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# Comparison of battery electric vehicles regarding their energy- and greenhouse gas emissions in real operation

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# Motivation and objectives

- 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
  - the energy supply is taken into account?

# Proceeding

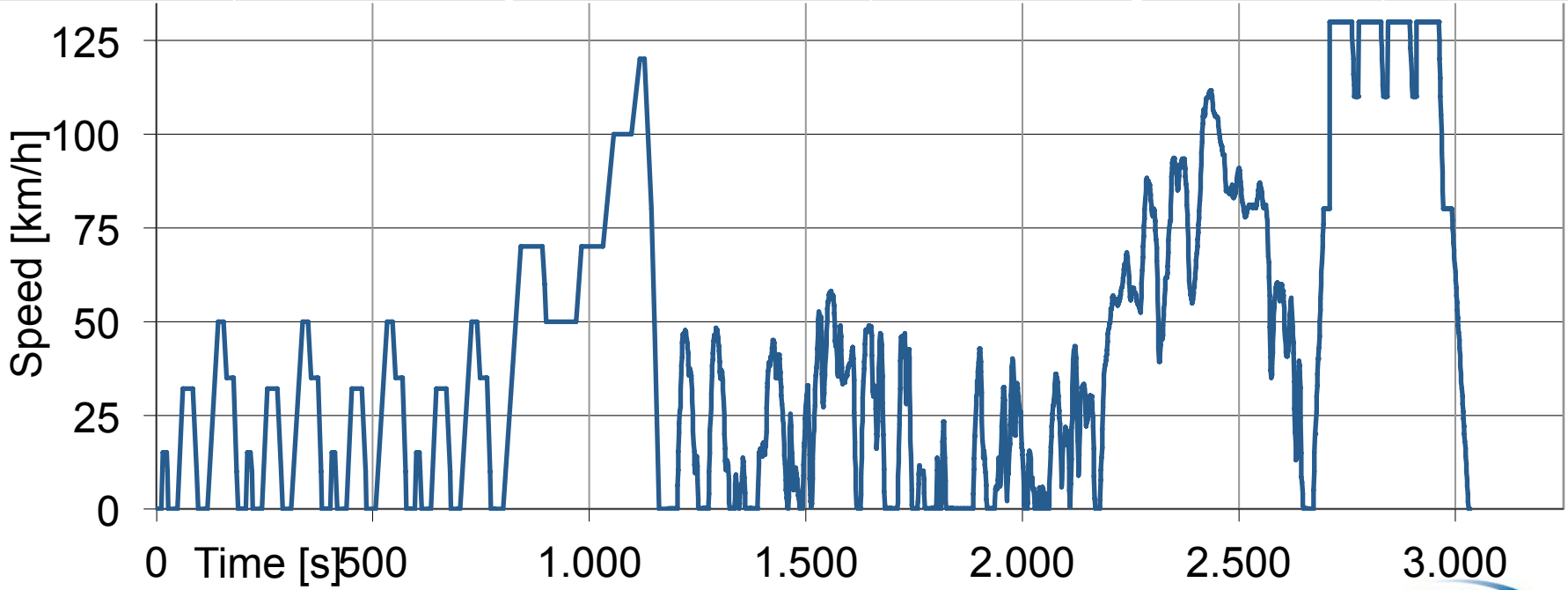
- To analyse the benefits, **four battery electric vehicles** were examined.
- A **diesel-engined car** with combustion engine served as a reference vehicle.
- To compare the real **annual energy requirements** and the real **greenhouse gas emissions**, we set out to:
  - the temperature curves for Austria and European Union over a periode of one year. (Focus: heating and air conditioning)
  - examine the influences of the driving conditions in urban, extra urban, motorway and stop-and-go situations.
  - examine the influences of the road gradients +2 %, -2 % and +/-2 %
  - take account of the greenhouse gas emissions generated as part of the energy provision as well as the energy required for the provision.
- In addition we also
  - determined the ranges of the vehicles
  - determined the efficiency of the current transformers and traction battery
  - calculated the annual energy costs.

