TLK-Thermo GmbH

FAT | Forschungsvereinigung Automobiltechnik

The influence of heating and air conditioning systems on the cruising range of electric cars

12. Oktober 2011 – Dr. Christof Böttcher, Martin Konz

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  - Vehicle parameters
  - Modeling of internal space and AC system
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Introduction

Introducing the FAT

- FAT = Forschungsvereinigung Automobiltechnik
- Formation of the FAT in 1971
- Preparing and supporting research projects
- Community research program of the VDA manufacturers and subcontractors
- Publishing the results:
  - FAT-Series
  - FAT-Symposia and engineering conferences of the VDA
  - FAT-Webpage

Introduction

Motivation / Goals of the study

Motivation

- Cruising range is highly impacted due to the relatively low energy density of electric storage systems in electric vehicles
- Heating and air conditioning systems need to meet new requirements

Goals

- Evaluation and Analysis of heating and air conditioning concepts
- Development of new concepts

Methodological approach

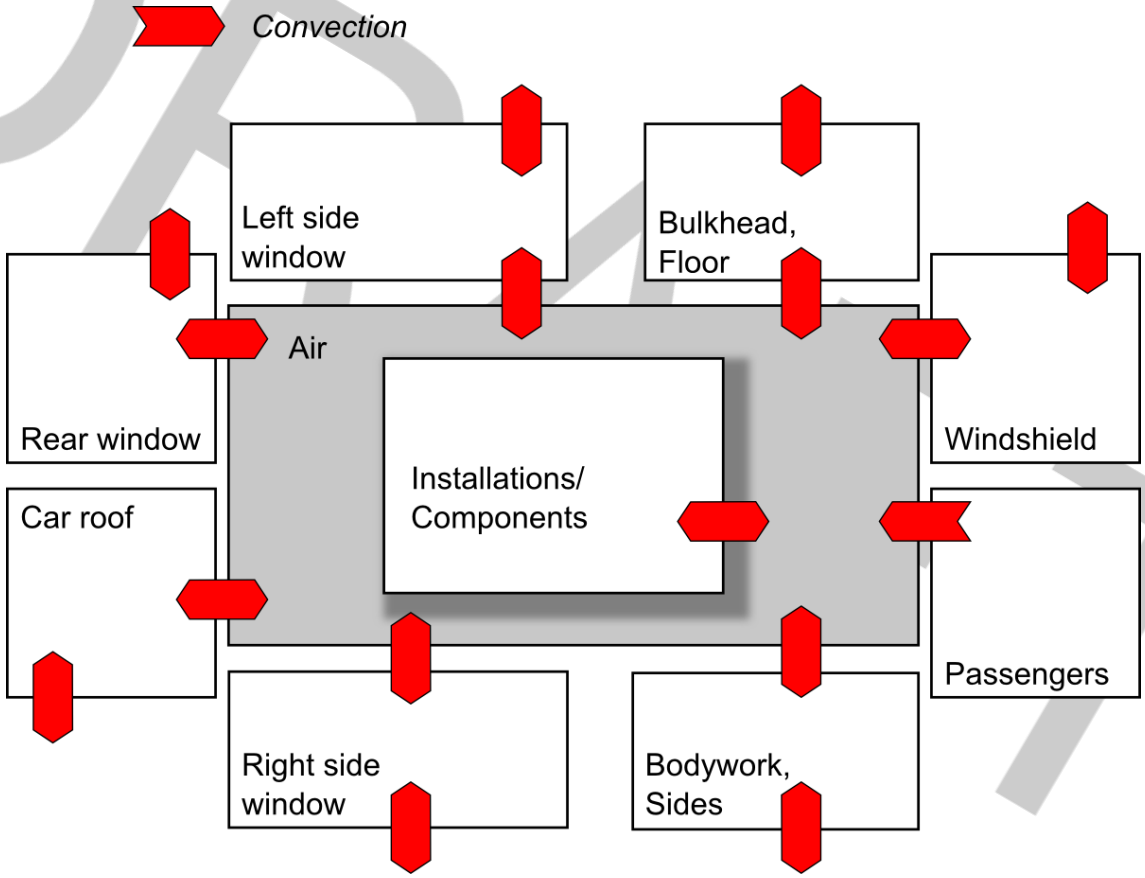
Vehicle parameters

The FAT working group „AC systems“ defined an electric vehicle with 4 seats („Golf-class“) and the following parameters:

- **Driving power:** **80 kW**
- **Vehicle weight:** **1600 kg**
- **v_{max}:** **160 km/h**
- **Cruising range:** **190 km**
- **Battery capacity:** **30 kWh**

