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The energy requirement of battery electric vehicles under different conditions

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Database

- Study **Battery Electric Vehicles in Practice** - Costs, Range, Environment, Convenience (2nd extended and corrected edition)
- Study and detailed data are **on www.oevk.at free available for download**.

- Motivation and objectives of the study
  - **Electro mobility** is widely regarded as the **solution for the future mobility**.
  - Politics and media see an **effective way in the electrification**
    - to increase the energy efficiency,
    - to reduce the dependence on fossil fuels and
    - to significant lowering the greenhouse gas emissions.
  - How big are the **advantages** of battery electric vehicles
    - based on real operating conditions over an entire year and
    - if the energy supply is taken into account?

Analysed e-cars

- ☐ Mitsubishi i-MiEV
- ☐ Smart Fortwo Electric Drive

- ☐ Mercedes Benz A-Klasse E-Cell
- ☐ Nissan Leaf

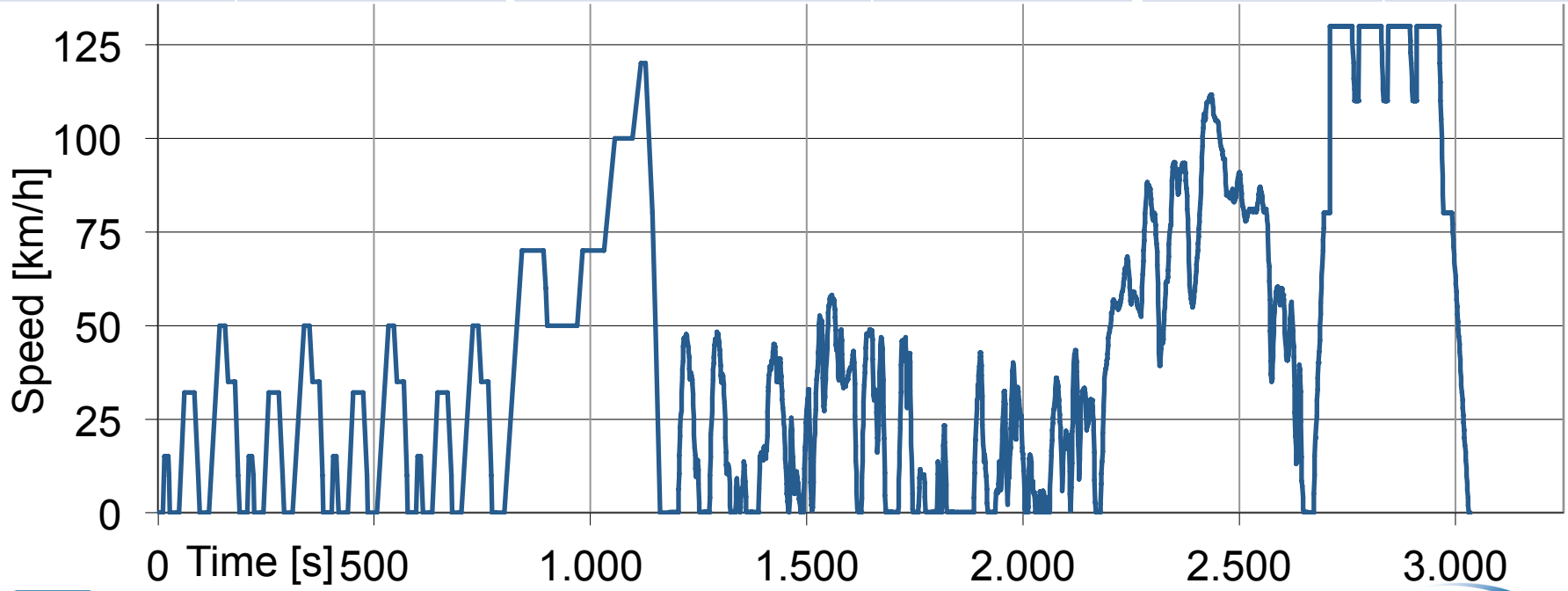
- ☐ Citroén Berlingo
  (ZEBRA... Sodium nickel chloride)

Used test cycles

Eco-Test and Stop-and-Go

- The Eco-Test cycle consist of existing test cycles with an overall length of 35,506 km.

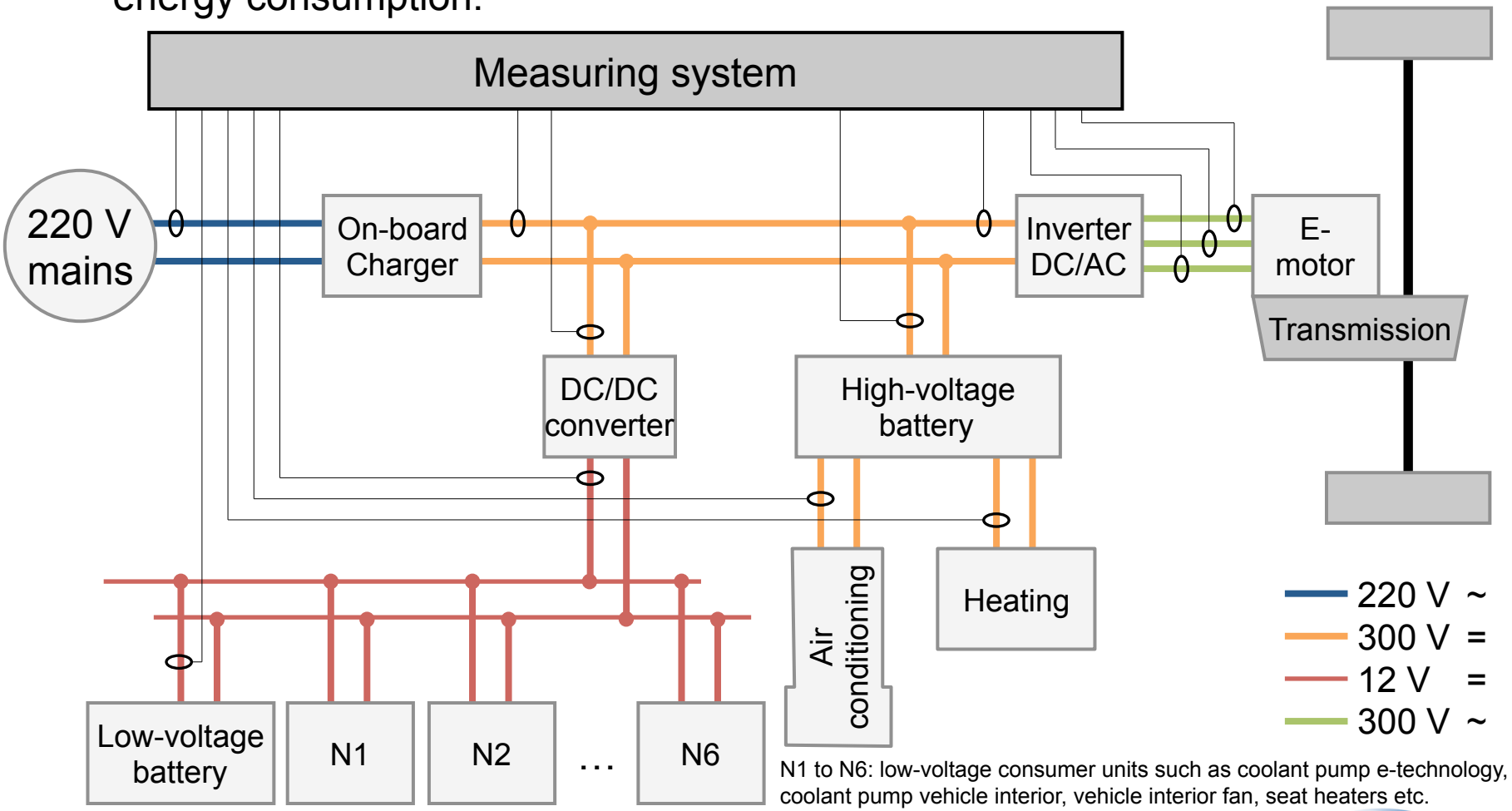
Test cycles	Distance [km]	Test cycles	Distance [km]	Test cycles	Distance [km]
NEFZ ECE	3,920	NEFZ EUDC	6,920	BAB 130	9,270
CADC Urban	4,930	CADC Extra Urban	8,966	Access/exit	1,500
Urban	*24,93%*	*Extra urban*	*44,74%*	*Motorway*	*30,33%*