# Examineded test cycles

## Eco-Test and Stop-and-Go

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

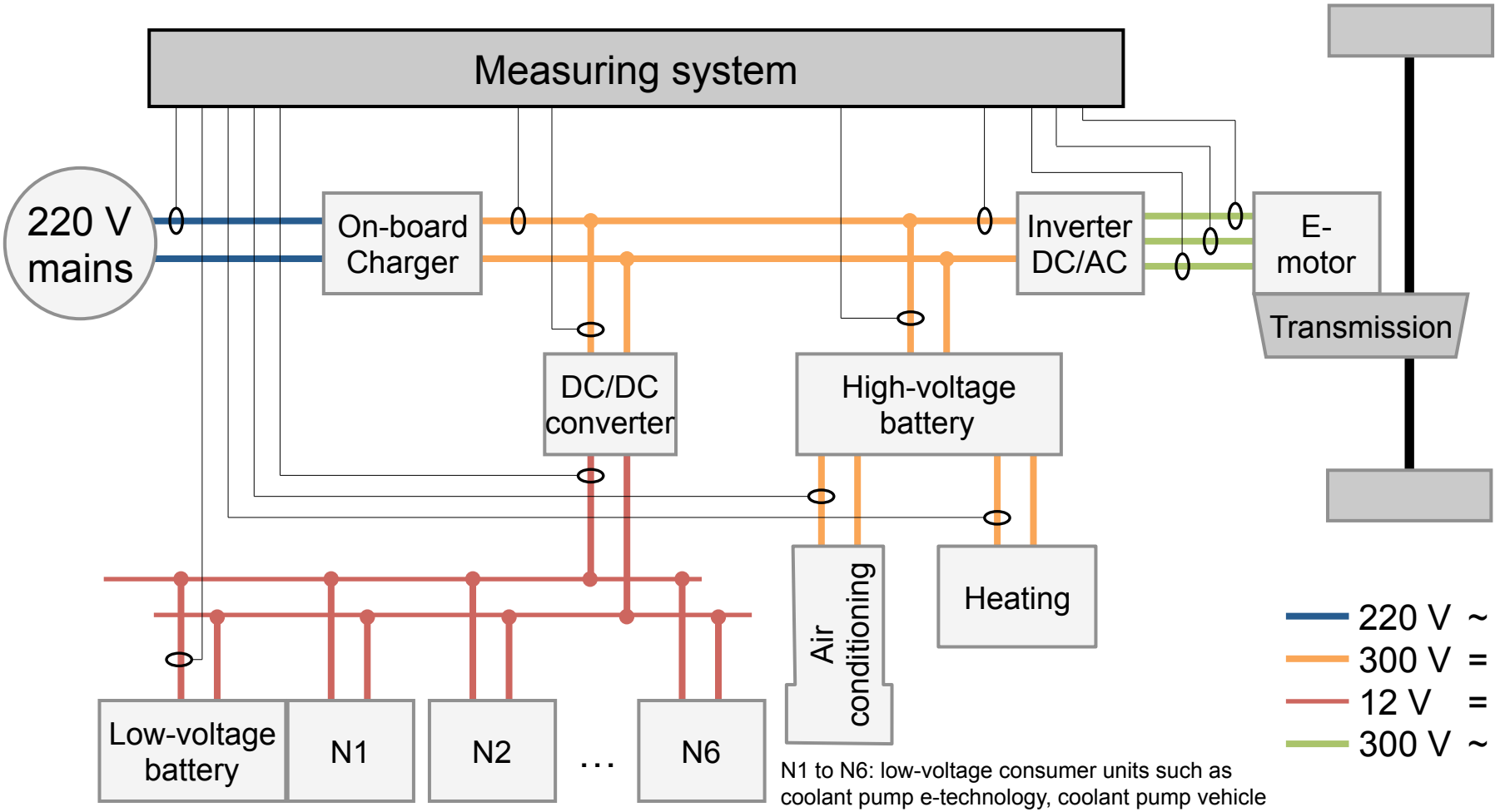
| Test cycles | Distance [km] | Test cycles | Distance [km] | Test cycles | Distance [km] |
|---|---|---|---|---|---|
| NEFZ ECE | 3,920 | NEFZ EUDC | 6,920 | BAB 130 | 9,270 |
| CADC Urban | 4,930 | CADC Extra Urban | 8,966 | Access/exit | 1,500 |
| *Urban* | *24,93%* | *Extra urban* | *44,74%* | *Motorway*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