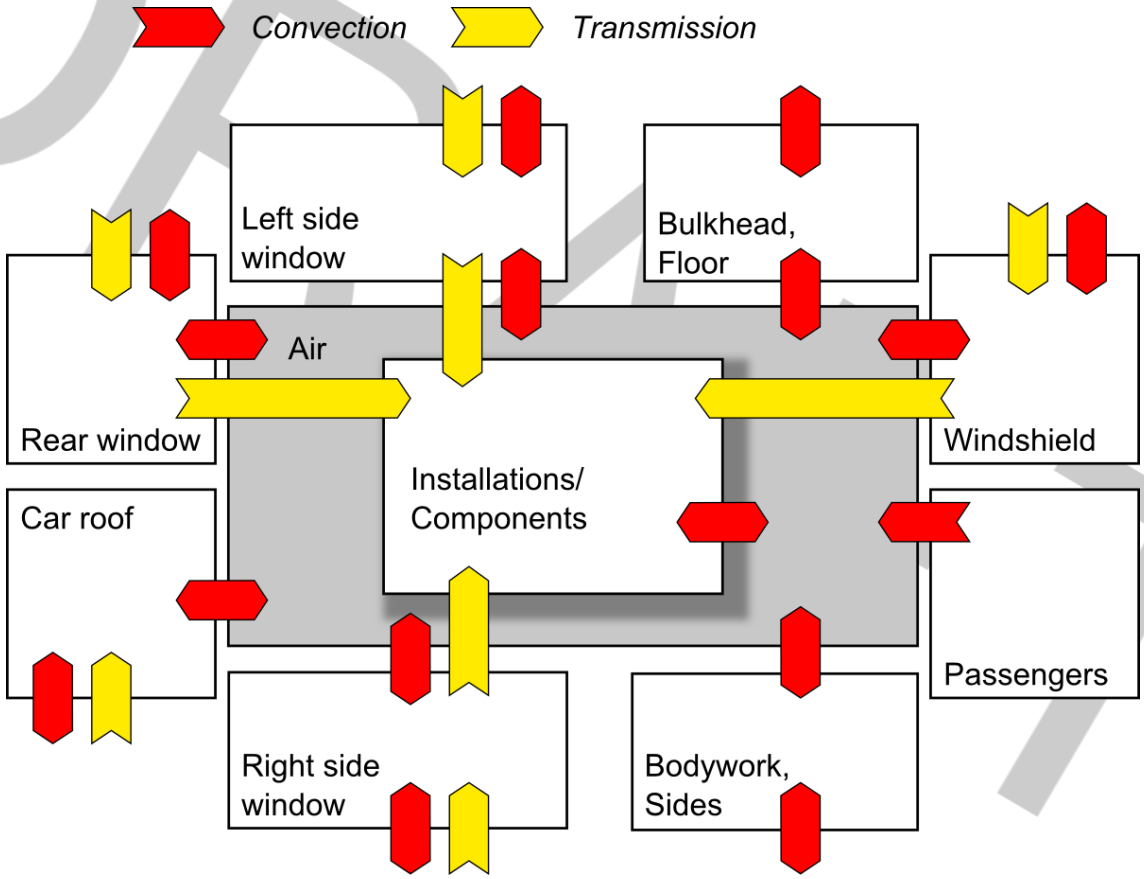
Methodological approach

Modeling of cabin and AC system



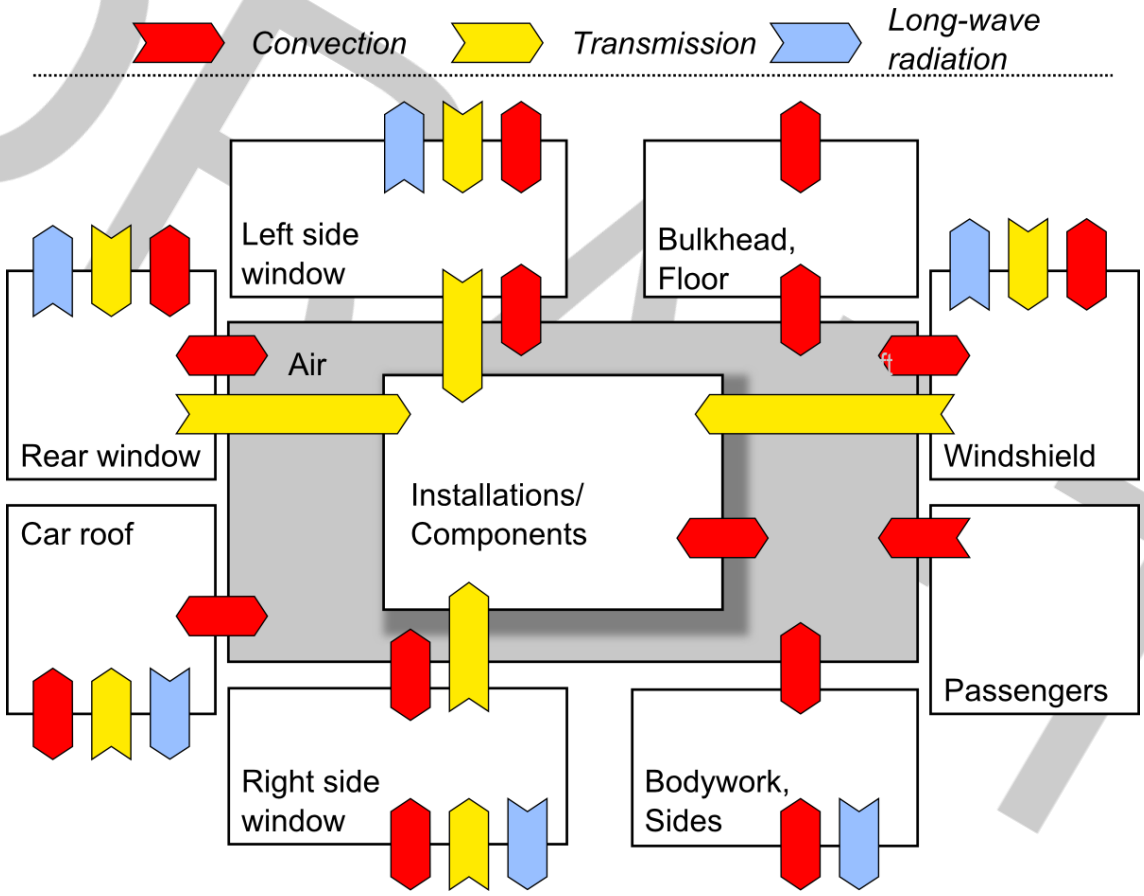
Methodological approach

Modeling of cabin and AC system



Methodological approach

Modeling of cabin and AC system



Methodological approach

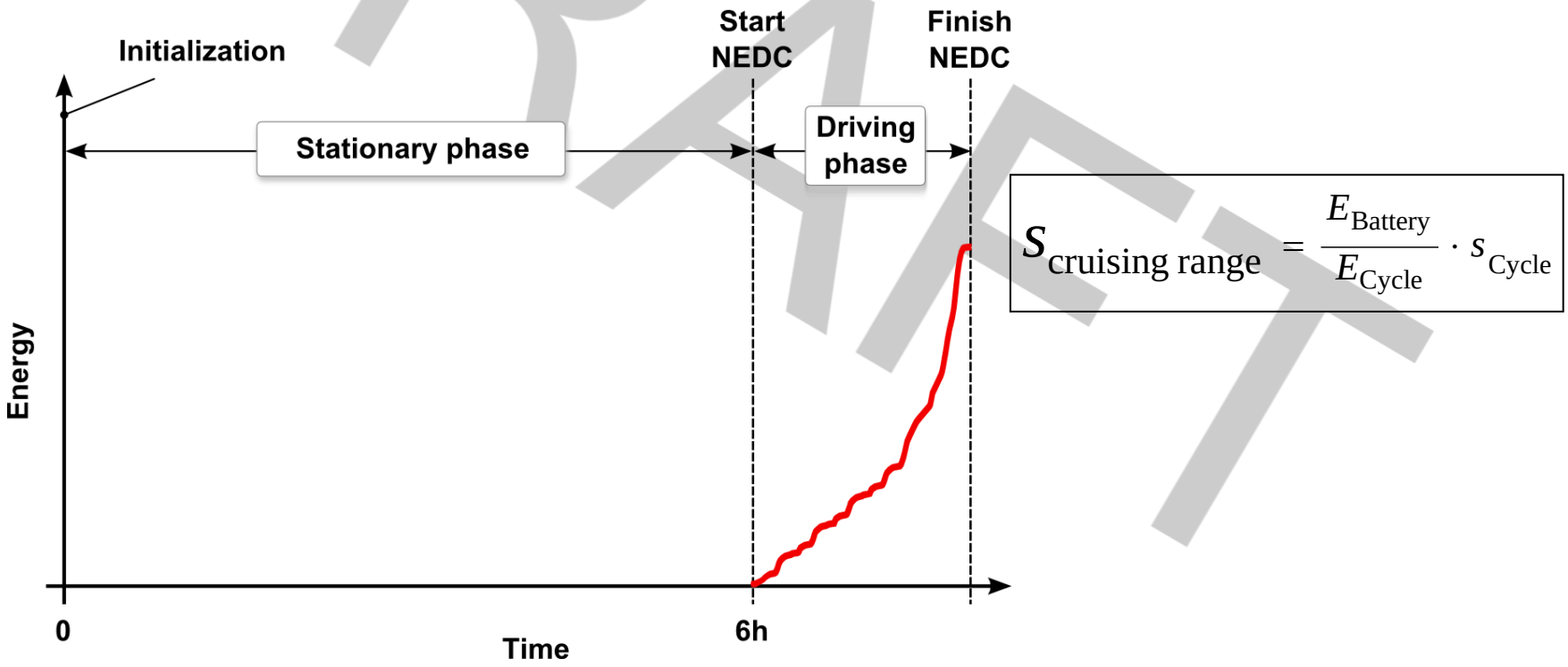
Boundary conditions and reference scenarios

	Heating scenario	Cooling scenario
Solar radiation	100 W/m² Vertical	1000 W/m² Vertical
Ambient temperature	-20°C…20°C In 5K steps	10°C…35°C In 5K steps
Ambient humidity	50 rH	50 rH
Comfort temperature	20°C	20°C
Air mass flow	3 kg/min	8 kg/min

Methodological approach

Driving cycle and cruising range evaluation

Energy consumption of ONE driving cycle is used to evaluate the cruising range



$$S_{\text{cruising range}} = \frac{E_{\text{Battery}}}{E_{\text{Cycle}}} \cdot s_{\text{Cycle}}$$

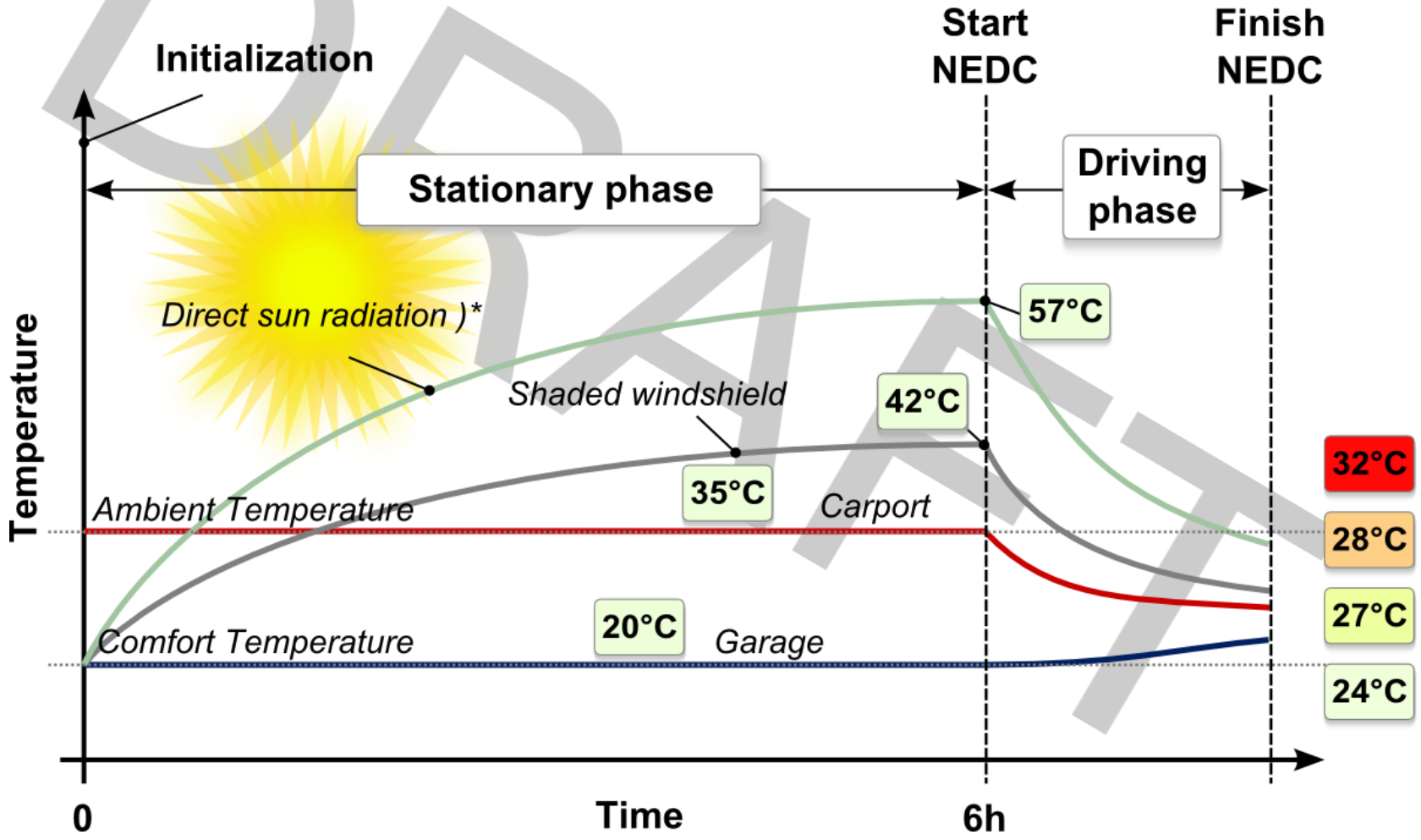
Contents

Results

- Cooling scenario
- Heating scenario
- Insulation of bodywork
- Circulating air mode (window deicing and anti fogging)
- Heat pump operation
- Usage of optimized glazing
- Variation of the thermal relevant passenger compartment mass
- Combination of different measures