Measurement setup

To analyse the losings and to set up a energy balance

- Current and voltage measurement to analyse the required electric power and the energy consumption.



N1 to N6: low-voltage consumer units such as coolant pump e-technology, coolant pump vehicle interior, vehicle interior fan, seat heaters etc.

Measurement technology requirements

- Currents up until 500 A.
- Voltage up until 600 V.
- Current sensors need to have:
  - high linearity
  - low offset
  - high band width
  - small phase error
  - temperature stability

- No interaction of the current measurement system with the car electronics
- High sampling rate (up until 400 kHz necessary, depends on the inverter).
- Variable sampling rate (e.g. temperature at 1 Hz)
- High processing power for high calculation rates (up until 200 kHz, in real time)

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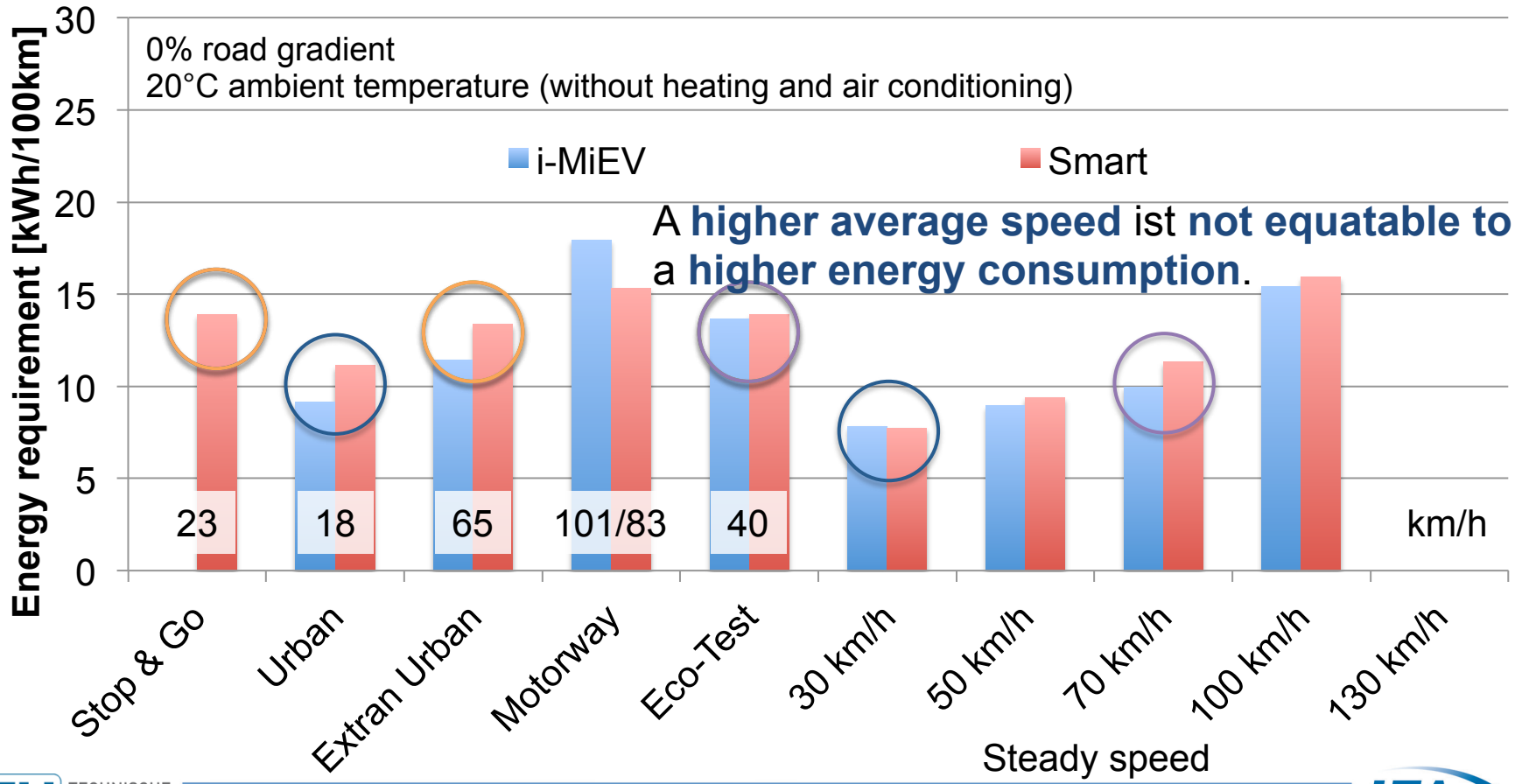
Energy requirement as a function of the driving situation

