Development of Use Cases for Battery Electric Vehicles

Agenda

- User Centric Approach
- Defined Use Cases
- Boundary Conditions

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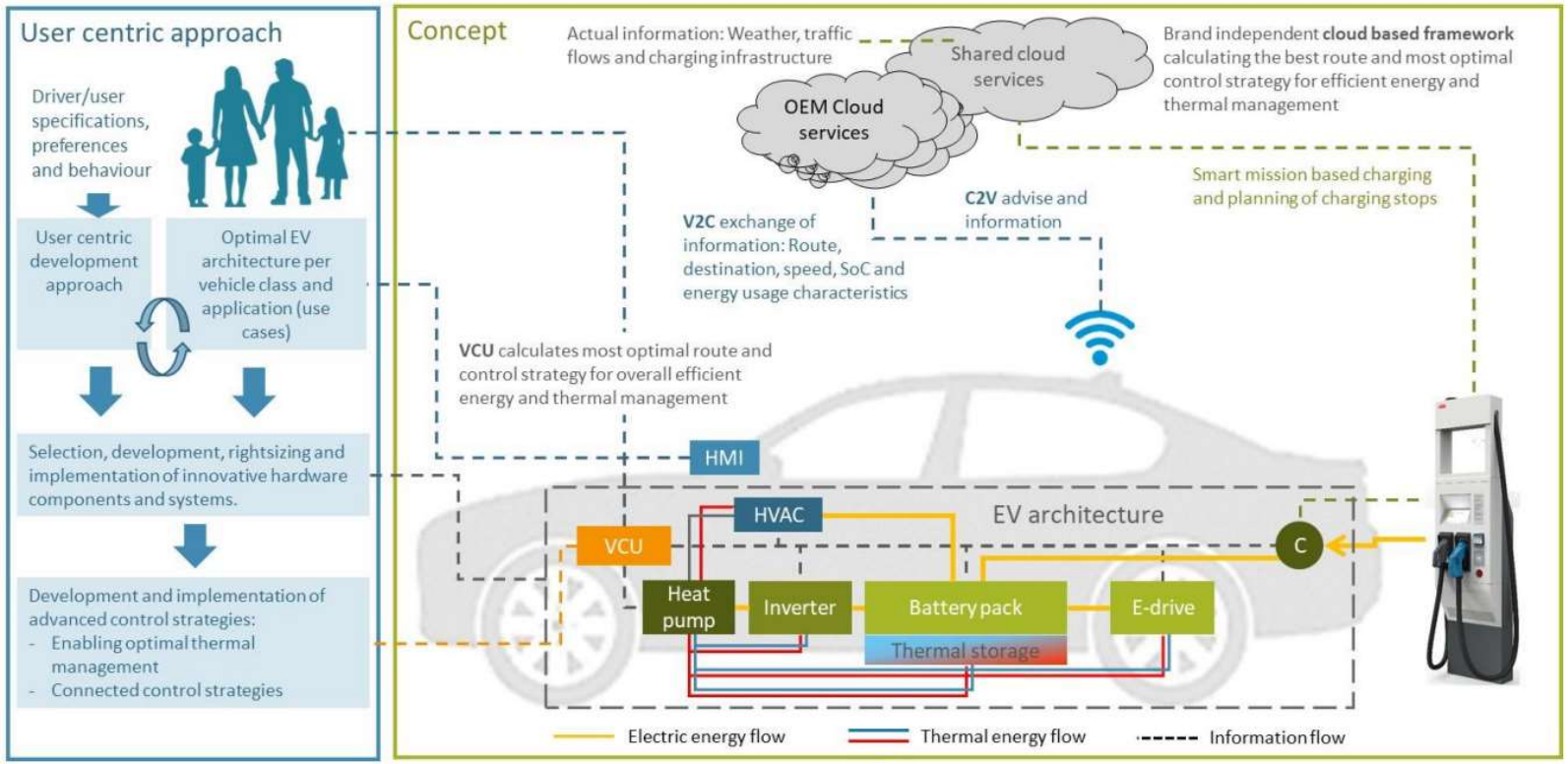
CEVOLVER Objective

The project takes a user-centric approach to create battery-electric vehicles that are comfortable and usable for long day trips whilst components and the installed battery is sized for both affordability and usability.



User Centric Approach

The conventional approach for the component and system sizing is based on market researches as well as the legacy knowledge from the development of the conventional vehicles. Especially for battery electric vehicles this approach potentially leads to a potential oversizing of the components and systems resulting in increased vehicle cost.

