MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

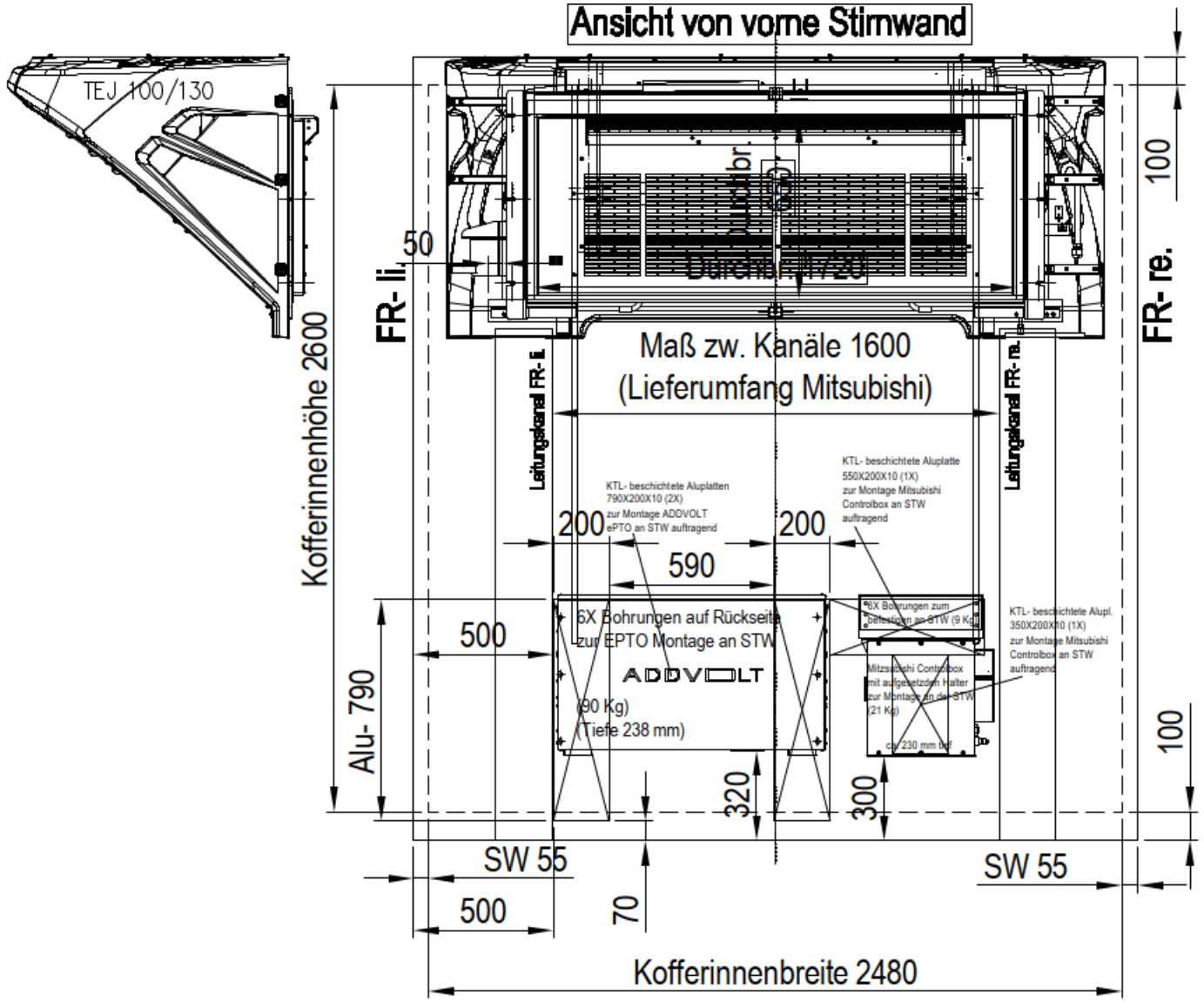
DAF XD Electric with TEJ 130 and Addvolt Power Unit

December 2024
G.Hilge

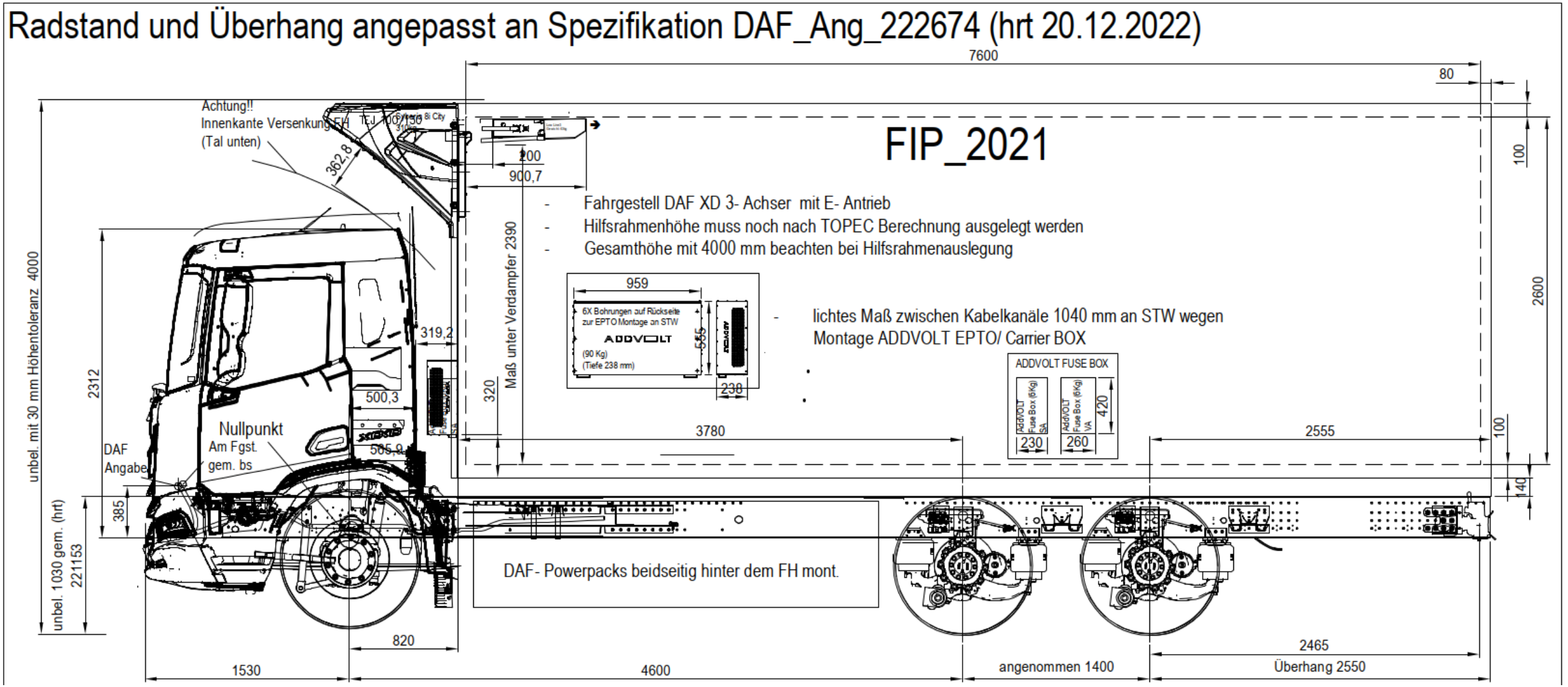
MITSUBISHI HEAVY INDUSTRIES THERMAL TRANSPORT EUROPE

