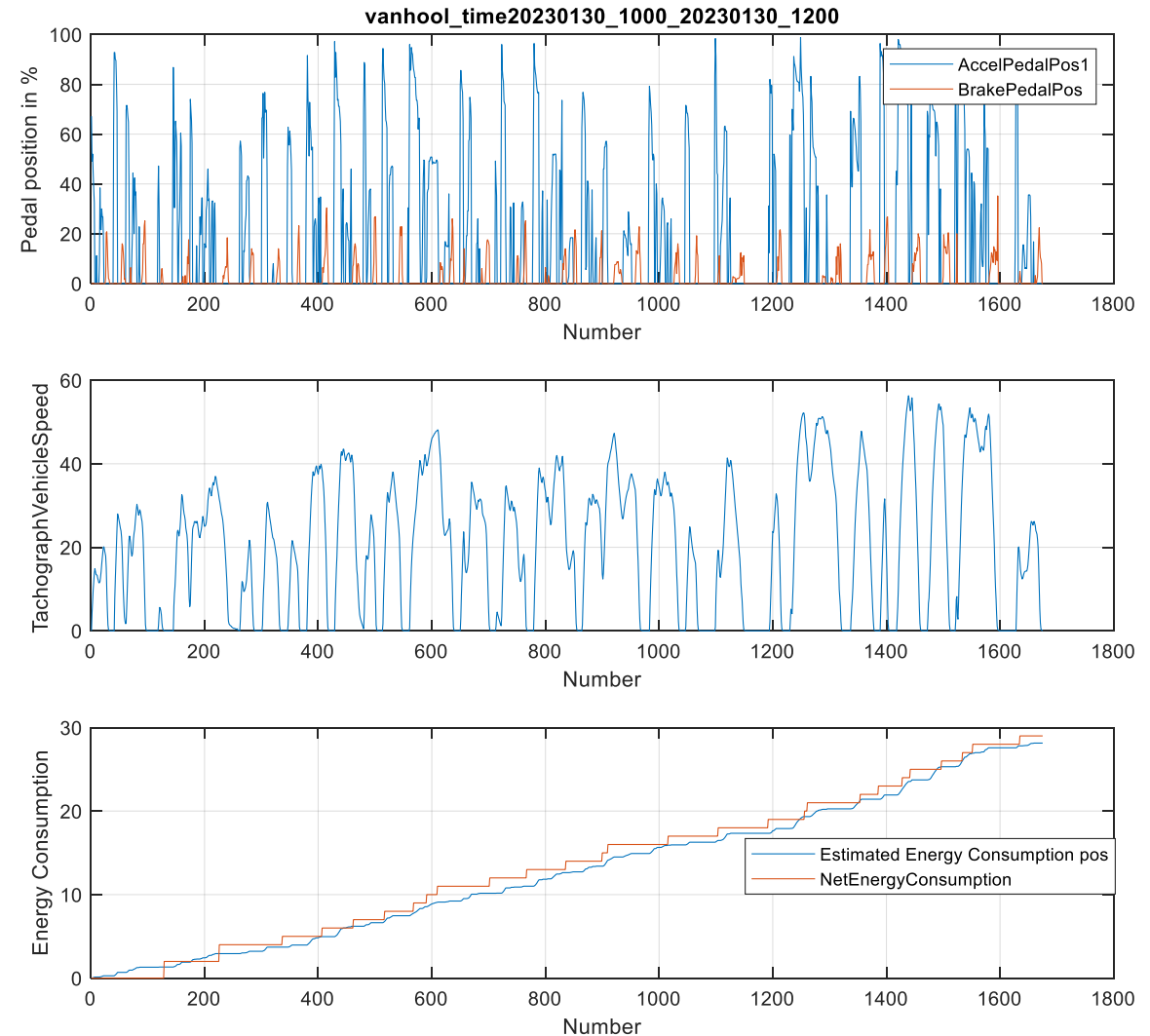
- 25% reduction of heating energy leads to
- 4K lower cabin temperature (15°C)



This means **~10% total energy savings**
(actual benefit for investigated standard cycle operation)