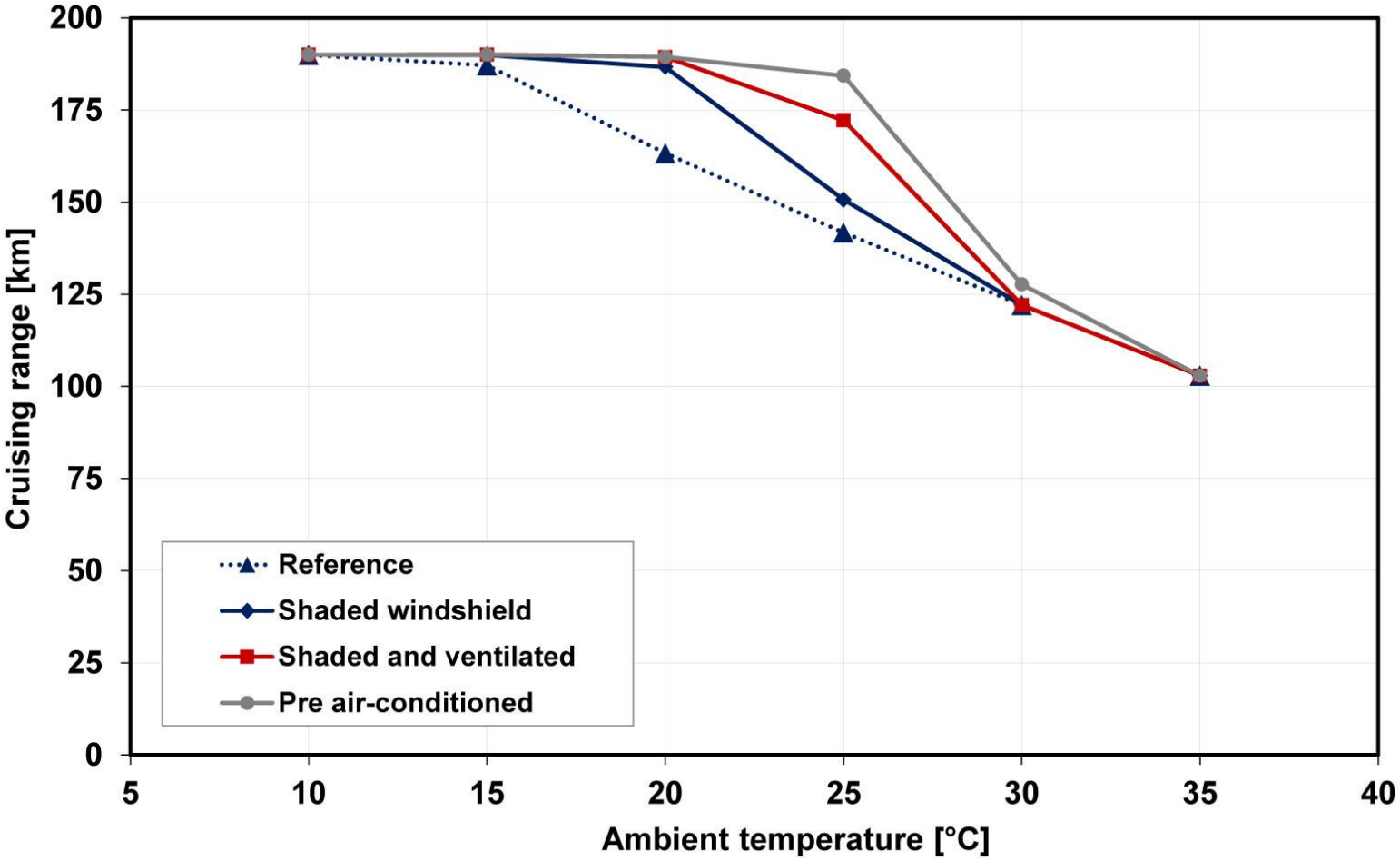
Methodological approach

Boundary conditions and reference scenarios



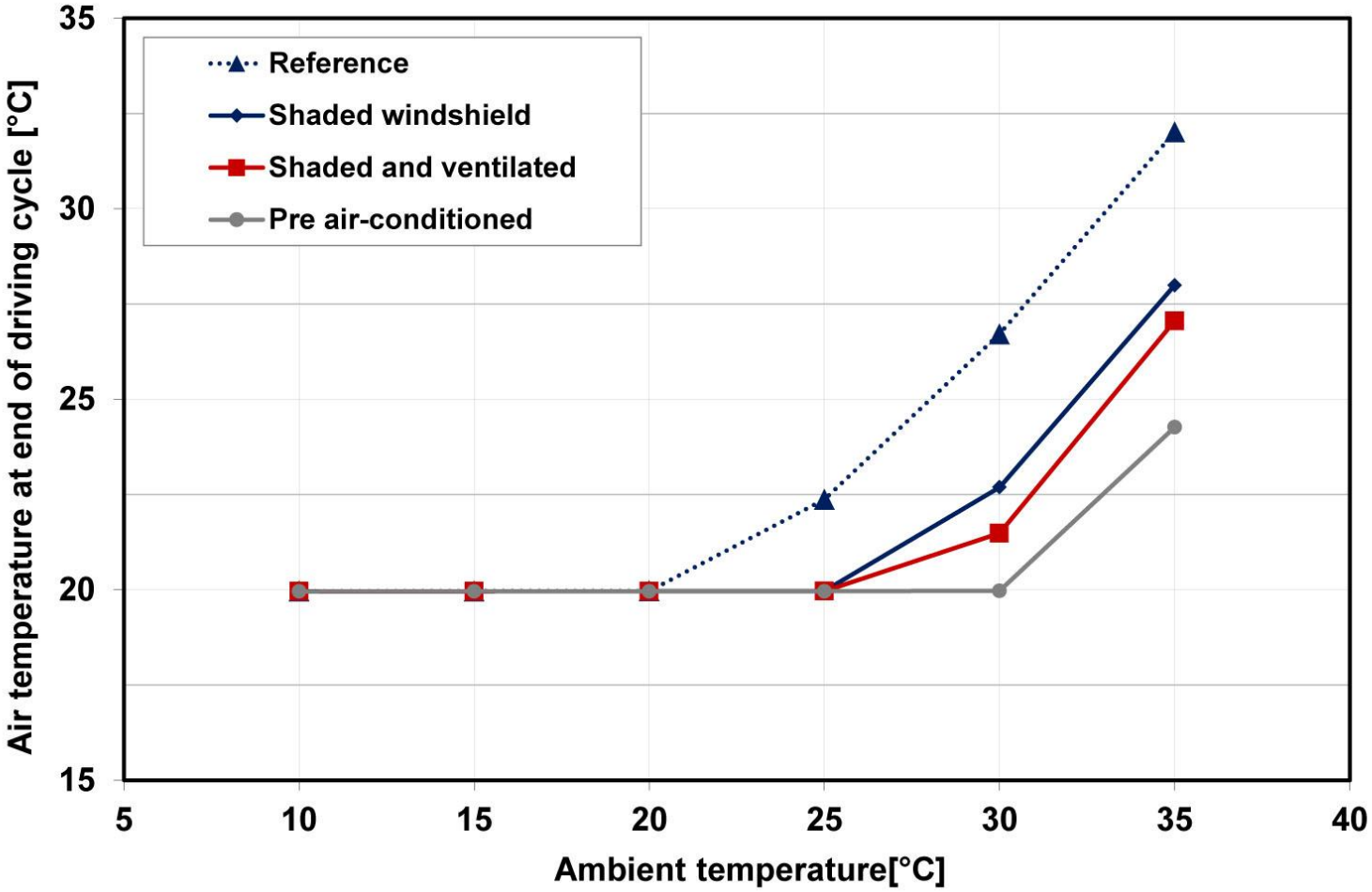
Results – Measures in stationary phase

Cool down – Cruising range



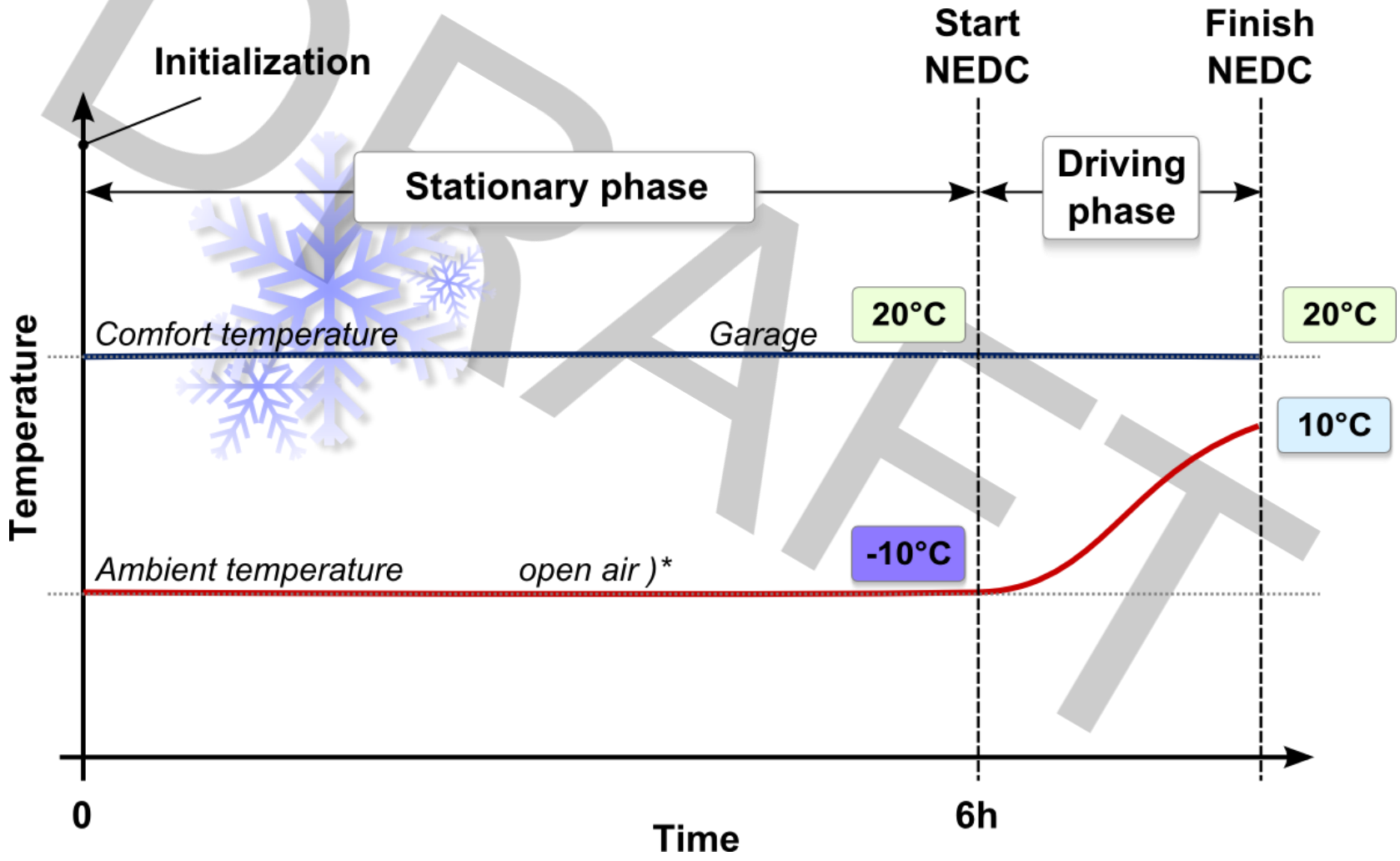
Results – Measures in stationary phase

Cool down – Comfort



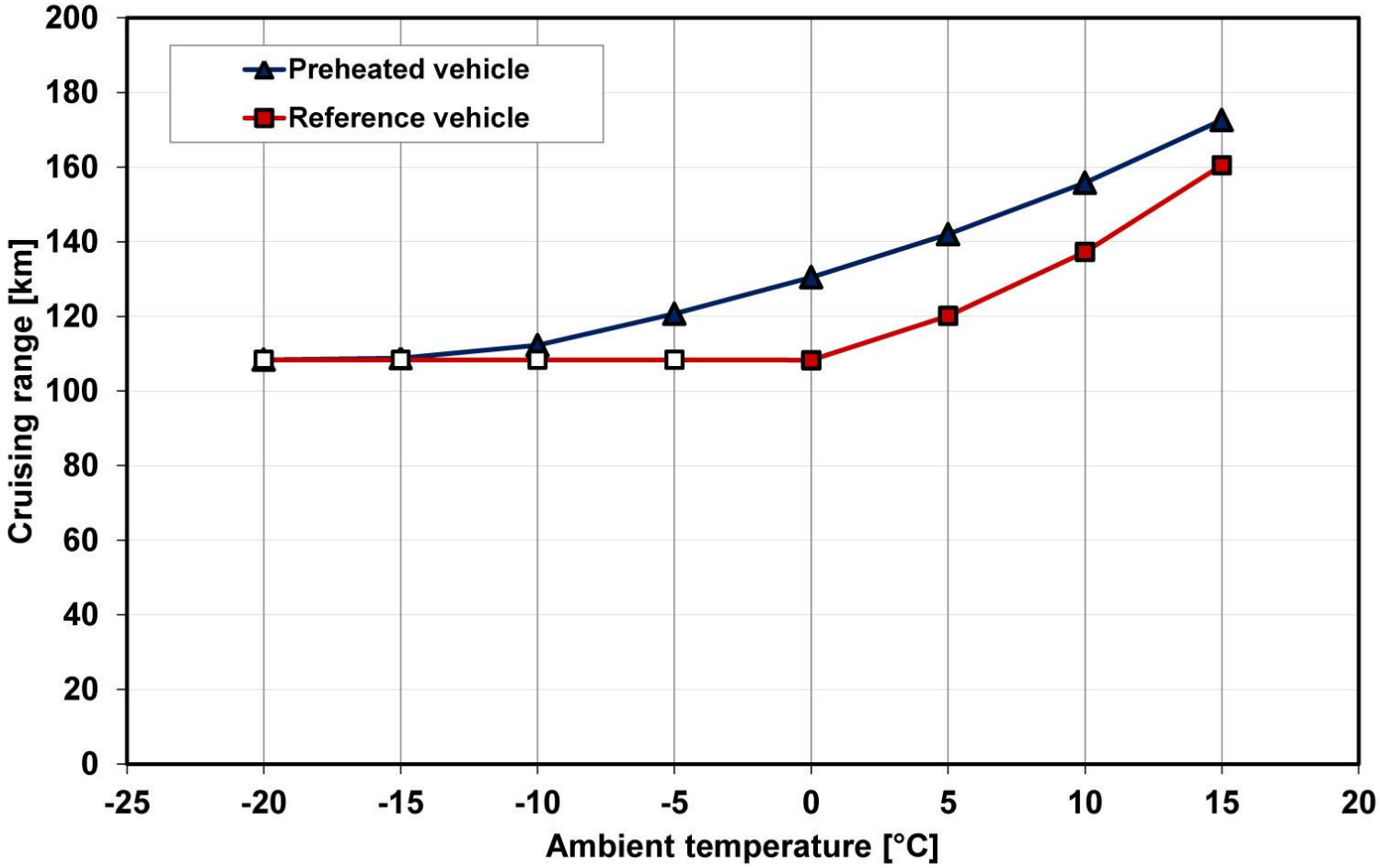
Methodological approach

Boundary conditions and reference scenarios



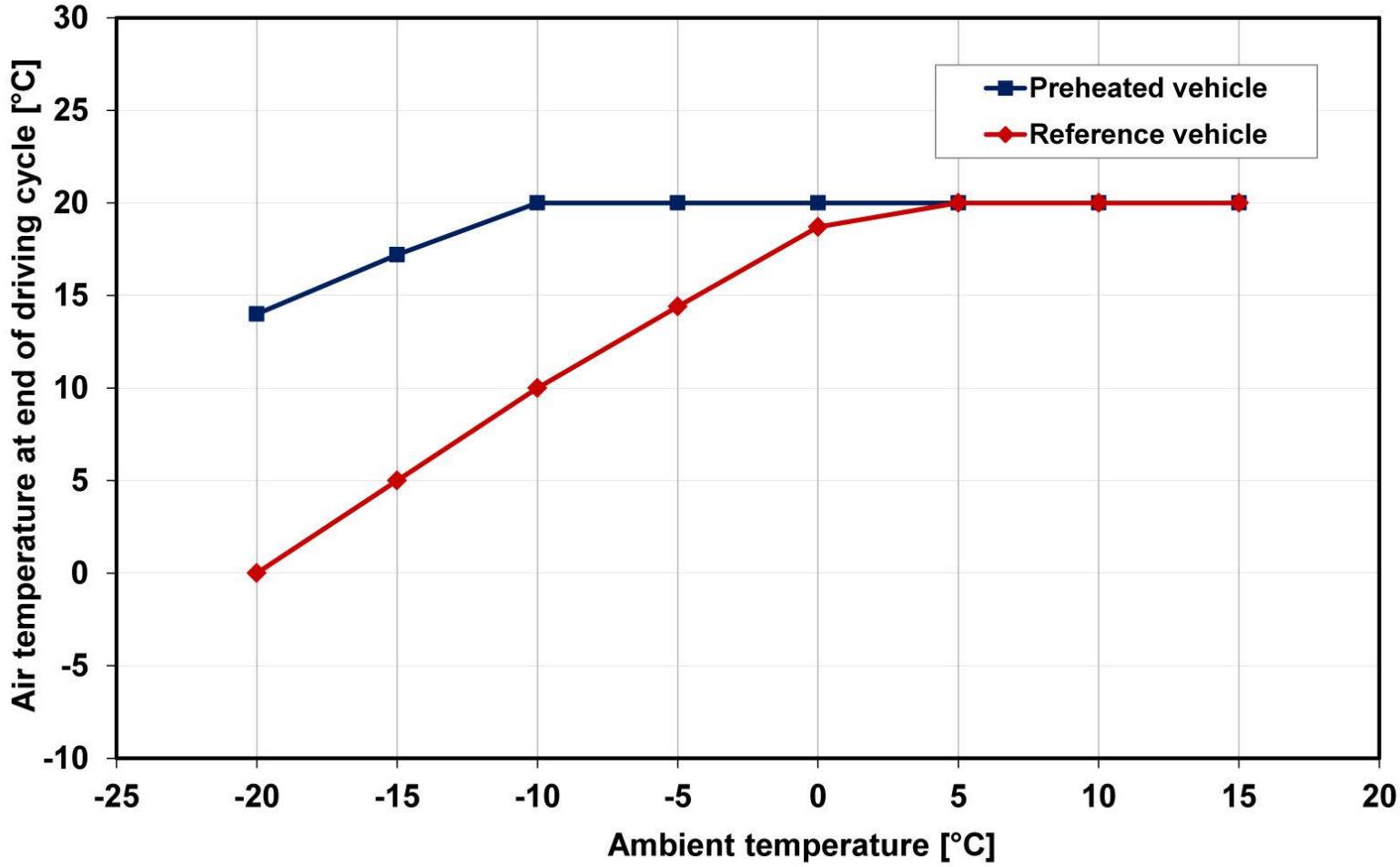
Results – Measures in stationary phase