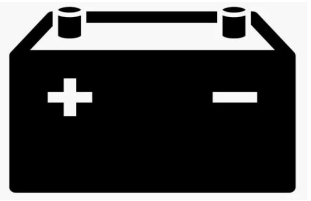
Example: Range of a vehicle with internal combustion engine vs. BEV

Vehicle with internal combustion engine
Fuel consumption:
7l/100km

Tank size: 42L vs. 49L
Range: 600km vs. 700km
-minor cost impact
-mainly package
-minor weight impact

BEV
Energy consumption:
20kWh/100km

Battery capacity: 60kWh vs. 80kWh
Range: 300km vs. 400km
-high cost impact
-package
-significant weight increase



On the contrary to the conventional approach, user centric approach includes two aspects, the right sizing of the powertrain components and the development of the control strategies.

User Centric Approach

- Usage scenarios and use cases were developed using user centric approach.
- Big data analysis were used to support the selection of driving profiles for the use-cases.

Define Usage Scenarios & Use Cases

Analyze user behavior and user data

Estimate load profiles using simulation based on fleet velocity profiles

UC_ID	Use Case	Use case description
UC_1.1	Parcel service daily job standard conditions	Parcel service with multiple stops for (un-) loading: delivery in urban areas and loading out of the city at standard conditions. 11 kW or 22 kW charging after returning to the distribution centre.
UC_1.2	Parcel service daily job cold/winter condition	Same as standard conditions, but additionally snowy roads, low ambient temperature and lower average speed
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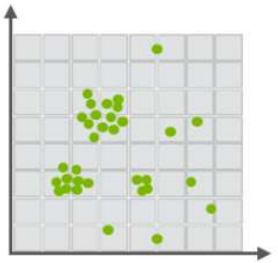
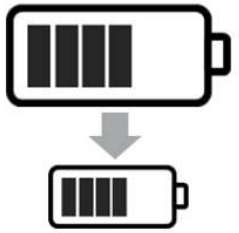




Define requirements, functional architecture, and functions

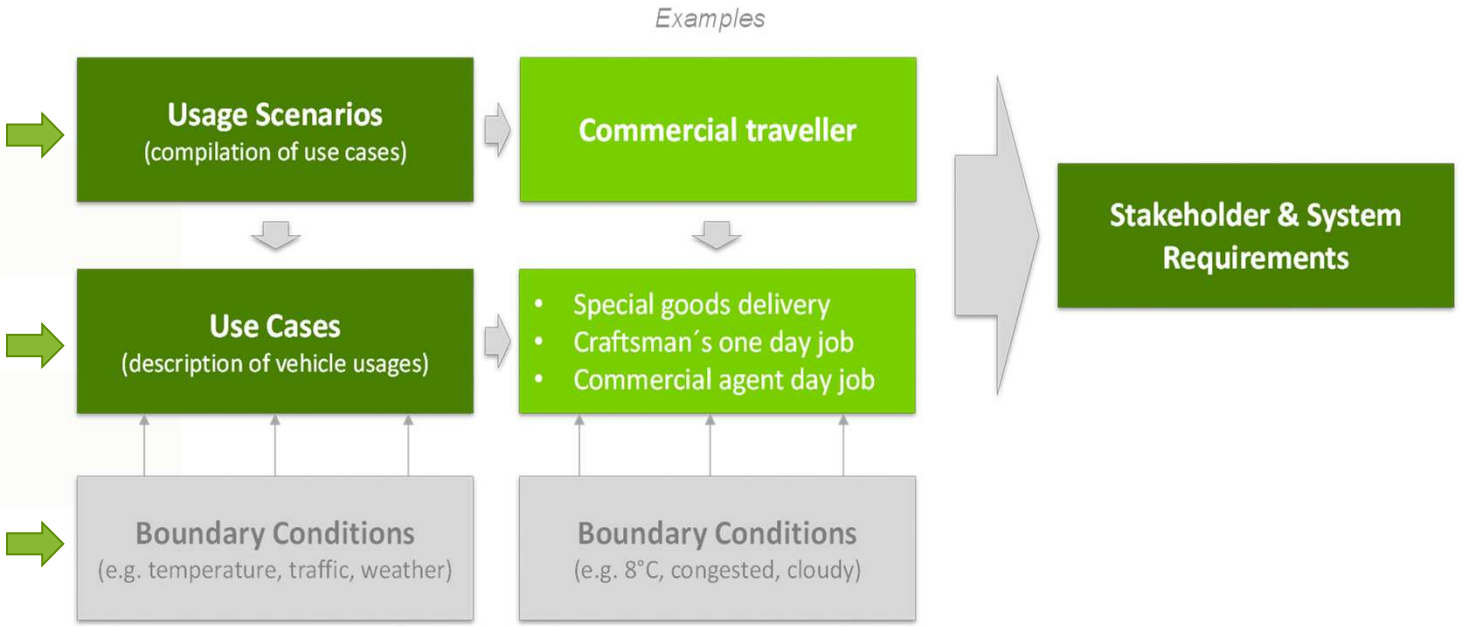
Right-sizing components

Use Case Development

In first step usage scenarios are defined. They describe how different types of vehicles are used by a particular group of users.