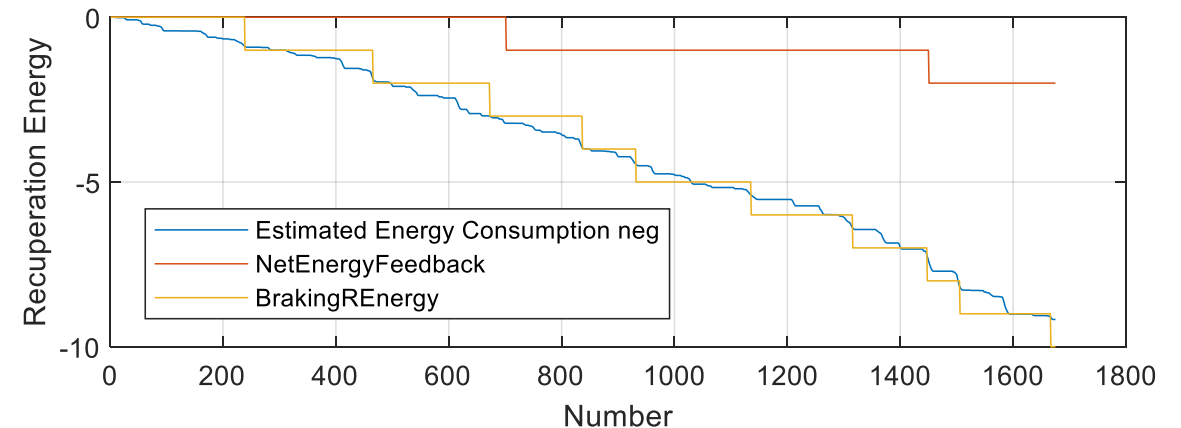
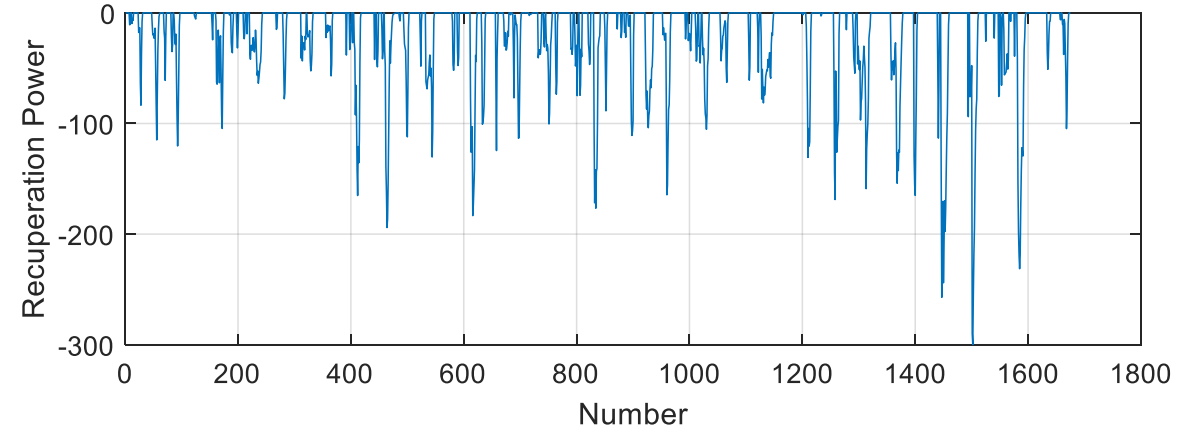
Powertrain Modelling

- Scenario
 - 50 passengers → 4000 kg load
 - Energy demand modelling based on speed profile and derivation of speed
- Input
 - Pedal positions
 - Vehicle speed
- Goal
 - Powertrain model validation



Powertrain: Recuperation

- Model
 - Recuperation power estimation
 - Driving resistance calculation
- Results
 - Potential of $\sim 9\text{kWh}$ for recuperation energy
 - Overhead electrical supply can only take 2kWh



Improvements: Optimization Potential

- Brake energy utilization
 - ~ 75% of brake energy cannot be fed into overhead power supply
 - Use onboard battery for recuperation
 - Adapt charging strategy and battery size
- Driver training
 - Analysis of driving behavior and train for adaption to bus characteristics
 - Live view of energy consumption and improvement potential
 - Transparent cause-effect analysis during driving



Outlook & Next Steps

Future Potential

- Improve efficiency with real-time monitoring to
 - optimize routes
 - promote energy efficiency
 - reduce carbon emissions
 - prevent breakdowns and
 - reduce maintenance costs
- Reduce cost: Cloud-based data analysis is more cost-effective compared to traditional on-premise methods
- Enhance safety by detecting unsafe driving practices to reduce accidents
- Contribute to smart mobility initiatives, improve public transportation efficiency, sustainability and user experience
- Governments mandate telematics devices to monitor and report on public transportation vehicle performance