Heating – Cruising range



Results – Measures in stationary phase

Heating – Comfort



Measures

Overview

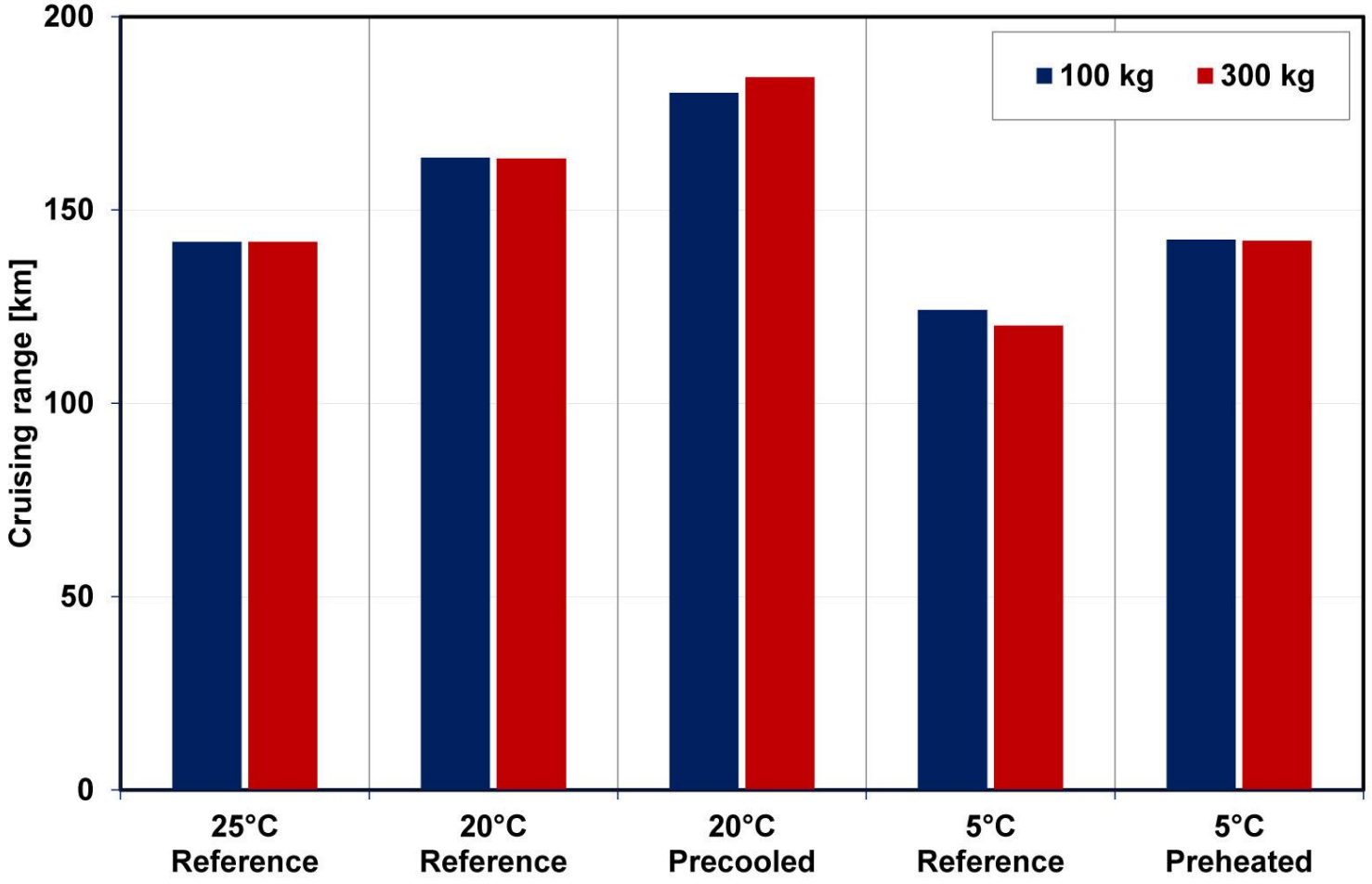
- Measures in stationary phase
- Variation of the relevant thermal mass in the passenger compartment
- Air recirculation (window deicing and anti-fogging)
- Heat pump operation
- Body work insulation
- Optimized glazing

Results – Thermal mass
Overview

	Mass	Characterization
Version I	300 kg	Golf-class
Version II	100 kg	Lightweight design

