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Thermal Management Systems Symposium

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October 14-15, 2025 | Ypsilanti, Michigan

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Next generation electric truck cabin and HVAC prototype with innovative type of thermal measures

Imre Gellai, Milan Kardos, Mirza Popovac, Simic Dragan

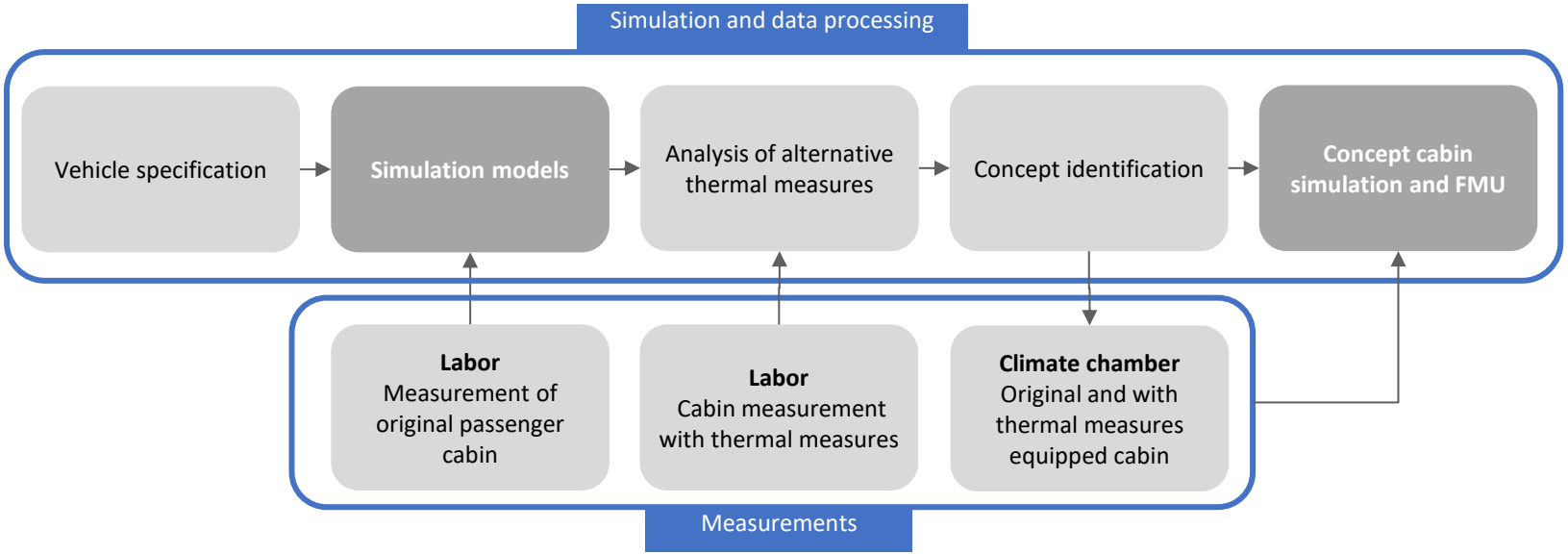
Overview

- Introduction
- Goal
  - Boost comfort & cut energy use in electric truck cabins
- Solutions
  - Insulation, heat exchanger, heating panels
- Measurement
  - Lab (technical) + Climate chamber (comfort)
- Result
- Conclusion

Introduction

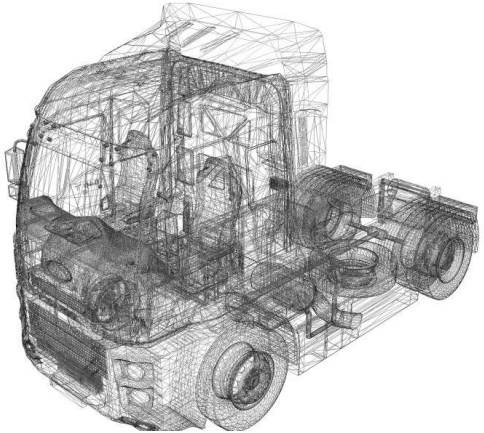
- NextETruck European project: Develops next-gen e-mobility concepts for medium freight haulage.
- Goal: Demonstrate zero-emission vehicles and ecosystems, decarbonize vehicle fleets.
- The study highlights an electric truck prototype with novel thermal measures
- Our aim is to set the standard for sustainable transportation solutions.
- https://nextetruck.eu/