iMiEV and Smart

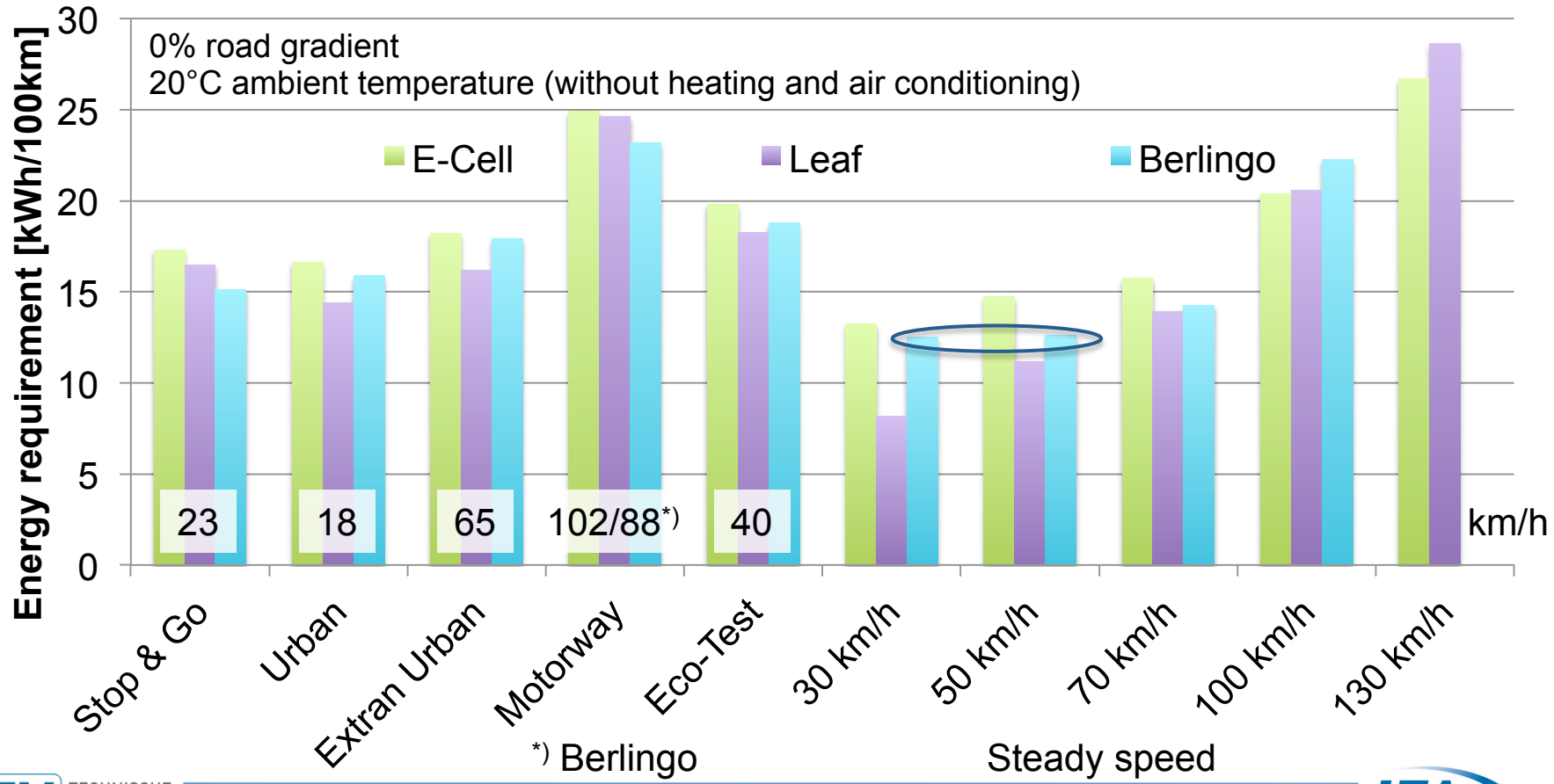
- The energy requirement is proportional to the required power.
- Basically it´s equal to the driving speed ← Does not apply for dynamic driving.



