CCA Work Area Energy
S2R Energy Saving Potential

EU Rail Innovation Days

07.12.2022

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WA Energy – S2R Energy Saving Potential

1. Energy calculation and simulation methodology
   Michel Mermet Guyennet (Alstom)

2. Energy saving due to S2R innovations
   Jürgen Ernst (Deutsche Bahn)

3. Innovative solutions to save HVAC energy in BEMUs
   Sylvio Donner (Deutsches Zentrum für Luft- und Raumfahrt, DLR)

4. Outlook
   Jürgen Ernst (Deutsche Bahn)

Introduction

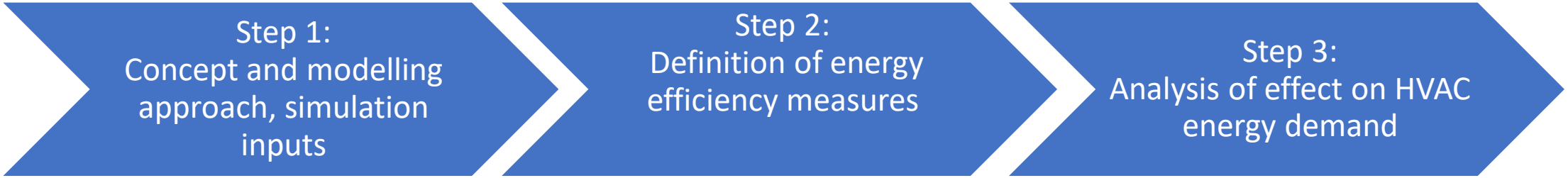
Motivation: Reduction of CO2-emissions as well as the reduction of the HVAC energy demand in BEMUs

Why need of HVAC energy savings in BEMUs?

- In regional trains like BEMUs the share of HVAC energy compared to traction is higher than in long-distance trains
- HVAC reduces the range; especially in winter

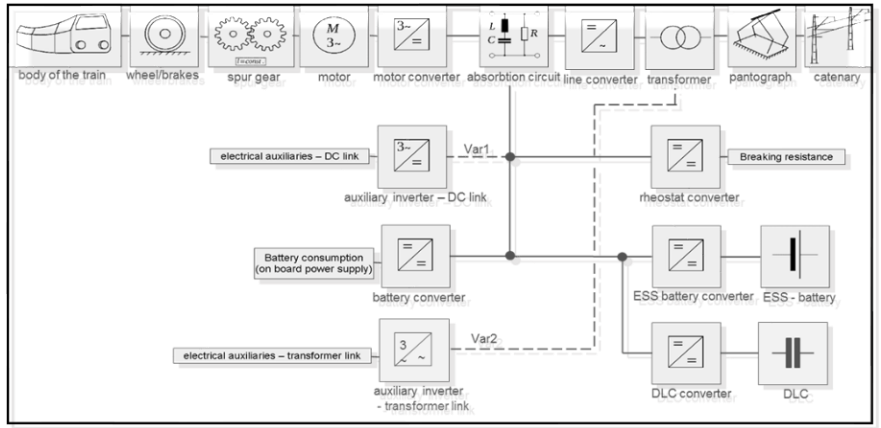
Objective of the HVAC study:

- Identification of measures to reduce HVAC energy demand and increase BEMU range
- Evaluation of potential range improvements and yearly energy savings