Impressions of the DAF Truck with TEJ130

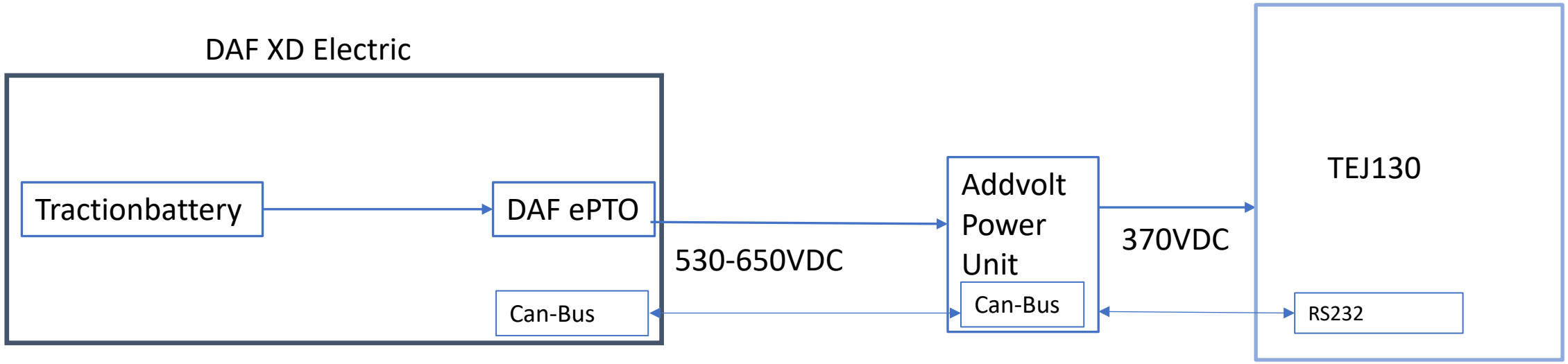
Drawings Frontwall

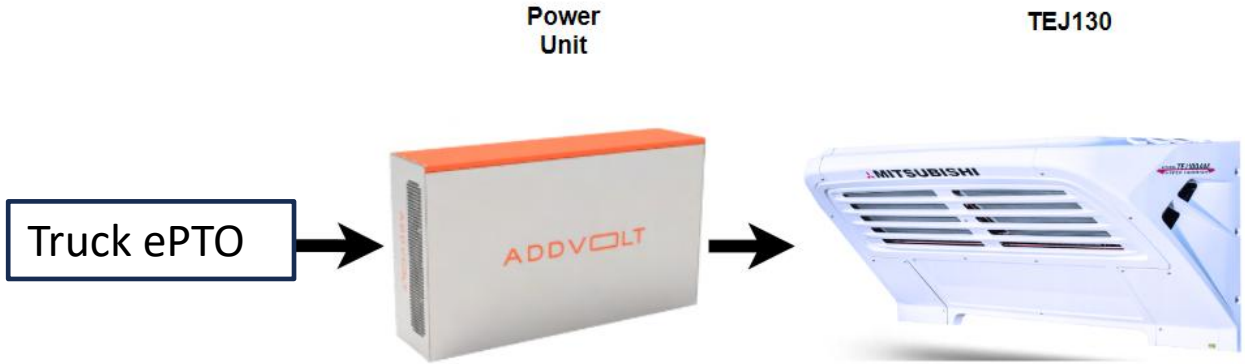


Drawings Sideview

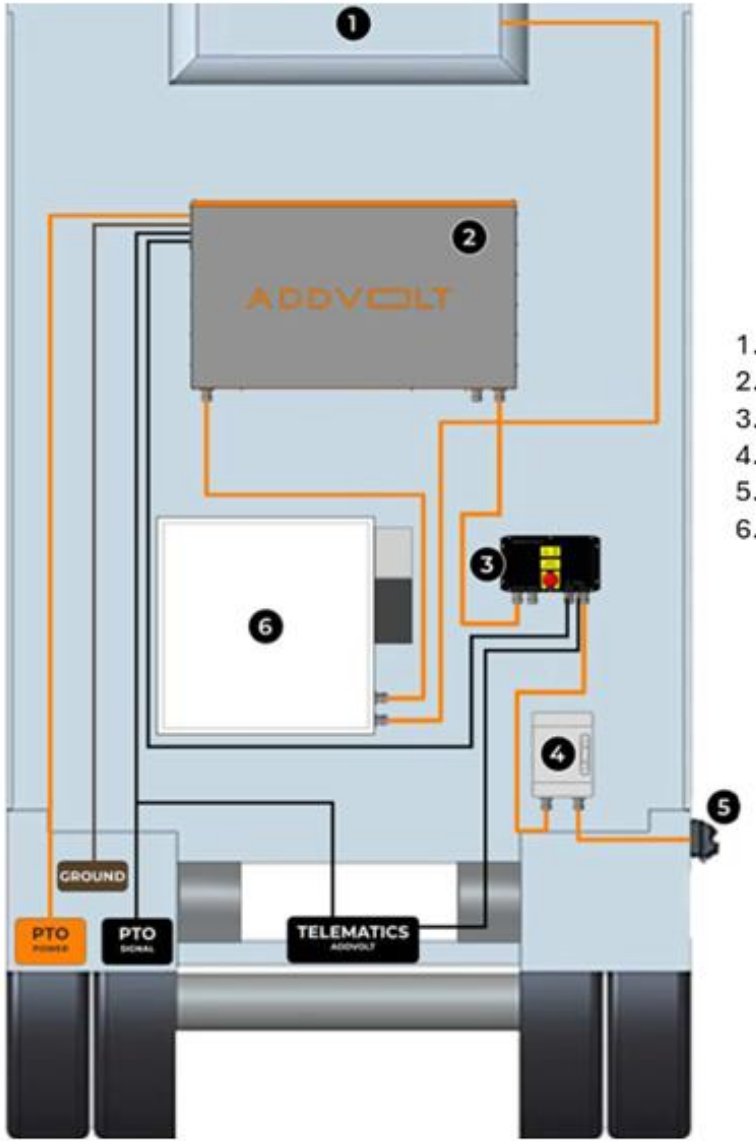


Current connection concept DAF XD Electric via Addvolt ePTO with Mitsubishi cooling unit TEJ130





Current connection concept DAF XD Electric via Addvolt ePTO with Mitsubishi cooling unit TEJ130



1. Mitsubishi TEJ130
2. Addvolt power unit
3. Service disconnect
4. RCD-Typ B
5. CEE
6. Mitsubishi Controlbox

Mitsubishi Reefer Units – Heavy Duty eTrucks

TEJ130 / TEJ 130 MT

Nosemount Unit For Heavy Duty Trucks		
cooling capacity	@ setpoint 0°C and AT 30°C	12966W / 14182W
	@ setpoint 0°C and AT 30°C commertial operation / grid connection	12966W / 14182W
heating capacity	@ setpoint 12°C and AT -10°C	6391W / 5539W
air volume flow		4020 m³/h
amount of refrigerant		4.4 / 5.7 kg
refrigerant		R 410 A
weight		278 kg

Semi-trailer unit		
cooling capacity	@ setpoint 0°C and AT 30°C	14700 W
	@ setpoint 0°C and AT 30°C commertial operation / grid connection	14741 W
heating capacity	@ setpoint 12°C and AT -10°C (heatpump → high power at low consumption)	15900 W
air volume flow		5629 m³/h
amount of refrigerant		5.7 kg
refrigerant		R 410 A
weight		ca. 450 kg

General information and introduction of Mitsubishi refrigeration units

Semi-trailer unit	TFV 150
Energyconsumption @ Setpoint 0°C and AT 30°C	11,9 kW
Energyconsumption @ Setpoint -20°C and AT 30°C	10,3 kW
Energyconsumption (heating) @ Setpoint 12°C and AT -10°C	7,3 kW

Nosemountunit for big rigid trucks	TEJ130 / TEJ130MT
Energyconsumption @ Setpoint 0°C and AT 30°C	9,5 kW
Energyconsumption @ Setpoint -20°C and AT 30°C	7,7 kW
Energyconsumption (heating) @ Setpoint 12°C and AT -10°C	10 kW

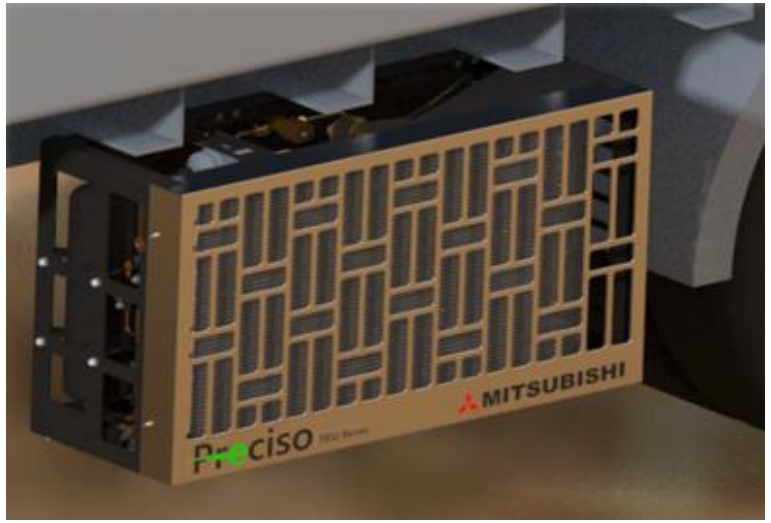
Hint:
The average consumption per hour is considerably lower.
The cooling units are operated at maximum power up to the setpoint in order to reach the setpoint as quickly as possible.
The compressor switches off until the actual temperature deviates from the setpoint.
The cooling unit is only active for a short time within an hour, the average consumption is considerably lower than when it is active.