In a next step, use cases are described with a details of the trip.

Variation of the boundary conditions results in new use cases. Especially low ambient temperatures have a significant impact on the vehicle range of BEVs.

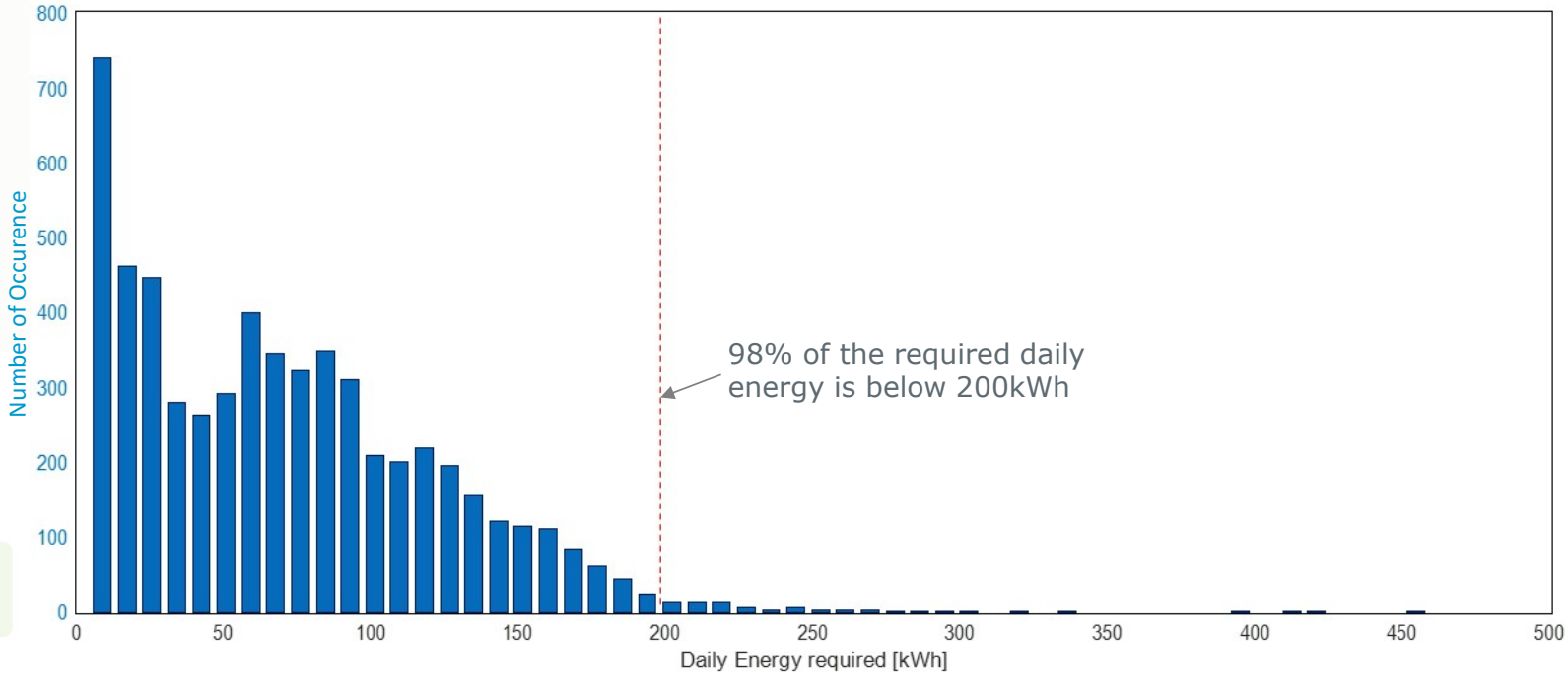


Use Case Development

Analyzing data statistically collected by OEMs and institutions from end users in real world enables the extraction of load points for components and classification regarding their frequency of occurrence. As a result, outliers that occur only in rare cases over the lifetime can be identified. This gives the initial intention for reducing the power level of the corresponding components.