AIT's Role in the NextETruck Project



Truck

- Project consortium with Ford OTOSAN
- Truck: Ford Cargo 1846T
- Conventional truck cabin as the starting point
- Most of the data is sensitive
- Physical cabin and HVAC data are available

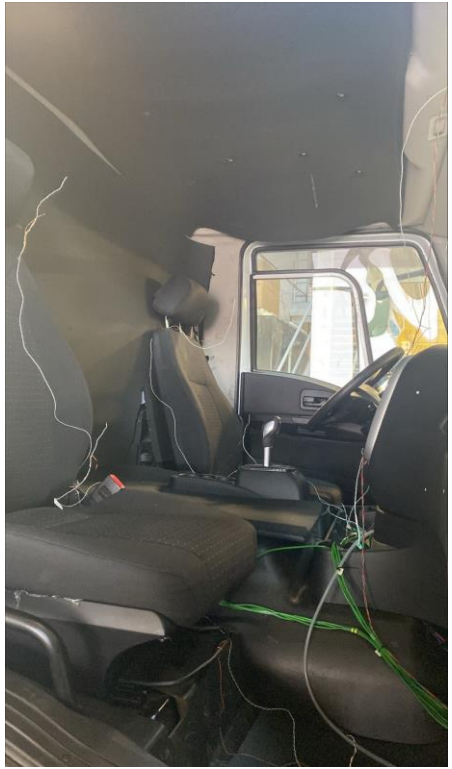


CAD model of Ford Cargo 1846T

Electric Ford Cargo 1846T

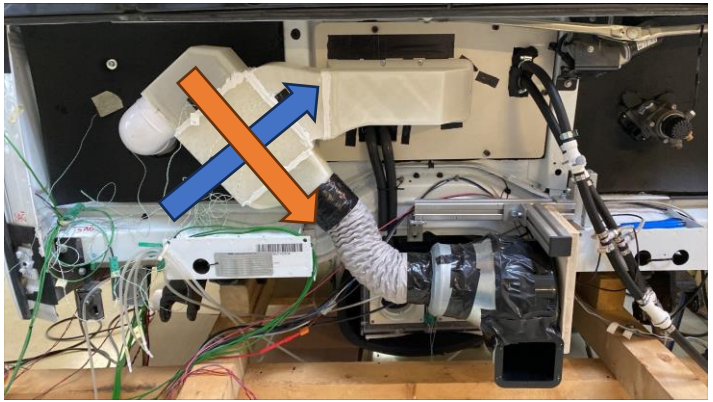
Thermal measure 1 - Thermal insulation

- Goal: Reduce thermal conductivity
- Material: Armacell 230-0015 (25mm)
  - Armaflex ACE, Self-AdhesiveEuro Class D-s3, d0 | λ = 0.036 W/m·K
- Windows: Not insulated
- Applied Areas:
  - Front Panels (L/R), Headliner, Back Panel
  - Mid Bottom Panel, Floor (L/R), Doors (L/R)