Energy requirement as a function of the driving situation

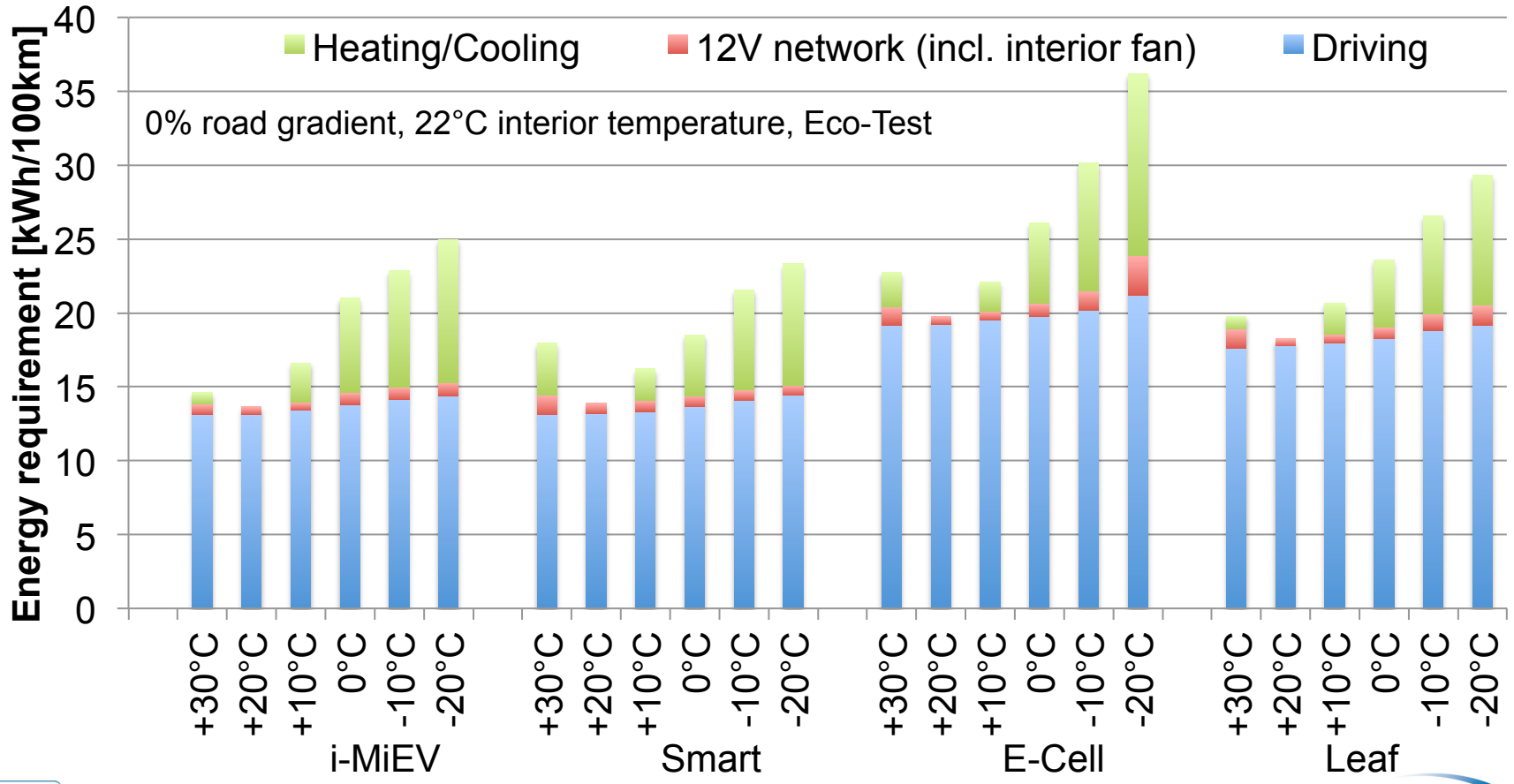
E-Cell, Leaf and Berlingo

- The energy requirement depends also on the load point (efficiency) of the electric motor.



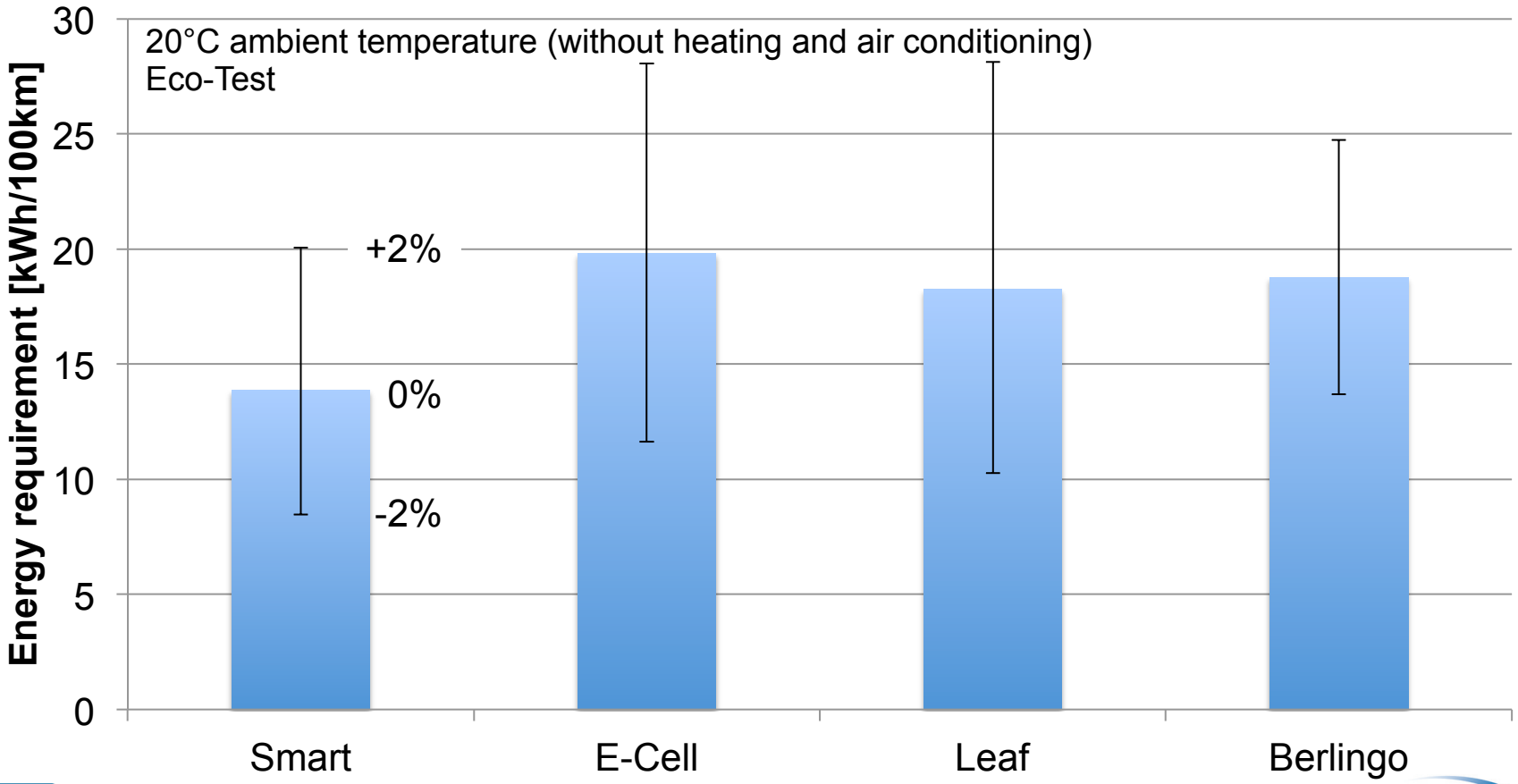
Energy requirement as a function of the ambient temperature

- Heating and cooling have also a influence on the 12 V energy requirement.
- The total add. energy req. for climat. @ +10°C: 10 - 20 %, @ -10°C: 40 - 55%



