EVS 32
A world of E MOTION
2019 MAY 19 22

INTERNATIONAL
ELECTRIC VEHICLE SYMPOSIUM & EXHIBITION

EVS 50th anniversary 1969-2019

Efficiency Analysis of Electric Vehicles

Results Out of Real-Drive Tests

Booth F14

Dipl.-Ing. Bernhard Grasel
DEWESoft GmbH

DEWESoft

- Founded in 2000
- ~ 200 Employees worldwide
- Turnover >20 Mio. Euro

French Office in Paris
Offices worldwide

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Agenda

- Driving Cycles
- Challenges Real-Drive Measurements
- Measurement Systems
- Analysis Examples

Definition “Efficiency”

Power Generation
(incl. Resources)

Power Transmission

Charging

Energy Usage

Well-to-Wheel Efficiency

Well-to-Tank Efficiency

Tank-to-Wheel Efficiency

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Range specification Nissan Leaf (2018)

Technische Daten

Typ		VISIA	ACENTA	N-CONNECTA	TEKNA
Motor / Kraftübertragung					
Motor-Bauart		Elektromotor			
Leistung, max.	kW (PS) bei U/min	110 (150)/3.283 - 9.795			
Drehmoment, max.	Nm bei U/min	320/0-3.283			
Batterie / Ladesystem					
Batterie		Laminierte Lithium-Ionen-Batterie			
Batteriekapazität	kWh	40			
Batteriezellen		192			
Batteriespannung	V	350			
AC Ladesystem****		Typ 2 (bis 6,6 kW)			
DC Ladesystem		CHAdeMO (bis 50 kW)			
Ladekabel****	kW	EVSE (2,3 kW) & Mode 3 Typ 2 auf Typ 2 (7,4 kW)			
Fahrleistung					
Reichweite städtisch*	(nach WLTP) km	415		389	
Reichweite kombiniert*	(nach WLTP) km	285		270	
Reichweite kombiniert**	(nach NEFZ) km	378			
Elektrischer Verbrauch kombiniert*	(nach WLTP) gesamt kWh/100 km	19,4		20,6	
CO_2-Emissionen	g/km	0			
(Messverfahren nach EU-Norm)					
Beschleunigung von 0 auf 100 km/h	sec	7,9			
Höchstgeschwindigkeit	km/h	144			

5 different energy consumption specifications

What's true?

https://www.nissan-cdn.net/content/dam/Nissan/at/brochures/pkw/leaf-2018-broschuere-preisliste.pdf

Range specification Nissan Leaf (2018)

Modell VISIA

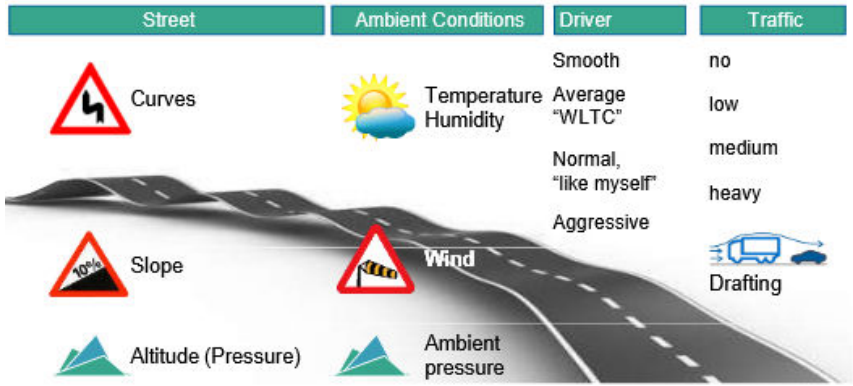
	Reichweite
WLTP City	415 km
WLTP combined	285 km
NEDC	378 km
EPA	243 km

https://www.nissan-cdn.net/content/dam/Nissan/at/brochures/pkw/leaf-2018-broschuere-preisliste.pdf

- **5 different energy consumption specifications**

What's true?

Real-Drive Tests (RDE)



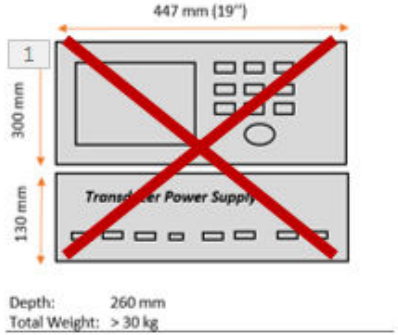
- Still only for emission measurement defined
- **Only China with Real-drive test cycle**

Challenges

Real-Drive Measurements

Challenges I

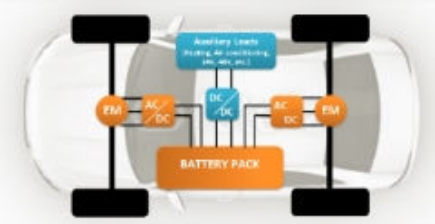
- High-Accurate Voltage and Current Measurement needed
  < 1%
- Measurements for wide operating temperature range
  -40°C …. +100°C
- Independet power supply for measurement
  low power consumption + battery powered
- Additional Temperature measurement for detection of drifts
- A lot of different drive trains



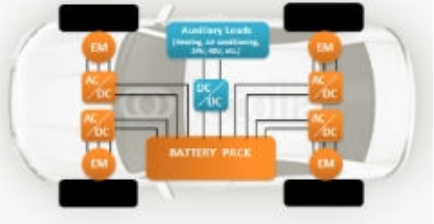
Challenges II

Electric Two-Wheeler

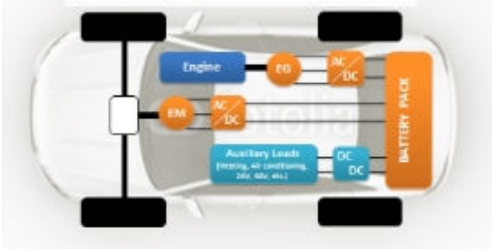
EV with 2 motors



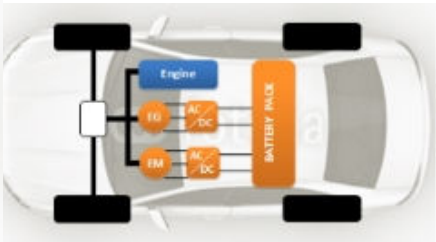
EV with In-Wheel motors



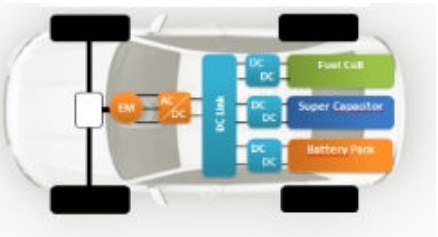
Series Hybrid (Range Extender)