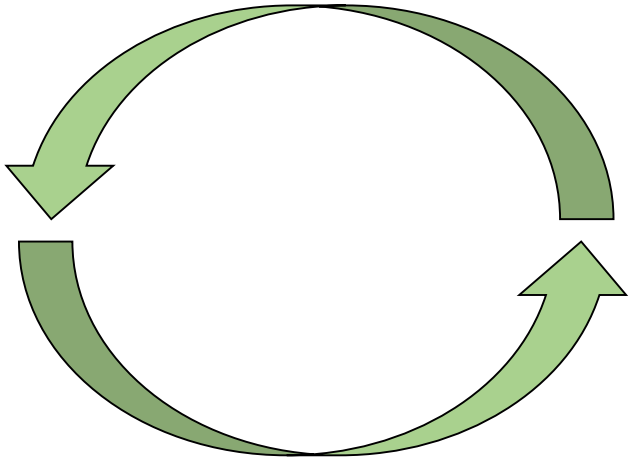


Overall concept: Combination of OPEUS-Tool & Thermal Carbody Model

OPEUS Simulation Model with BEMU Baseline

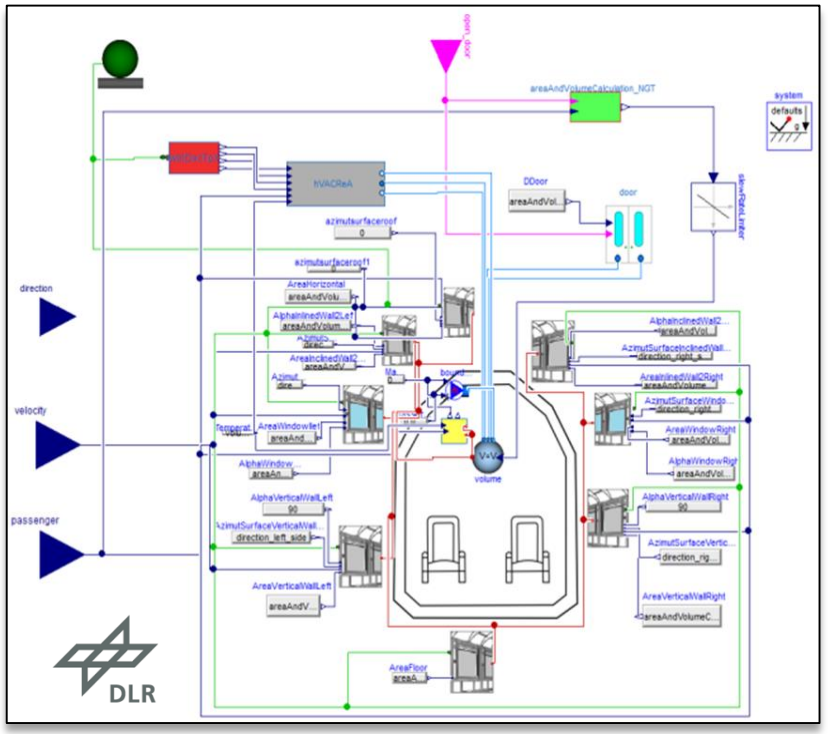


- dynamic HVAC power demand for 13 OP defined in EN50591



- OPEUS BEMU speed profile
- BEMU energy baseline carbody parameters

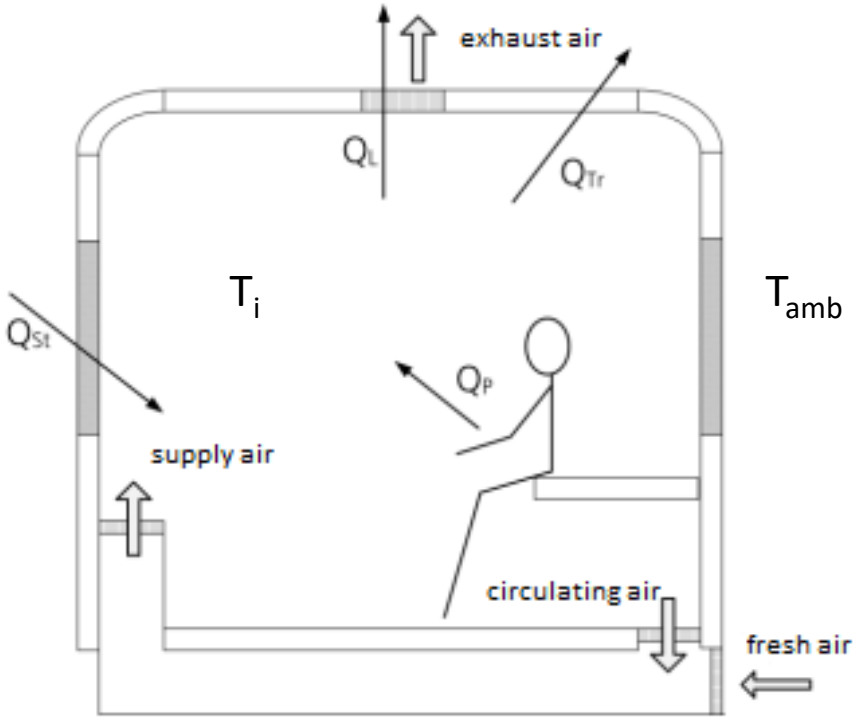
DLR Thermal Carbody Model (TCBM)