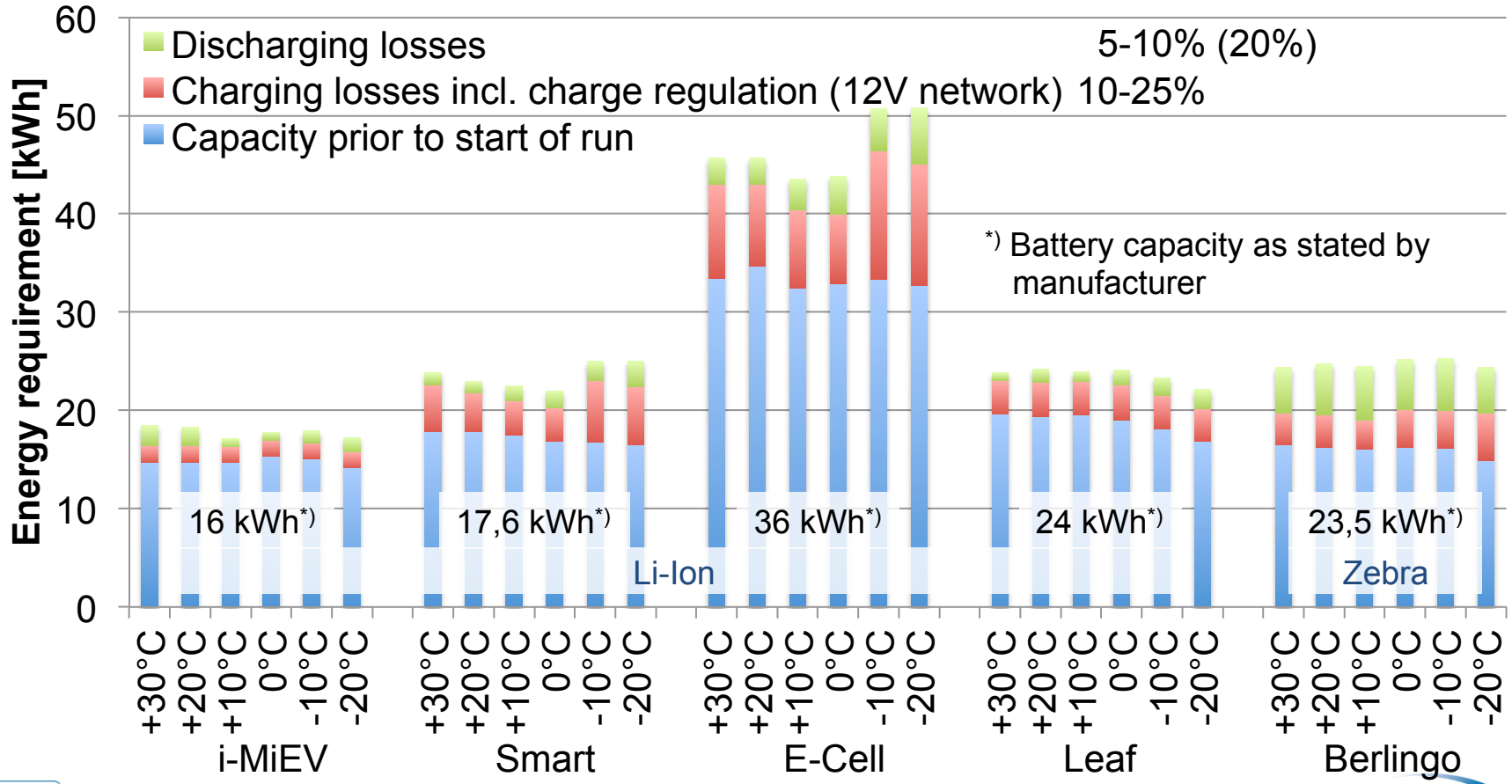
Energy requirement as a function of the road gradient

- A +2% road gradient results in 30-50% higher energy consumption.
- The energy saving at -2% is nearly as high as the higher energy demand at +2%.



Energy required for a full charge as a function of the ambient temperature

- Up to -10°C only ≈ 5% less capacity (prior to start) will be observed.
- Charging and discharging losses increase with low temperatures.