Under- and nosemount unit for big rigid trucks		
cooling capacity	@ setpoint 0°C and AT 30°C (L evaporator)	>11000 W
	@ setpoint 0°C and AT 30°C (MW evaporator)	>9000 W
	@ setpoint -20°C and AT 30°C (L evaporator)	>6400 W
heating capacity	@ Setpoint 12°C and AT -10°C	6300 W
air volume flow		4800 m³/h
amount of refrigerant		3.5 kg
refrigerant		R 410 A
weight (condenser- & compressor-kit + e-box + L evaporator)		ca. 200 kg

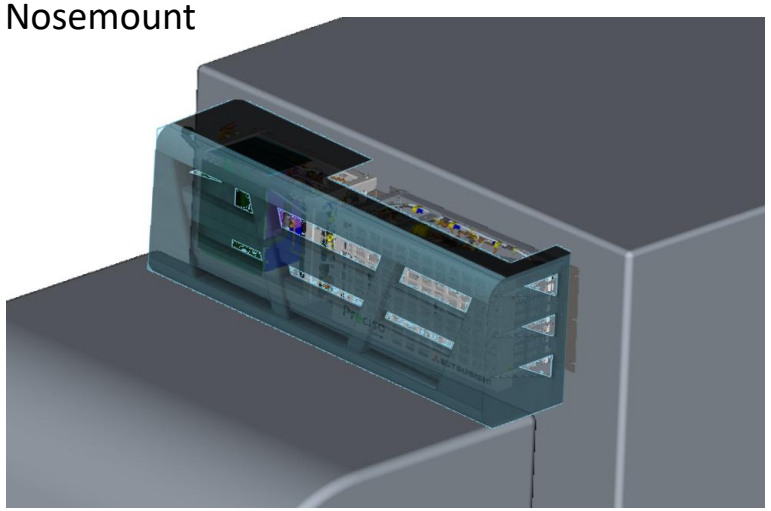
TEU (full electric inverter-controlled cooling units)

TEU
Modularity - Undermount - Nosemount - The condenser and compressor parts can be mounted also separately.
Max. 3 rooms operation
High efficiency
Higher air volume than TEJ130 - Condenser fan +20% - Evaporator fan (large) +15%

Undermount

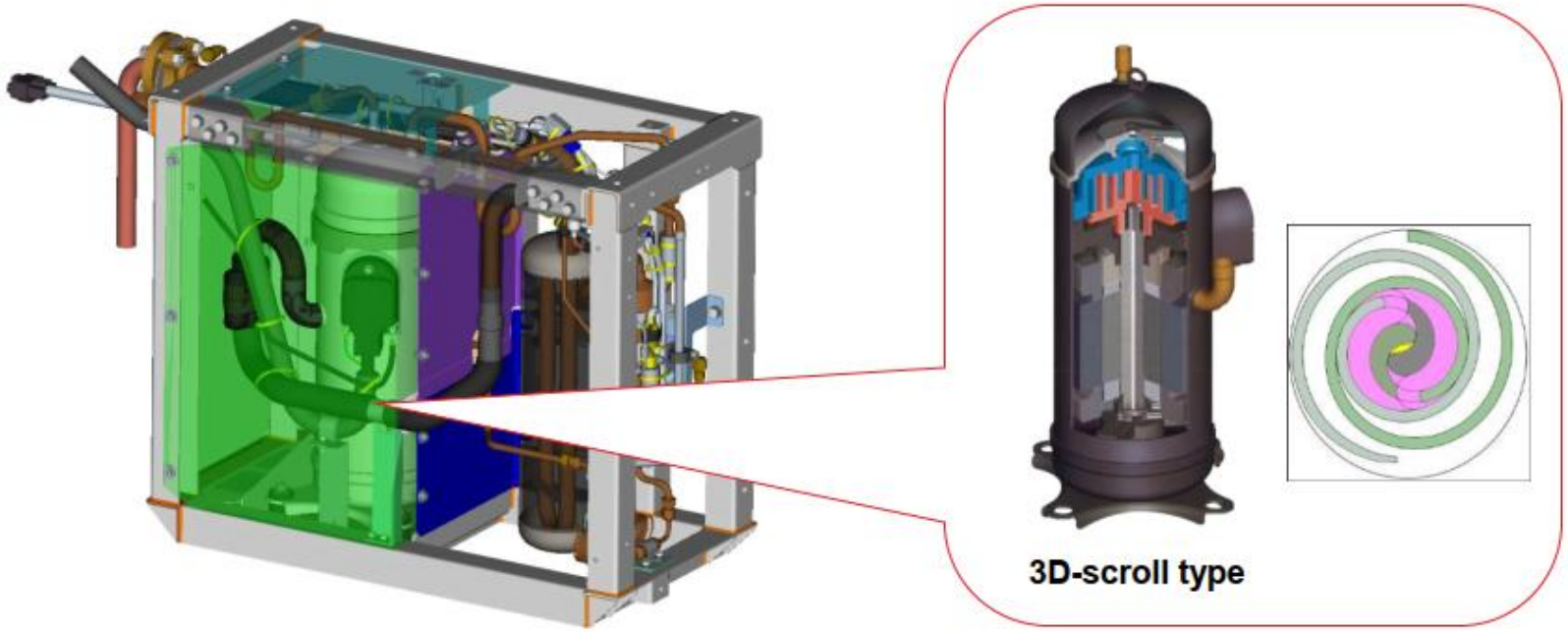


Nosemount



HIGH EFFICIENCY OPERATION

Invertor technology



Hermetic compressor

- **Long life** : 20000 hour or more
- **Experience of hundreds of thousands** or more of air conditioners.

Energy sources TEJ / TEU / TEF1500

Energy sources TEU / TEF1500
Battery pack (optional with eAxis and / or Solarroof) Energy supply via battery / energy axis / solar roof possible. Energy supply through an additional battery pack, which is optimised to the customer's requirements.
ePTO Connection to the traction battery of a fully electric vehicle via the ‘ePTO’.
Hydraulic System Power supply via hydraulic generator, which is driven via the ‘mPTO’ on the truck's diesel engine.
Grid power Commertial power supply for precooling.

Highly efficient inverter technology of Mitsubishi refrigeration units

In refrigeration cycles the temperature control due to compressors using inverters offers several key features:

1.Variable Speed Operation: Inverters allow the compressor to operate at varying speeds, adjusting to the cooling demands more efficiently. This results in energy savings and precise temperature control.