Example of specific customer data:

Required energy per day



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Overview of usage scenarios and use cases

5 usage scenarios and in total 14 different use cases have been defined

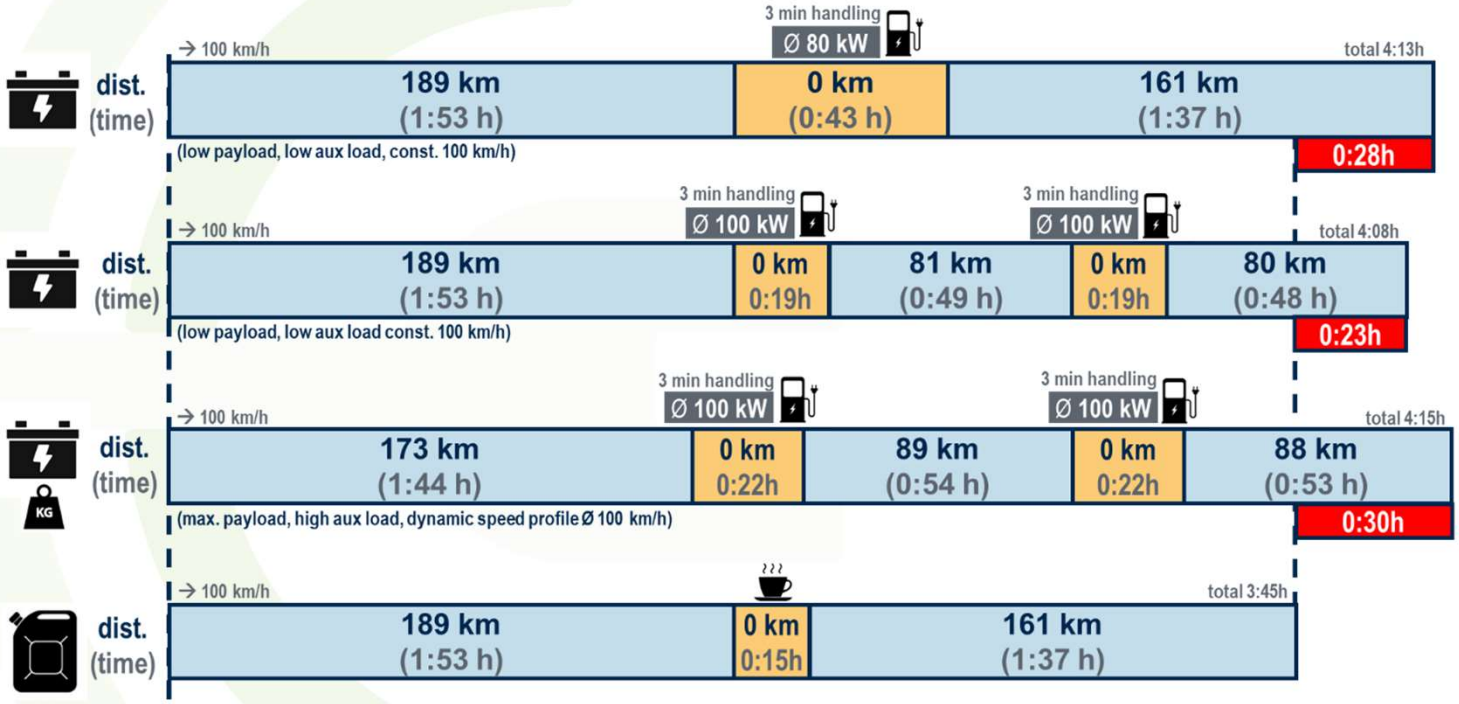
⇒ not all use cases are relevant for all applications

Examples:

- A light duty vehicle is most likely not be used for a holiday trip
- A passenger car is not intended to be used for parcel delivery