# Measurement setup

## To determine the losings and to set up a energy balance

- Current and voltage measurement to determine the electric demand and power.




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 from 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 processing rates (up until 200 kHz, in real time)

# Vehicles assessed

## ICE passenger car

- ☐ Volkswagen Polo BlueMotion


## E-car

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



- ☐ Mercedes Benz A-Klasse E-Cell
- ☐ Nissan Leaf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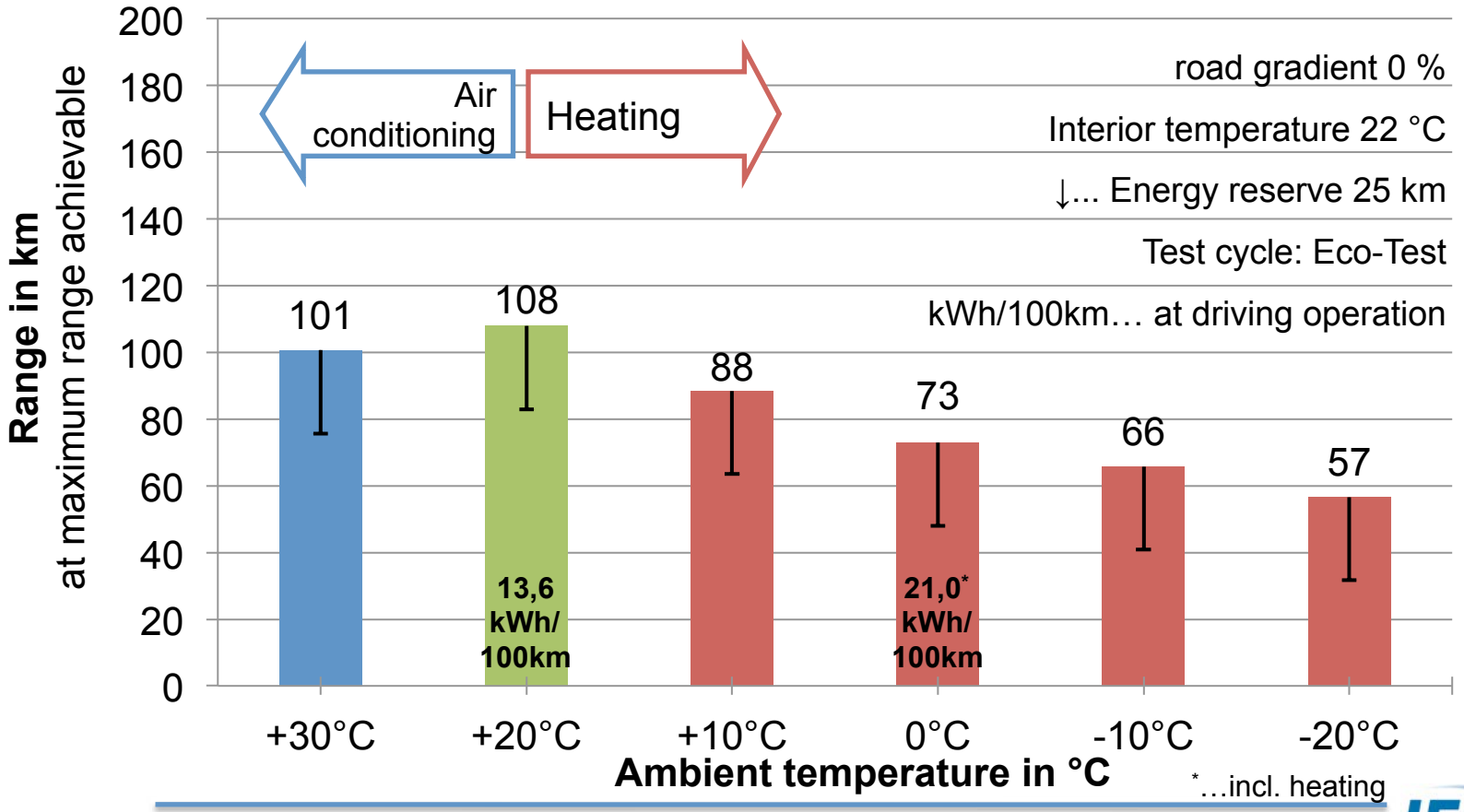
# Range of the Mitsubishi i-MiEV