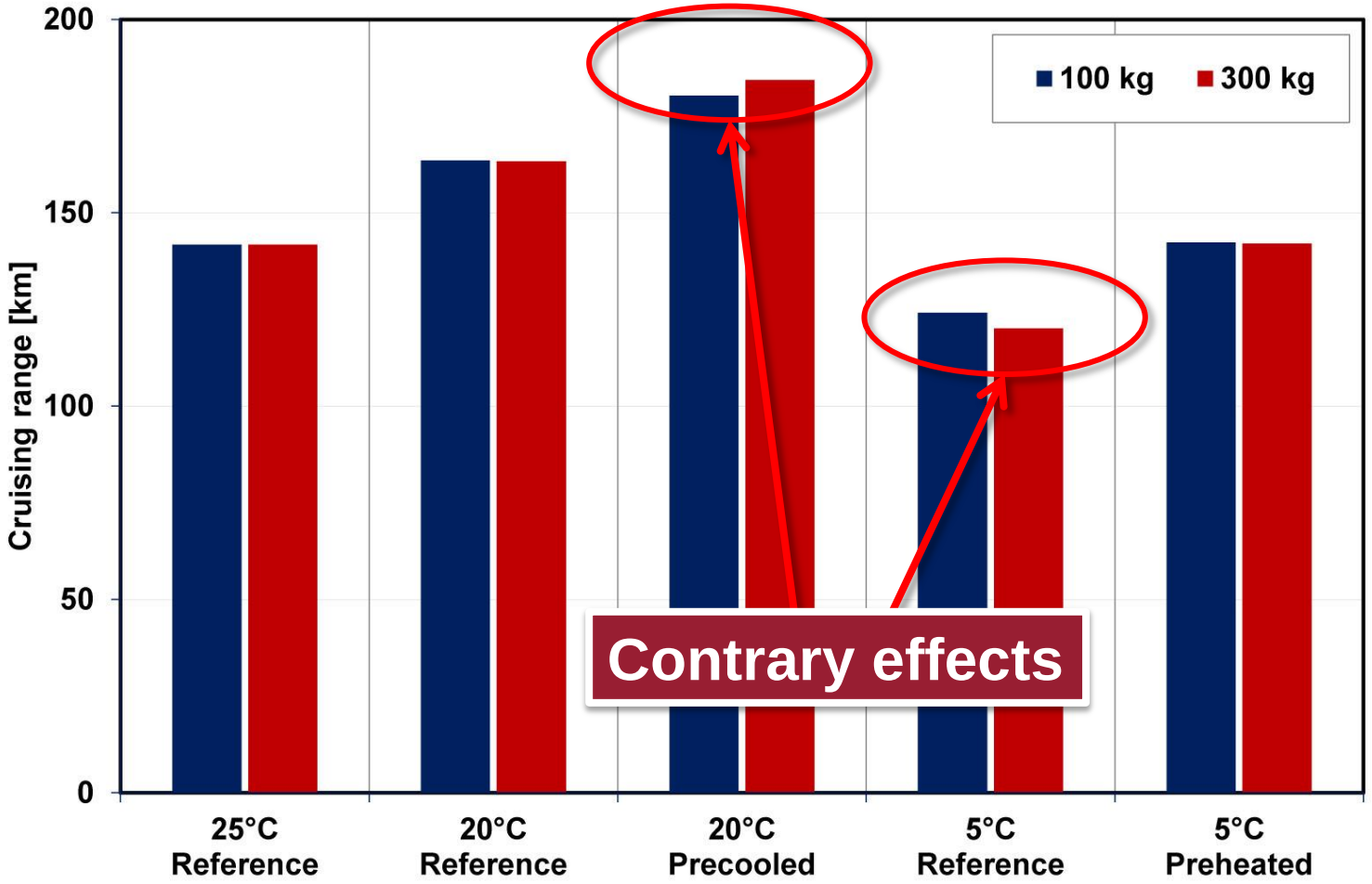
Results – Thermal mass

Cruising range



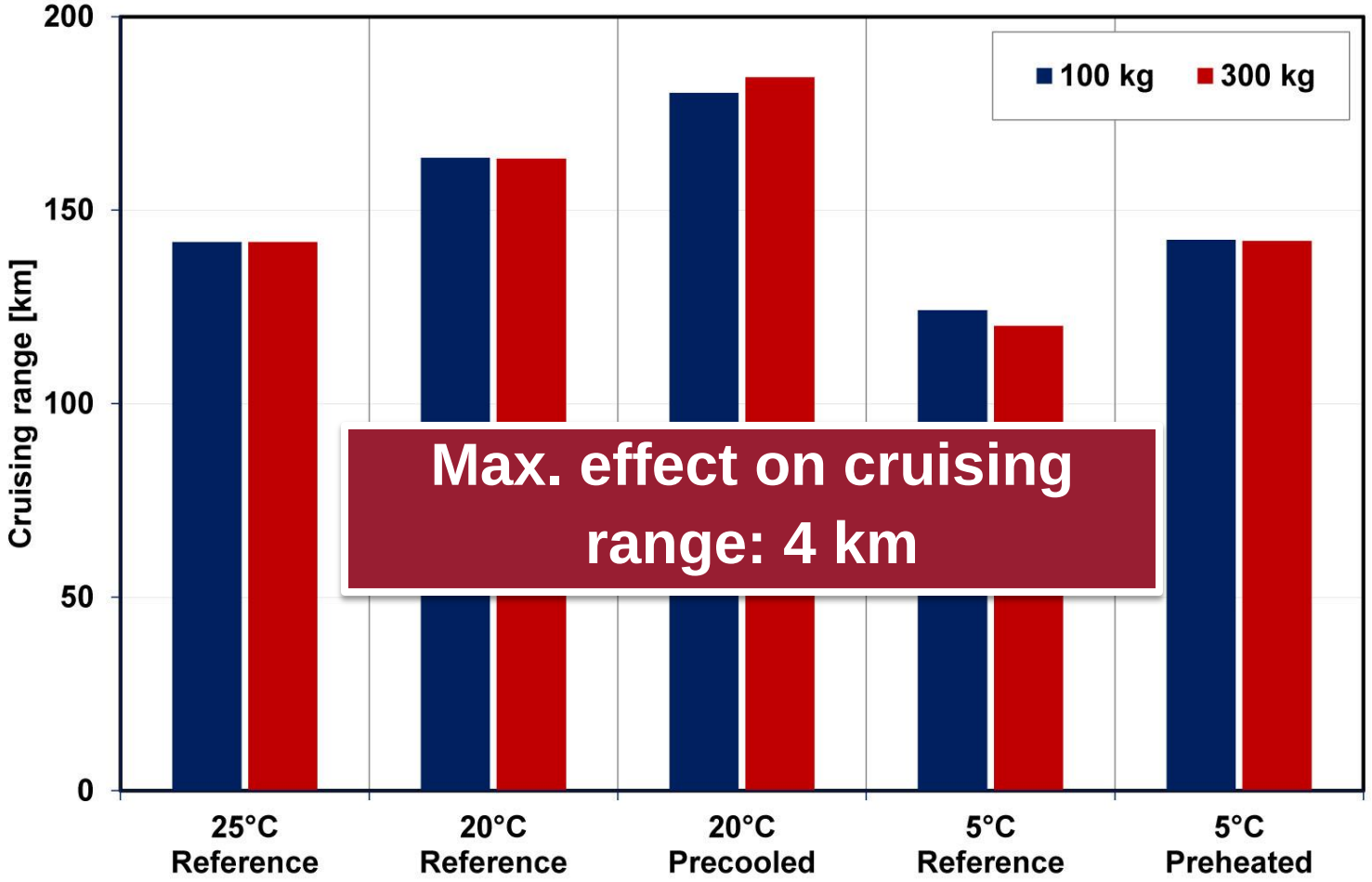
Results – Thermal mass

Cruising range



Results – Thermal mass

Cruising range



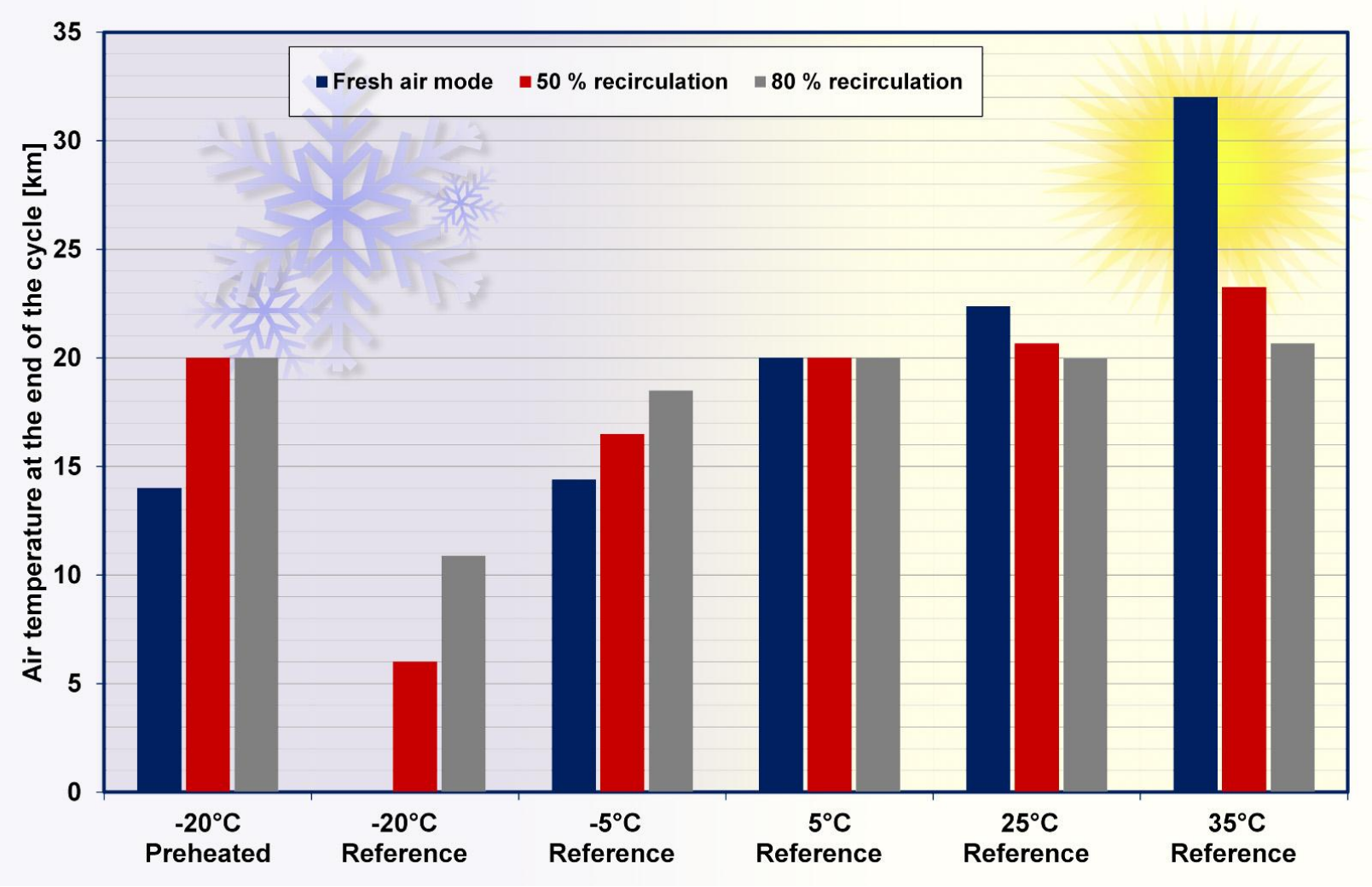
Results – Air circulation

Overview

- Variation of the recirculating mass flow
  1. *Fresh air*
  2. *50% recirculating air*
  3. *80% recirculating air*
- Comfort potentially reduced
  - *CO_2*
  - *Odor*
  - *Fogged windows*