Modeling: DLR Thermal car body model (TCBM)

Characteristics of the TCBM:

- Description of the car body through various wall and window elements
- A passenger model describes the heat and moisture emission
- The number of passengers defines the fresh air rate
- EN 14750 specifies the target temperature in the carbody
- By balancing of the supplied and dissipated heat the HVAC energy demand is determined



➔ **The TCBM has been validated in FINE-2 Deliverable D4.2**

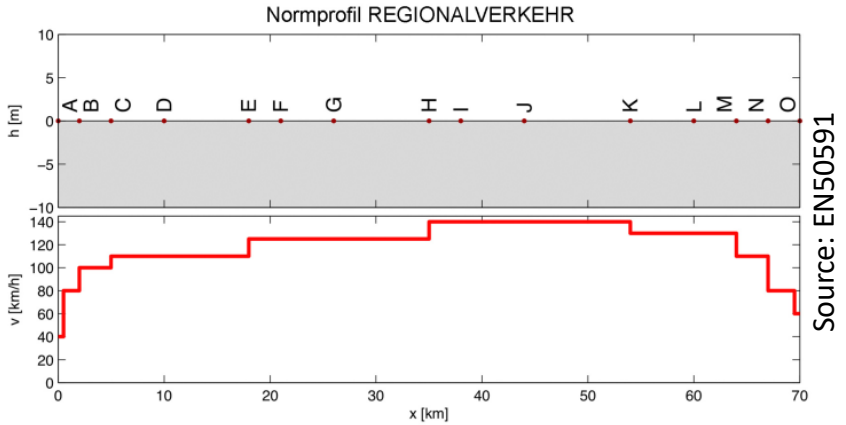
Inputs and boundary conditions

BEMU energy baseline:

- Definition of a reference vehicle and EN50591 service profile Regional 140
- Train and carbody parameters

Thermal boundary conditions:

- 13 operation points (OPs) according to EN 50591 in climate zone II
- Ambient temperature, occupancy, humidity,…



Source: EN50591

Bild B.2 – Normprofil REGIONALVERKEHR

Reference parameter	value
Number of carriages	2
Train length	40 m
Train mass	90 t (inc. battery)
Number of seats	100
Traction power	4 x 320 kW = 1280 kW

Furthering Improvements in Integrated Mobility Management, Noise and Vibration, and Energy in Shift2Rail