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

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

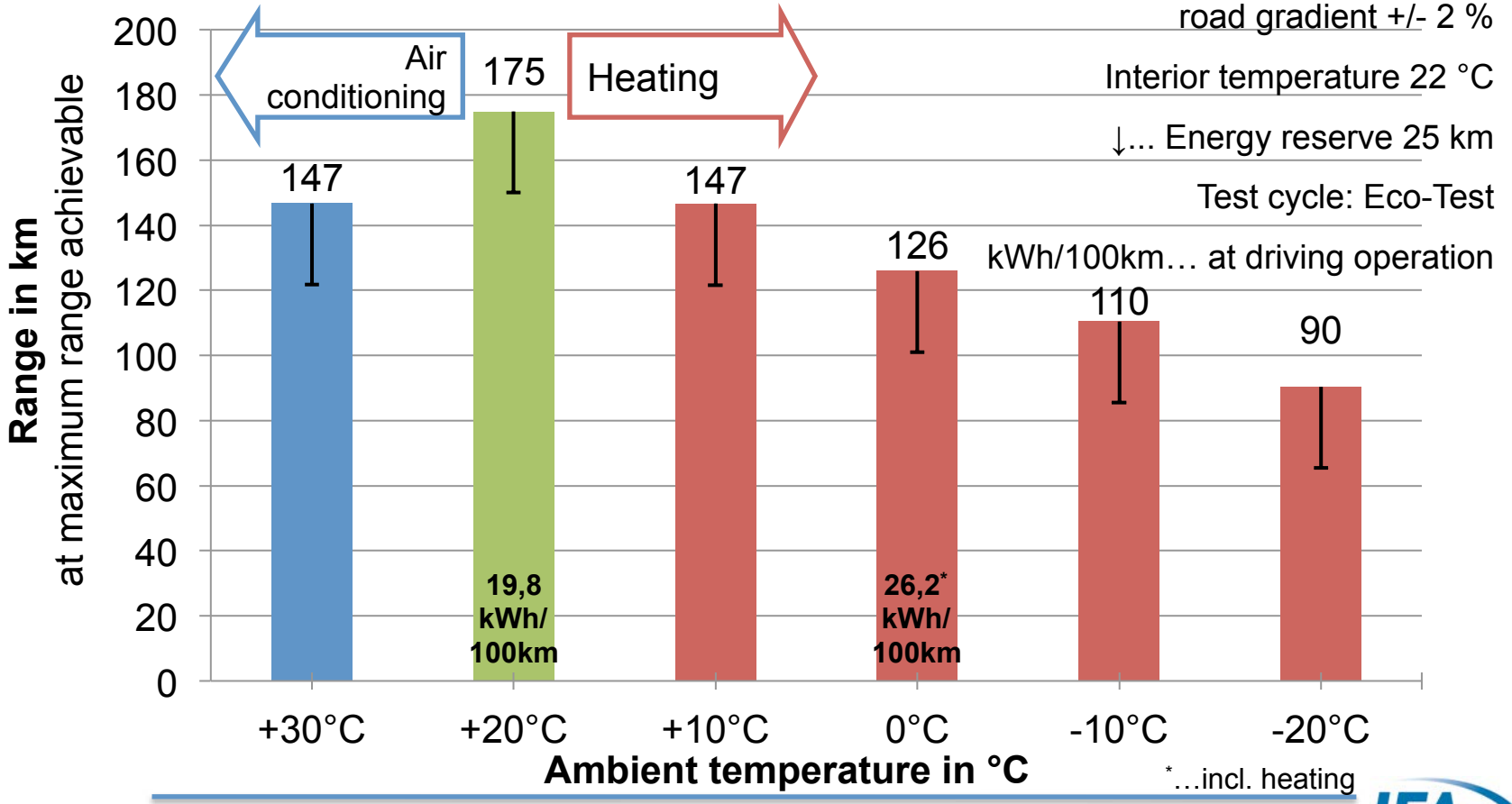
heating 3,8 kW



# Range of the Mercedes Benz A-Klasse E-Cell

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

