Rail Transit HVAC Energy Optimization

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Agenda

Introduction

- Energy consumption optimization provides
  - cost savings for energy
  - reduced environmental impact

- Heating, Ventilation and Air Conditioning (HVAC) is an important consumer of electrical power on rail vehicles
- HVAC power consumption can be reduced by several simple means, including
  - Demand controlled ventilation
  - Free cooling
  - Multiple refrigeration circuits
  - Speed controlled compressors
  - Heat pump operation

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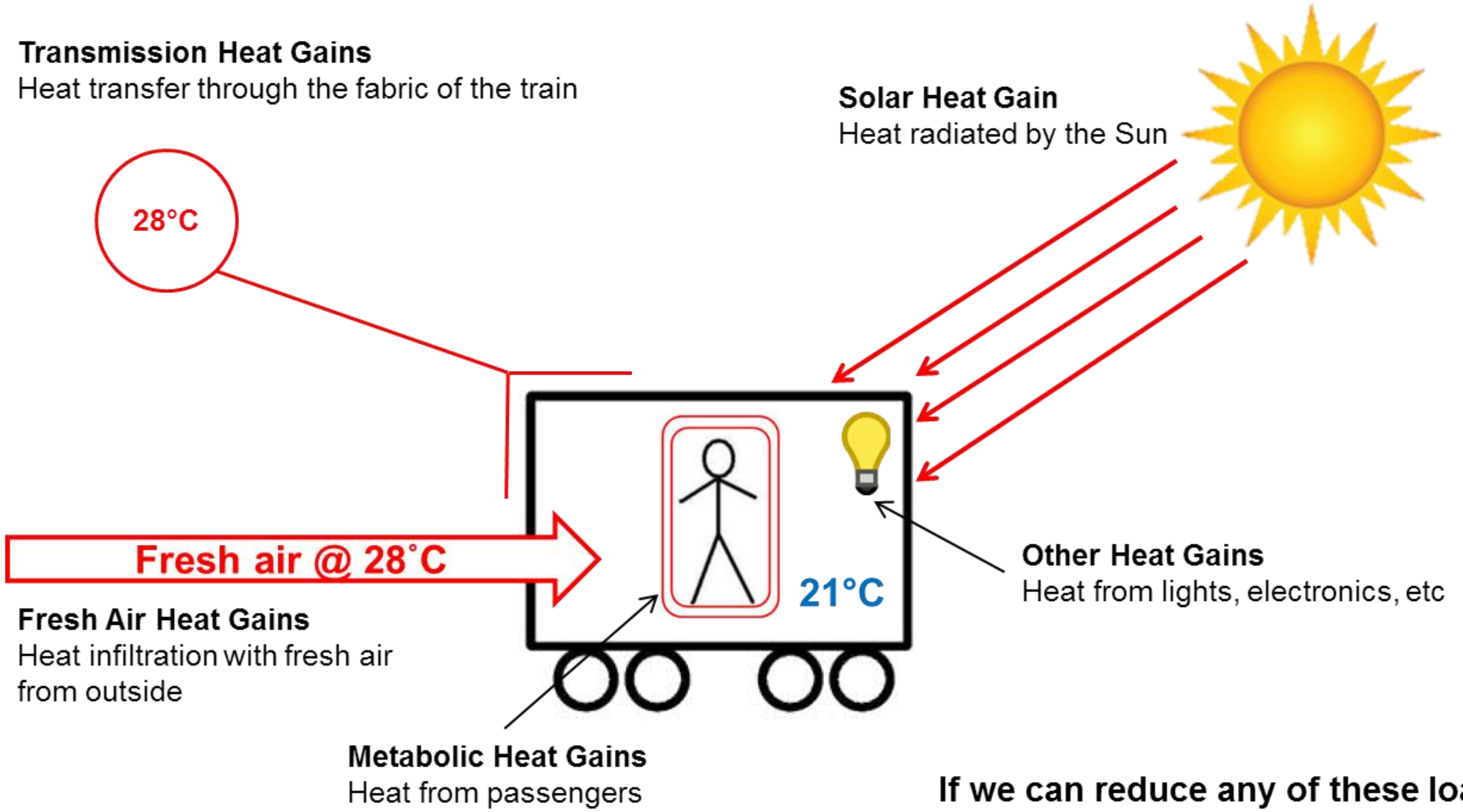
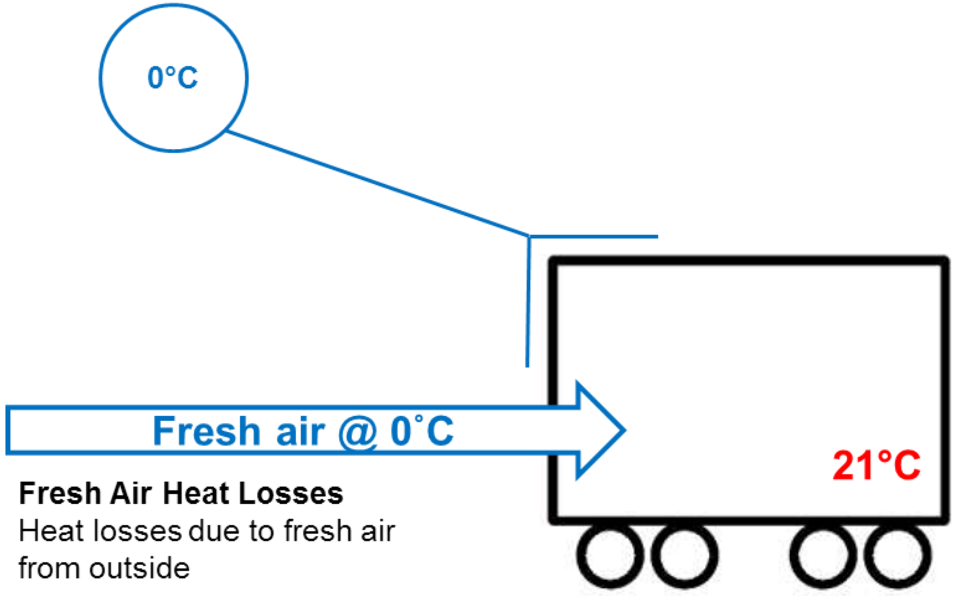
Demand Controlled Ventilation