Thermal measure 2 – Air to air heat exchanger

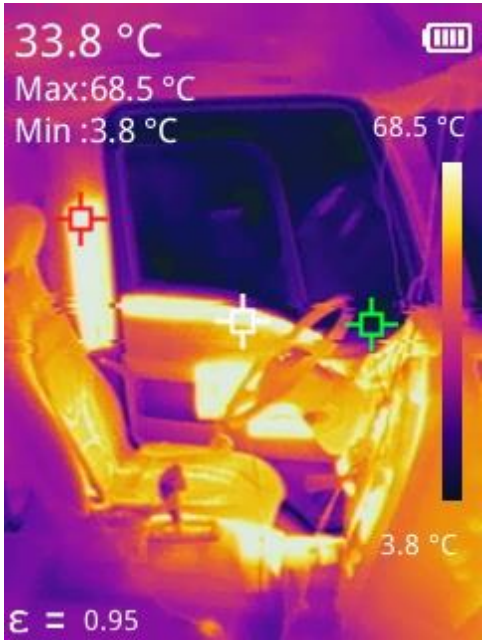
- Goal: Reduce outlet air heat loss
- Approach: Tested various heat exchanger designs
  - Top Figure: Conventional HEXA unit
  - Bottom Figure: 3D-printed compact heat exchanger with TPMS geometry (used for measurements)
- Exhaust: Additional ventilation was integrated



Dvorak, D.; Kardos, M.; Gellai, I.; Šimić, D. Experimental Performance Investigation of an Air–Air Heat Exchanger and Improved Insulation for Electric Truck Cabins. World Electr. Veh. J. 2025, 16, 129. https://doi.org/10.3390/wevj16030129