- Caused by the higher battery capacity,
  - and the higher energy demand, affected by the vehicle category,
  - is it possible the reach higher ranges.



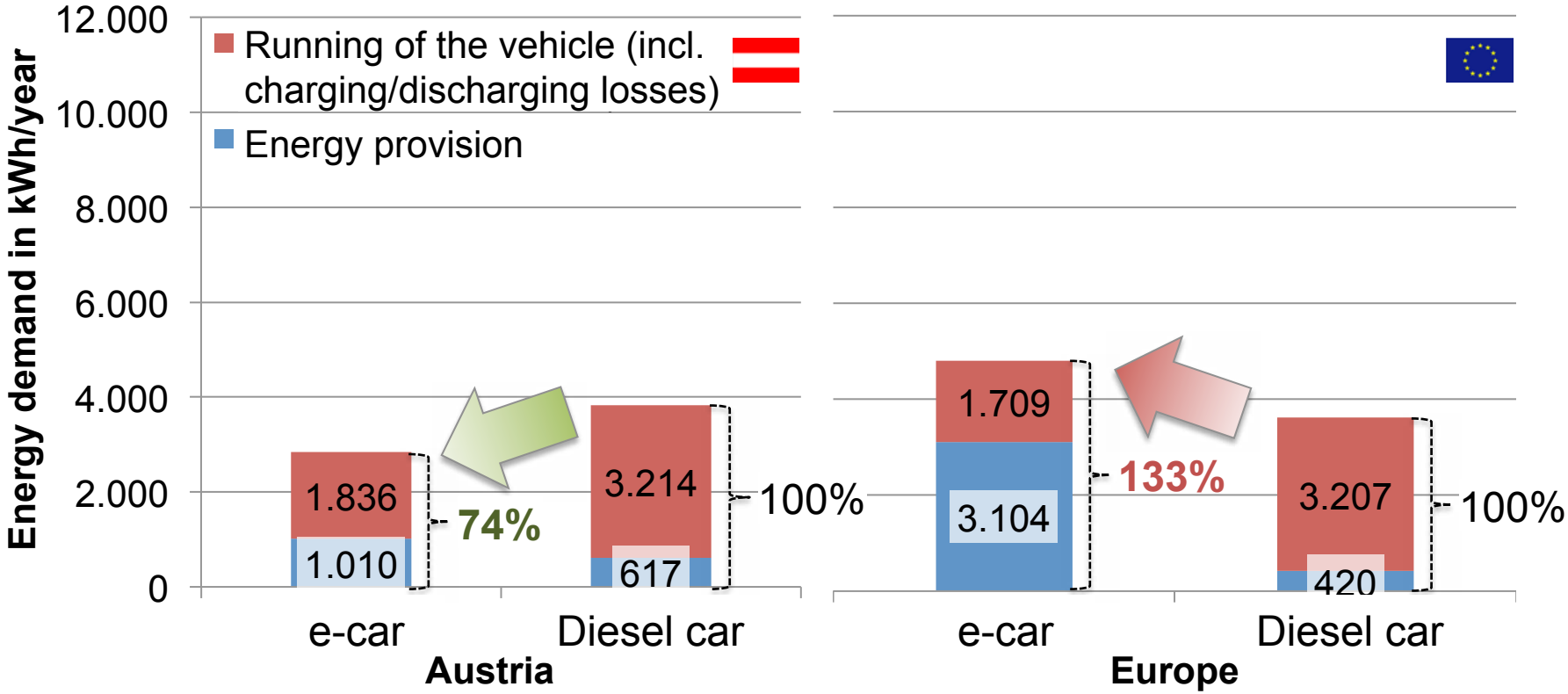
# Energetic and climatic benefit
## Outline conditions