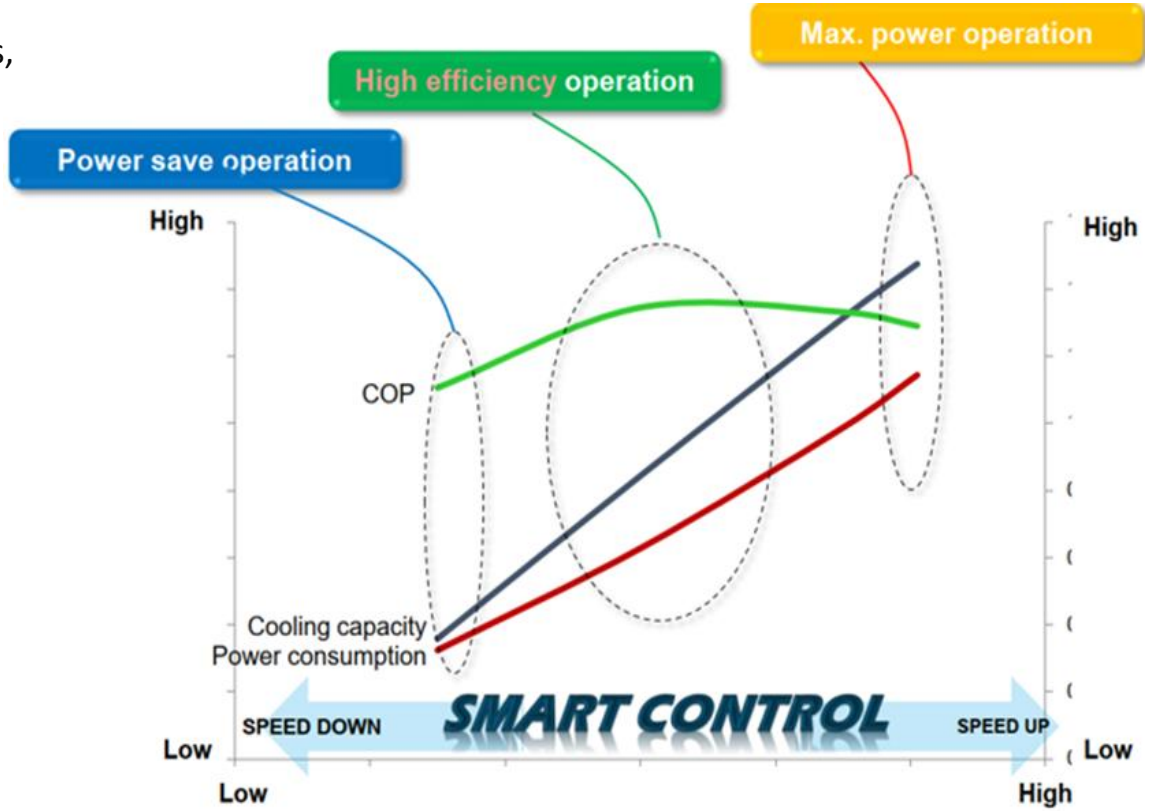
2.Smooth Start-Up: The use of inverters enables smooth start-up of the compressor, reducing the stress on the system and extending its lifespan.

3.Precise Temperature Regulation: Inverter-controlled compressors can maintain a more stable and precise temperature range, providing better control over the cooling process.

4.Improved Energy Efficiency: By adjusting the compressor speed according to the load requirements, inverters optimize energy usage, leading to lower operating costs.

5.Reduced Noise and Vibration: Inverter-driven compressors often operate more quietly and with reduced vibrations compared to traditional compressors, enhancing user comfort and system durability.

Overall, the use of inverters in compressor temperature control contributes to better performance, energy efficiency, and operational stability in refrigeration systems.

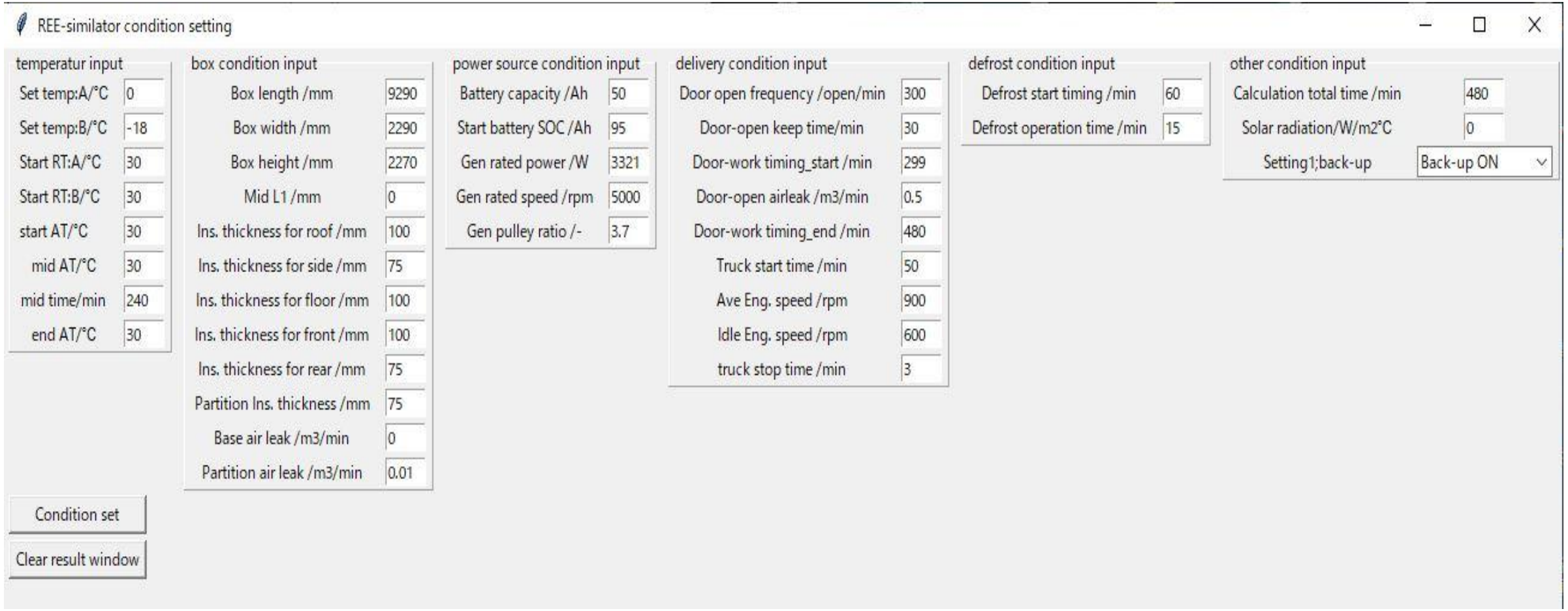


→ This technology is comparable to the speed control of an electric engine in a fully electric vehicle, with the difference that the driver does not set the speed, but this is done automatically via a microcontroller.

Calculation Example TEJ130 / TEU

For Rigid Truck / Drawbar Trailer

Mitsubishi simulationstool – inputmask



Energy consumption TEJ130 Example – Calculation result

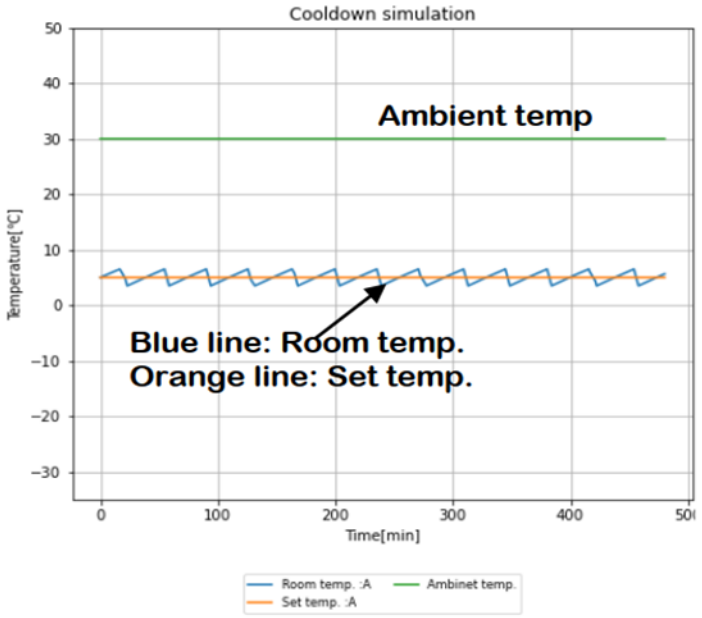
TEJ130 Monotemp consumption values Fresh service case (IN / k=0.7)