Parallel Hybrid



Hydrogen



… a couple of different drivetrains

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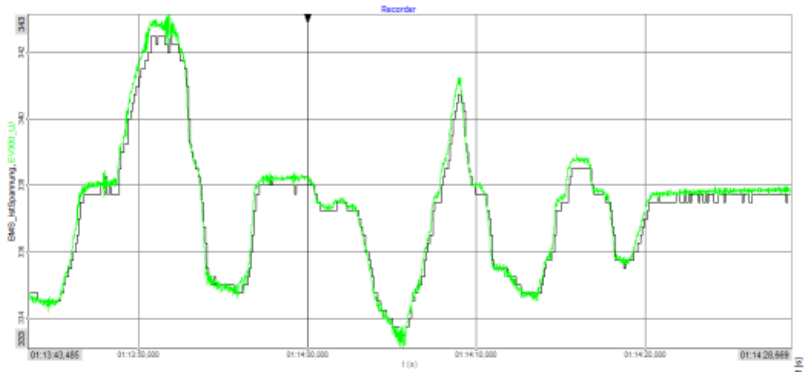
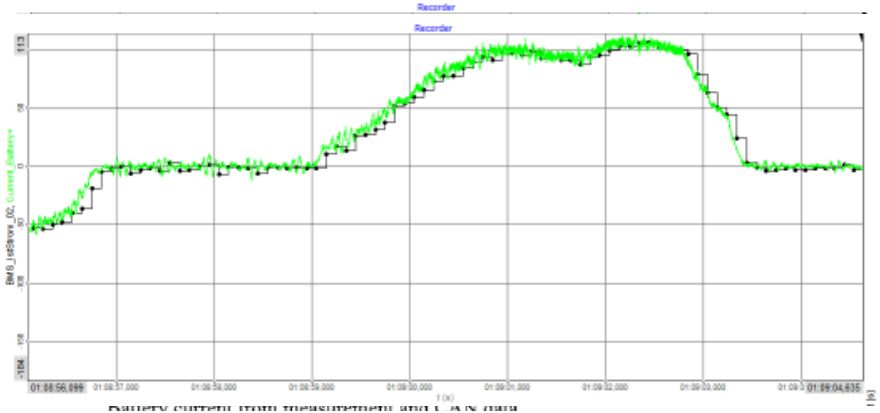
Data of vehicle bus ?



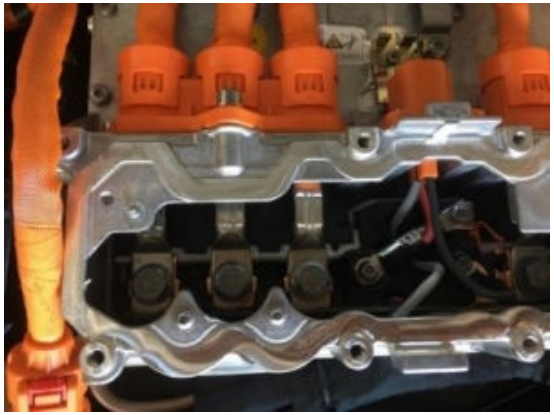
Voltage comparison from measurement and CAN data



Battery current from measurement and CAN data

- Deviation **up to 15%**
- Slow Data (10Hz)
- Not allowed

How to measure voltage and current ?



Power Distribution Unit (PDU)

- **High-voltage Safety System – No access to battery voltage**
- **No Space**
- **Shielded Cables**

Current Measurement

- Current measurement via shielded cable?

Influence of shielded HV DC Battery cable

Measurement Signal

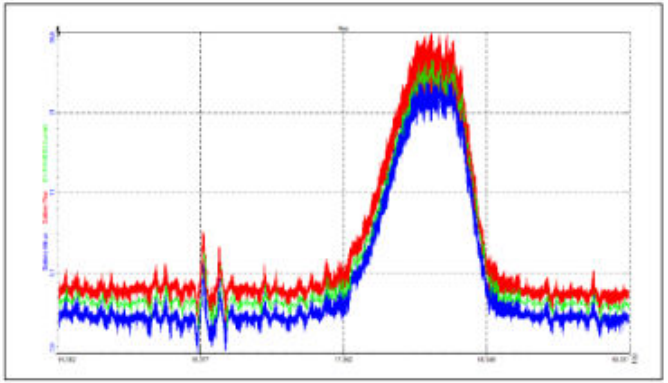


Figure 20. Influence of shielded motor cable

FFT of signals on shielded cable

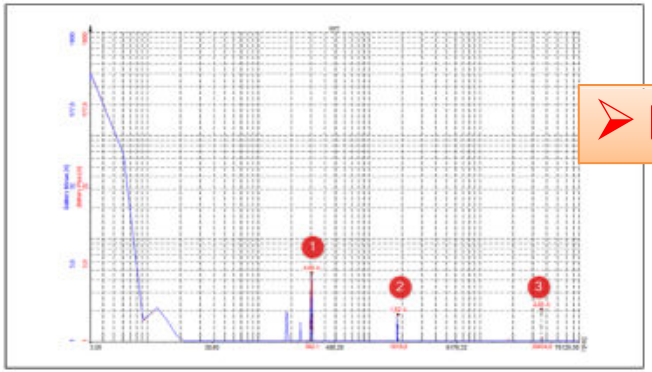


Figure 21. FFT analysis of the battery current signals

➢ **Deviation > 3%**

Quelle: Grasel B. (2018) Efficiency Measurements at Electric Vehicles

Measurement at HV DC battery cable

- Battery Plus with Shield
- Battery Plus without Shield
- Battery Minus with Shield

Signals on shield of HV DC cable

(1) Fundamental Motor frequency

(2) Higher Frequencies (Multiple of fundamental)

(3) Switching Frequency

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Influence of shielded HV DC cable at Auxiliary Loads