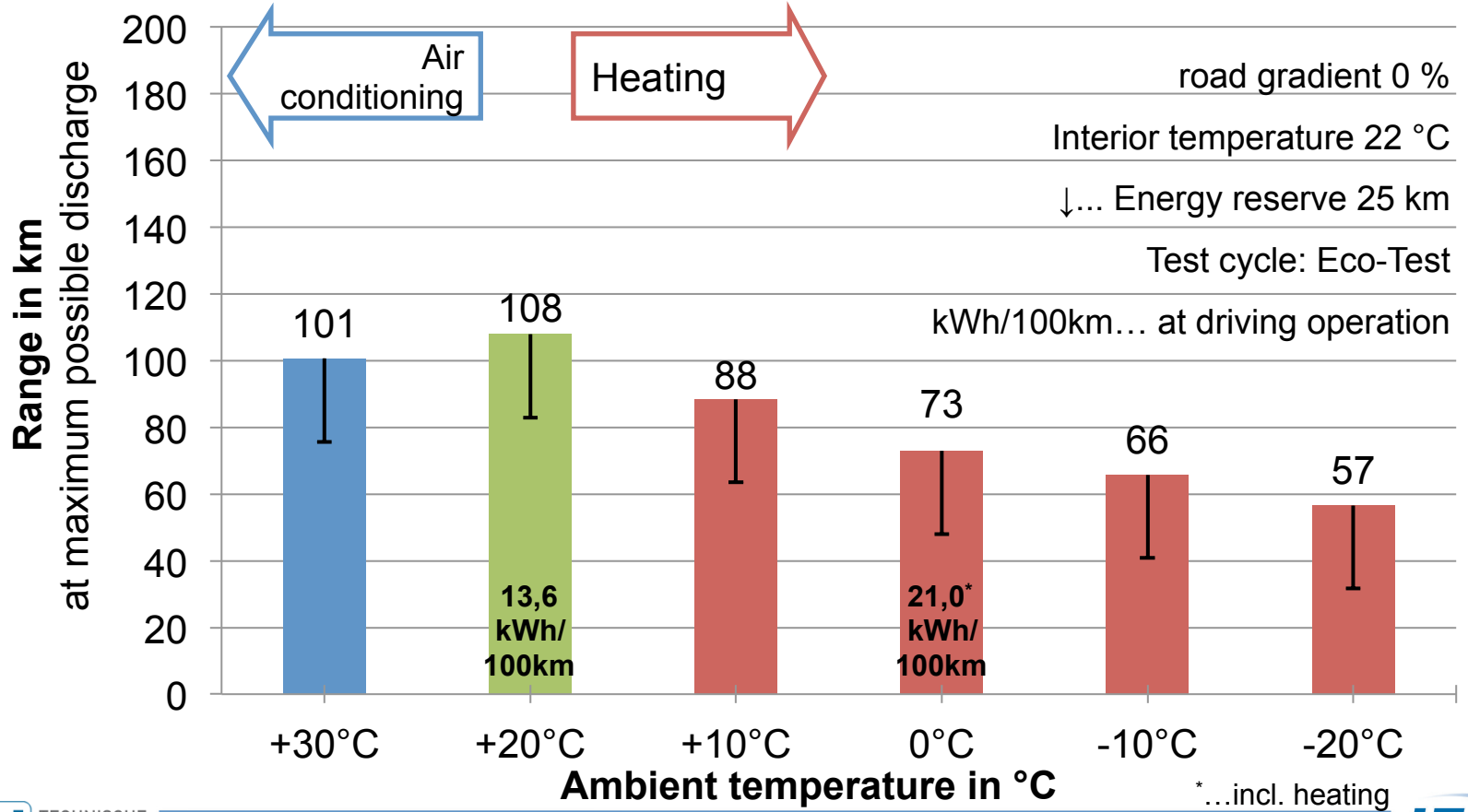


Range of the Mitsubishi i-MiEV

Battery capacity as stated by manufacturer [kWh]: 16 Measured: 14,1-15,3

☐ Average power demand in the Eco-Test at -20 °C: e-motor 5,7 kW

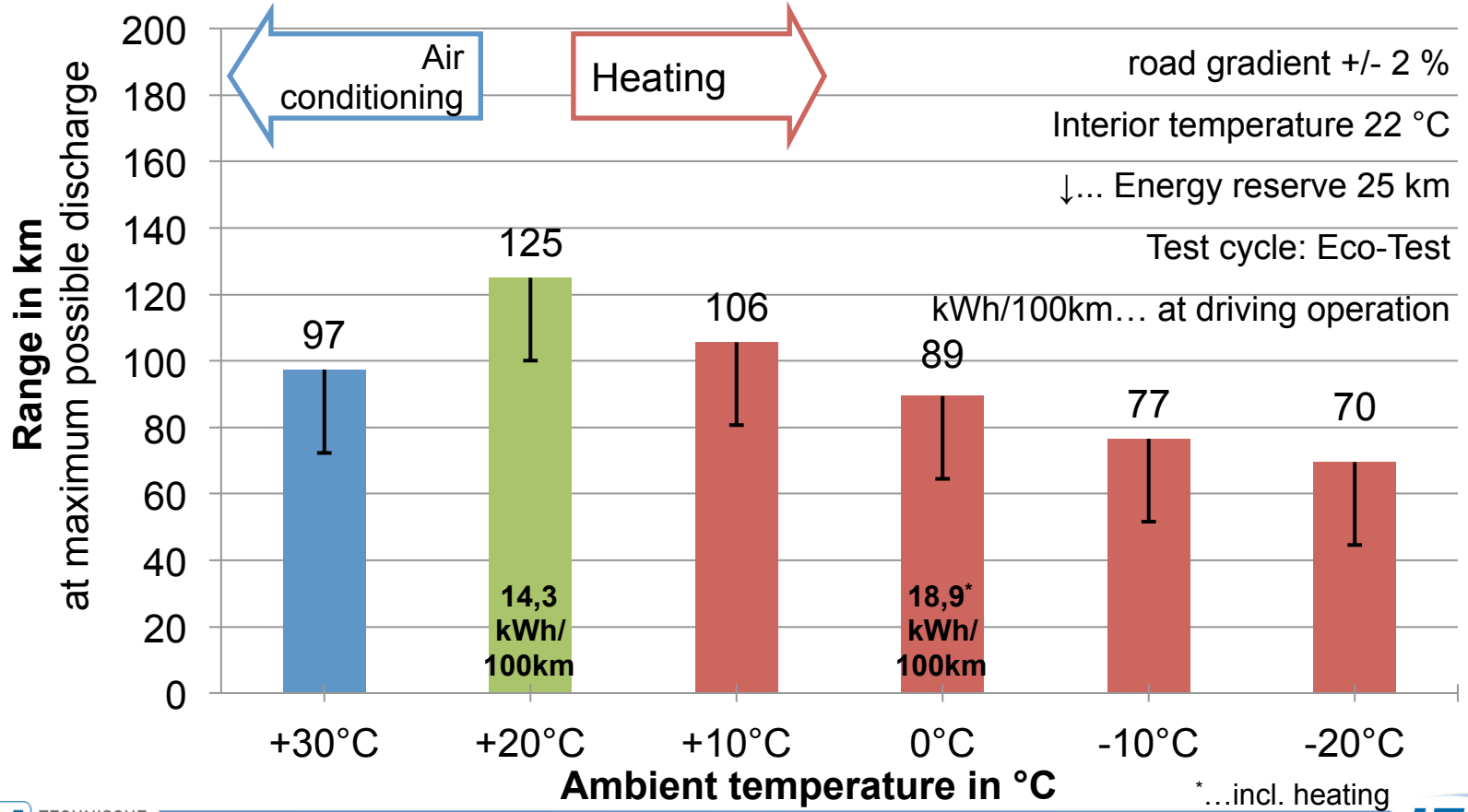
heating 3,8 kW



Range of the Smart Fortwo Electric Drive

Battery capacity as stated by manufacturer [kWh]: 17,6 Measured: 16,5-17,8

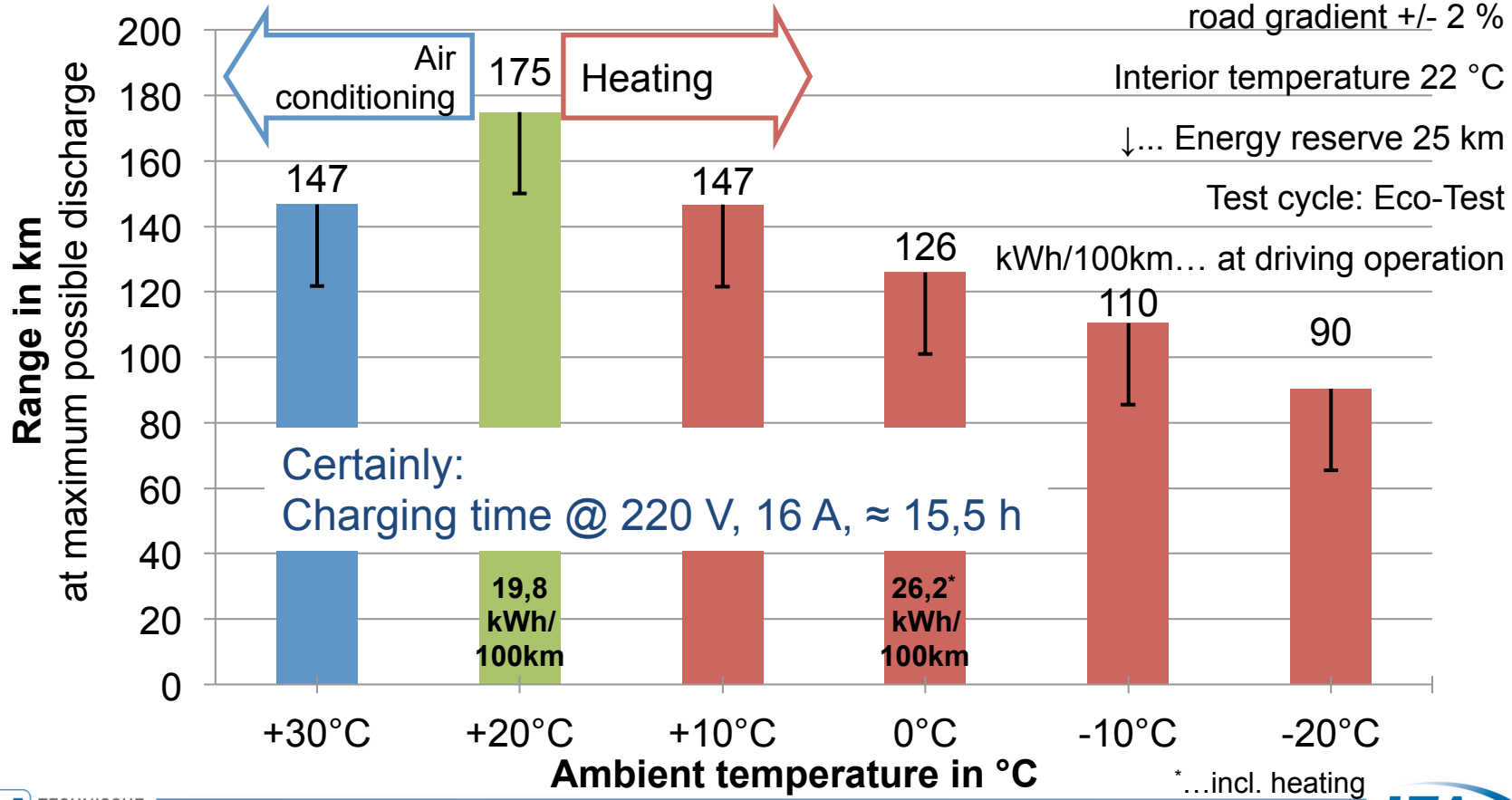