Usage Scenario	Use Case ID	Use Case
Parcel delivery service	**UC_1.1**	**Parcel service daily job** standard conditions
	UC_1.2	**Parcel service daily job** cold/winter condition
	UC_1.3	**Parcel service daily job** hot/summer condition
Private & commercial traveller	**UC_2.1**	**Commercial agent** daily customer visit usage
	UC_2.2	**Special Goods Delivery** daily usage w/o intermediate charging
	UC_2.3	**Special Goods Delivery** special usage with intermediate charging
	UC_2.4	**Private visit** of 350 km (distance) away living relatives
	UC_2.5	**Craftsman's one-day job 350 km away** standard conditions, one stop per each 350 km trip
	UC_2.6	**Craftsman's one-day job 350 km away** standard conditions, two stops per each 350 km trip
	UC_2.7	**Craftsman's one-day job 350 km away** with traffic jam at cold condition, two stops per each 350 km trip
	UC_2.8	**Holiday trip (>700 km)**
Short city trip	**UC_3.1**	**Short urban trip(s)** (approx. 5 km)
Short range commuter	**UC_4.1**	**home => job => home** (approx. 30 km distance)
Long range commuter	**UC_5.1**	**home => job => home** (approx. 60 km distance)

Example Application Specific Use Case



Analyses of light duty fleet data have shown:

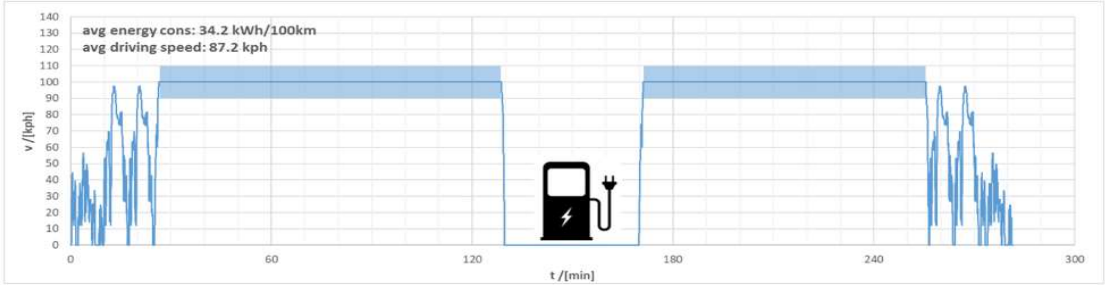
- long distance usage is expected to occur only in exceptional cases ⇒ 700 km day trip divided into a two-way journey, 350 km trip to a destination and returning later the same trip ⇒ in total ~700km
- average speeds are mainly between 80 and 110 km/h for comparable long distance transporter applications

700 km day trip with < 60 min additional travel time seems possible, considering an avg. speed of 100 km/h and 100 kW avg. charging power!

Example Application Specific Use Case

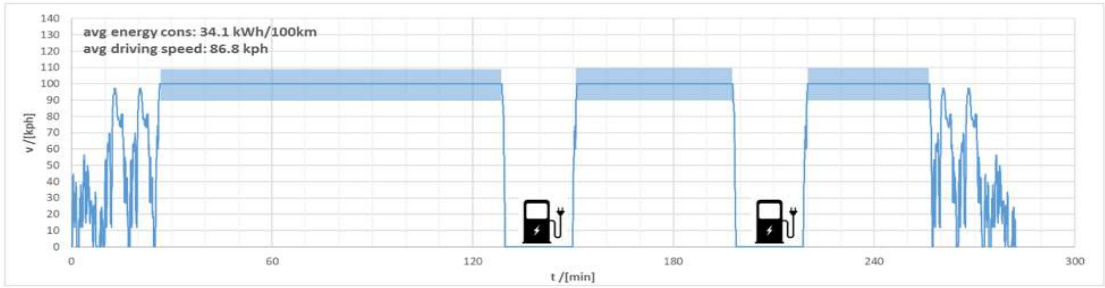
Craftsman´s one day job 350km away use cases derived from customer data:

UC_2.5



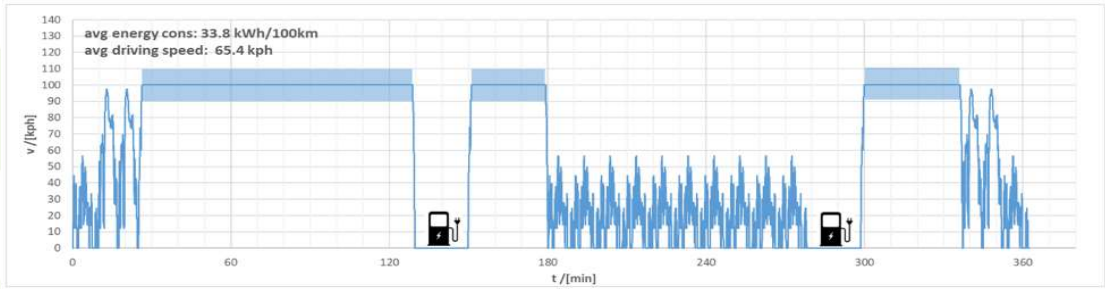
1xWLTC low (3.1 km)
2xWLTC high (each 7.1 km)
WLTC extra high / const spd (~173 km)
DC-Charging
WLTC extra high / const spd (~143 km)
2xWLTC high (each 7.1 km)
1xWLTC low (3.1 km)
total: 350 km (4:02 h w/o charging)