Deliverable 2.2 Energy Baseline Update

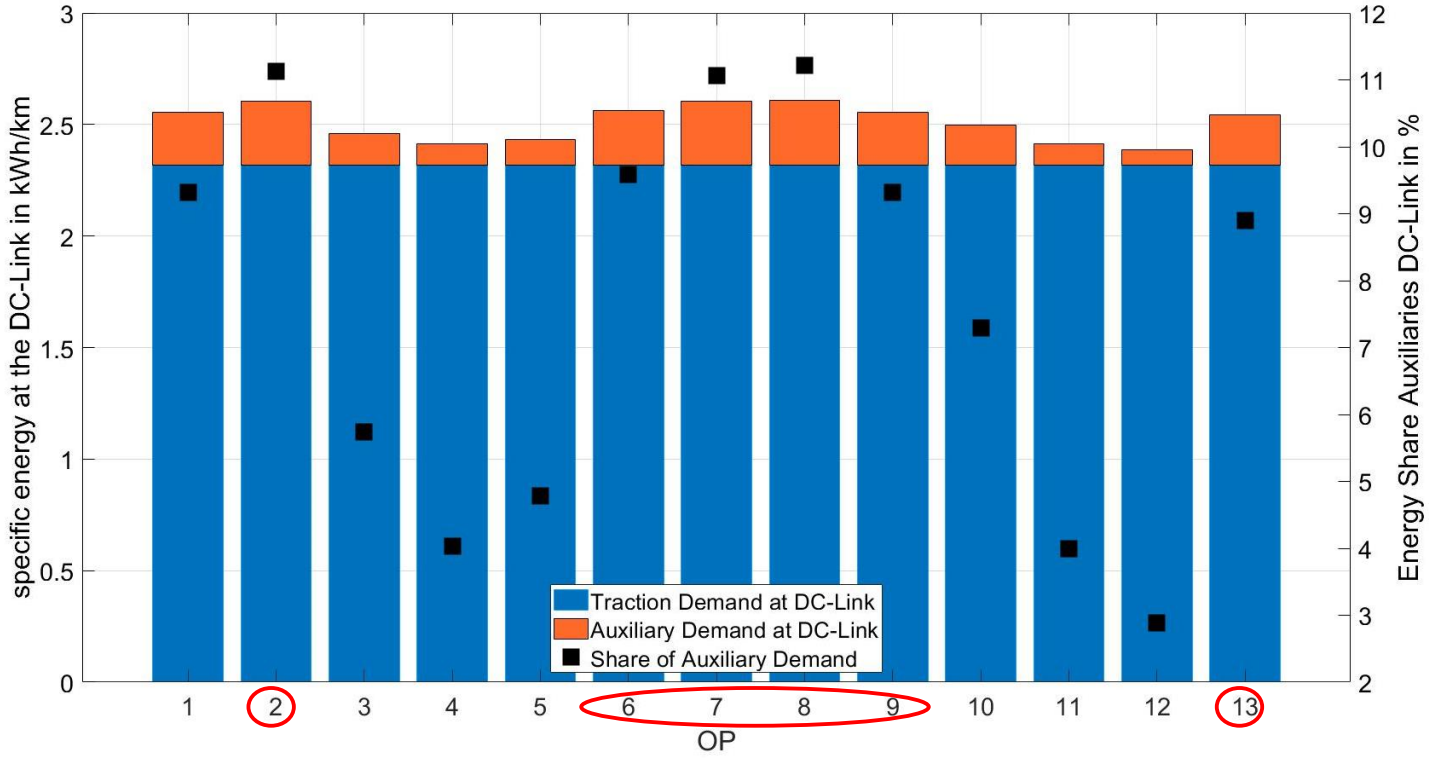
Due date of deliverable: 30/11/2020
Actual submission date: dd/mm/2022

Leader/Responsible of this Deliverable: Jürgen Ernst (DB)

Identification of critical OPs with high energy demand

- Comparison of traction and HVAC energy demand for 13 EN50591 OP

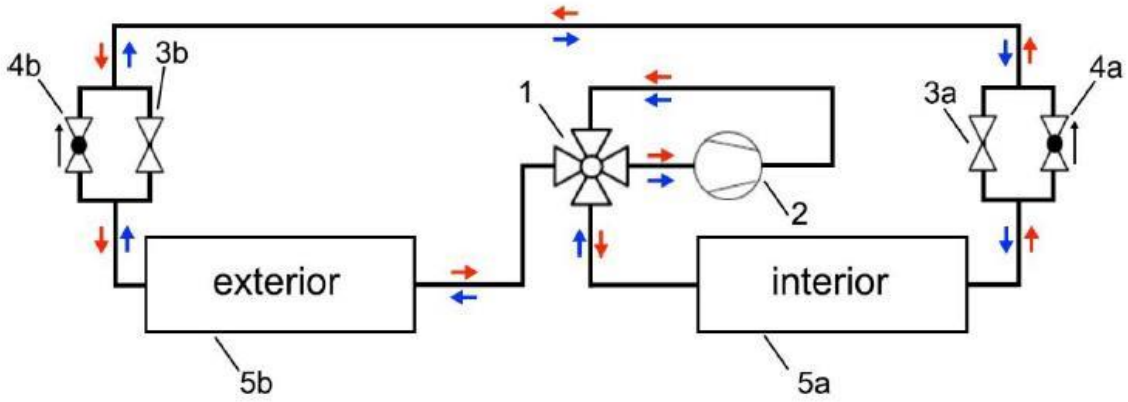
Operation point	Temperature T_{amb} in °C	Humidity $H_{r,amb}$ in %	Sun radiation in W/m²	Passenger load in %
1	-10	90	0	0
2	0	90	0	100
3	10	90	0	50
4	15	90	0	50
5	22	80	0	100
6	28	70	600	100
7	35	50	700	100
8	-20	90	0	0
9	-10	90	0	0
10	0	90	0	0
11	15	80	0	0
12	22	80	0	0
13	35	50	700	0