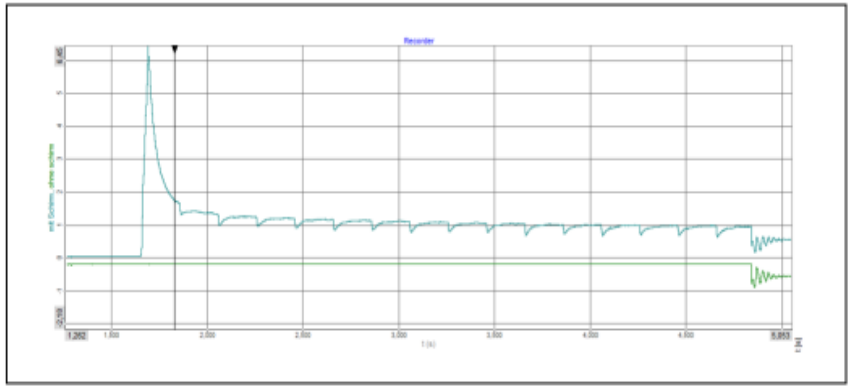

Figure 18. Current measurement with and without shielded cables

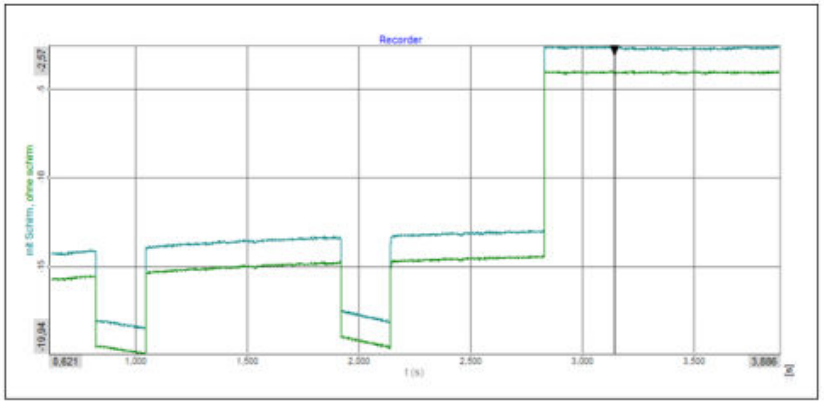

Figure 19. Influence of shielded motor cable

Quelle: Grasel B. (2018) Efficiency Measurements at Electric Vehicles

- Measurement at shielded DC cable
- Measurement without shield

➢ **Deviation 30% to >100%**

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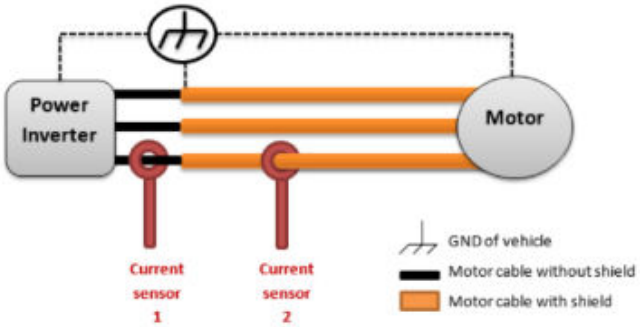
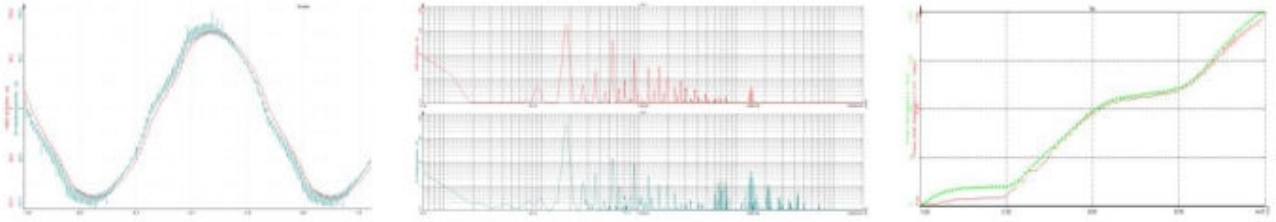
Current measurement with Clamps?



Smoothed Signal & Damping at higher Frequenices & Phase Shift

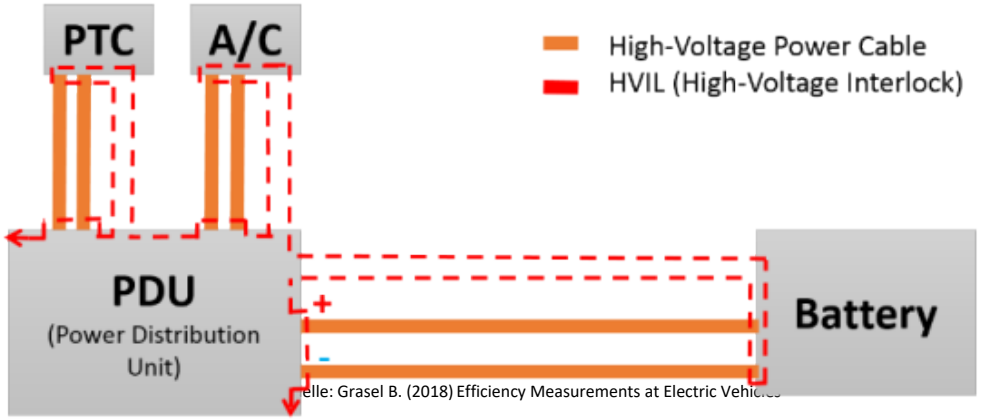


➢ Heavy influence of shielded cable

High-Voltage Safety

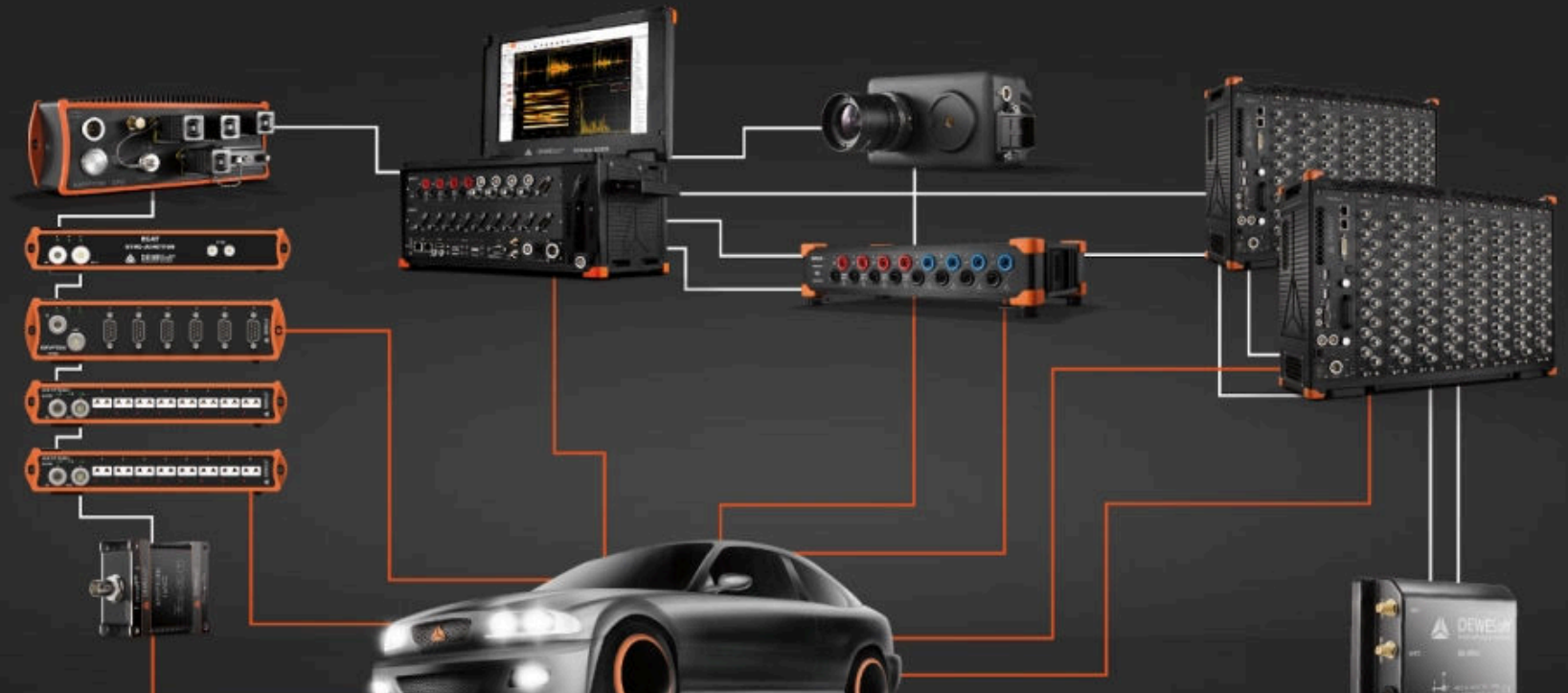
Voltage measurement at vehicle HV system