If we can reduce any of these loads by any means we can save power while still maintaining passenger comfort

Demand Controlled Ventilation

Transmission Heat Losses
Heat transfer through the fabric of the train



Fresh Air Heat Losses
Heat losses due to fresh air from outside

If we can reduce any of these losses by any means we can save power while still maintaining passenger comfort

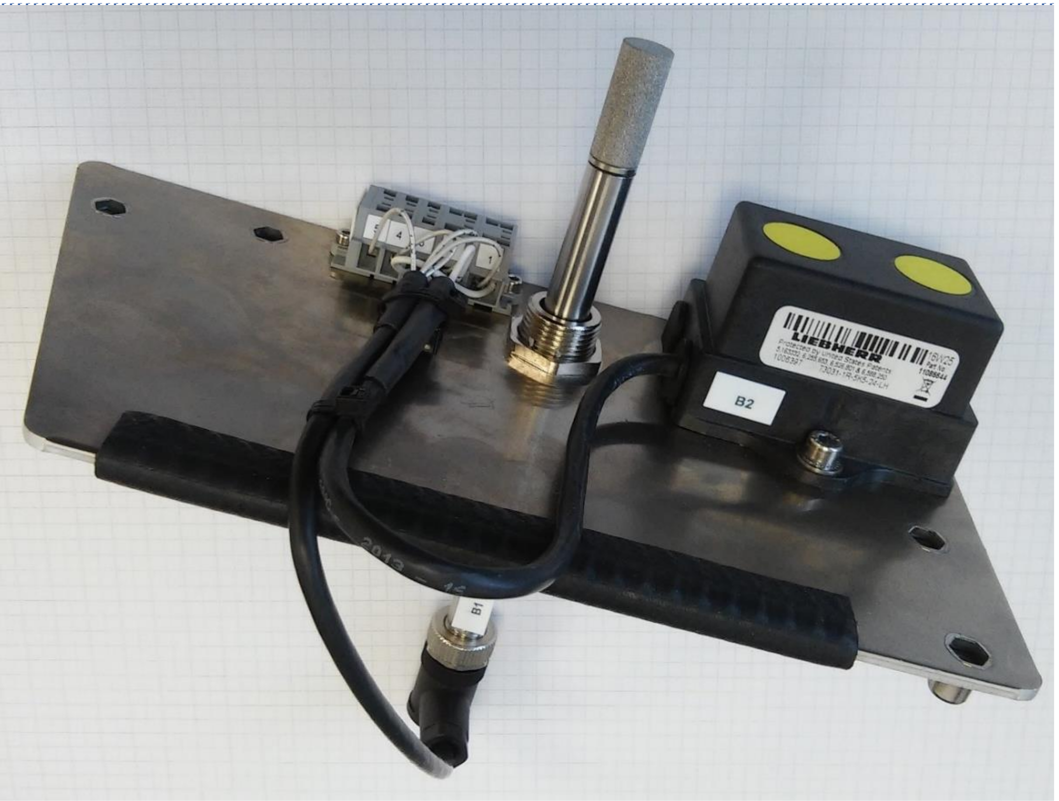
Fresh Air is Needed to Maintain Air Quality