➔ **OPs with high or low ambient temperatures are most demanding in terms of HVAC energy demand**

Reference BEMU: Use of a heat pump

- In modern reference vehicles heat pumps are integrated for covering heating demand in BEMUs
- Heat Pumps use technical work to take thermal energy from a reservoir with a lower temperature and transfers it as useful heat to a system with a higher temperature
- high efficiency (COP>1) by transfering electric power into heating



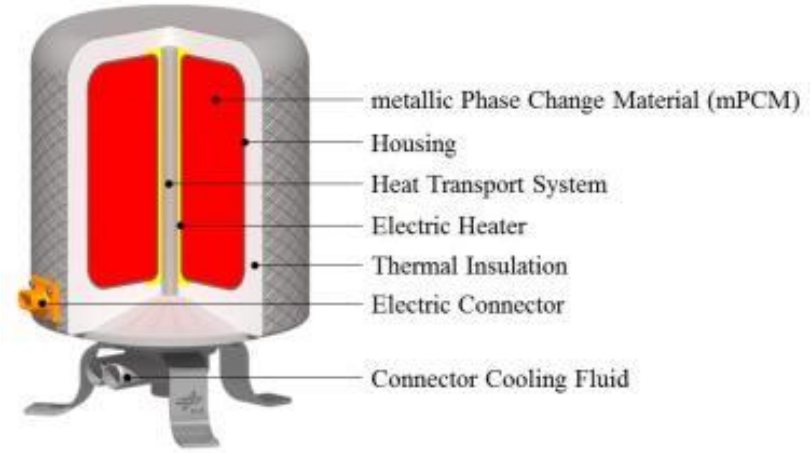
HVAC with reversable process. Blue – mass flow of cooling mode red – heat pump mode (Trygstad, 2017) The function of the two heat exchanger (condenser and evaporator) vary if operated in heatpump or cooling mode

➔ **This measure is regarded as state of the art in BEMU Baseline (reference)**

➔ **The study evaluates the higher demand of a conventional solution with resistance heater**

Energy efficiency measures for HVAC

Measure 1: Heat Storage

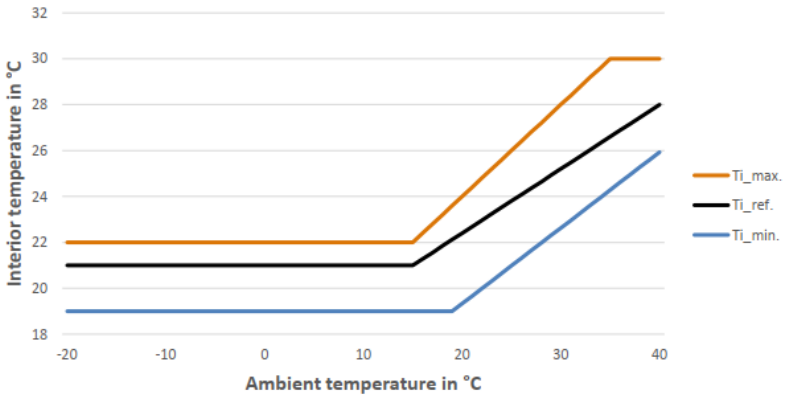


- Integration of high-performance thermal heat storage to relieve the HVAC-load on the traction battery

Measure 2: Improvement of heat transfer

- Significant amount of heat in trains is lost through walls and windows ➔ add insulation or use of materials with less thermal conduction

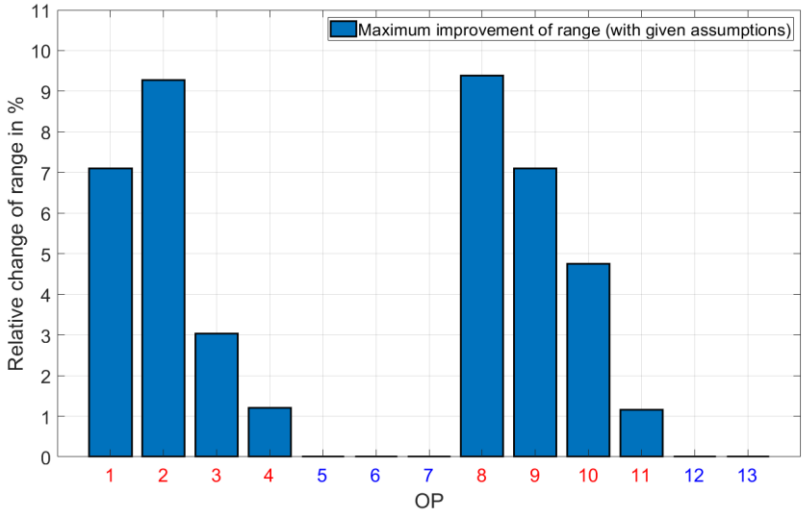
Measure 3: Utilisation of reference temperature limits