UC_2.6



1xWLTC low (3.1 km)
2xWLTC high (each 7.1 km)
WLTC extra high / const spd (~173 km)
DC-Charging
WLTC extra high / const spd (~80 km)
DC-Charging
WLTC extra high_ltd (~63 km)
2xWLTC high (each 7.1 km)
1xWLTC low (3.1 km)
total: 350 km (4:03 h w/o charging)

UC_2.7



1xWLTC low (3.1 km)
2xWLTC high (each 7.1 km)
WLTC extra high / const spd (~173 km)
DC-Charging
WLTC extra high / const spd (~49 km)
10xWLTC low (each 3.1 km)
DC-Charging
WLTC extra high / const spd (~63 km)
2xWLTC high (each 7.1 km)
1xWLTC low (3.1 km)
total: 350 km (5:22 h w/o charging)

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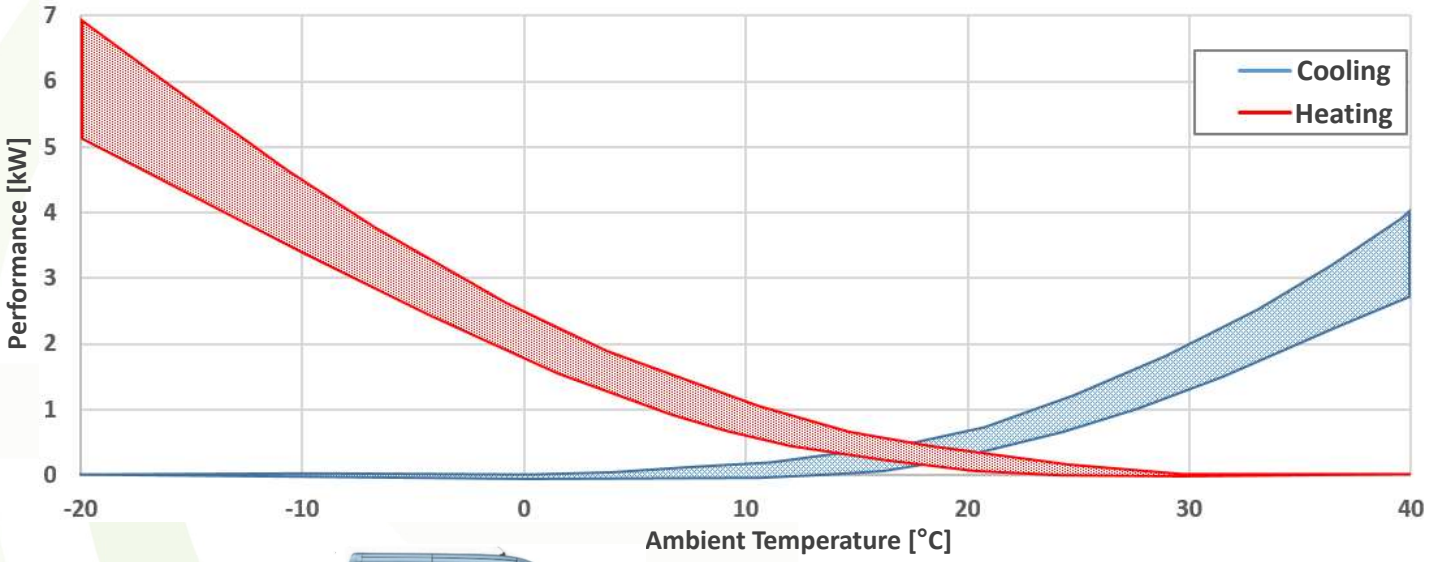
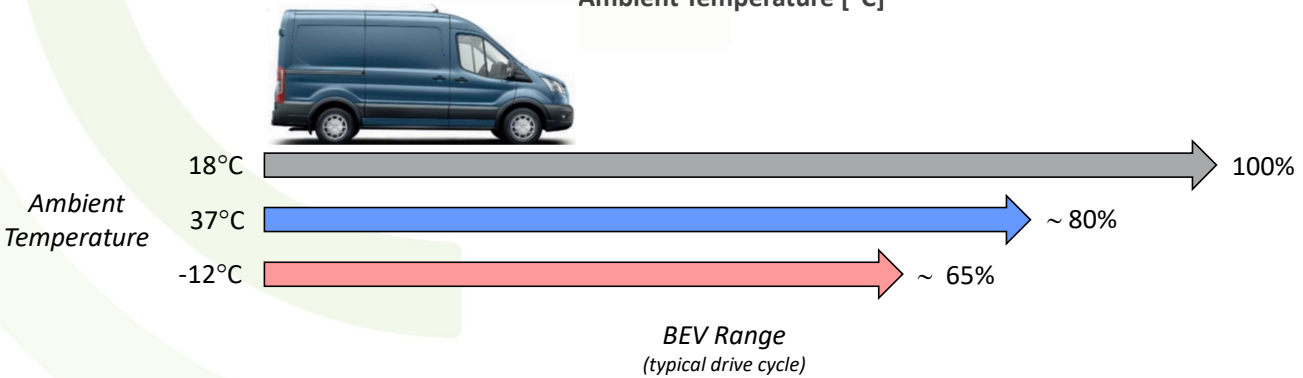
Boundary Conditions