- Not (easy) accessable
- Modifications at vehicle needed
- High-Voltage test leads through driver cabin !
- HV Interlock (HVIL)



elle: Grasel B. (2018) Efficiency Measurements at Electric Vehi

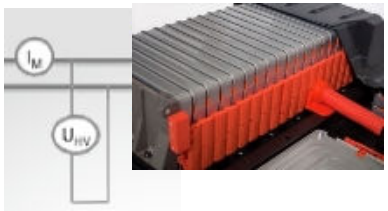
Measurement System



Measurement

1) Energy Consumption

→ **Power Measurement HV - Battery**



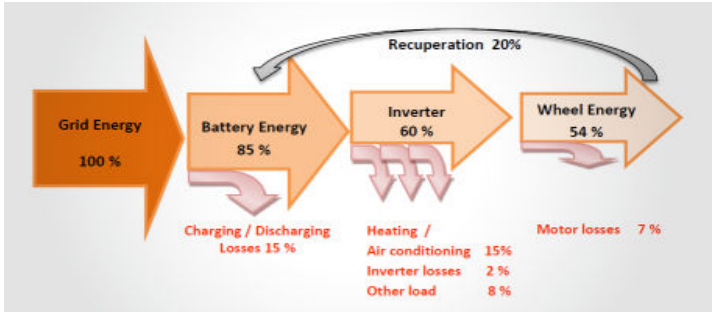
2) Detailed Energy Consumption

→ **Power HV Battery**

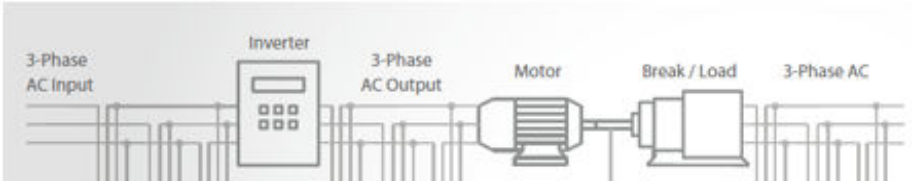
→ **Power Motor**
(electrical + mechanical)

→ **Power Auxiliaries**
(PTC, Klima, DC/DC 12V etc.)

→ **Power Charging**



Conventional Approach



GPS

Power Meter 1

Power Meter 2

Power Meter 3

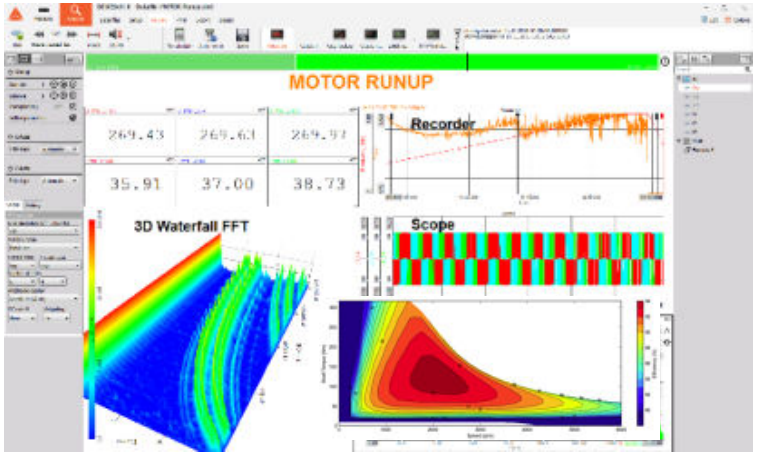
CAN Logger

Data Logger

Power Quality

Problem 3:

- **Couple of Instruments**
- **Data Synchronization**
- **Data Merging**
- **No Raw data**



Key Features

- Highest Accuracy 0.03%
- Synchronous Measurement
- High Samping Rate 1 MS/s
- Isolated Inputs CATII 1000V
- Multiple Power Calculation

DEWESoft Power Analyser

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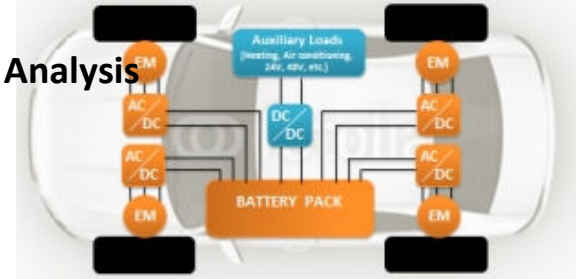
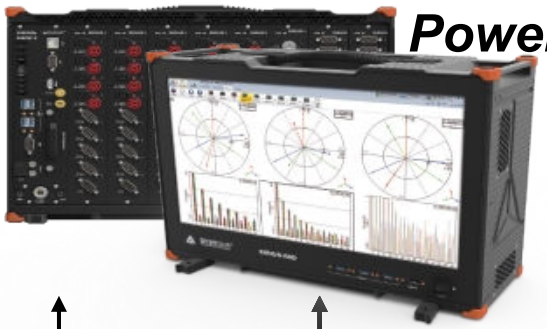
Multiple Power Analysis
4x 3-phase AC
10x DC Power



Next Generation
Power Analysis !



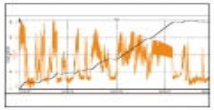
DEWESoft®
measurement innovation

Sensor Power Supply & Battery

Analog Inputs

GPS

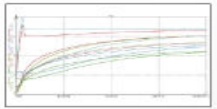
CAN



Interfaces

CAN out, DCOM, OPC, Digital In/Out, Analog Out etc.