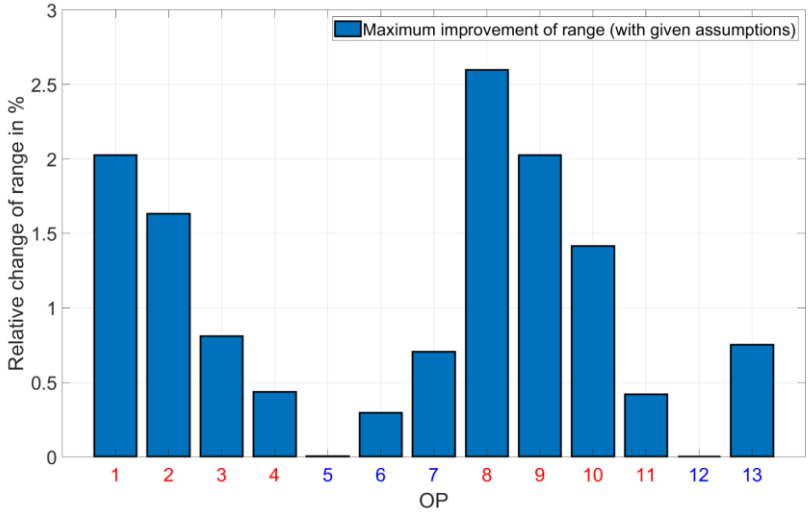
- Boundaries of comfort temperature are given by EN14750 ➔ Reduction of HVAC energy demand by utilisation of the full temperature range