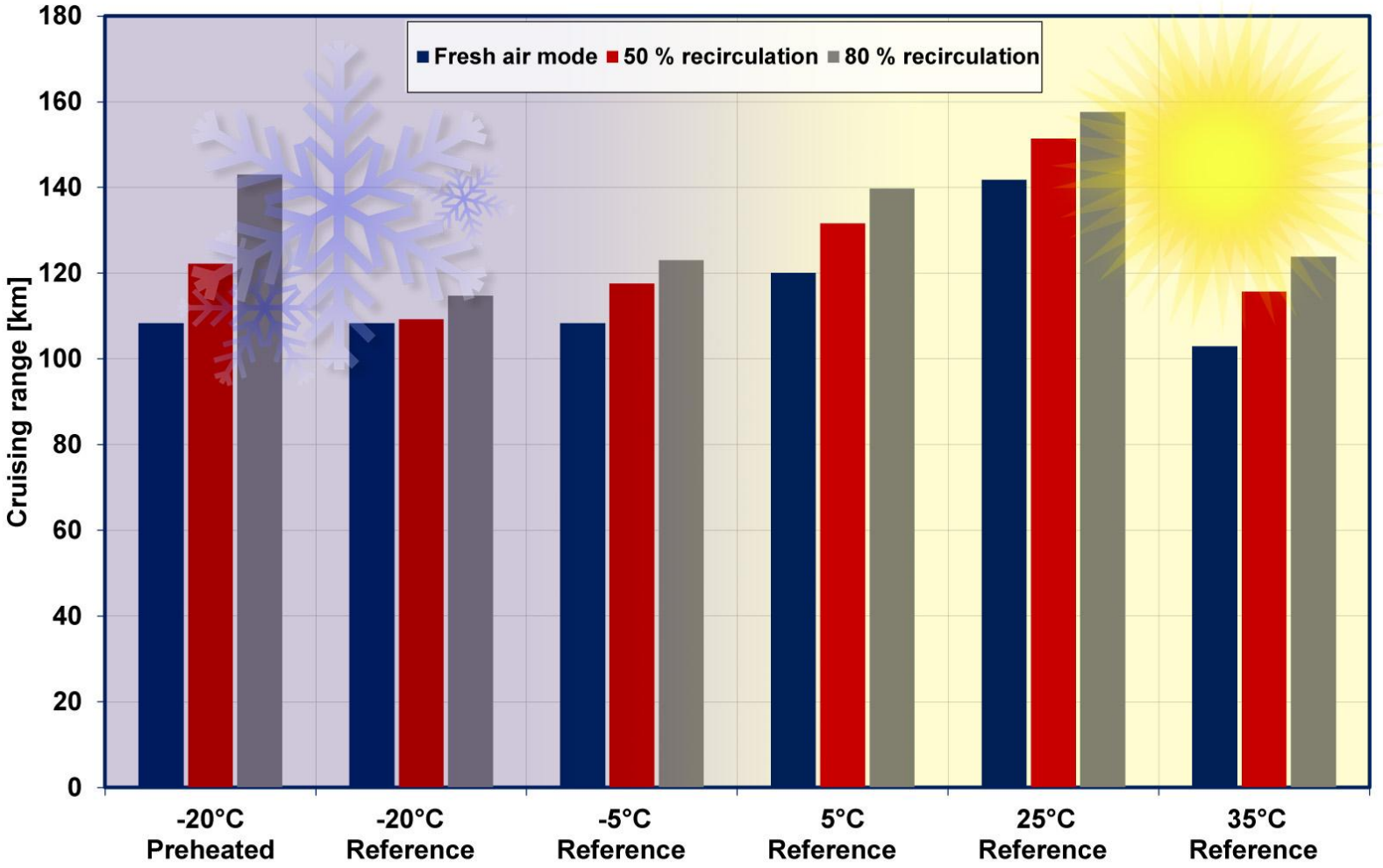
Results – Air circulation

Comfort



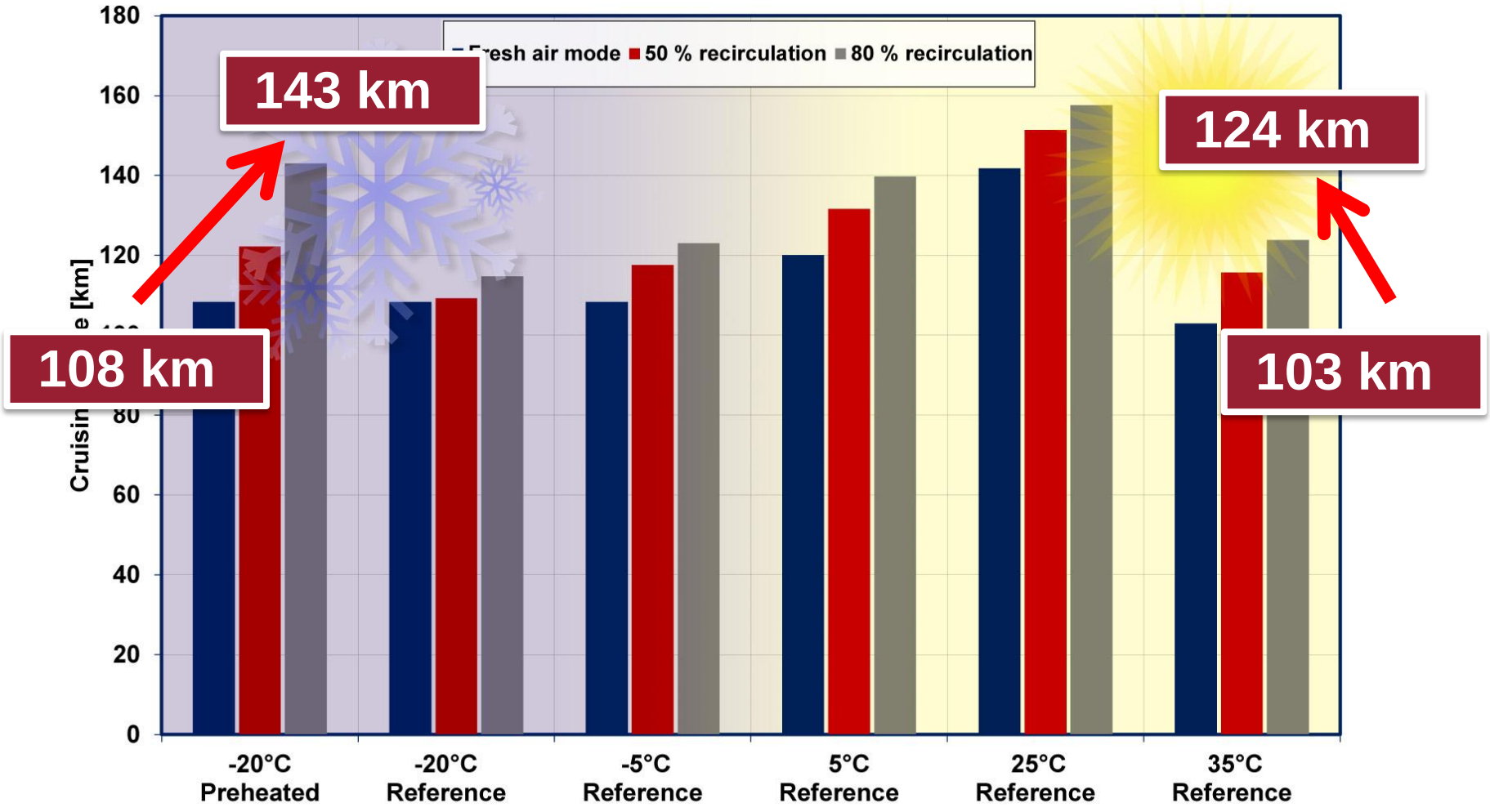
Results – Air circulation

Cruising range



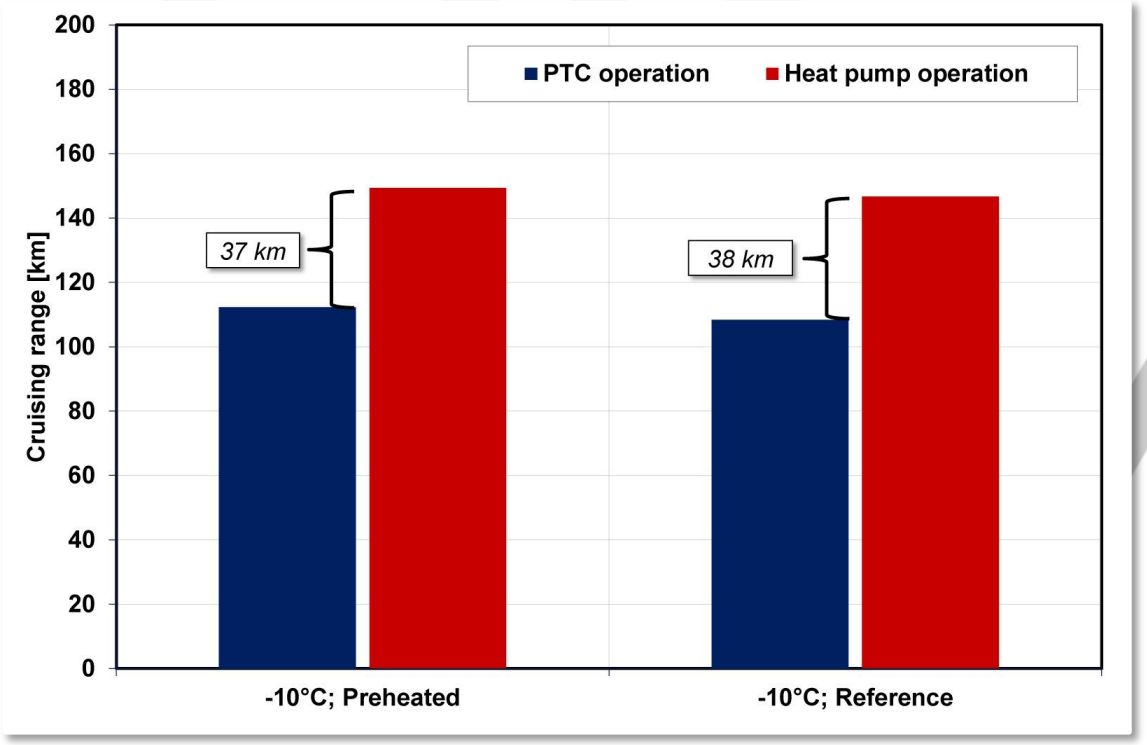
Results – Air circulation

Cruising range

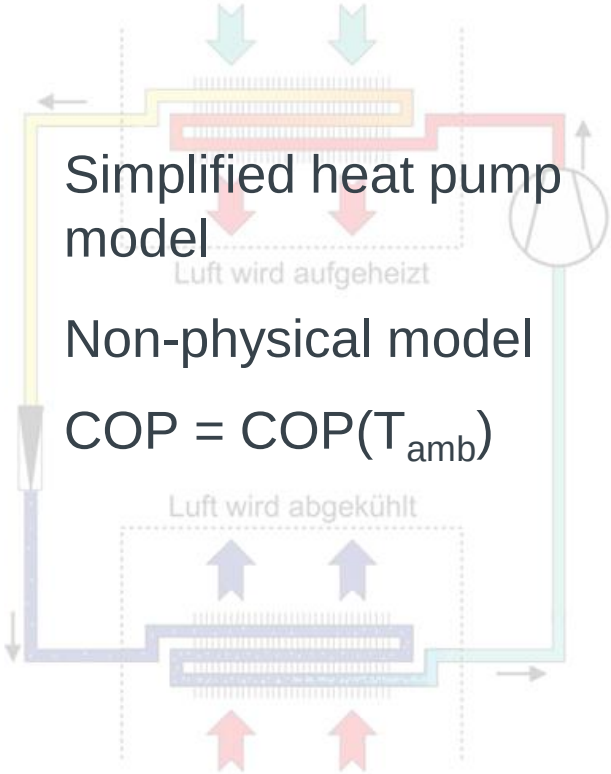


Results – Heat pump

Overview



- Simplified heat pump model
- Non-physical model
- COP = COP(T_{amb})



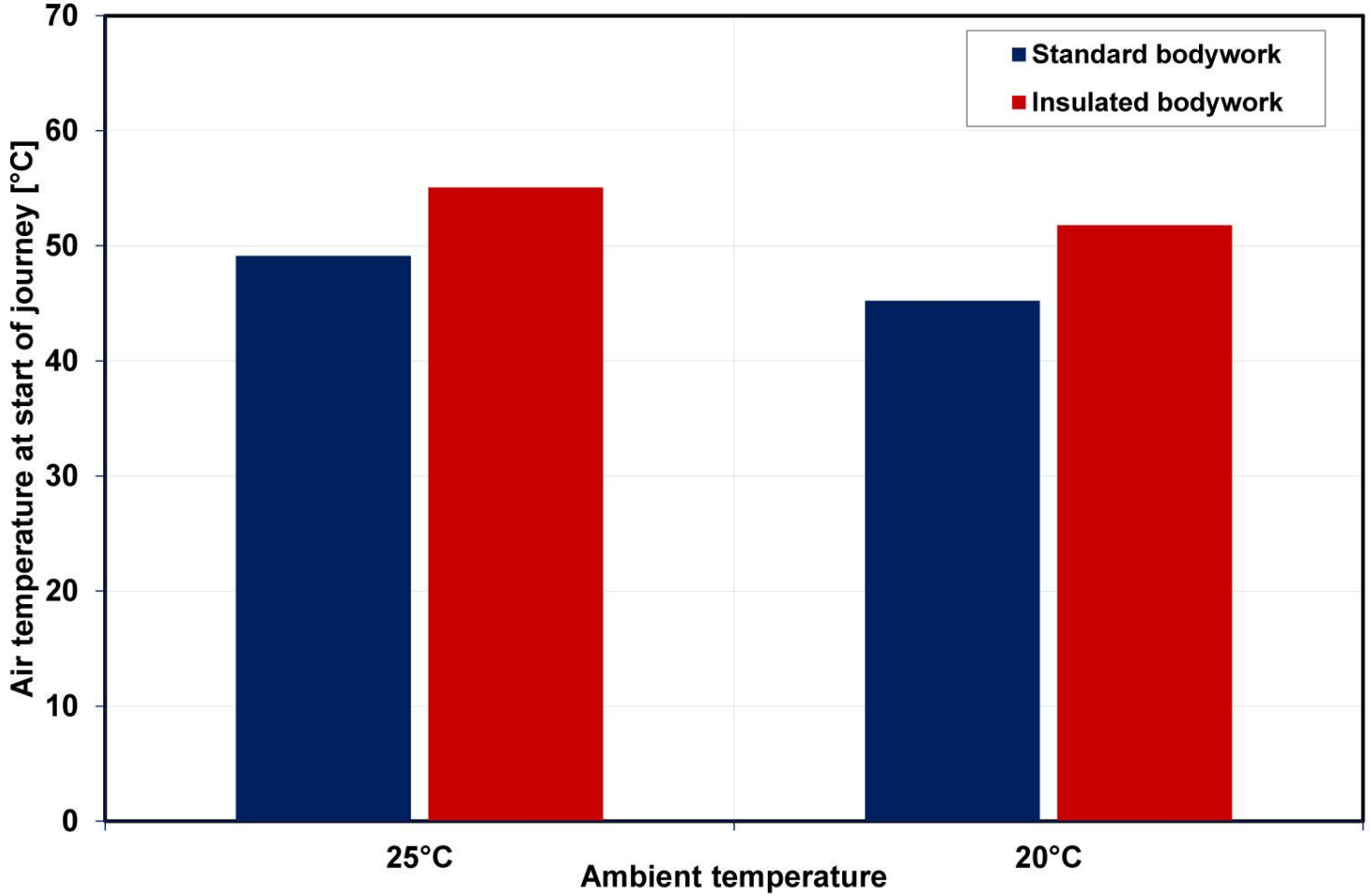
Results – Bodywork insulation

Overview

Heat transfer coefficient is reduced from 2,3 W/(m²/K) to 0,5 W/(m²/K) (typical value for refrigerated trucks)