Temperature



Video

DEWESoft Power Analyser

EWESoft®

HV-SHUNT Adapter

- Voltage & Current measurement integrated
- Safe Measurement
- CAN, Ethernet, Ethercat, XCP

Plug & Play

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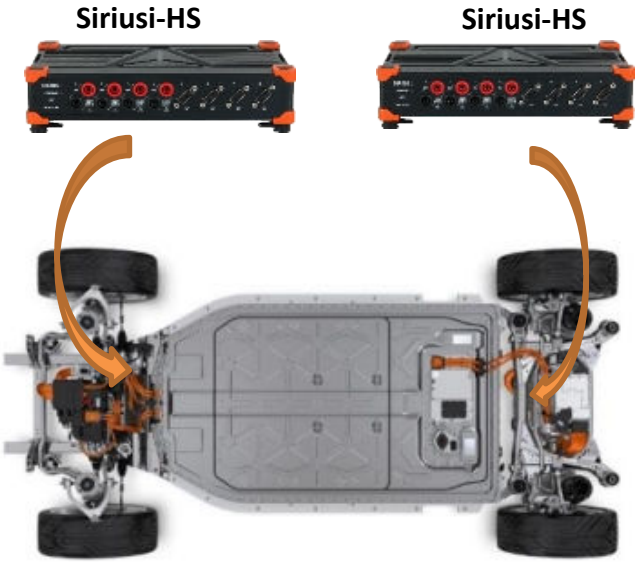
Distributed Measurement

Jaguar i-Pace

https://commons.wikimedia.org/wiki/File:Jaguar_I-Pace_IMG_0491.jpg



https://paultan.org/2016/11/15/jaguar-i-pace-all-electric-suv-concept-breaks-cover/jaguar-i-pace-platform-2/

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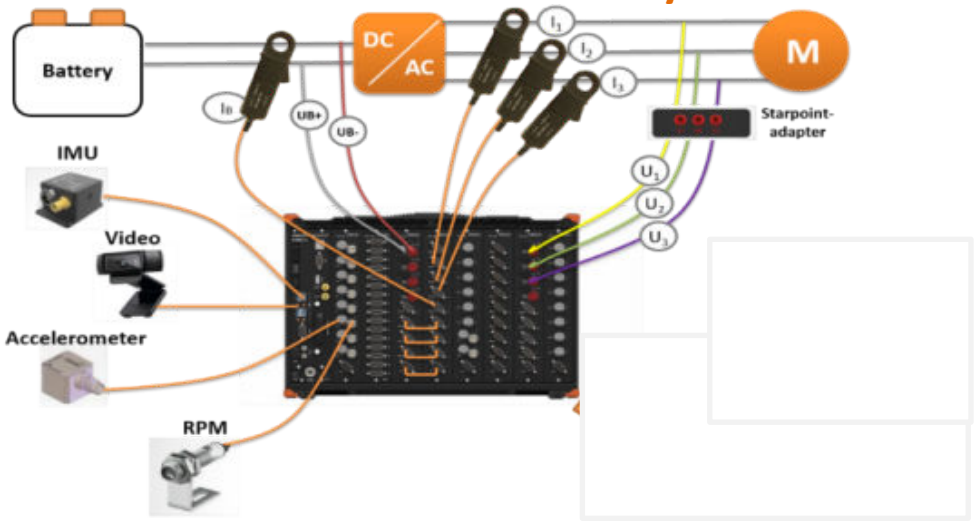
Electric Motorcycle

- DC and AC Power
- GPS and Video
- Vibration, RPM, Torque

DEWESoft R8D Power Analyser



- 20 measurement channels
- Power supply for current transducers out of instrument
- Battery pack integrated

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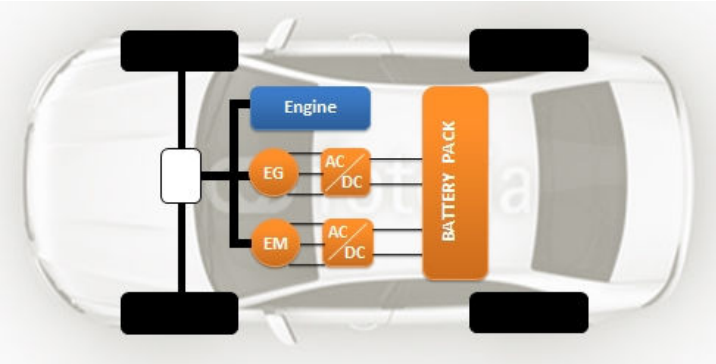
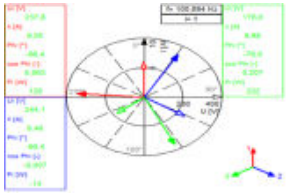
Example: Hybrid Vehicle

- 2x 3-phase AC Power Analysis
- 12x DC Power Analysis
- 1x Combustion Analysis
- In-vehicle and testbed use

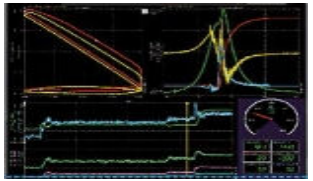


DEWESoft R8D Power Analyser

> 100 measurement channels



Power Analysis



Combustion Analysis

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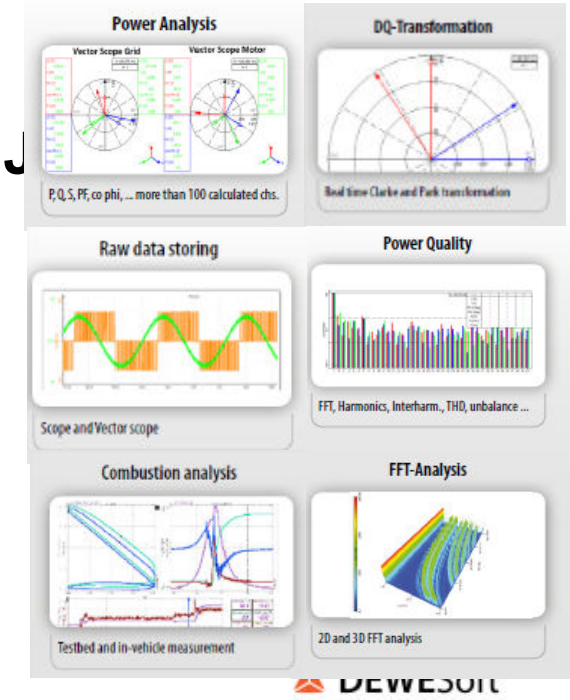
Analysis Examples

