

# MINDED

Thermal and energy **M**anagement for **I**ncreased  
**D**riving range of an **E**lectric minibus including  
improved user-centric **D**esign and thermal comfort

# Overall project presentation

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## General Project Information

- HORIZON-CL5-2023-D5-01-01: **User-centric design and operation of EV for optimised energy efficiency (2ZERO Partnership)**
- Grant agreement number: **101138202**
- Maximum grant amount: **4,999,301.25 EUR**
- Project duration: **01/2024 – 12/2026**

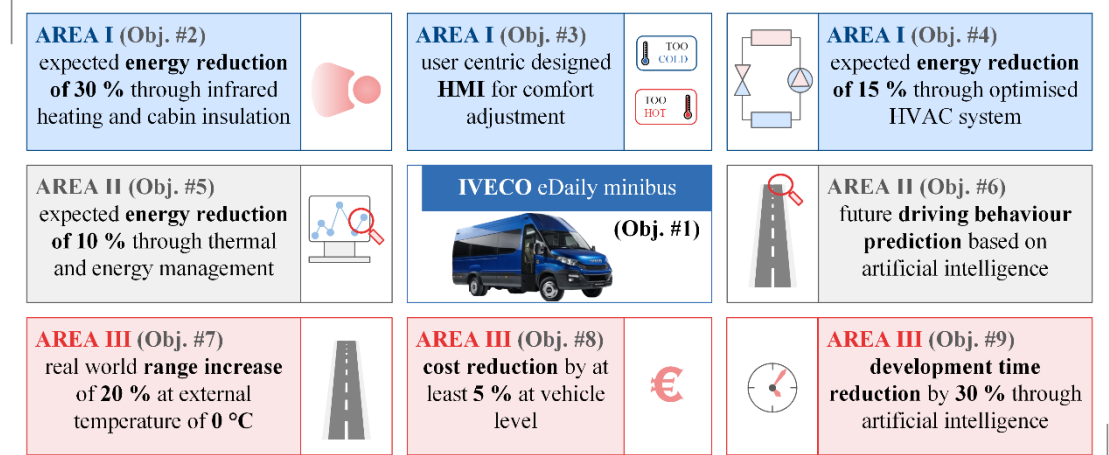


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## Objectives

- The **objective** of MINDED is to deliver a **battery-electric, zero-emission** IVECO eDaily **minibus with 20 % improved range at 0 °C** against the 2023 baseline
- A **highly efficient heating system** based on infrared heating panels, controlled by an optimised thermal and energy management strategy, and supported by an innovative human-machine interface will be implemented and **demonstrated on a chassis dynamometer at 0 °C** ambient temperature at TRL 7
- An **optimised air conditioning system in heat pump mode**, with innovative oil-free centrifugal e-compressor with gas bearing technology will be implemented and **demonstrated on the ThermoLab testbed** under various operating conditions at TRL 6



# Results presentation

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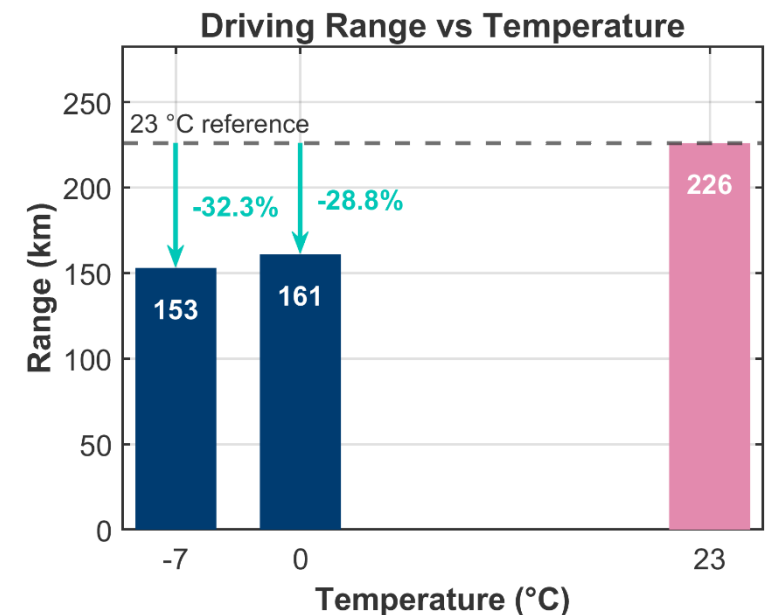


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## Baseline measurement

- **Instrumentation of vehicle** with sensors
- **Measurements** on climatised **Dynamometer** for baseline determination and model parametrisation at **-7, 0 and 23 °C**
- Empty vehicle (no passengers), driver present only
- WLTP class 2 with capped speed at 85 km/h
- **Driving range** is **reduced by** approx. **one third** at low ambient temperatures due to needed heating power
- **Heating system** consumes about **23 %** of energy used