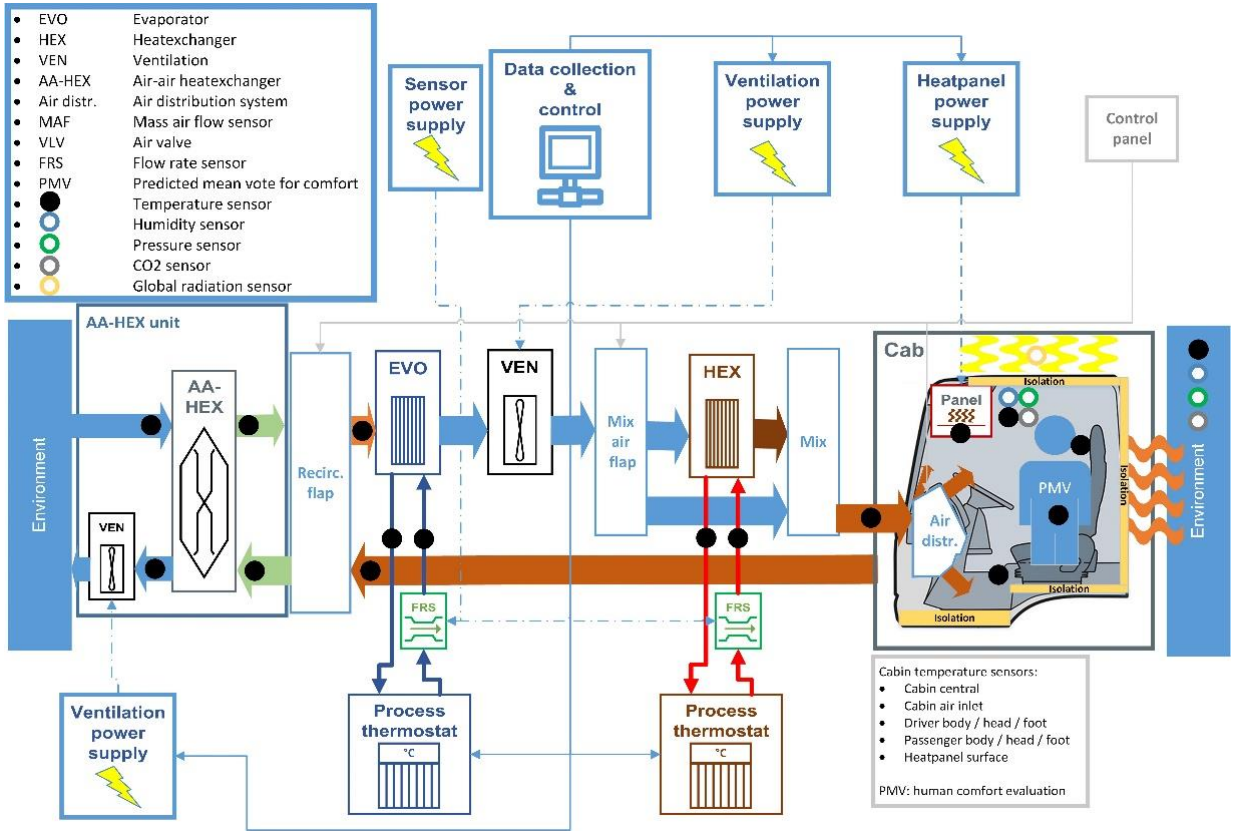
Thermal measure 3 – Heating panels

- Heating Panels for Efficient Cabin Comfort
  - Enabled comfort at lower cabin temperatures
  - Reduced energy needed for cabin heating
  - Helped reach comfort level faster
- Installed around passenger area
  - Surface temperature: 50–70 °C (thermal camera)
  - Soft outer layer prevents burning sensation



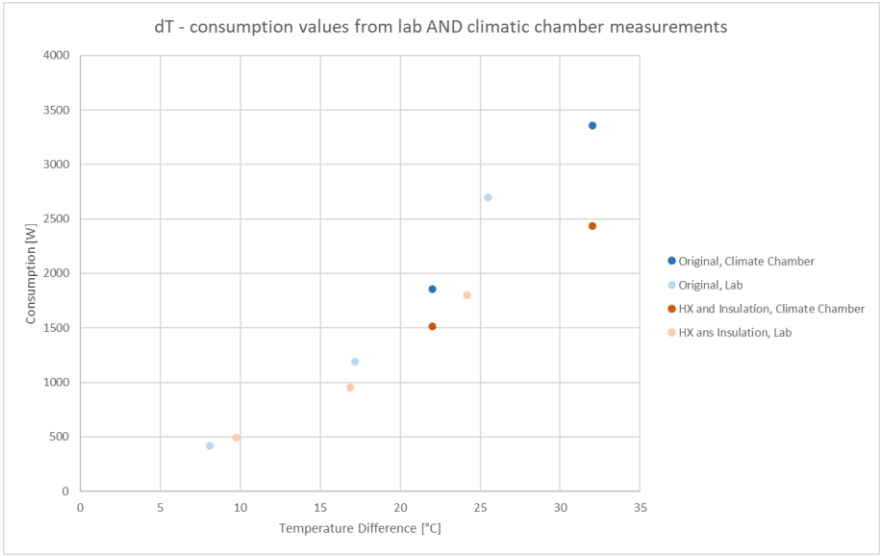
Numerical analysis of the energy efficiency measures for improving the truck cabin thermal performance. (2024). *Engineering Modelling, Analysis and Simulation*, *2*(1). https://doi.org/10.59972/tmsa26ss

Measurement - Overview



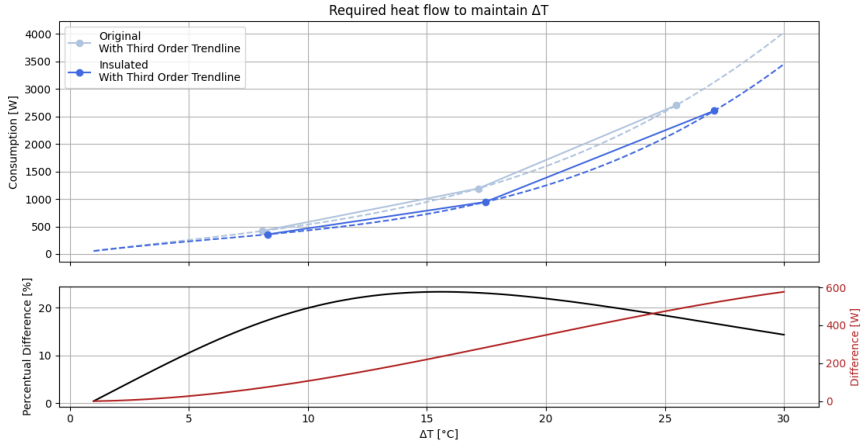
Measurement – Labor and climate chamber

- Lab Tests:
  - Focus on technical performance (insulation, heat exchanger)
  - Cabin interior was heated to create temperate differences
  - Used for setup selection
- Climate Chamber Tests:
  - Simulate real-world conditions with people
  - Use colder, realistic temperatures
  - Validate comfort and overall system performance