Demand Controlled Ventilation

- Fresh air enters the rail car from outside through the fresh air intake of the HVAC unit, open doors, open windows and various other small gaps
- Fresh air plays an important role in maintaining air quality
- The necessary fresh air volumetric flow to maintain CO_2 levels below predetermined threshold at crush load is calculated
- Fresh air supply of the HVAC system is adjusted to supply the needed amount of fresh air with the doors and windows closed, allowing for a small additional margin

Fresh Air is Needed to Maintain Air Quality

Demand Controlled Ventilation

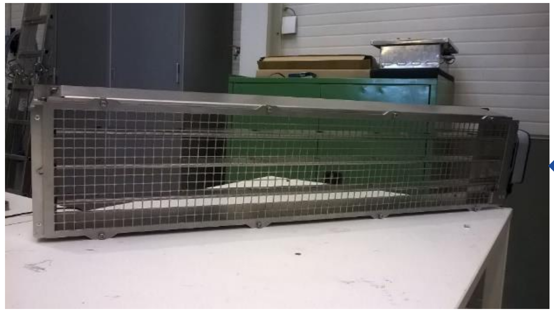


CO$_2$ and Humidity Sensor

- However, when the car is not fully occupied and/or if air changes are introduced when doors are open, there is no need to introduce the prescribed maximum fresh air to maintain air quality
- Modern HVAC unit controls can be designed to regulate the fresh air supply based on occupancy
- This gives an opportunity to save power in service with the obvious cost and environmental benefits this brings without negatively impacting passenger comfort

CO_2 Sensor General Concept

Demand Controlled Ventilation



Fresh Air Damper

Additionally, in some cases also:

- Return Air Damper
- Supply Air Blower

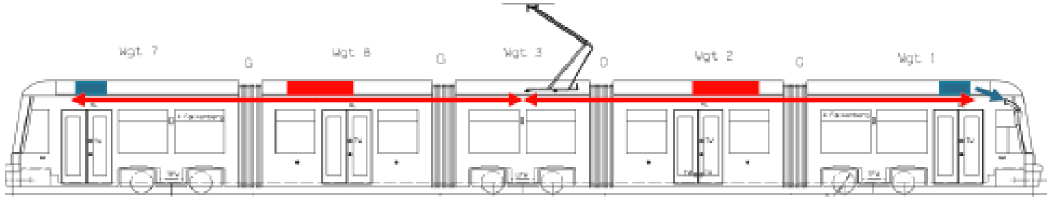
Controller

Humidity Sensor

CO_2 Sensor

CO_2 Sensor Energy Savings Potential - Example

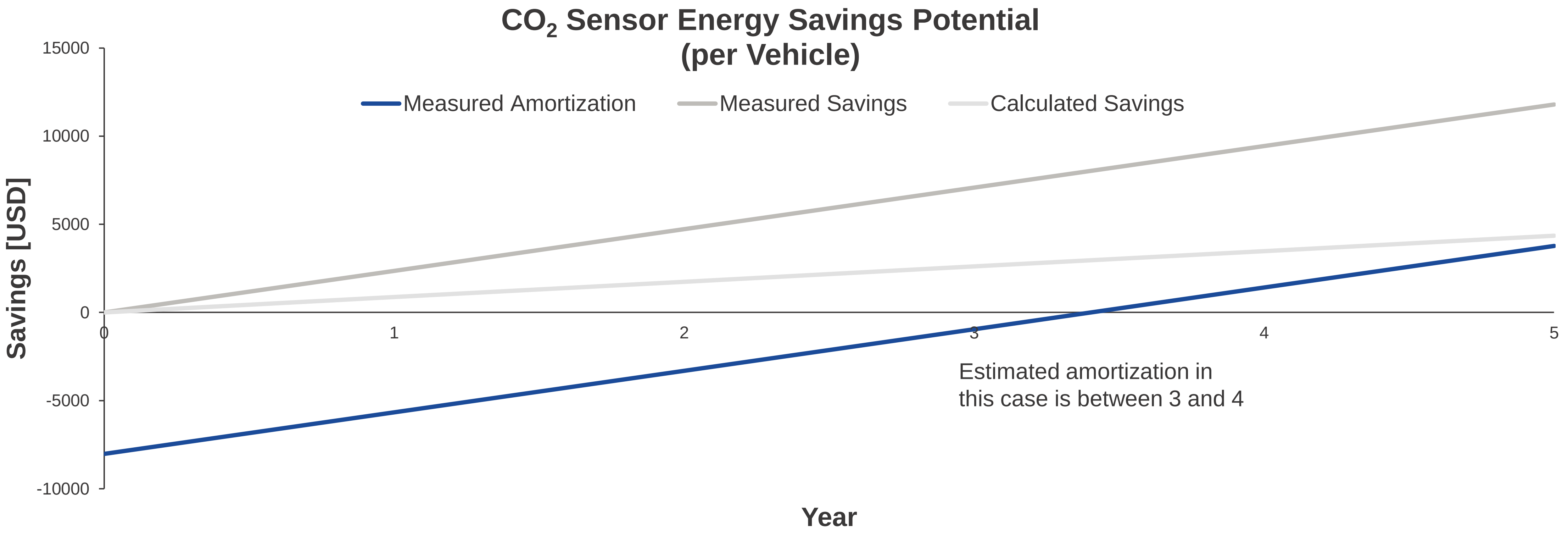
Demand Controlled Ventilation



- Demand Controlled Ventilation based on CO_2 sensing approach was tested on light rail vehicles in Berlin, Germany (climate zone 2)
  - CO_2 sensor, humidity sensor and additional test equipment were fitted to one light rail vehicle
  - Test equipment was fitted to a second light rail vehicle to document the baseline energy consumption
- Each passenger HVAC unit offers
  - 16.5 kW cooling capacity (4.7 tons)
  - 2 x 13 kW heating capacity (44,000 BTU/hr)

CO_2 Sensor Energy Savings Potential - Example

Demand Controlled Ventilation



Amortization calculation for energy optimization retrofit project: Initial calculation and subsequently a test run of the measurements over a test period of one year in Berlin with the BVG and extrapolated over 5 years; cost of electricity is assumed at 0.12 USD / kWh

Note: amortization is expected to be shorter if DCV is implementated at the design stage rather than retrofitted at a later stage

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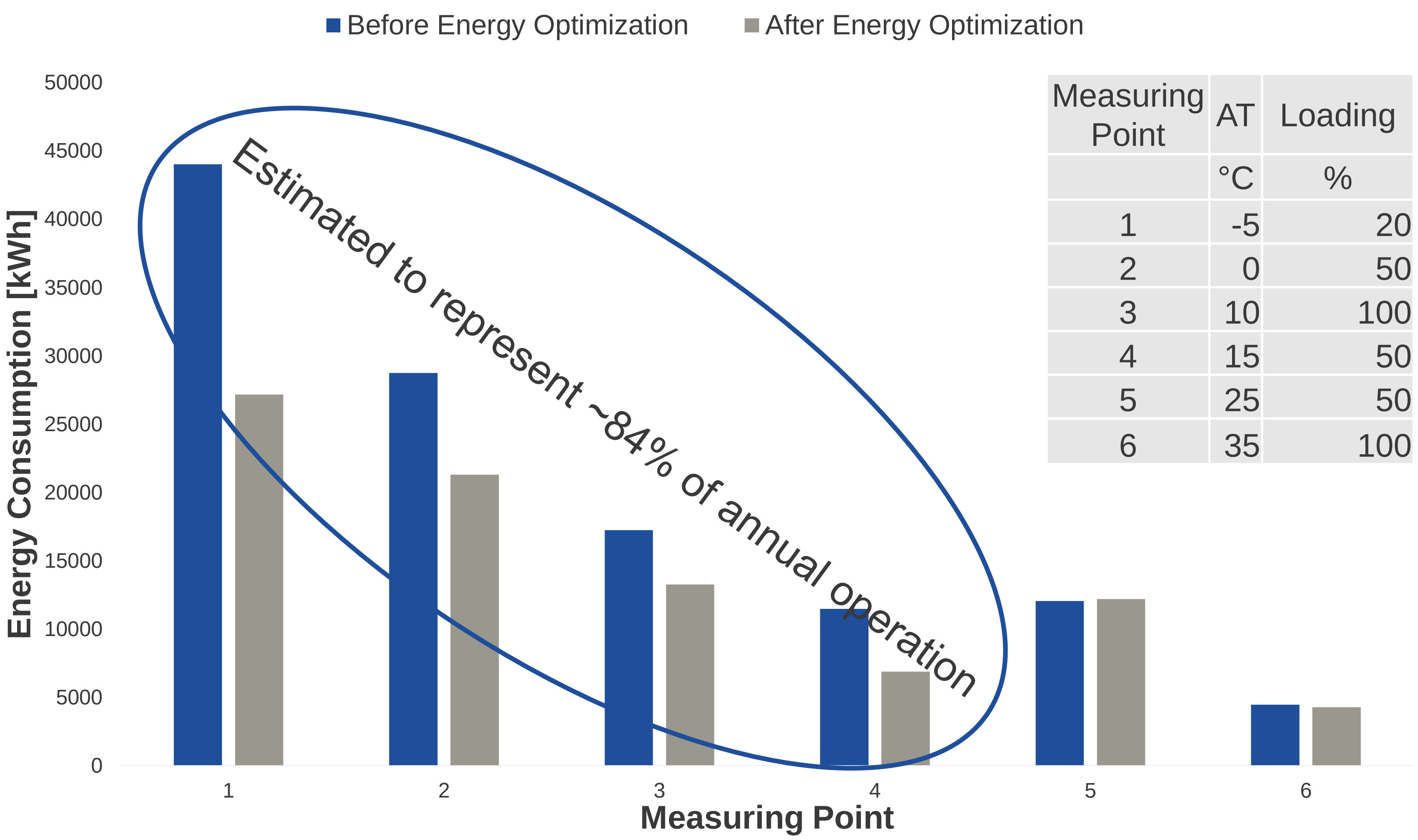
CO_2 Sensor Case Study 2: DB (Do2003)