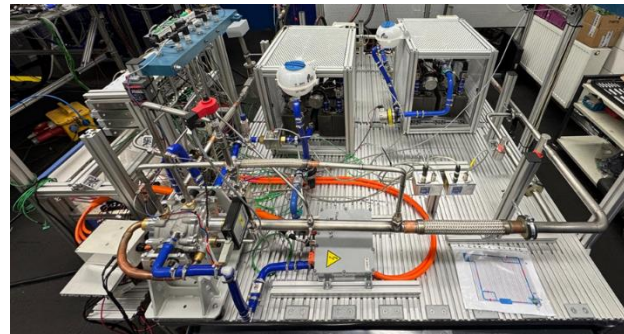
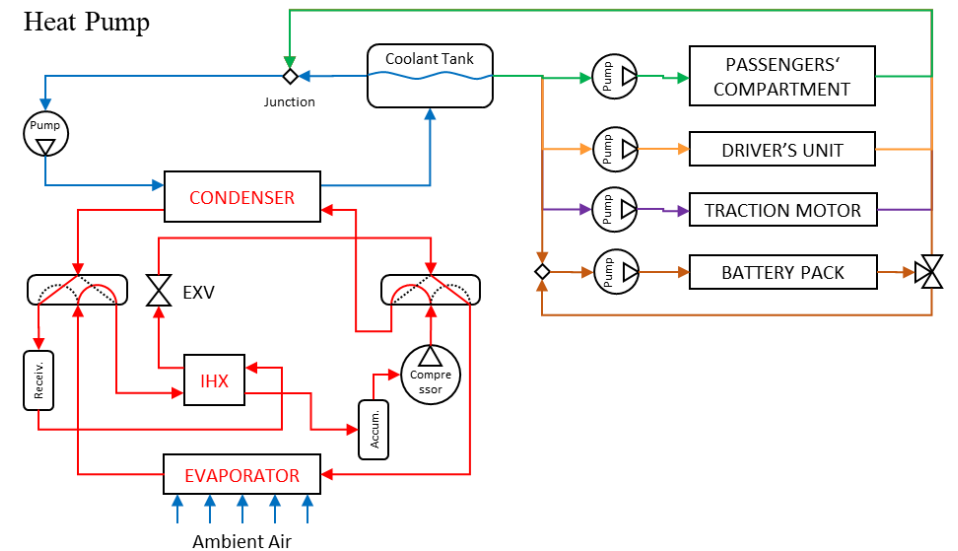
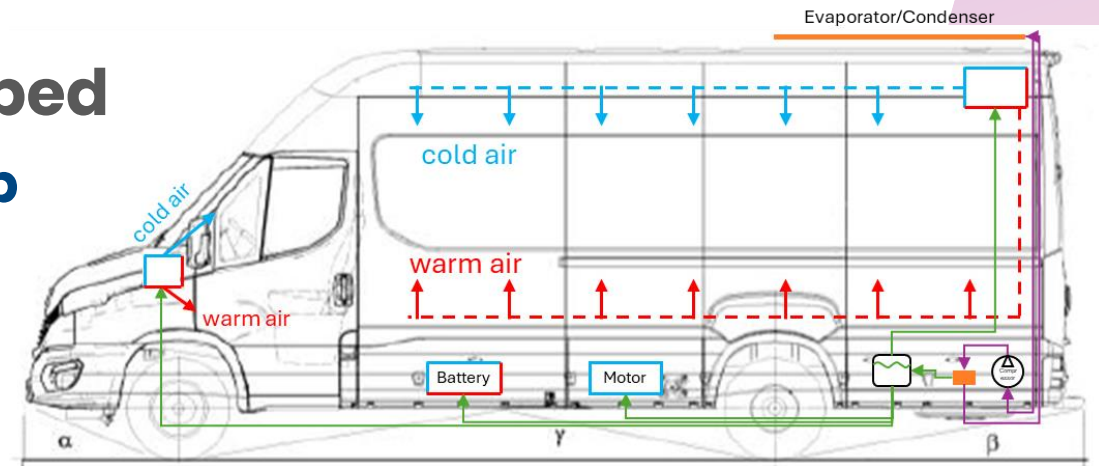


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## Heat pump system / ThermoLab testbed

- Development of **AC System with heat pump functionality** at  $-7$  and  $0$  °C
- Baseline vehicle has 3 PTC elements (5 kW each) plus one air PTC (1 kW) → **heating capacity** of heat pump has to cover **~16 kW**
- Simulation shows a **reduction** of heating power by **up to 50 %**
- Test of system on **ThermoLab testbed**