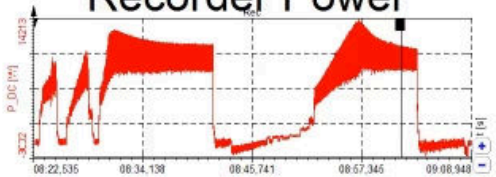
Applications EV Testing

- **Power Analysis**
- **Efficiency Mapping**
- **Energy consumption and Range (SAE J**
- **DQ Transformation**
- **Summer + Winter Testing**
- **Coast Down Tests (SAE J2951)**
- **HEV Net power rating (SAE J2908)**
- **Short Circuit Tests**
- **Back EMV Tests (FFT Analysis)**
- **Overshoot Voltage Measurement**

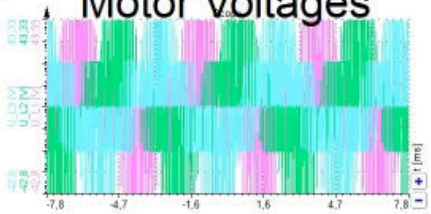


Electric Vehicle Real-Drive

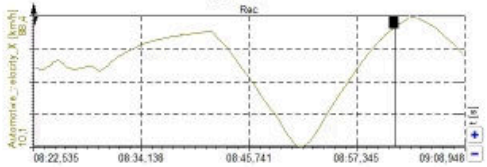
Recorder Power



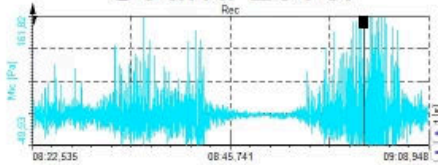
Motor Voltages



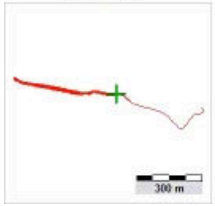
Velocity



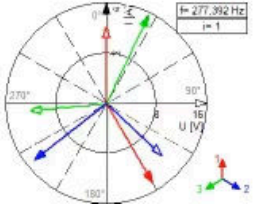
Sound Level



GPS

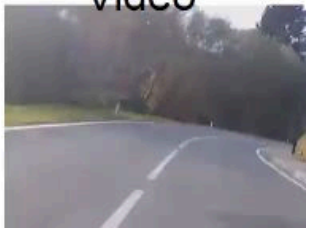


Vector Scope



Power

Video



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DEWESoft X - Datafile: DS-E-Mobility_ZeroXU.dxd
Recorder Power
Motor Voltages
Velocity
FFT
GPS
Vector Scope
Energy
Video
17.27
6.98
9.933

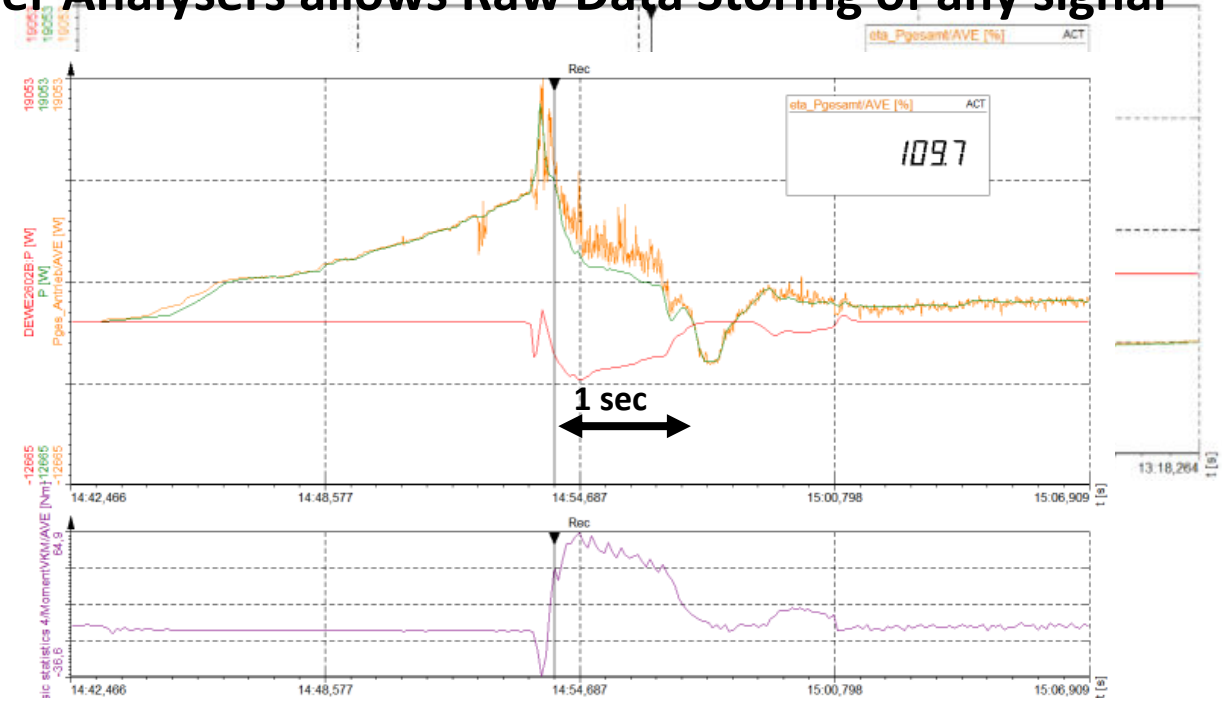

DEWESoft X - Datafile: downhill_uphill.d7d
Acquisition
Analysis
Power
GPS
VIDEO
Recorder
Speed
Energy
6740

The DEWESoft Power Analysers allows Raw Data Storing of any signal

Electrical Parameter

incl. Raw Data

Mechanical Parameter

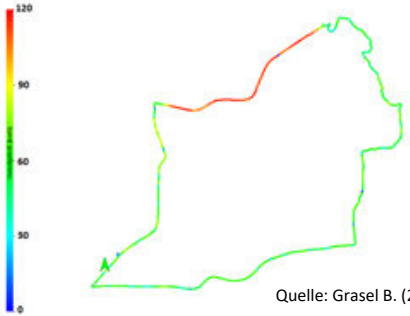


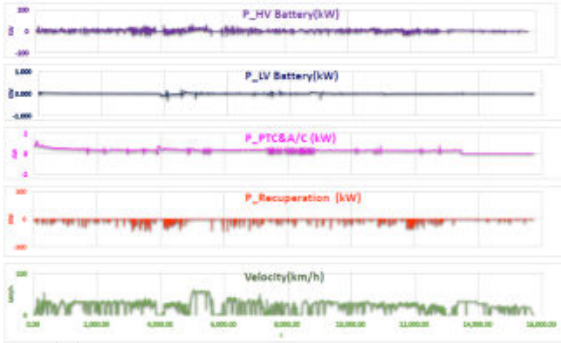
Motor Power — Generator Power — Total Power — Combustion Engine Torque