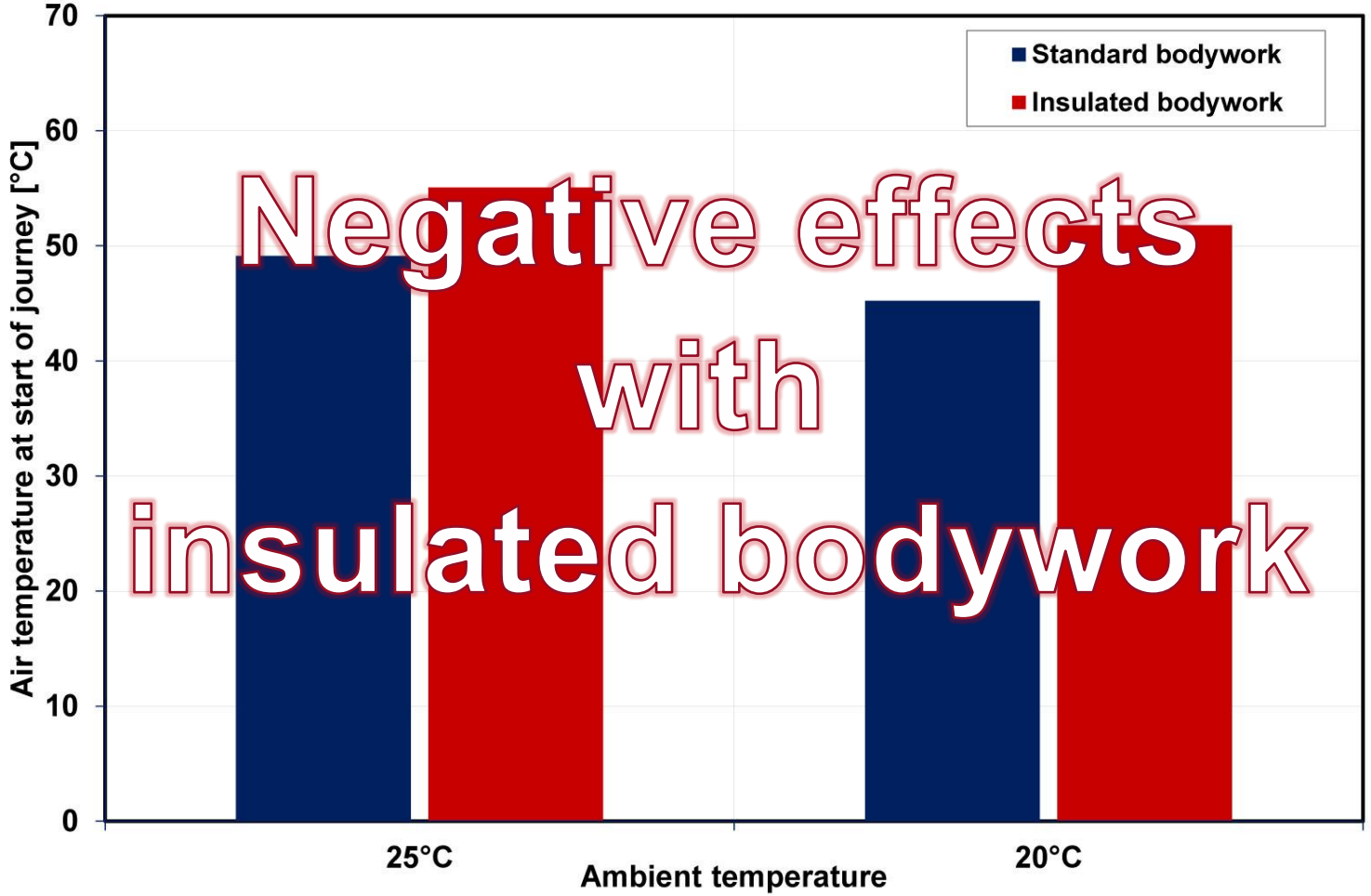
Results – Bodywork insulation

Thermal Entry Comfort



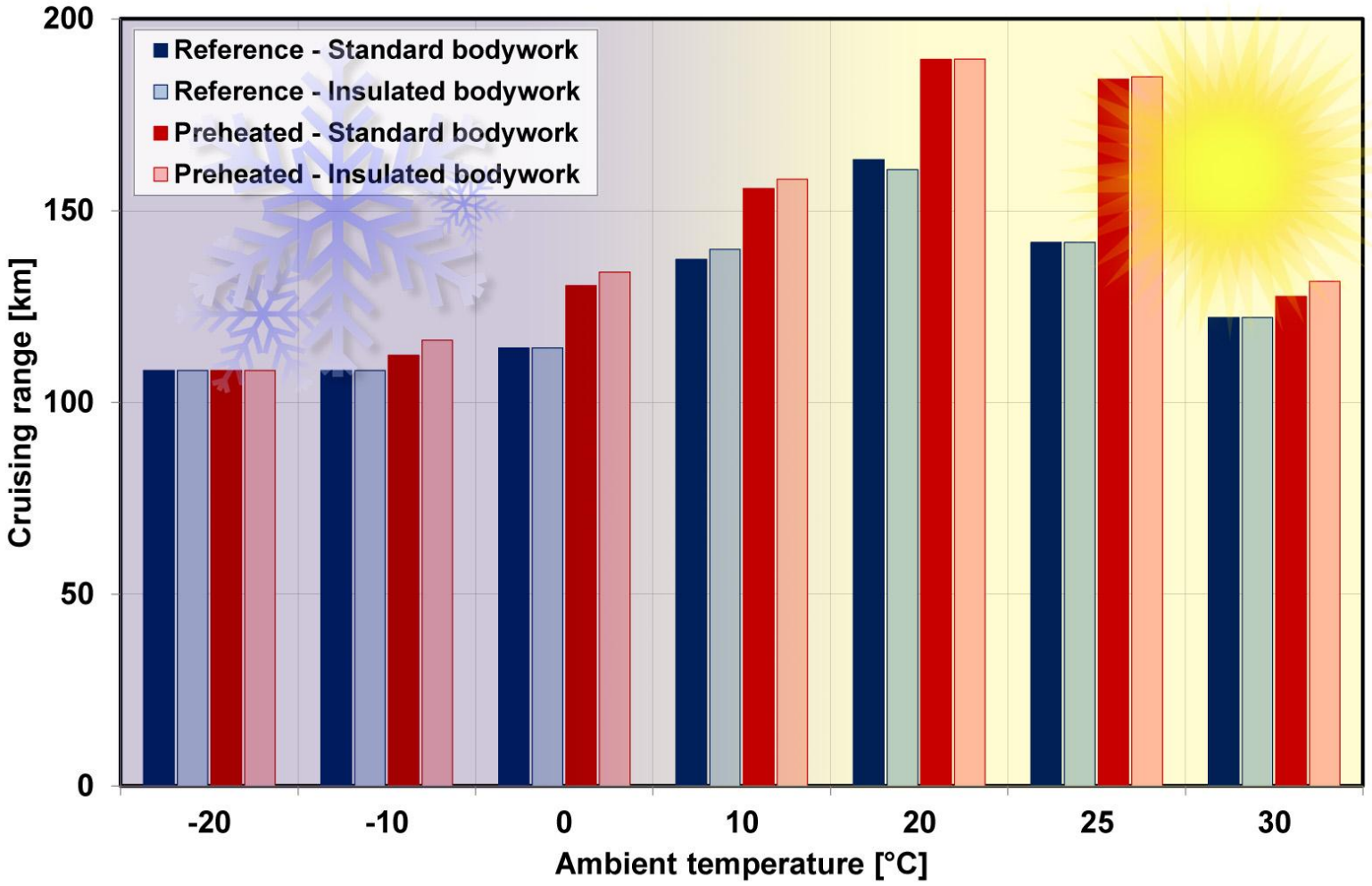
Results – Bodywork insulation

Thermal Entry Comfort



Results – Bodywork insulation

Cruising range



Results – Bodywork insulation

Summary

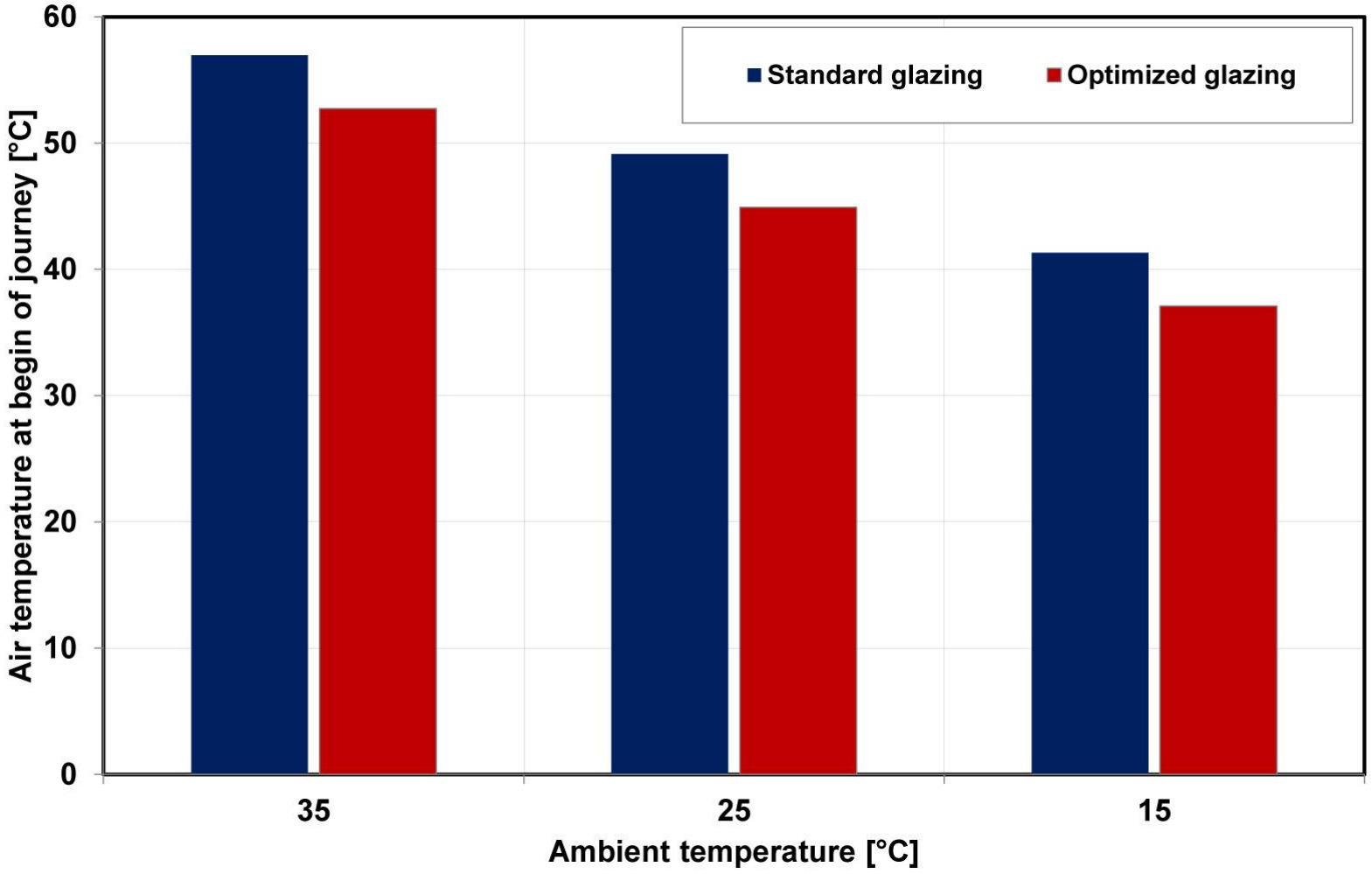
Effects of bodywork insulation:

- Reduced entry comfort in summer scenarios without preconditioning
- Increased cruising range in every temperature scenario (except -20°C) with preconditioning
- Reduced cruising range without preconditioning when cooling down

Suitable for general use?

Optimized glazing (reduced transmission)

Thermal entry comfort



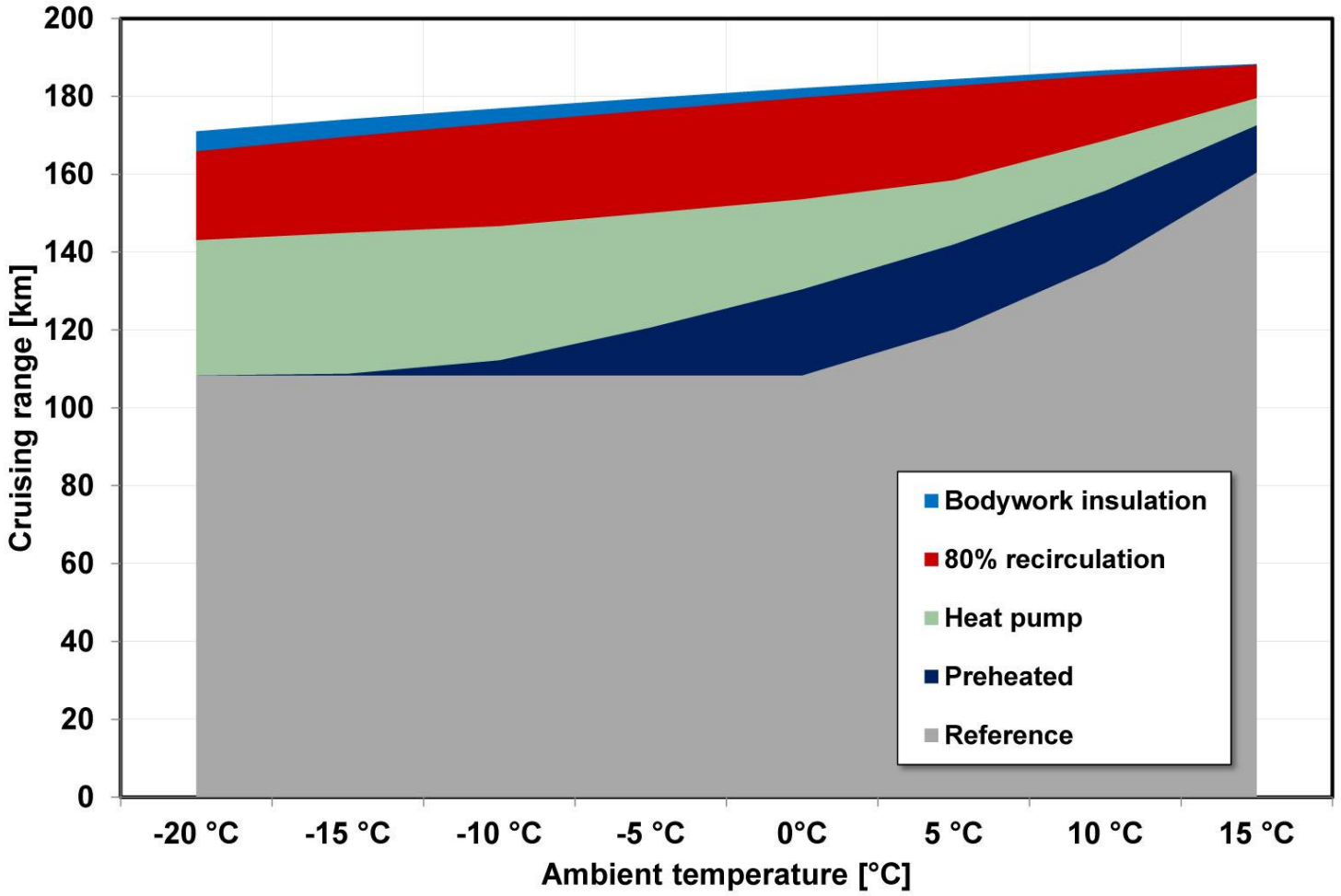
Results – Combination of measures

Overview

- Measures are sequently applied:
  1. *Reference*
  2. *Stationary measures*
  3. *Heat pump operation*
  4. *Air recirculation*
  5. *Insulated bodywork*
- An individual consideration of single measures is not possible
  (To rate individual measures in this package the sequence has to be followed)