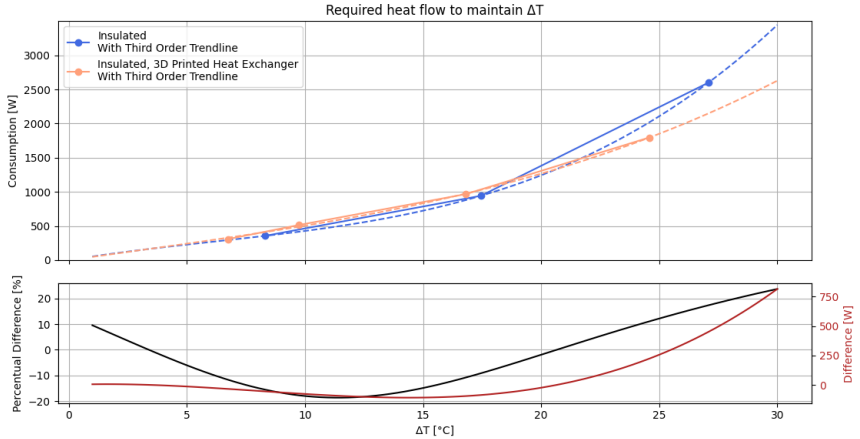
Results – Effect insulation

- Graph compares original cabin vs. insulated case
- Insulated cabin performed better:
  - ~100 W (20%) reduction at +10 °C
  - ~480 W (18%) reduction at +25 °C



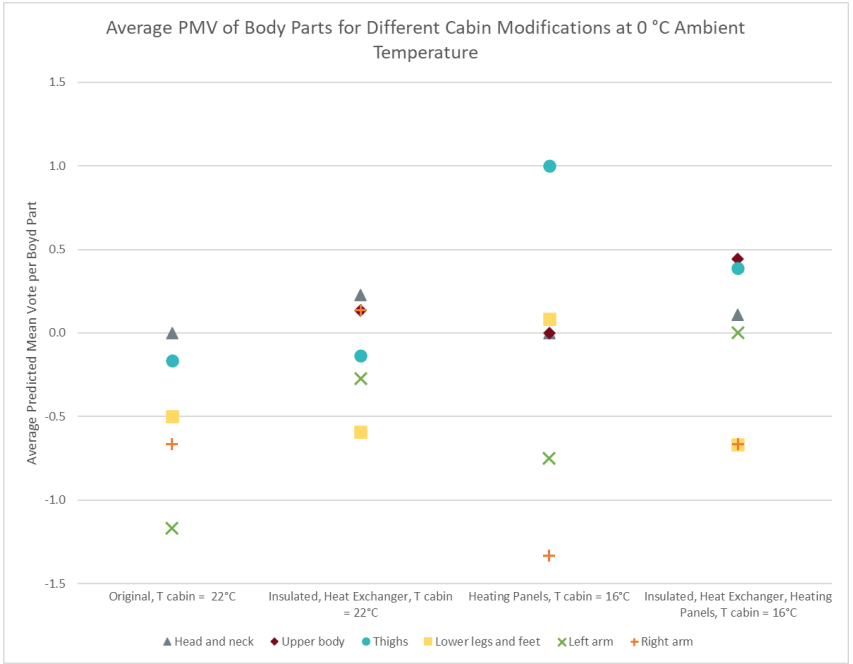
Results – Effect heat exchanger

- Heat Exchanger Comparison
  - 3D-printed unit (compact design)
  - After ΔT > 15 °C, performance drops due to higher heating air demand
  - HEXA performs slightly better but 3D-printed chosen for size and easy integration
  - Performance did not meet expectations