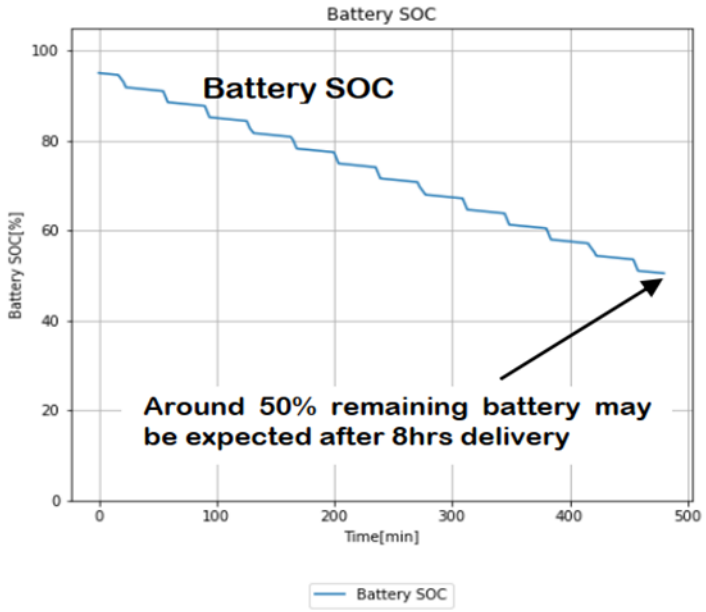
Box data:
Internal dimensions: L7790mm x W2504mm x H2300
Insulation: 85mm roof, 126mm floor, 45mm rest

Setpoint: 5°C
Outside temperature: 30°C
Delivery time: 8h
Openings: 30 (3,75/h)
Opening time: 3min (short opening time)
Door air leakage rate: 0.2m³/min (good cold curtain / low air exchange)
Precooled case

Battery capacity: 23kWh
Start 21.85kWh - end 11.5kWh = 10.3kWh consumed

→1,29kW per h consumption





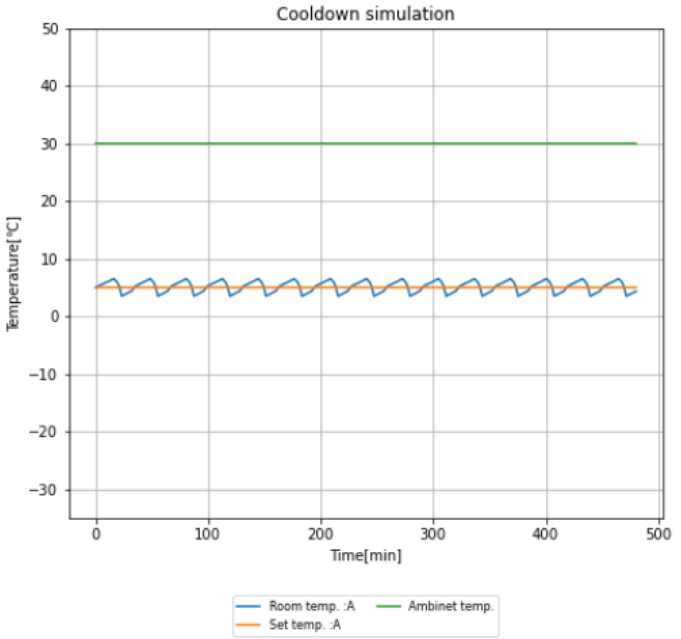
Energy consumption TEJ130 Example – Calculation result

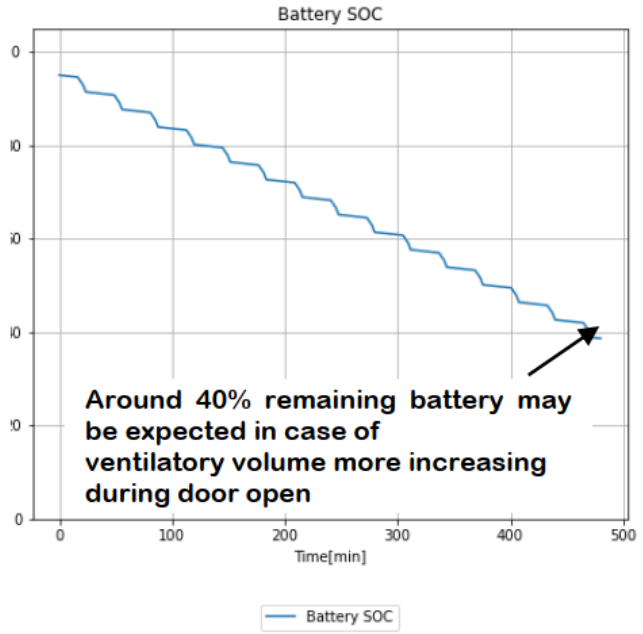
TEJ130 Monotemp consumption values Fresh service case / high air exchange at opening

Box data:
Internal dimensions: L7790mm x W2504mm x H2300
Insulation: 85mm roof, 126mm floor, 45mm rest
Setpoint: 5°C
Outside temperature: 30°C
Delivery time: 8h
Openings: 30 (3,75/h)
Opening time: 3min (short opening time)
Door air leakage rate: 5m³/min (simple cold curtain / high air exchange)
Precooled case

Battery capacity: 23kWh
Start 21,85kWh - End 9,2kWh = 12,65kWh consumed

→1,58kW per h consumption





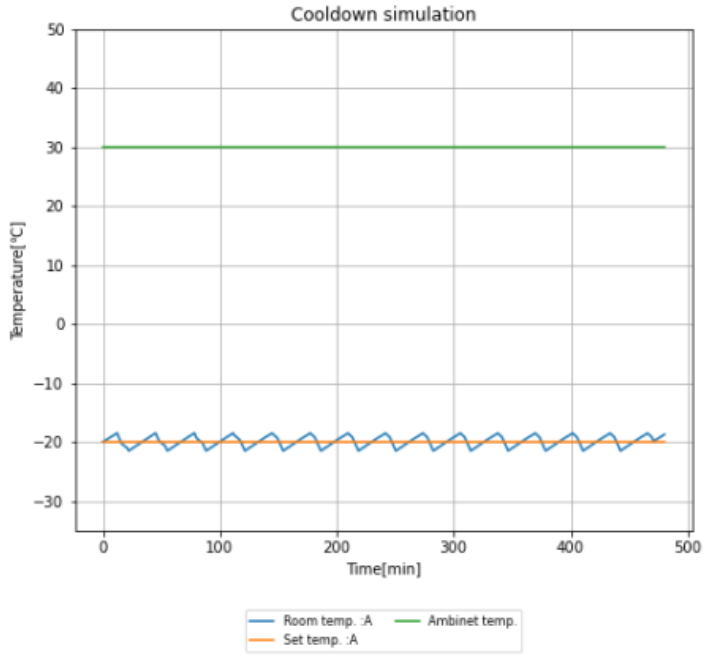
Energy consumption TEJ130 Example – Calculation result

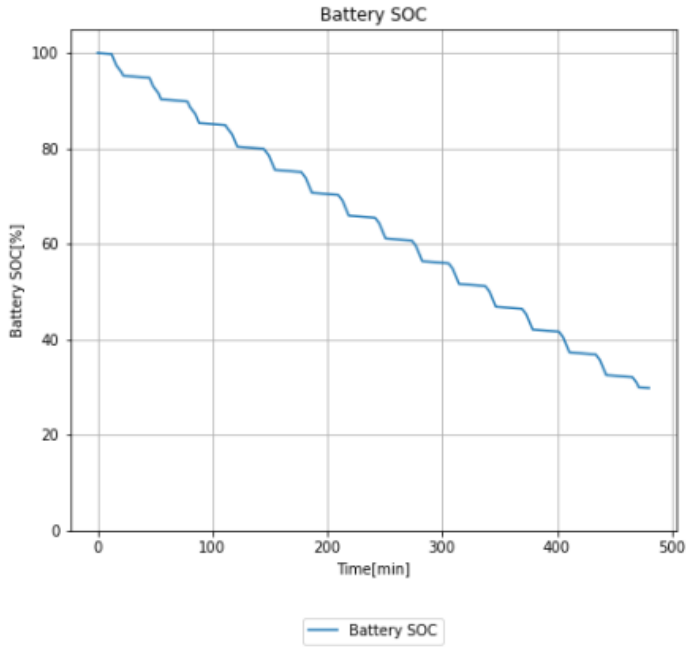
TEJ130 Monotemp consumption values deep-freeze case (IR / k=0.4)