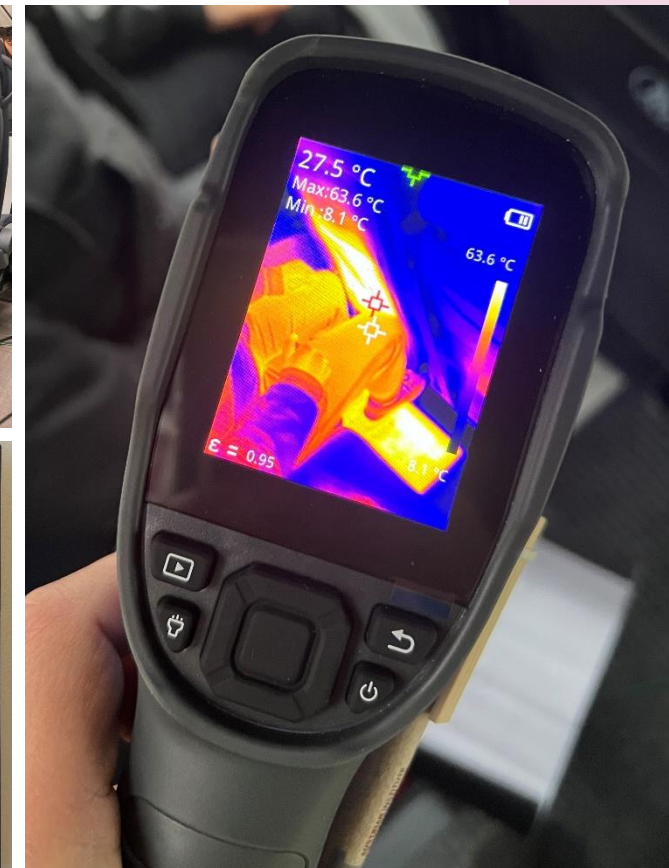
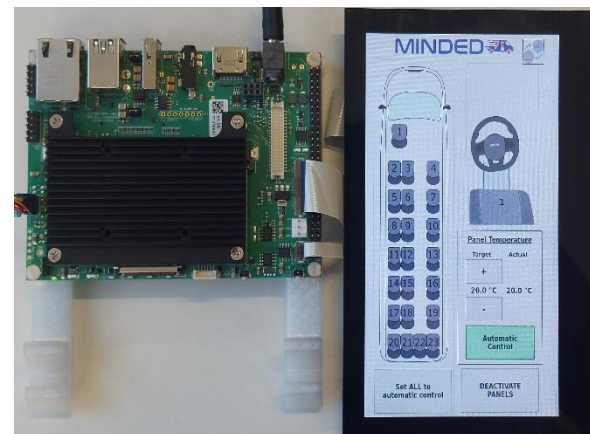


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## IR Panels and HMI

- Integration of **IR heating panels** on backrests and floor
- Development of **power electronics and temperature control** of IR panels
- Implementation of **human-machine interface** for driver and passengers
- IR panels **accelerate cabin warm-up** and **improve passenger comfort** by reducing cold surfaces

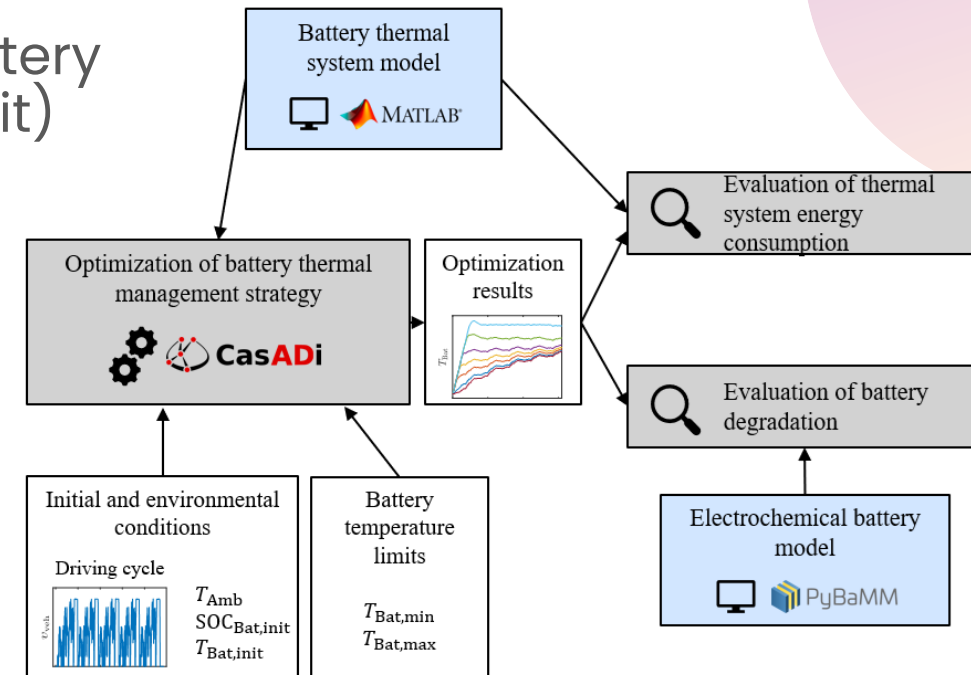


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## Powertrain and battery control strategy