- For the comparison, an average battery electric vehicle gets compared with a car with a combustion engine (VW Polo).
- Under consideration are taken:
  - average road gradients
  - different driving situations (urban, extra urban, motorway and stop-and-go).
  - User behaviours
    - Urban motorist (7.500 km per year, 65% stop-and-go and urban) and
    - Interurban motorist (15.000 km per year, 65% extra urban and motorway).
  - charging/discharging losses of the high voltage battery.
  - The operation of the heating system or air conditioning system based on the monthly average temperature (Austria and EU)
  - The energy required for the provision (Austria and EU).
- The energy required to manufacture the high-voltage battery and the vehicle are not taken into account.

# Energetic benefits

## Annual energy requirement of an urban motorist

- The energy requirement for the energy provision of an e-car is higher than for an diesel car.
- The lower share of renewable energy in the energy provision in the EU is leading to an energetic disadvantage of the e-car compared to the diesel car.

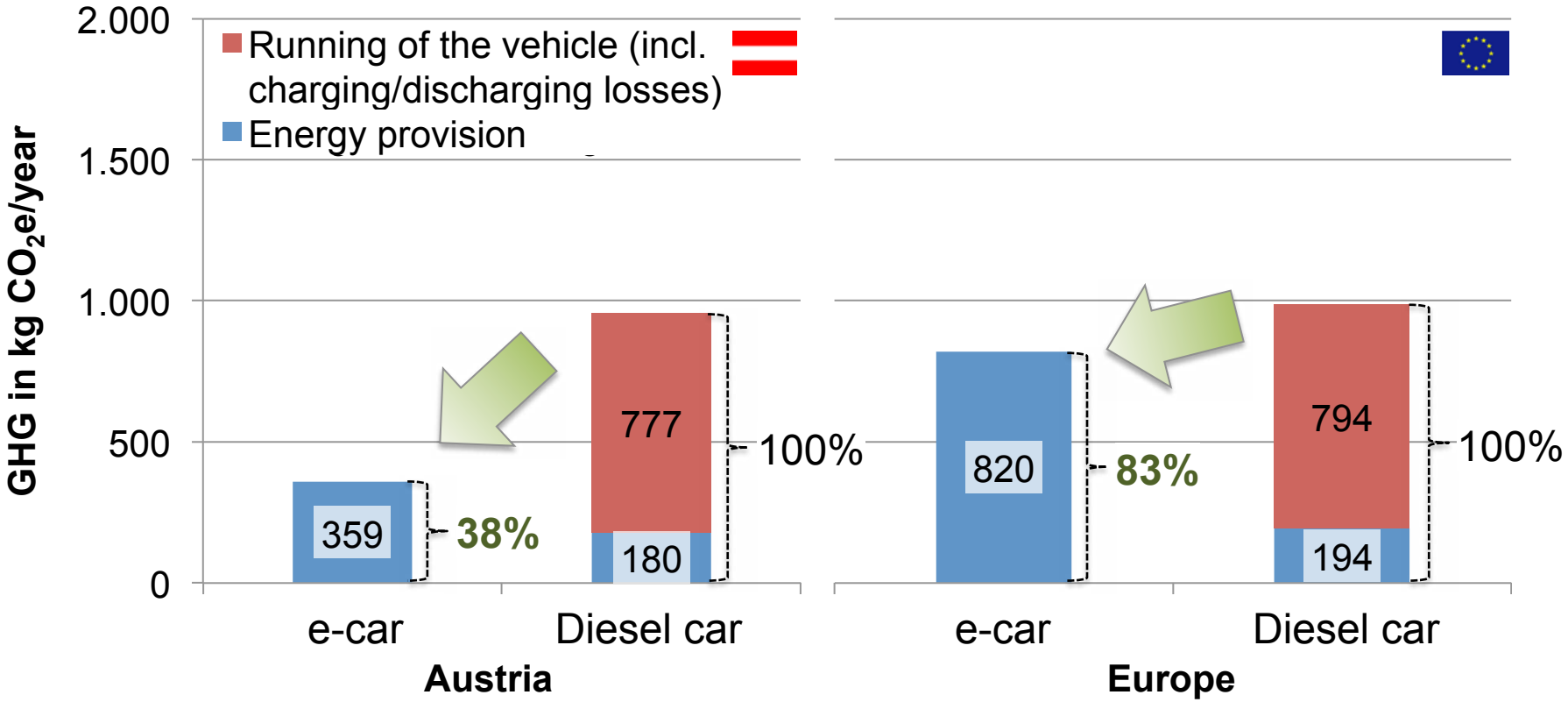



Kilometric performance: 7.500 km per year, 65% Stopp-and-Go and urban

# Climatic benefits

## Annual greenhouse gas emissions of an urban motorist

- The greenhouse gas emissions for the electric energy provision is higher than the one for diesel
- The advantages compared to a diesel car can be shown as well in Europe.




Kilometric performance: 7.500 km per year, 65% Stopp-and-Go and urban

# Summary
## Range and energy requirement

### ☐ Range

- The **range** achievable by the testes e-cars that are currently on **regular scale** in the motor trade is **severely limited** compared with conventional vehicles and **dependent on the ambient temperature**.
- These particular circumstances are **not expected to change in the long term either**.