Box data:
Internal dimensions: L7790mm x W2504mm x H2300
Insulation: 120mm roof, 160mm floor, 60mm rest
Setpoint: -20°C
Outside temperature: 30°C
Delivery time: 8h
Openings: 30 (3,75/h)
Opening time: 8min (average opening time)
Door air leakage rate: 0.2m³/min (good cold curtain / low air exchange)
Precooled case

Battery capacity: 32kWh
Start 32kWh - end 9.6kWh = 22.4kWh consumed

→ 2.8 kW per h consumption





Energy consumption TEJ130 Example – Calculation result

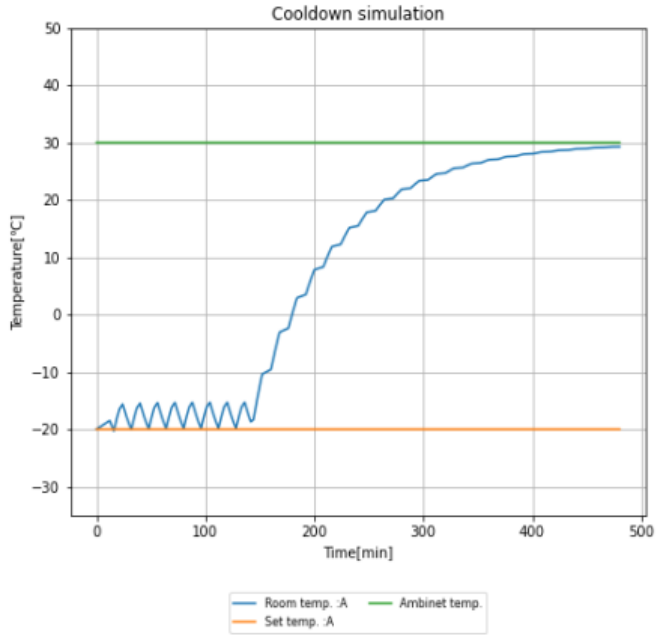
TEJ130 Monotemp consumption values deep-freeze case/ very high air exchange at opening

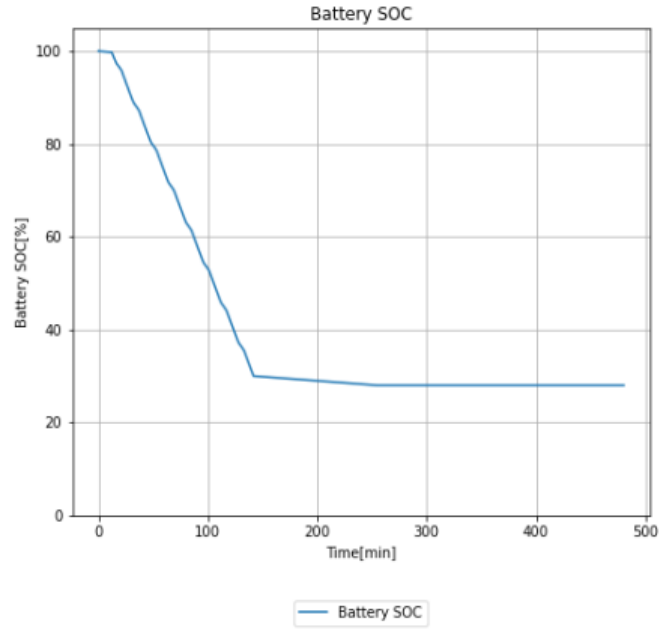
Box data:
Internal dimensions: L7790mm x W2504mm x H2300
Insulation: 120mm roof, 160mm floor, 60mm rest
Setpoint: -20°C
Outside temperature: 30°C
Delivery time: 8h
Openings: 30 (3,75/h)
Opening time: 8min (average opening time)
Door air leakage rate: 10m³/min (no cold curtain / very high air exchange)
Precooled case

Delivery time 8h is not reached with 32kWh
after 135min 30% SOC

Battery capacity: 32kWh
Start 32kWh - end 9,6kWh = 22,4kWh consumed in 135min

→ 9,95 kW per h consumption





Energy consumption TEJ130 Example – Calculation result

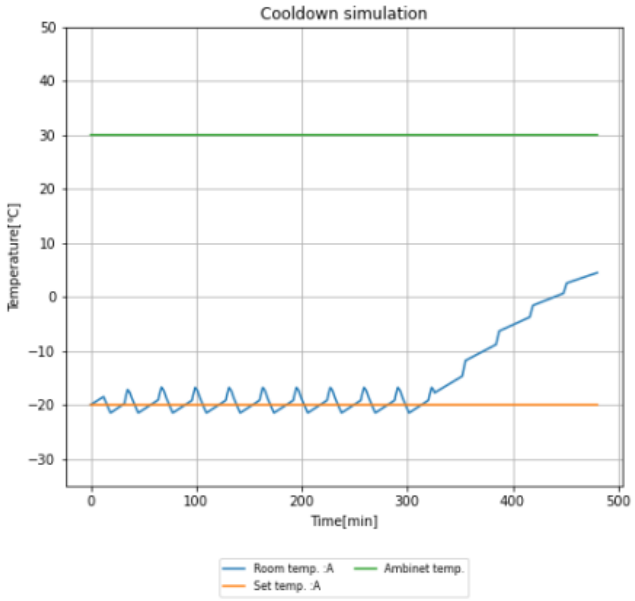
TEJ130 Monotemp consumption values deep-freeze case/ very high air exchange at opening / fewer openings

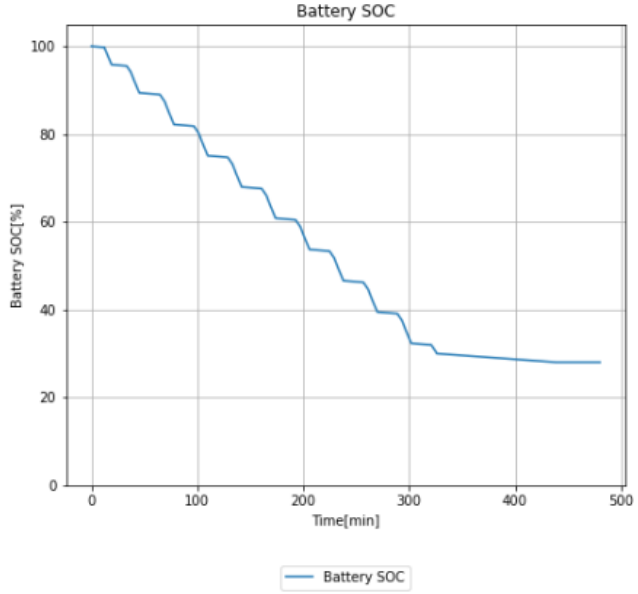
Box data:
Internal dimensions: L7790mm x W2504mm x H2300
Insulation: 120mm roof, 160mm floor, 60mm rest
Setpoint: -20°C
Outside temperature: 30°C
Delivery time: 8h
Openings: 15 (1,88/h)
Opening time: 8min (average opening time)
Door air leakage rate: 10m³/min (no cold curtain / very high air exchange)
Precooled case

Delivery time 8h is not reached with 32kWh
after 320min 30% SOC

Battery capacity: 32kWh
Start 32kWh - end 9.6kWh = 22.4kWh consumed in 320min

→3,73 kW per h consumption





Energy consumption TEJ130 Example – Assumption and Consideration Points

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This simulation is a trial calculation under specific conditions and it may fluctuate in actual operation.
The assumptions for calculation are as follows:

(1) **Effect of solar radiation:**
   a. Effect of solar radiation is not considered in this simulation.
   b. Effect if considered: Energy consumption shall increase
      [Reason: Radiation shall lead to increase in thermal load]

(2) **Semi-trailer body thermal load modeling**:
   a. Model considers air volume and body metal+insulation. Model excludes load due to luggage [Fruit, flower etc.]
   b. Effect if considered: Energy consumption shall increase
      [Reason: Thermal load shall increase due to breathing of different luggage components]

(3) **Tail Lift modeling:**
   a. Energy consumed by tail lift operation is variable depending on number of operations and time. [Currently excluded]
   b. Item to be considered: To include tail lift energy consumption based on actual system spec and usage routine.