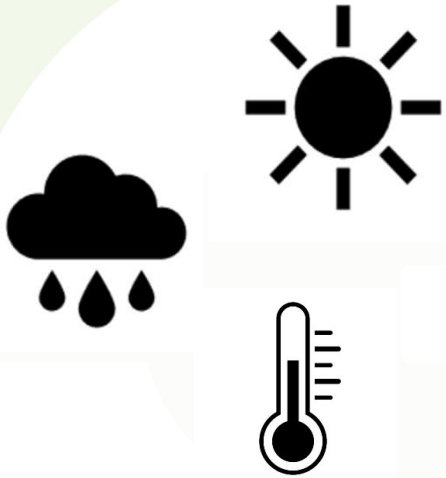




Significant amount of power required for interior climatization especially at cold ambient temperatures

Reduced vehicle range

Boundary Conditions



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UC_1.3	**Parcel service daily job** hot/summer condition	Same as standard conditions, but additionally high ambient temperature and solar radiation

The impact of certain boundary conditions as ambient temperature and solar radiation have a high impact on low load cycles due to that fact the ratio between propulsion and interior climatization energy is unfavourable.

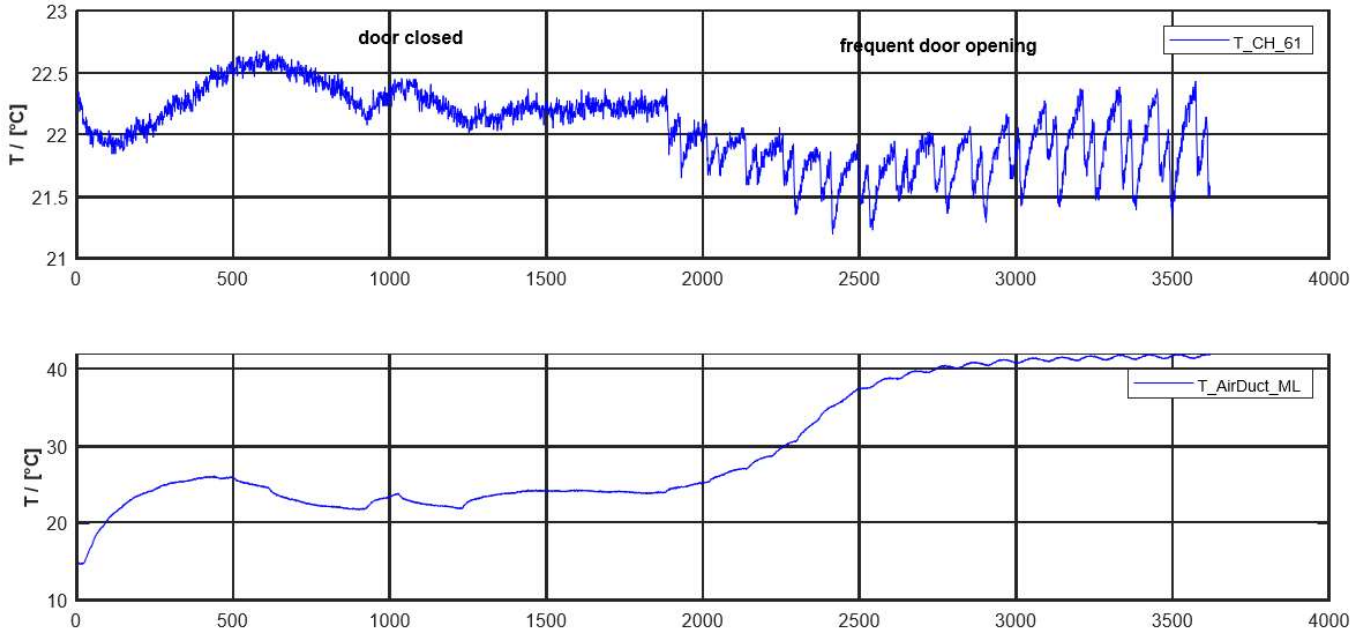
Hence, these boundary conditions have been varied for the parcel delivery service usage scenario.