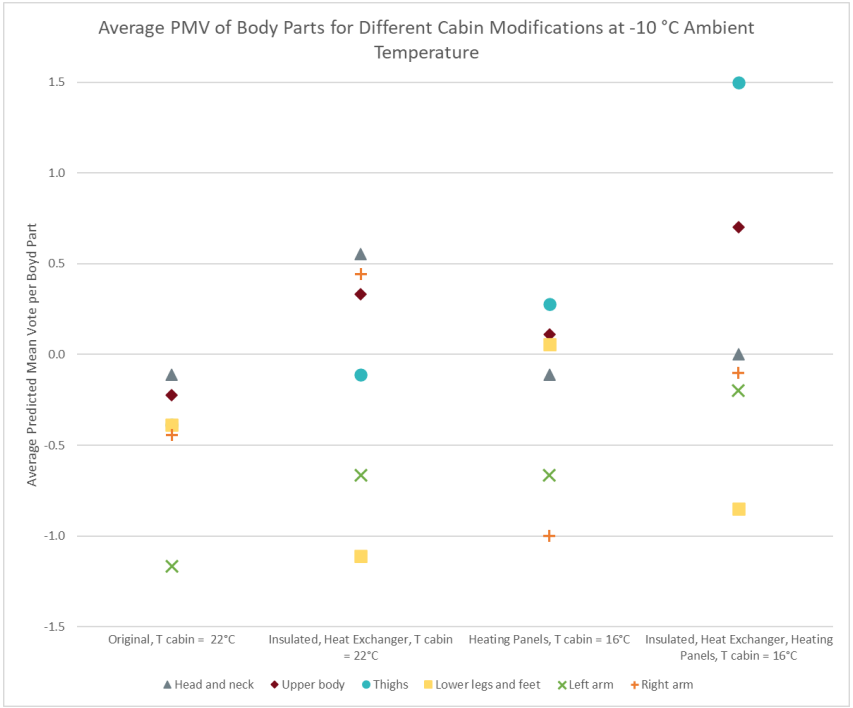
Results – Comfort measurement

- Climate Chamber Comfort Test (with Participants)
  - Goal: Assess if heating panels provide similar comfort at 16 °C vs. 22 °C cabin temperature
  - Method:
    - Participants rated comfort after 10 minutes
    - Scale: –3 (cold) to +3 (hot) for each body part
  - Result at 0°C and -10 °C
    - With Insulation + Heat Exchanger
    - Comfort ratings centered closer to neutral (0).



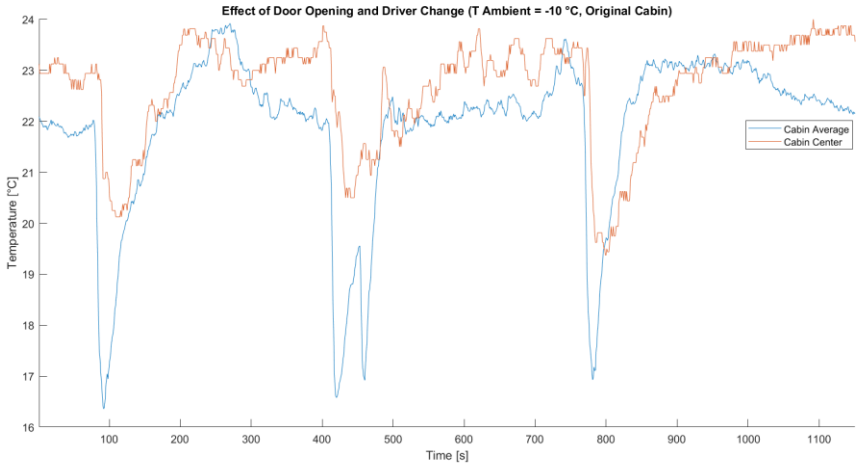
Results – Effect heating panels

- Heating Panels & Seat Heating
  - Air temperature reduced to 16°C while maintaining comfort.
  - Some discomfort due to uneven heat distribution (e.g., cold right arm).
  - Cabin temperature can be lowered without sacrificing comfort if localized heating (panels + seat) is used.
  - Challenges include:
    - Vertical temp differences
    - Overheating from seat heaters
- Conclusion
  - Optimized surface heating can match the comfort of a 22°C cabin at just 16°C.