(4) **Door Open/Close modeling:**
   a. Refrigeration Unit is switched OFF during Door OPEN condition
   b. Temperature labelled 'cargo room temperature' is average of complete 40feet trailer.
   c. Item to be considered: Air temperature near door shall rise higher than average value.

(5) **Effect of Operation location:**
   a. Temperature conditions of requested simulations are localized to Berlin and Frankfurt.
   b. Consideration: To consider operation at complete Europe, evaluation at 32°C [Max. Europe Temp] is required.

Calculation Example TFV150 (Trailer Unit)

Energy consumption of Mitsubishi refrigeration units and simulation to predict energy consumption - customer and bodybuilder information

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Simulation conditions

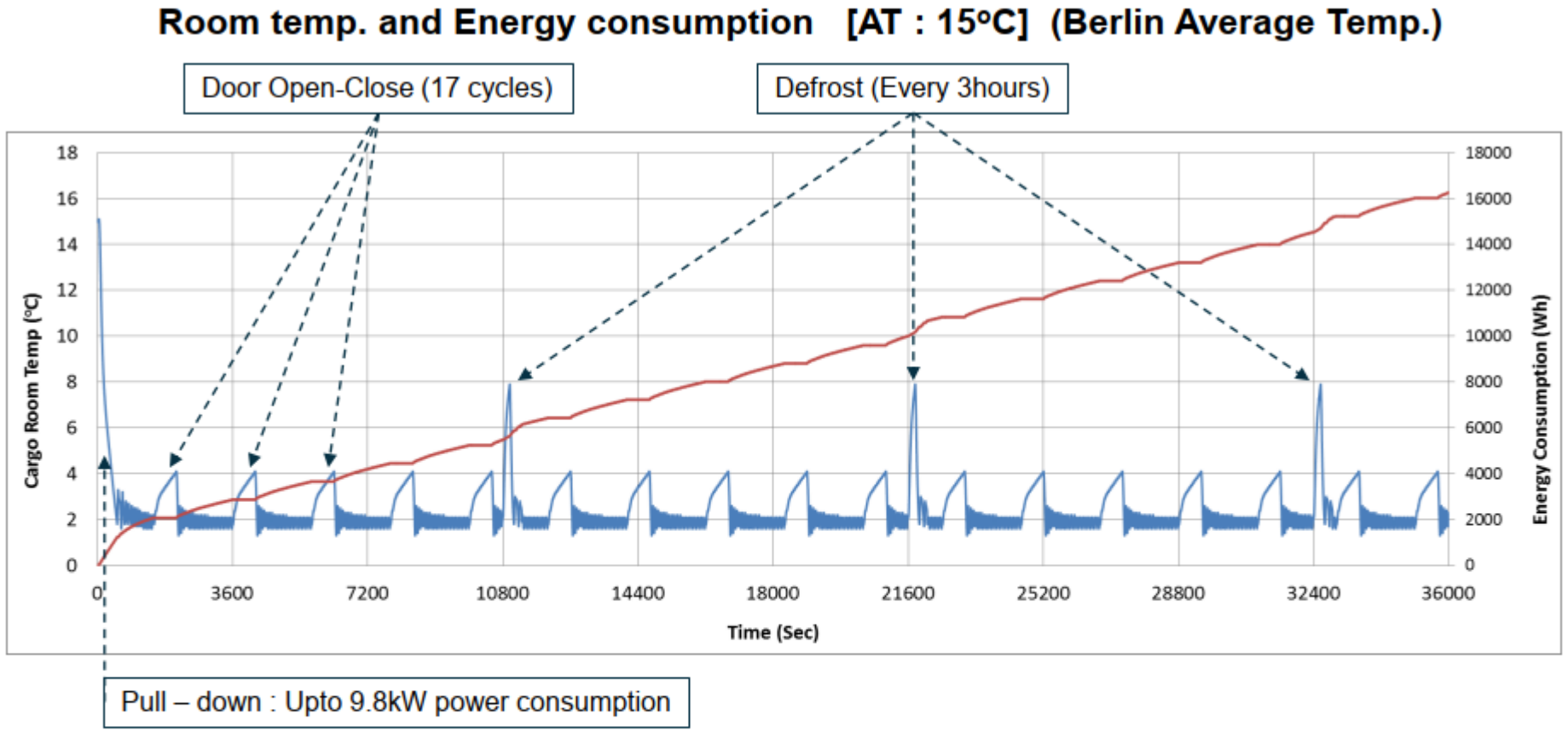
Item	Details	Reference / Comment
Operation Location	Berlin, Frankfurt	
Ambient Temp.	+15°C	Berlin Average Annual Temp
	+24°C	Berlin Max. Summer Temperature
	+32°C	Europe Max. Summer Temperature
Cargo Humidity	50 %RH	
Set Point Temp	2°C	
Operation Mode	Continuous Mode	
Solar radiation	Not assumed	
Total time	10 hours per day	
Door opening	17 times per day	
Door open time	10 minutes	
Defrost	Every 3hr	

Semi-Trailer Body

Cargo Room	40ft semi-trailer [L:12.192m x W:2.438m x H:2.591m]
Insulation thickness	80 mm [Side wall + Door]; 100mm [Base, roof, front]
Effective K Value	0.41 W/m².K