Boundary Conditions

Especially for the parcel delivery cycle a „frequent door opening" test has been conducted to investigate the impact on interior heating requirements

More energy is lost to the ambient which has to be compensated by increased air inlet temperature from the interior heating system

⇒ Boundary conditions (interior heating performance) has to be adapted for this specific test



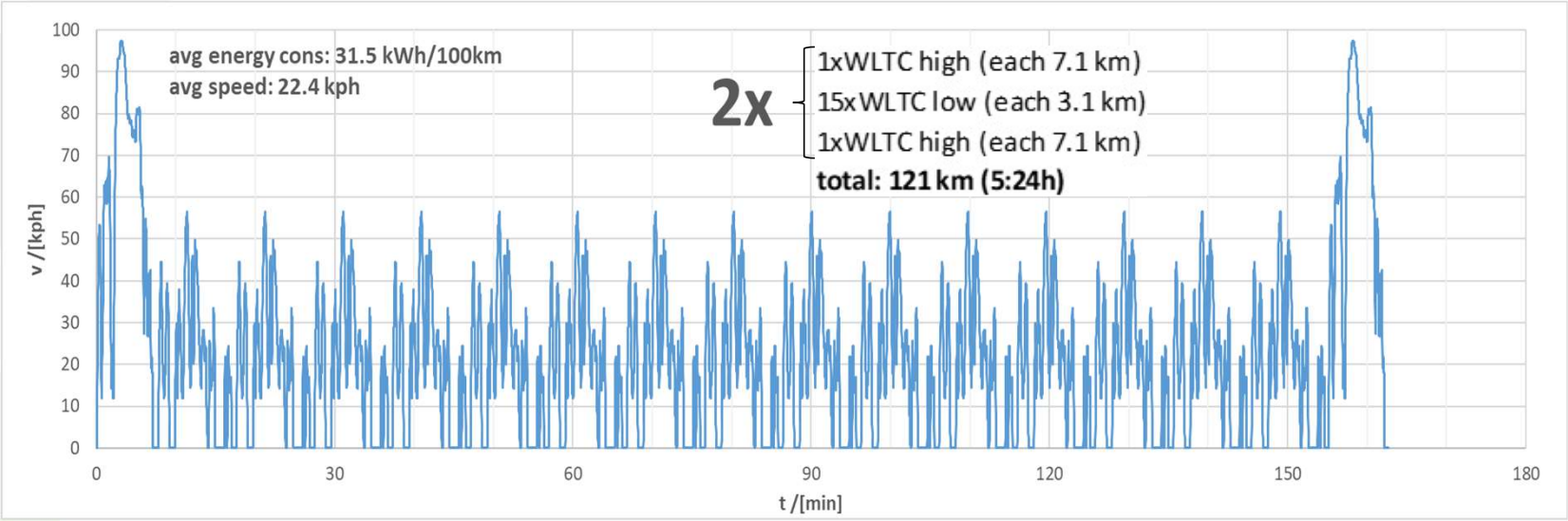
A heat pump system is a high efficient system for interior heating, but does it make sense for all applications and use cases?

Based on the findings for this specific use case, maybe other technologies are more appropriate.

⇒ See also later Thermal Management section

Boundary Conditions - Specific Use Cases

Parcel delivery use cases derived from customer data:



⇒ UC_1.1 Standard conditions (14°C)
⇒ UC_1.2 Cold/winter conditions (-7°C)
⇒ UC_1.3 Hot/summer conditions (35°C)

Conclusions

- The conventional approach for component and system sizing is not practical for battery electric vehicles
- The user centric development approach enables rightsizing of components/systems in combination with attractive functions
- Statistical evaluation of “Big” real world customer data facilitates the definition of driving profiles for the use cases
- Usage scenarios and specific use cases have been defined for a wide range of battery electric vehicle applications
- Consideration of the boundary conditions are important for the defining appropriate use cases especially for low load drive cycles