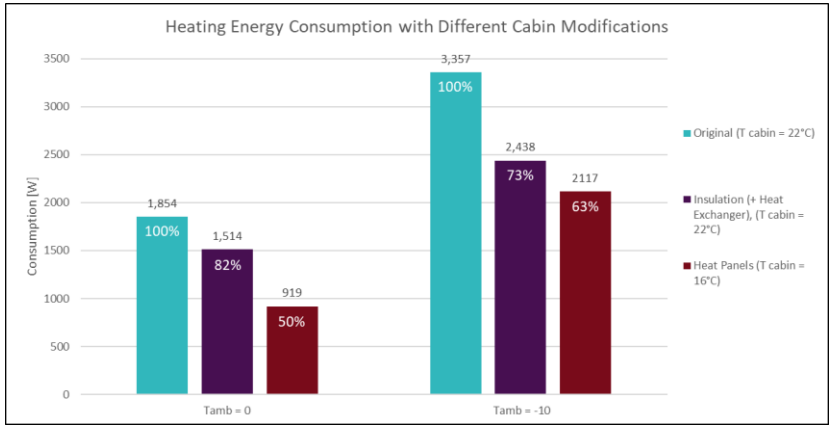
Results – Door opening

- Effect of Door Opening
  - The impact of door opening was also investigated
  - Relevant for short and medium freight trucks
  - Typical temperature drop: 3–5 °C inside the cabin
  - Recovery time: Temperature returns to normal within 2 minutes



Results – Original and best case

- Energy Consumption Reduction – Compared to Original Setup
  - Case 1:
    - Insulation + Heat Exchanger–18% at 0 °C ambient
    - –27% at –10 °C ambient
  - Case 2:
    - Heating Panels (16 °C Cabin Temperature)
    - –50% at 0 °C ambient
    - –37% at –10 °C ambient
  - Conclusion:
    - Heating panels offer the largest reduction, especially effective when combined with insulation and lower cabin air temperature.



Conclusion

- **Heating panels** offer the highest potential for energy savings and improved comfort, particularly when used with thermal insulation and lower cabin air temperatures.
- **Insulation** is a key contributor to passive energy reduction, especially in colder climates.
- **Air-to-air heat exchangers**, while compact and integrable, show limited standalone effectiveness in this application.
- **Human comfort** measurement is critical to validating thermal measures beyond technical performance.

Conclusion

- The combined use of lab measurements and climate chamber tests supports an efficient, data-driven approach to HVAC optimization—laying the foundation for digital twin-based thermal system design.

ACKNOWLEDGMENT

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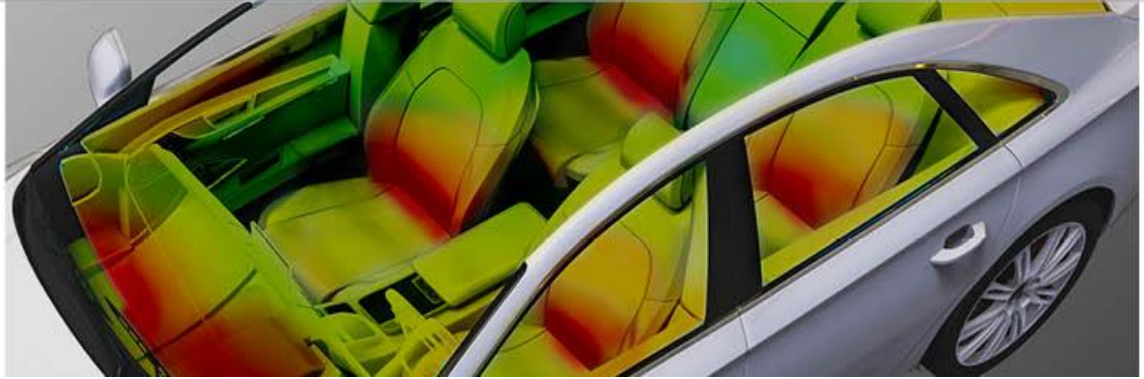

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Thank you for your attention!

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