RDE Report

Measurement Configuration	
	
Sample Rate [S/s]	500
Sensor Type	EV-POWER-300A DS-CLAMP-500DCS
High-Voltage Measurement: □ Battery Pack □ Air Conditioning □ PTC □ Motor (MCU) □ DC/DC 12V □ Charger	√ Battery Pack √ PTC &Air Conditioning
Low-Voltage Measurement: □ DC/DC □ Waterpump □ Fans □ Auxiliary □ 12V Battery □ _____	√ 12V Battery

Test Result	
Journey Length [km]	198.9322 km
Average Speed[km/h]	46.5 km/h
Maximun Speed[km/h]	125.6 km/h
Journey Length [km]	198.9322 km
SOC Start[%]	100%
SOC End[%]	0%
Remaining Mileage[km]	0 km
Total HV Energy [kWh]	36.761 kWh
Total Energy Consumption[kWh] (include recuperation energy)	32.215 kWh
Total Recuperation Energy [kWh]	4.546 kWh (12.37%)
Total PTC&A/C Energy [kWh]	1.403 kWh (4.36%)
Total LV Battery Energy [kWh]	0.026 kWh (0.08%)
Energy consumption Rate[kWh/100km]	16.2 kWh/100 km

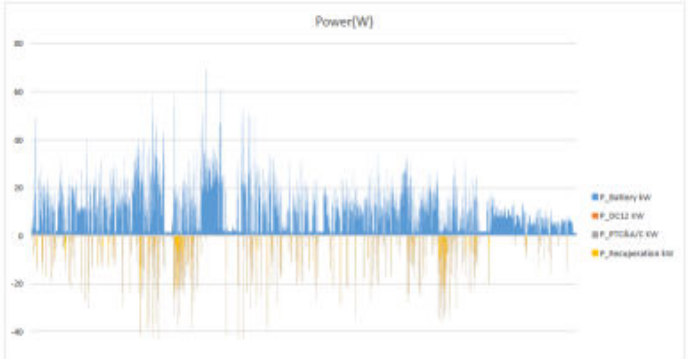




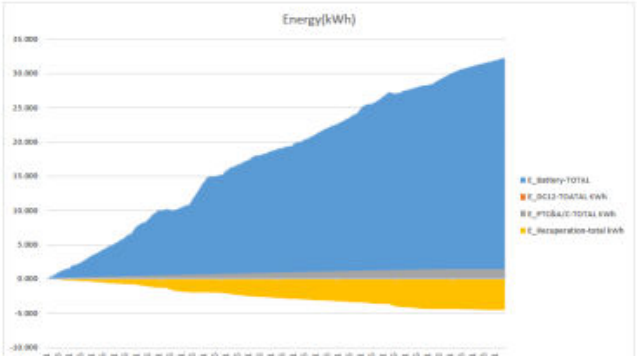
Quelle: Grasel B. (2018) Efficiency Measurements at Electric Vehicles

Energy Consumption – Analysis I

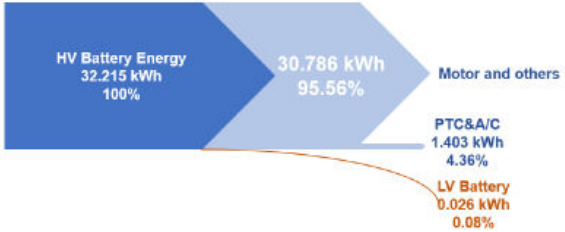
Power
Consumption & Recuperation



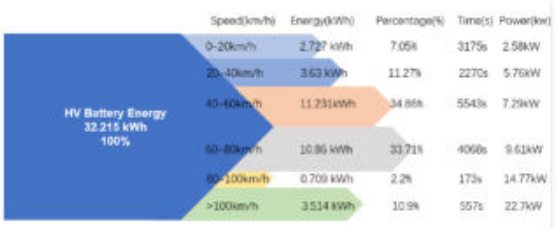
Energy
Consumption & Recuperation



Energy Flow



Energy Flow
Speed Classes

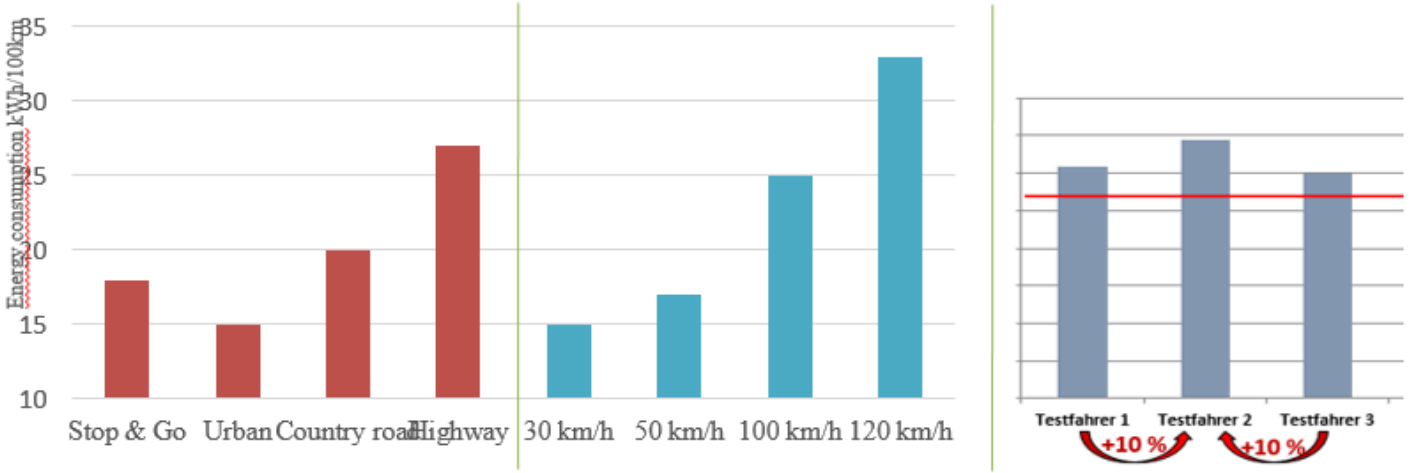


Quelle: Grasel B. (2018) Efficiency Measurements at Electric Vehicles

DEWESoft®

Energy Consumption – Analysis II

Route **Speed** **Driver**

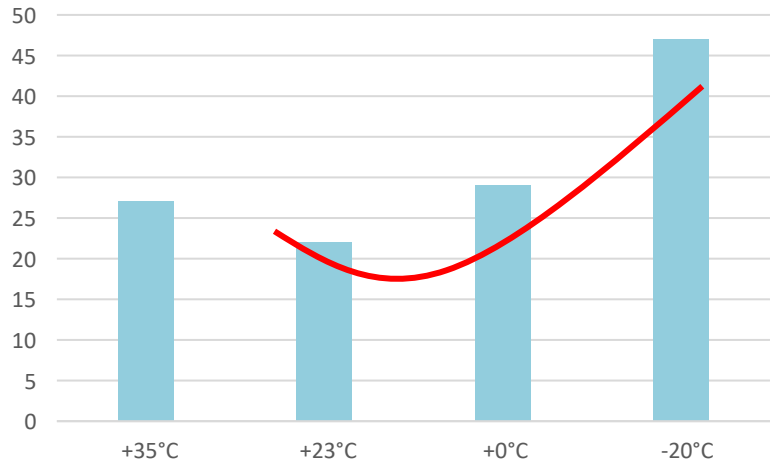


Source: DEWESoft und Grasel B.