Demand Controlled Ventilation

Assembly situation at ÖBB (Railjet) (high speed coach)	installation on 36 units completed
Assembly situation at DB (Do2003) (double deck coach)	performance verified on 3 units planned to be installed on further 964 units
Assembly situation at BVG (Berlin) (light rail vehicle)	performance verified on 3 units currently being installed on further 420 units
Assembly situation at DB (ET423) (electric multiple unit)	planned installation on 1800 units

CO_2 Sensor Energy Savings Measurements

Demand Controlled Ventilation



Measuring Point	AT	Loading
	°C	%
1	-5	20
2	0	50
3	10	100
4	15	50
5	25	50
6	35	100

- Measurements acc. to DB measuring cycle on double-deck coaches
- Each measuring point represents a combination of ambient temperature and passenger loading
- Measurements performed one hour WITHOUT and WITH energy-saving function at each measuring point
- Annual savings of ~32900 kWh per coach (28%)

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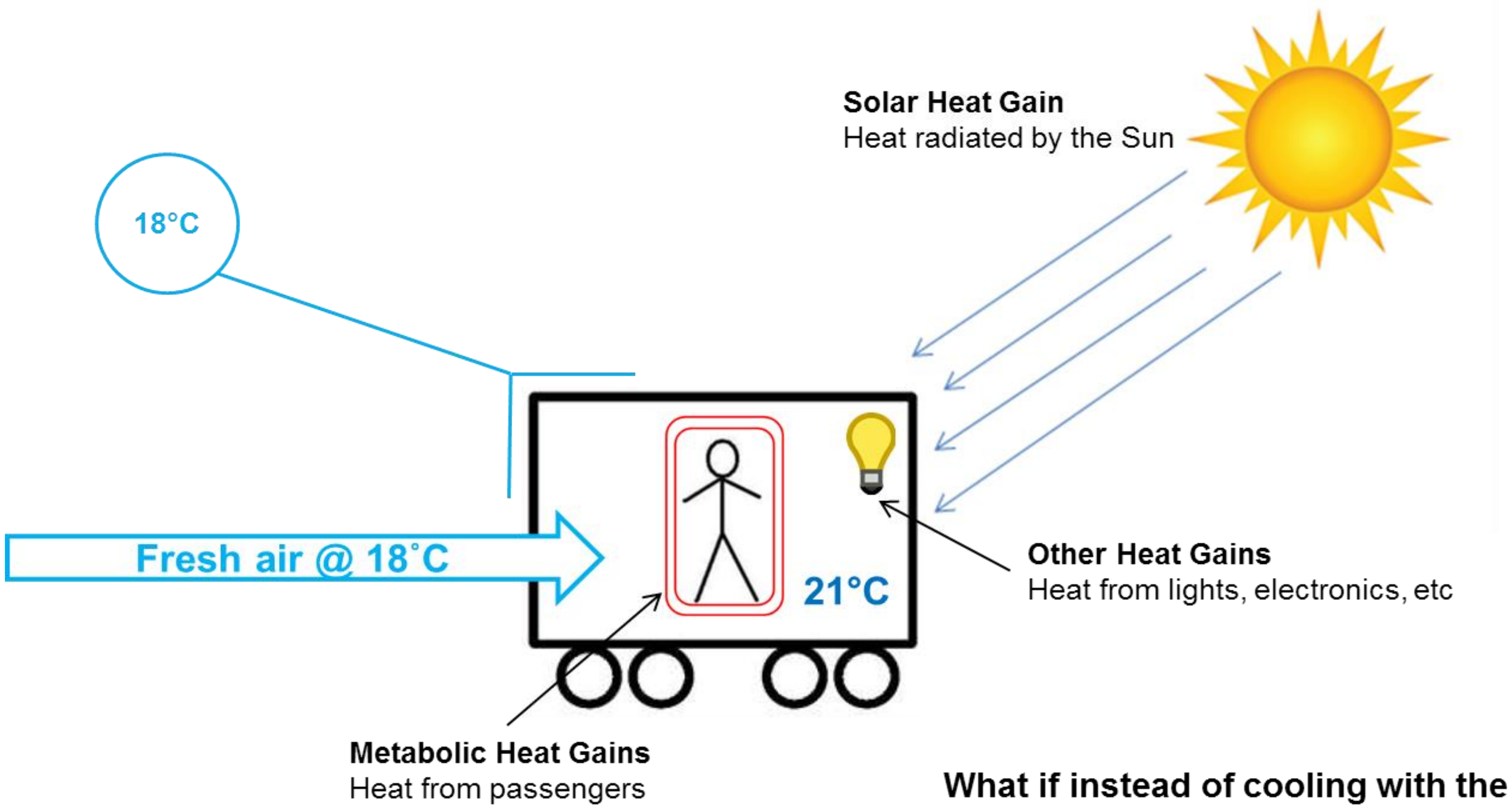
2 Demand Controlled Ventilation