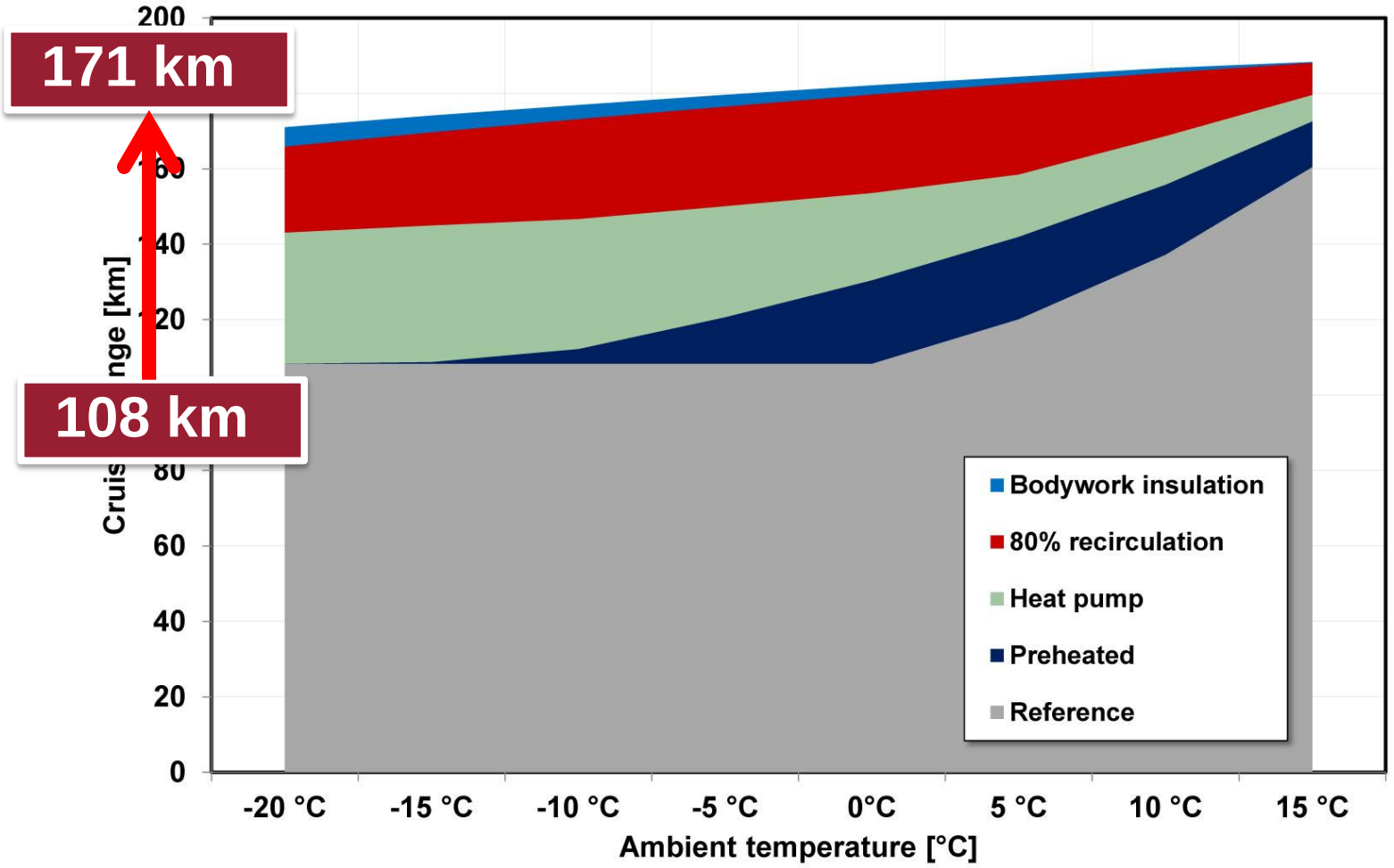
Results – Combination of measures

Heating – Cruising range



Results – Combination of measures

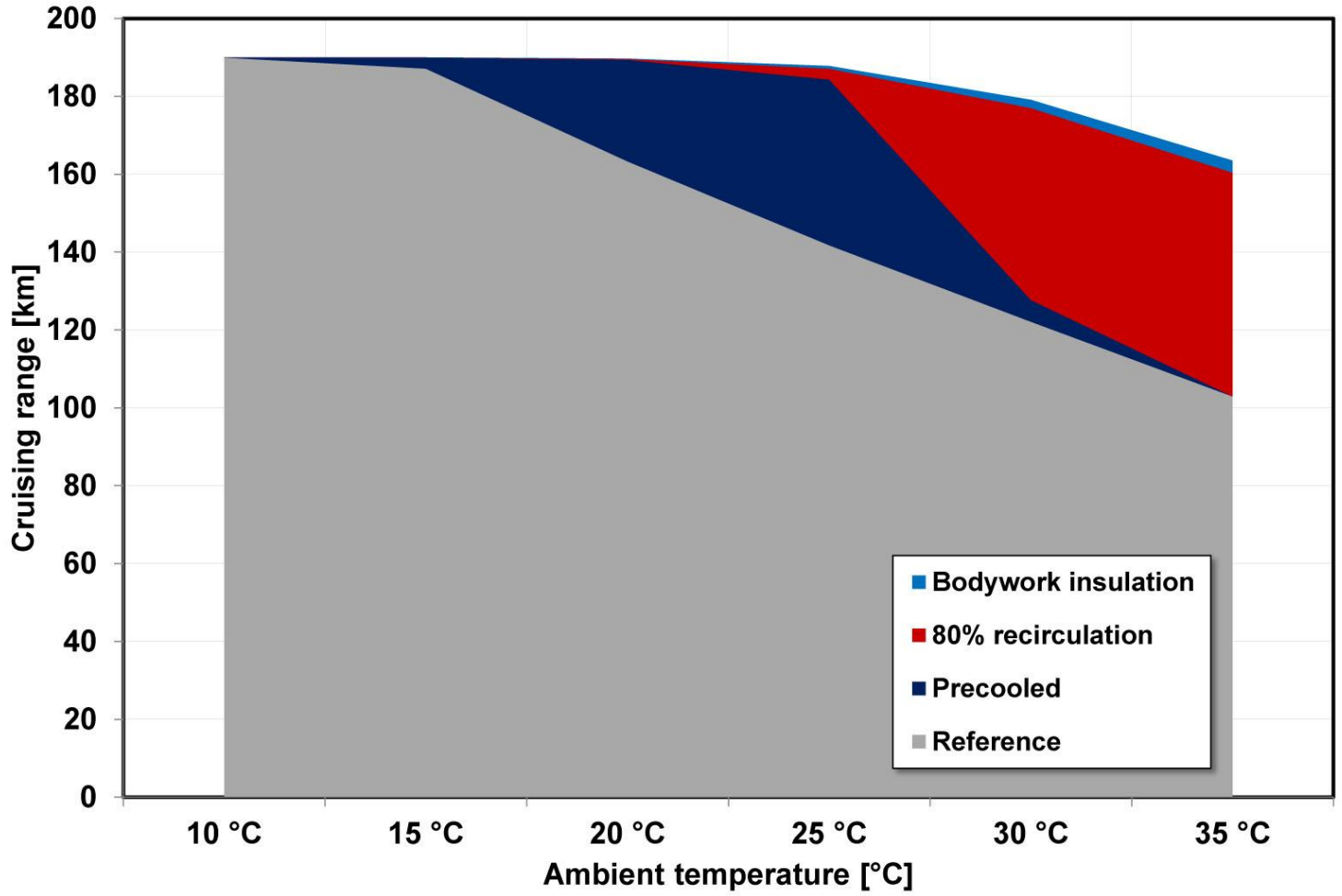
Heating – Cruising range



Outside temperature

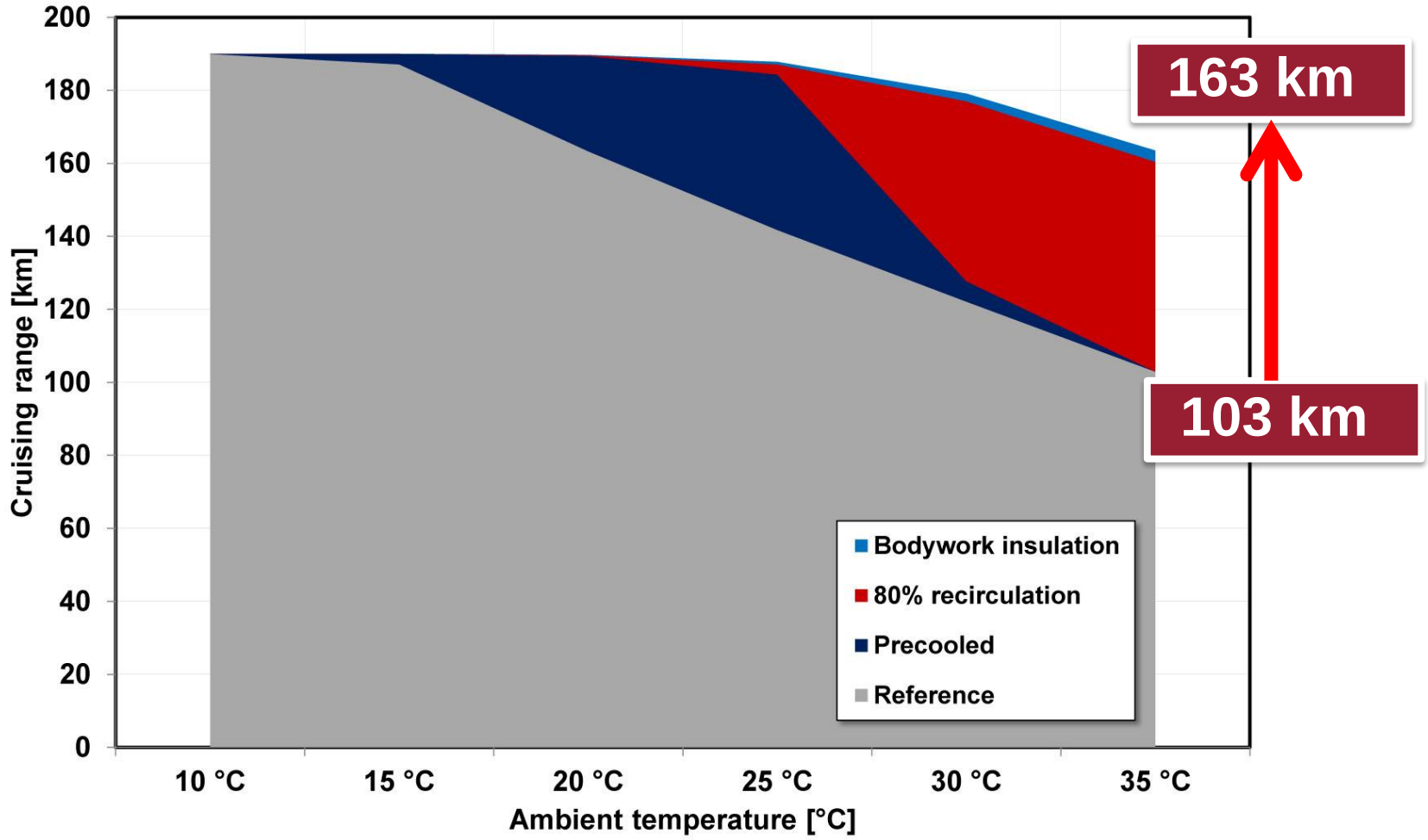
Results – Combination of measures

Cool down – Cruising range



Results – Combination of measures

Cool down – Cruising range



Conclusion

- Huge drops in cruising range due to heating and AC-operation if no measures are applied
- Air recirculation and measures for stationary phases have great potential
- Positive impacts with heat pump operation
- Insulated bodywork is beneficial in combination with measures in stationary phase only
- Car glasses influence the entering comfort but has little effect on cruising range
- Combining appropriate measures results in very less cruising range loss while realizing a wide temperature range

Thank you
for your attention!