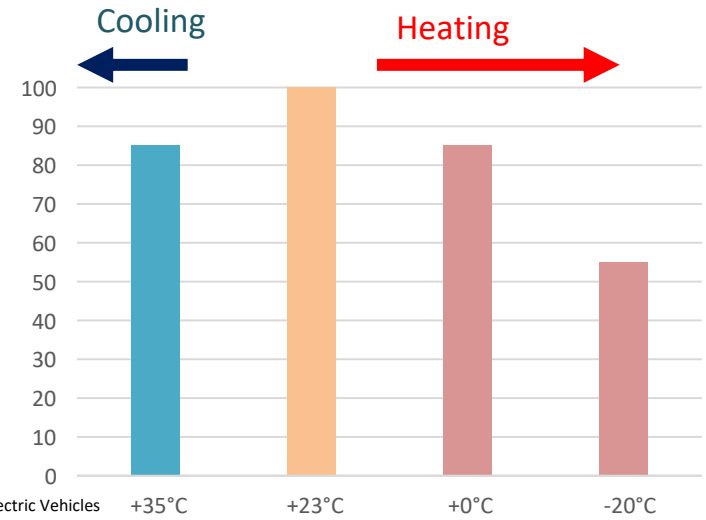
Energy demand of a selected electric test vehicle under different driving situations at ambient temperature (+20°C) in kWh/100km

Energy Consumption – Analysis III

Specific energy consumption [Wh/100km]



Range [%]



Quelle: Grasel B. (2018) Efficiency Measurements at Electric Vehicles

Energy Consumption – Influence factors

Description	Energy Consumption
Reference Energy consumption	20 kWh/100km [4]
Driving cycle on testbench	± 60 % [2]
Temperature-depended capacity of HEV-battery	± 10 % [4]
Behaviour of test driver	± 10 % [1]
Drive train technology (Hybrid Vehicles)	+ 20 % [4]
Hot weather (Cooling)	+ 20 %
Cold weather (Heating)	+ 100 %
Uphill	+ 800 % [1]
Auxiliary loads (e.g. light, fans, radio etc.)	± 10 %
Summer/Winter Tires	± 7 %
Speed 130 km/h	+ 100 %
Tires (Winter, Summer)	± 8 %

Source: Grasel, Contala, Schweiger, Pirnar (2016) Efficiency determination of electric vehicles under real driving conditions

Influence Factor Tires

Tesla Model S

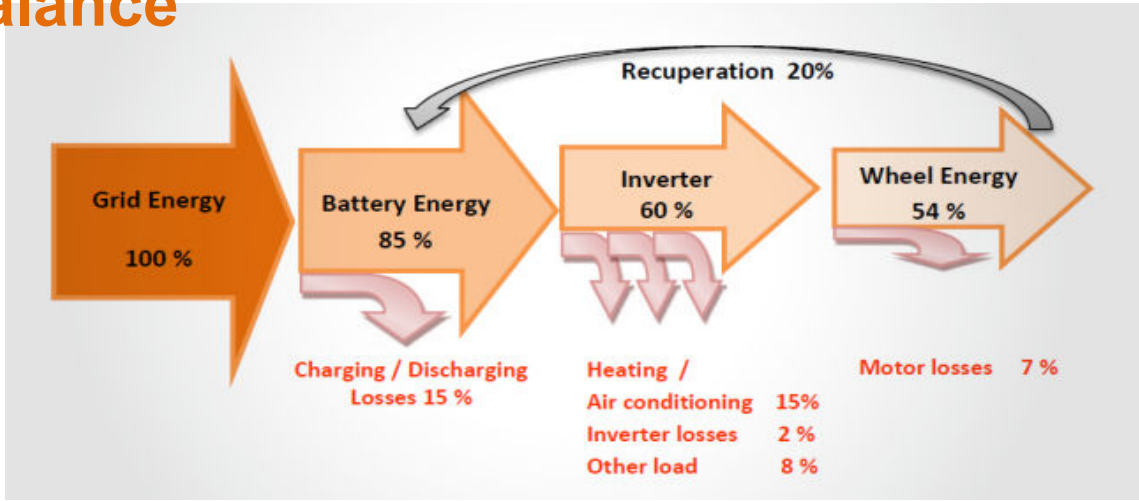
Winterreifen **+ 7%**

Winterreifen: 357 Wh/mi (222 Wh/km)

Sommerreifen: 334 Wh/mi (208 Wh/km)

https://insideevs.com/tested-snows-tires-increase-energy-consumption-7-tesla-model-s/

Energy Balance



Source: Grasel, Contala, Schweiger, Pirnar (2016) Efficiency determination of electric vehicles under real driving conditions

Description	Efficiency
Charging/Discharging	20 – 90 %
Battery	60 – 95 %
Inverter	80 – 98 %
Electric Motor	70 – 99 %
Recuperation	0 – 20 %

Example Improvement EV

Nissan Leaf 2018 – Improvements to 2016

1) Battery

New 40kWh (Nissan Leaf 2016: 24kWh)
same number of battery cells, same size ...
Improvements in heating & chemistry
Range improved by 100%
(2011: 73miles, 2018: 150miles … NEDC)

2) Motor / Inverter

Improvements at Efficiency, Cooling & Control

→ Increased Peak Power by 37% to 110 kW,
→ Increased Torque by 26% to 352 Nm

Quelle: https://insideevs.com/2018-nissan-leaf-got-range-ratings-in-wltp-cycle/

Conclusion

- „Know-How“ for measurement needed
  - Right Equipment
  - Attention to shielded cables
  - High-Voltage safety system

- Energy Consumption
  - Big difference of real consumption vs. specification
  - Real-Drive Emissions show real energy consumption
  - A lot of factors which influence energy consumption
  - Measurement of other signals (GPS, video, etc.) for detailed analysis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