3 Free Cooling

4 Multiple Standardized Units

5 Summary

Free Cooling



What if instead of cooling with the refrigeration circuit and mostly return air, we increased the fresh air flow rate?

Fresh Air is used to Provide Cool Air

Free Cooling

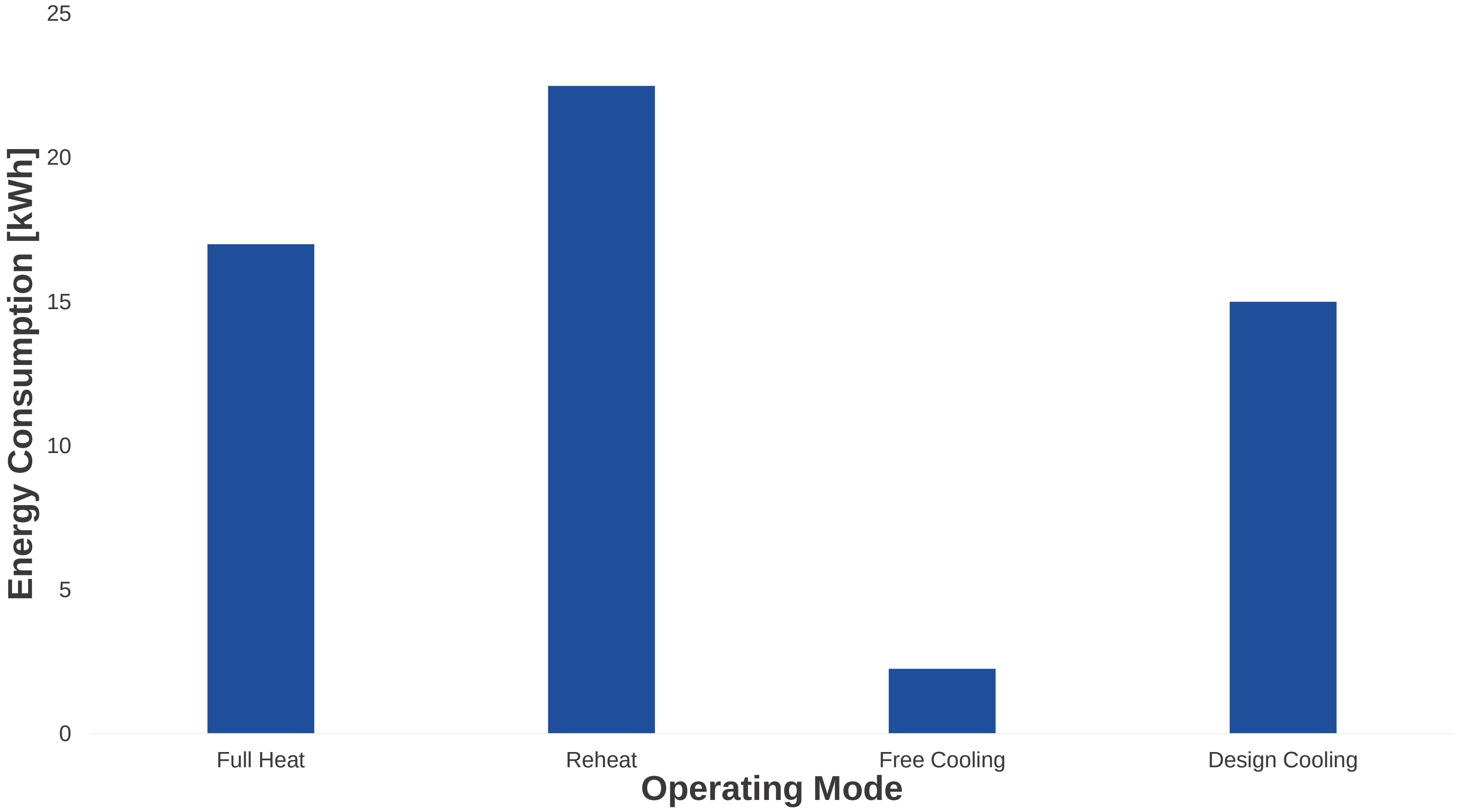
- Fresh air flow rate is increased when
  - In ventilation mode or low ambient temperature prevents cooling function; AND
  - The return air temperature rises above a predetermined value; AND
  - The return air temperature is higher than the fresh air temperature