- Moderate range advantages compared to the i-MiEV, because
  - of the effective higher useable battery capacity of 3 kWh and
  - the lower energy consumption (below +20°C).



Range of the Mercedes Benz A-Klasse E-Cell

Battery capacity as stated by manufacturer [kWh]: 36 Measured: 32,4-34,7

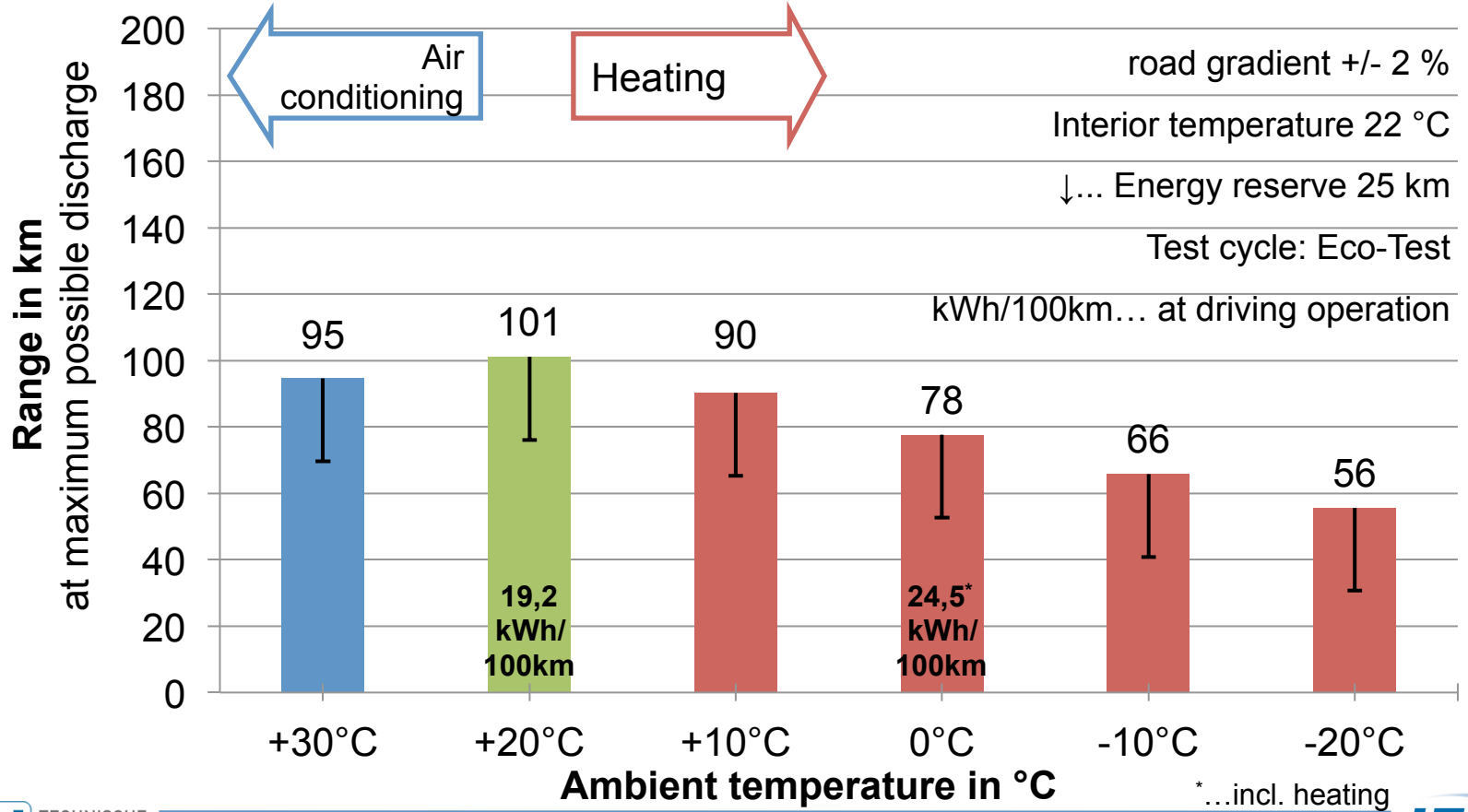
- Caused by the higher battery capacity,
  - despite the (class-related) higher energy consumption,
  - much higher ranges can be achieved.