Results for each EN50591 OP in terms of additional BEMU range

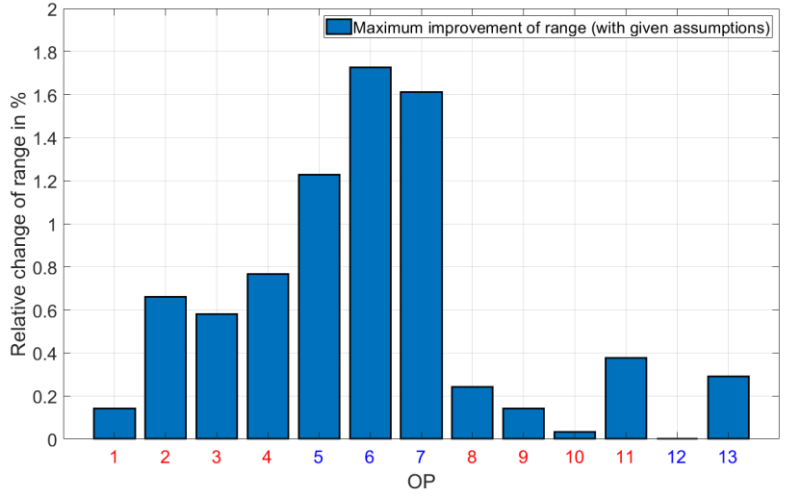
Measure 1: Heat Storage



Measure 2: Improved heat transfer



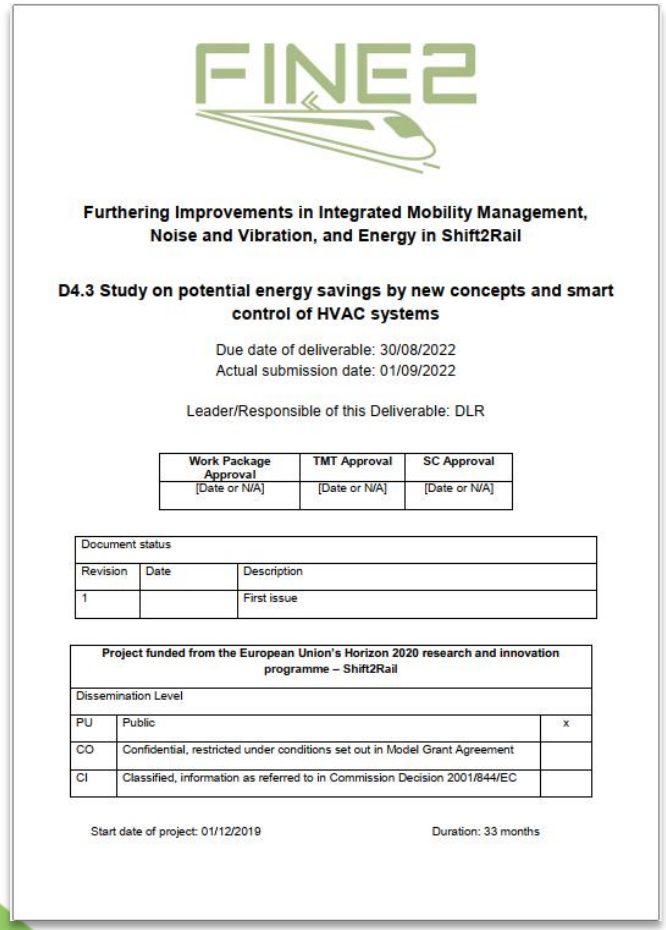
Measure 3: Utilisation of full T-range



➔ **Heat storage is very effective in heating OPs, but inneffective in cooling OPs**

➔ **Improved Heat Transfer and Utilisation of full T-range are effective in heating and cooling OPs**

Comparison of yearly HVAC Energy Savings



FINE2

Furthering Improvements in Integrated Mobility Management, Noise and Vibration, and Energy in Shift2Rail

D4.3 Study on potential energy savings by new concepts and smart control of HVAC systems

Due date of deliverable: 30/08/2022
Actual submission date: 01/09/2022

Leader/Responsible of this Deliverable: DLR

Work Package Approval	TMT Approval	SC Approval
[Date or N/A]	[Date or N/A]	[Date or N/A]

Document status		
Revision	Date	Description
1		First issue

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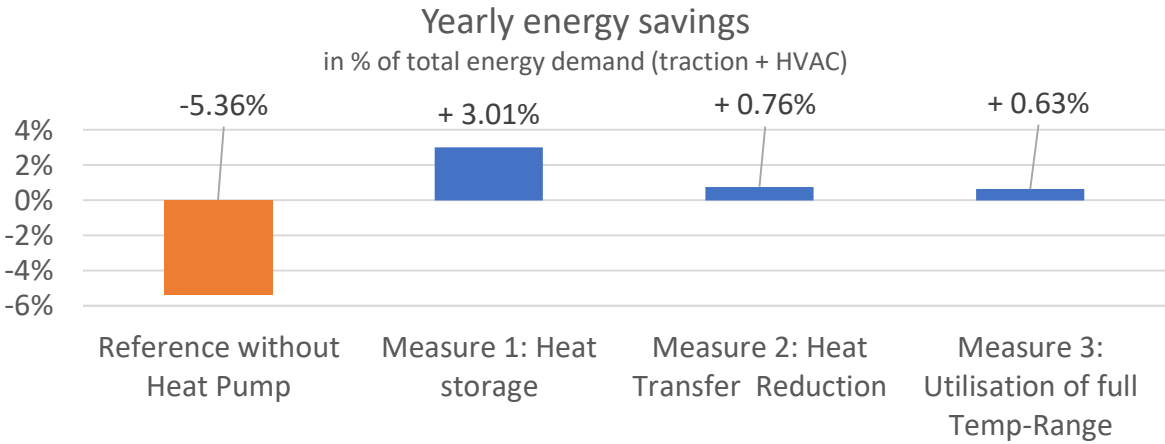
Dissemination Level		
PU	Public	x
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

Start date of project: 01/12/2019 Duration: 33 months



Results:

- Heat pump replacing conventional AC is most promising candidate for energy saving in regional BEMU
- Application of heat storage system is most effective, but only in heating OP.
- Modified passenger compartment temperature control recommended in particular for OP with cooling, low-effort measure
- Reduced heat transfer through the car body by improved insulation has good effect, but high effort.

Thank you for your Attention

Any Questions or Remarks?