- Development of **control-oriented models** for battery and powertrain (electrical, thermal, coolant circuit)
- Optimization of battery energy and **thermal management strategy** for the 0 °C scenario
- Evaluation of battery **aging and degradation**
- Results show a **possible reduction of 1.06 kWh** in energy consumption of battery thermal system
- This reduces auxiliary energy use without compromising battery lifetime

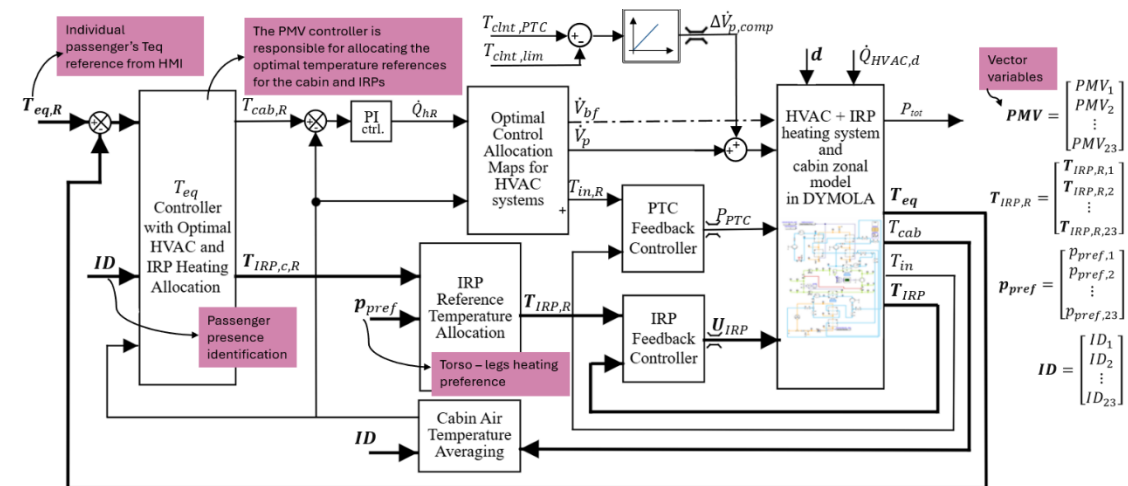


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## Optimised Energy- and Thermal Management Strategy

- Hybrid **cabin heating** implemented, combining PTC-based **convective air heating** with **localised infrared panels**
- **Nonlinear model predictive control architecture** coordinating HVAC and IRPs
- **Equivalent-temperature-based comfort control** applied at seat and body-zone level
- HVAC energy consumption **reduced by ~12 % during heat-up**
- Neutral **thermal comfort** achieved **significantly faster**, enabling lower cabin air temperature setpoints



# Mid to long term expected impacts of the project

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## Technological and Scientific Impacts

- Infrared heating panels, improved cabin insulation, a user-centric HMI and an optimised heat-pump HVAC system **reduce the cabin heating demand** by **20 %**, **lower auxiliary energy consumption** by **11.2 % at 0 °C**, and **reduce HVAC cooling demand** by **15 %**.
- Validated digital-twin models and AI-based driving behaviour prediction enable predictive thermal and energy management, targeting an additional **10 % reduction in overall energy demand** while maintaining passenger comfort.
- All developments enable a **20 % real-world driving range increase at 0 °C**, a vehicle-level **cost-reduction potential** of at least **5 %**, and a **30 % reduction in development time** through digital and AI-assisted design workflows.

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## Societal Impact, Long-Term Benefits, and Outlook

- By improving comfort, range and reliability, MINDED **increases user acceptance of electric public transport**. Intuitive HMIs, full-scale vehicle demonstration and targeted dissemination and exploitation activities support **faster market uptake** of zero-emission minibuses.
- At scale, the replacement of conventional vehicles enables an estimated **reduction of ~2.2 million tCO<sub>2</sub>e between 2028 and 2035**, together with improved urban air quality. This contributes to **EU climate-neutrality targets**.
- Beyond the project, MINDED provides quantified evidence to support **comfort-aware efficiency assessment** in future EU vehicle frameworks. It also identifies future research needs, including multi-zone comfort control for high-occupancy vehicles, closer integration of thermal management with route, weather and charging prediction.



#RTR2026

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