Range of the Nissan Leaf

Battery capacity as stated by manufacturer [kWh]: 24 Measured: 16,9-19,6

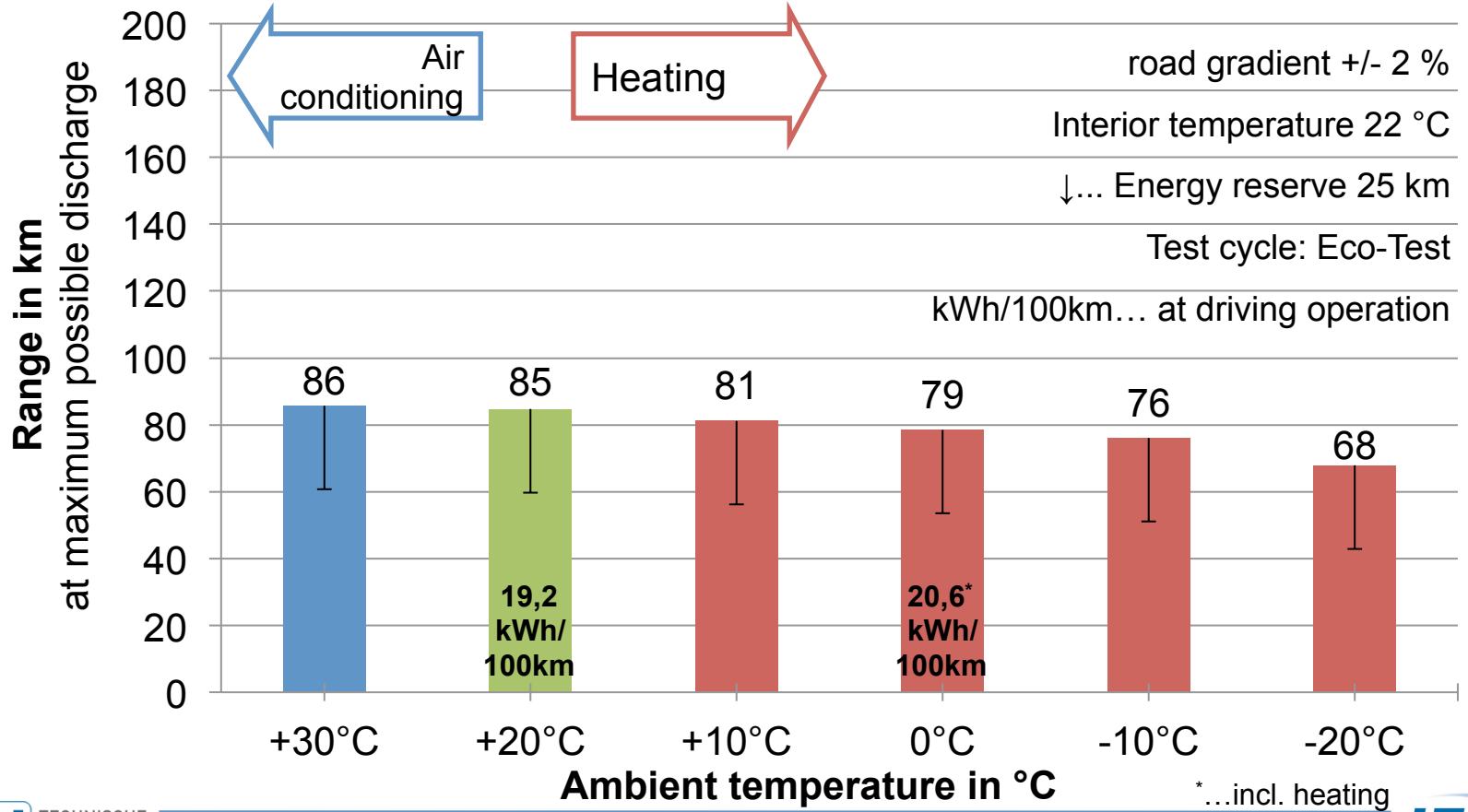
- ☐ The energy consumption per kilometer is less than that of the E-Cell.
- ☐ The lower useable battery capacity leads to moderate ranges.



Range of the Citroén Berlingo

Battery capacity as stated by manufacturer [kWh]: 23,5 Measured: 14,9-16,5

- ☐ Less impact on the range due to a gasoline heater as interior heater and the absence of an A/C (FC interior heater @ +10°C -> -20°C: 0,4 - 1,3 l/100 km)
- ☐ Need to preserve the battery temp. @ +20°C -> -20°C: 100 -> 229 Wh/h (from 230V grid)



Summary

- The **energy requirement** is **basically proportional to** (const.) **driving speeds**, but **dynamic driving** causes **higher required power**.
- The **average speed is not qualifed** to provide info about the **required power**.
  Therefore:
  A **higher average speed** ist **not equatable to** a **higher energy consumption**.
- **Low ambient temperatures** (-20°C) causes **up to 70% higher energy consumption**.
- A **road gradient** of only **+2% increases** the energy consumption **by 30-50%**.
- **Charging and discharging losses increase with low temperatures clearly**.
- The **ranges of the e-cars** under real operating conditions are **reduced by half between +20°C and -20°C**. Difference to type approval value not taken into account.

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Thank you for your attention!

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