### ☐ Energy requirement

- Also under real-life conditions (driving and ambient temperature), **the energy consumption of an average e-car** in pure driving operation (excluding the energy supply) **is just 60% of the energy of a conventional diesel-powered car**.
- In Austria, the **holistic approach** leads to a reduction of the benefits, so that the e-car has an **energy requirement of 74 to 79%** of a diesel-powered car.
- An **energetic disadvantage of e-cars from 33 to 43%** compared to diesel car results from the consideration of the energy provision in the **European Union**.

# Summary
## Greenhouse gas emissions

### ☐ Greenhouse gas emissions

- The **high proportion of renewable energy** in Austria is also responsible for causing that a e-car in Austria are only responsible for **38-40% of greenhouse gas emissions compared to a diesel car**.
- However, an e-car in the **European Union** produces **83 to 90% of the greenhouse gas emissions compared to a diesel car**, if greenhouse gases for the energy provision are taken into account.

# Outlook

- The 2nd edition of the Study „Battery Electric Vehicles in Practice- Costs, Range, Enviroment, Convience“ is on www.oevk.at for download available.
  - Study and detailed data's are free available
  - New: Citroen Berlingo
    - Molten salt battery (ZEBRA)
    - Gasoline heater as interior heater
    - No air conditioning
    - Range (+ 20 °C → -20 °C): 85 → 68 km
    - Fuel consumption of the interior heater (+ 10 °C-> -20 °C): 0.4-1.3 l / 100 km
    - energy from 230V network to preserve the battery operating temperature (+ 20 °C → -20 °C): 100 → 229 WH/h

Foto: Johann Wolf

- The current project is focused on the **optimization of PHEV- and REX** vehicles.
- The focus is equally on the **ICE- and the e-drive**, as well as on the **interaction** of both drives.

# Thank you very much
# for your kind attention!

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