- Refrigeration system is not active

- Limitations include
  - Air temperature / humidity
  - Air flow / air velocity

Energy Savings Potential

Free Cooling



- The refrigeration system is not active
  - Reduced power draw
  - Reduced compressor start/stop cycles

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Typical Arrangement

Multiple Standardized Units

- Typical modules are custom designs for a specific vehicle and often times even operator which results in a long engineering phase for both the unit design and integration with the vehicle (project approach)
- Vehicle cooling capacity designed for operating conditions which occur only at extreme heat conditions at high passenger loading (i.e. rush hour)
- Typical mass transit vehicles have one or two air conditioning modules per rail car
- Air conditioning operates in part load condition most of the year meaning that capacity is regulated by one or more means, including
  - on/off cycling,
  - hot gas bypass,
  - multiple refrigerant circles,
  - frequency variable power supply,
  - compressor internal modulation

One Module – Multiple Combinations

Multiple Standardized Units

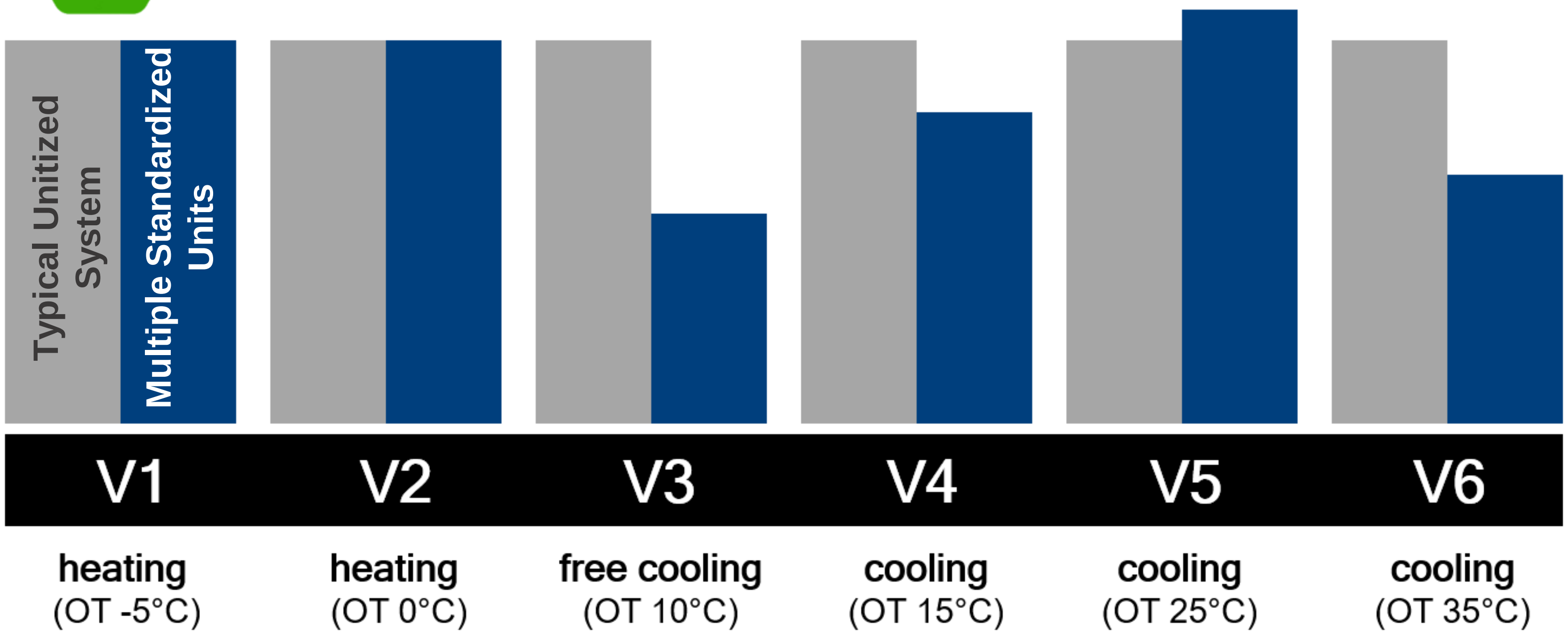
Flexible integration by arranging the modules in accordance with the individual car design and the required cooling power demand