→ Information coming from customer and bodybuilder

Energy consumption TFV150 Example 1 - Simulation result



Accumulated energy consumption

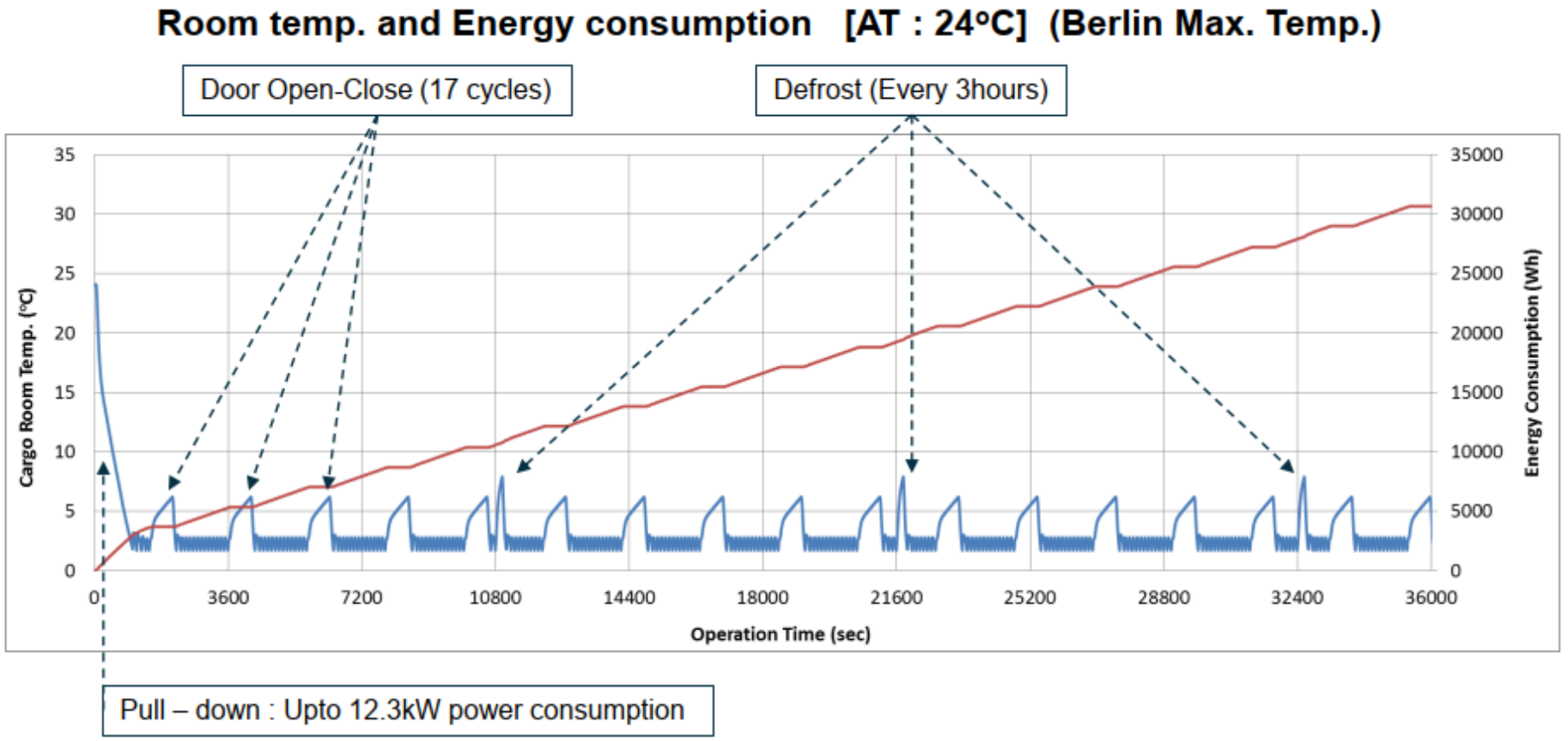
Temperature at return air sensor

→ It is recommended that pre-cooling (pull-down) is carried out via the grid connection of the refrigeration unit so that this energy is not taken from the traction battery.

Daily energy consumption = 16,2kWh

Average energy consumption per hour = 1,62kWh

Energy consumption TFV150 Example 2 - Simulation result



Accumulated energy consumption

Temperature at return air sensor

→ It is recommended that pre-cooling (pull-down) is carried out via the grid connection of the refrigeration unit so that this energy is not taken from the traction battery.

Daily energy consumption = 30,7kWh

Average energy consumption per hour = 3,07kWh

Benefits of calculating the energy consumption of the refrigeration unit

Calculation example 3 (Berlin annual average temperature): Setpoint 2°C / AT 15°C / 10h tour / 17 door openings / 10min opening time
Pre-cooling via the mains supply

Examplerange of a Truck with usable 480kWh batterie capacity : 535km.

480kWh (usable battery capacity of the truck)
- 16,2kWh (energy consumption TFV150 for 10h)
= 463,8kWh (available battery capacity of the truck for the day trip)

→ The energy consumption of the refrigeration unit reduces the range of the truck by approx. 18km.
→ The range of the truck is reduced by the refrigeration machine to approx. 517km (approx.3% Loss of range).
→ Grid pre-cooling leaves 10km more range.

Calculation example 4 (Berlin summer average temperature): Setpoint 2°C / AT 24°C / 10h Tour / 10h tour / 17 door openings / 10min opening time
Pre-cooling via the mains supply

Examplerange of a Truck with usable 480kWh batterie capacity : 535km.

480kWh (usable battery capacity of the truck)
- 30,7kWh (energy consumption TFV150 for 10h)
= 449,3kWh (available battery capacity of the truck for the day trip)

→ The energy consumption of the refrigeration unit reduces the range of the truck by approx. 34km.
→ The range of the truck is reduced by the refrigeration machine to approx. 501km (approx.6% Loss of range).
→ Grid pre-cooling leaves 14km more range.

Benefits of calculating the energy consumption of the refrigeration unit

Calculation example 1 (Berlin annual average temperature): Setpoint 2°C / AT 15°C / 10h tour / 17 door openings / 10min opening time

Examplerange of a Truck with usable 480kWh batterie capacity : 535km.

480kWh (usable battery capacity of the truck)
- 16,2kWh (energy consumption TFV150 for 10h)
- 9,2kWh (energy consumption TFV150 pull-down / precooling)
= 454,6kWh (available battery capacity of the truck for the day trip)

→ The energy consumption of the refrigeration unit reduces the range of the truck by approx. 28km.
→ The range of the truck is reduced by the refrigeration machine to approx. 507km (approx.5% Loss of range).

Calculation example 2 (Berlin summer average temperature): Setpoint 2°C / AT 24°C / 10h tour / 17 door openings / 10min opening time

Examplerange of a Truck with usable 480kWh batterie capacity : 535km.

480kWh (usable battery capacity of the truck)
- 30,7kWh (energy consumption TFV150 for 10h)
- 12,3kWh (energy consumption TFV150 pull-down / precooling)
= 437kWh (available battery capacity of the truck for the day trip)

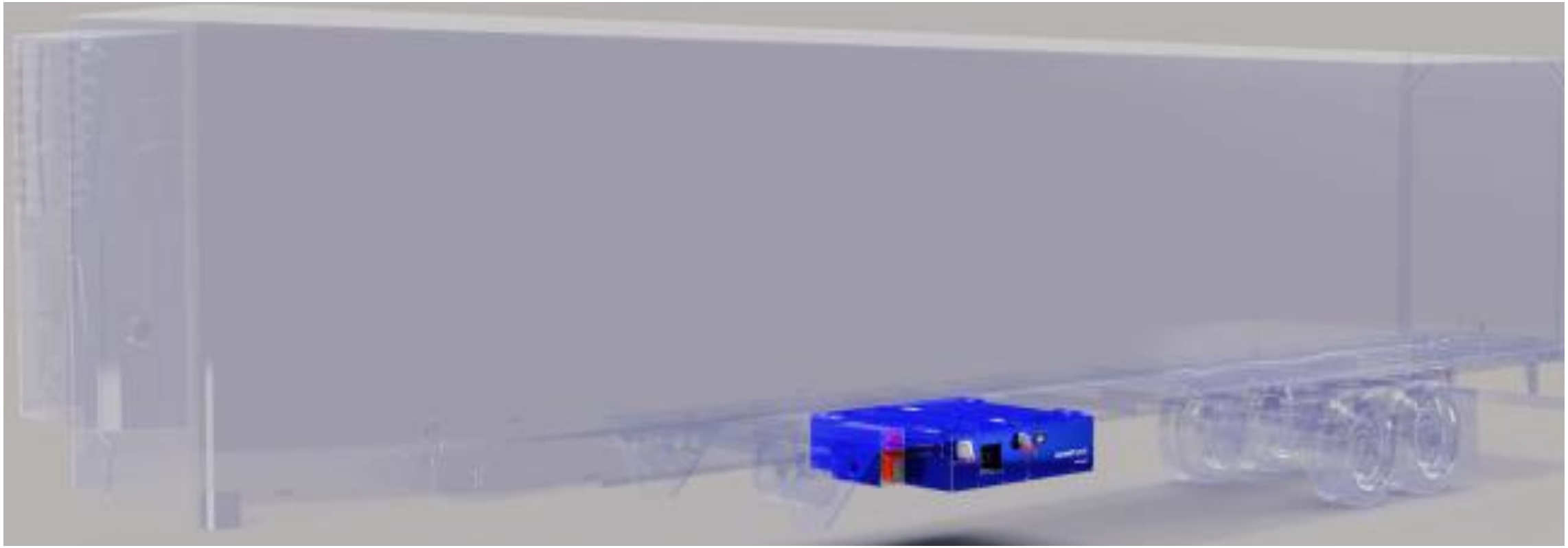
→ The energy consumption of the refrigeration unit reduces the range of the truck by approx. 48km.
→ The range of the truck is reduced by the refrigeration machine to approx. 487km (approx.9% Loss of range).

Battery pack on an all-electric refrigerated trailer

It is possible to operate the refrigeration unit on the semi-trailer independently of the semi-trailer truck using a battery system on the trailer.

A battery system on the semi-trailer weighs 350-1200 kg, depending on the capacity of the batteries and the technology (air-cooled vs. liquid-cooled)

No energy from the semitrailer is required, the range is not affected.



Result / Summary

The Mitsubishi simulation tool makes it possible to ideally plan the customer's tour.

Tests after various simulations have shown that the energy consumption is usually even slightly lower than predicted.

The simulation tool shows the low energy requirement of a refrigeration unit with inverter technology.

The planning reliability for the customer is very high, as the possible range with the refrigeration unit on the eTruck can be defined from the very beginning.

An additional battery on the semi-trailer could be recharged via the traction battery of the truck.

An additional battery on the semi-trailer could absorb additional energy from the vehicle's recuperation.

Question?

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