- Designed once and the interfaces are determined (product approach)
- Multiple units, with one refrigeration circle each can be used to meet the cooling capacity required
- Typical subway cars may need three or four air conditioning units

Lower Power Consumption

Multiple Standardized Units

Average 8% lower power consumption during a typical season cycle.

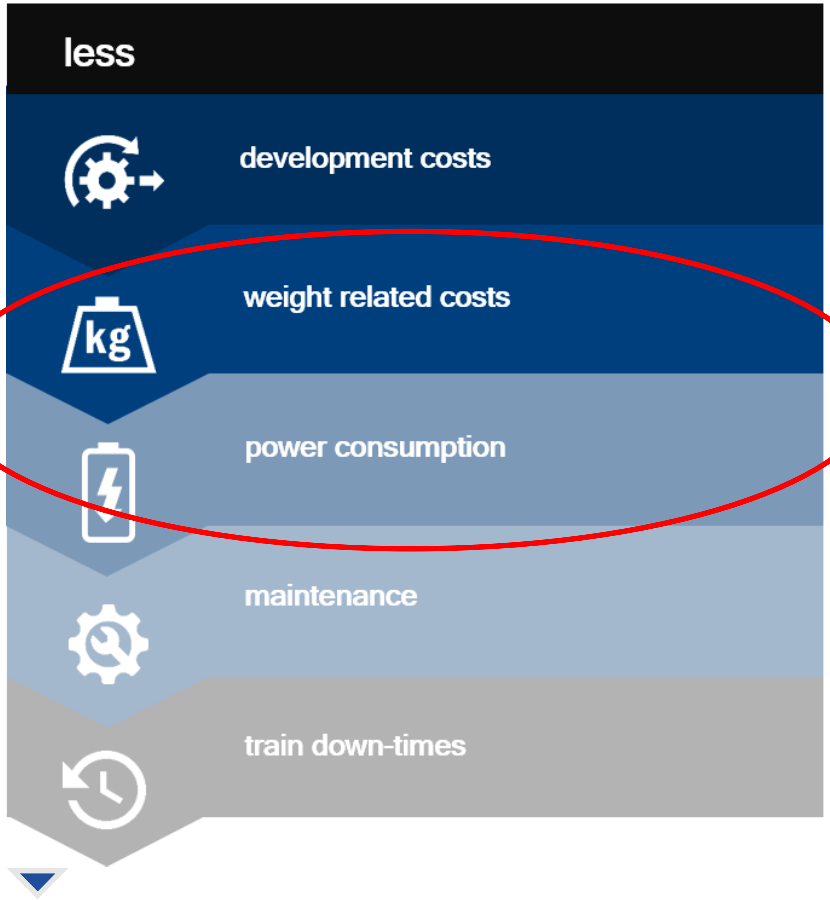


- Compressor with internal capacity regulation
- HVAC units which are not needed at any given time can be shut off or switched into a reduced power operating mode (such as ventilation mode)

Reduced energy consumption without need of frequency variable power supply on car level

Total Cost of Ownership

Multiple Standardized Units



Factors Reducing the Total Cost of Ownership

- “ready to use” products for customers
- extreme standardization (cab=saloon module)
- continuous product upgrades

- reduced weight

- partial load operation
- shut-off of units not needed

- optimized compressor cycle count by operating different units
- easy spares management
- off-car repair concept

- high availability of system function
- less impact of unscheduled maintenance

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Summary

- Demand controlled ventilation allows to save power by reducing energy needed to cool or heat more fresh air than necessary

- Free cooling makes use of ambient air to cool the inside of a rail vehicle without using the refrigeration system when ambient conditions allow to reduce energy consumption

- Multiple standardized units leverages the use of multiple small refrigeration systems and variable capacity compressors to provide the necessary cooling power with minimal waste of energy

- Energy consumption optimization provides
  - cost savings for energy
  - reduced environmental impact

Thank you for listening.

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