The background image shows a car chassis on a production line. A blue robotic arm is visible on the left, and the car's body is transparent, revealing the internal components. The scene is set in a modern, industrial environment with large windows in the background.

Continued Glimpses into xEV Batteries on the Market – AVL Series Battery Benchmarking

2019

Ramaka, Vishwasri

About Us



AVL is the world's largest independent company for development, simulation and testing technology of powertrains (hybrid, combustion engines, transmission, electric drive, batteries and software) for passenger cars, trucks and large engines.

The headquarter of AVL is in Graz, Austria.

EXPERIENCE
>70 years !

5 powertrain elements

RESEARCH 10%
of turnover in-house R&D

STAFF 10,300
employees

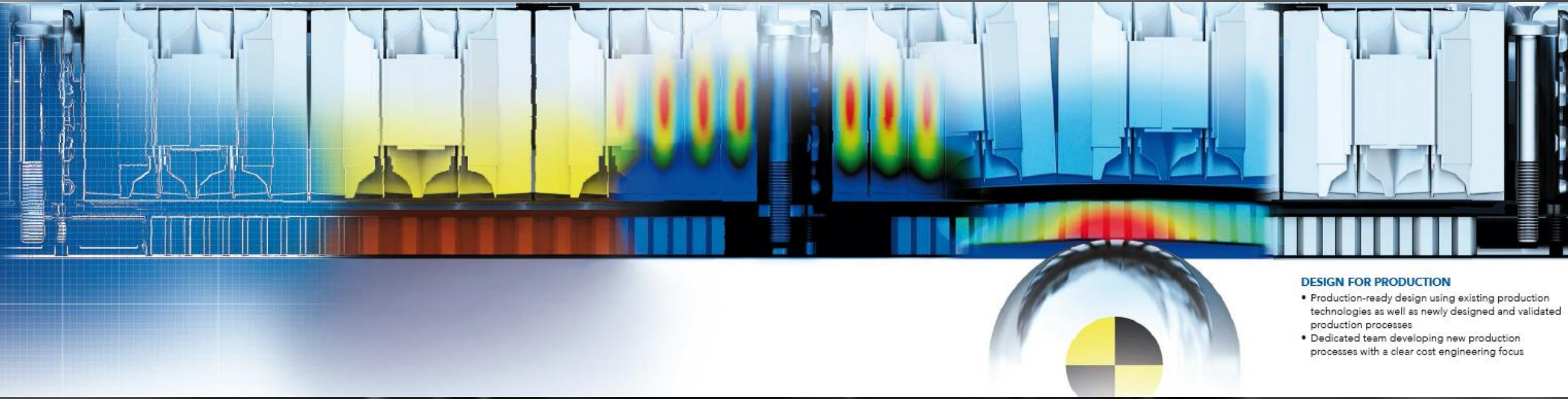
INNOVATION 1,500
granted patents

65% engineers and
scientists

GLOBAL FOOTPRINT

- 40** engineering locations
- **>220** testbeds
 - Global customer support network

AVL's battery activities: Involvement from Concept to Production



DESIGN FOR PRODUCTION

- Production-ready design using existing production technologies as well as newly designed and validated production processes
- Dedicated team developing new production processes with a clear cost engineering focus

Concept development
with AVL 25
concept points

**Mechanical,
electrical and
thermal design**

**Thermal,
mechanical and
EMC simulation**
for development

**Prototype based
validation and
verification**

**Design for
production**

Series Battery Benchmarking with **vehicle to screw analysis**
for benchmarking and development activities

AVL Series Battery Benchmarking STANDARDIZED WORK-PROCESS

AVL Series Battery Benchmark Standard Attributes



Performance



Driver Experience



Efficiency



Safety



Cost



Engineering Requirements



Producability



Serviceability

Level 0: Vehicle

Level 1: Vehicle Systems

Level 2: Elements

Level 3: Elements Sub-Systems

Level 4: HW Parts / SW Systems

Criteria Evaluation



Work Packages:

1. Global Vehicle Benchmark

2. Powertrain Tests

3. Vehicle Overview

4. Battery Interface

5. Battery Testing

6. Tear Down

7. Module Tests

8. Cell Tests

9. Cost Analysis

10. Abuse Tests

Deep dive battery benchmarking process: From vehicle to cell analysis involving all battery expert fields of AVL

AVL Series Battery Benchmarking STANDARD DELIVERABLES



Work-package Reports



Pictures, test data,
detailed analysis
(dis-/advantages)
& management summaries
- up to 1000 pages.

Evaluation Report



Analysis of 8 benchmark
attributes including the key
findings of each
benchmark.

Bill of Material



Part documentation
with all component
and sub-component
related information.

Test and Measurement raw data



Powertrain and battery tests
Cell perf. and abuse tests
Selected 3D scans.

Hand-Over Workshops

in which the reports are presented and technical solutions, advantages and disadvantages are highlighted.
At the AVL Benchmark Center or customer's premises.

AVL Series Battery Benchmarking YOUR CORE VALUE



Vehicle to cell analysis

Functions and performance on vehicle level is brought into context of design and parts.

Building functional understanding

AVL developed test program clearly shows function principles and their limits.

Orientation in the target system

Comparable evaluation transparently shows strengths and weaknesses rated by AVL's senior battery experts.

Worldwide experts for constant updates

4 new vehicles in the program / year benchmarked in China, US or Europe to be ahead of the market with the latest results.

AVL Series Battery Benchmarking

LATEST BENCHMARKED VEHICLES



Audi e-Tron Quattro



Hyundai Kona



JLR iPace



Tesla Model 3

Other available battery deep dive analysis:

- Chevrolet Bolt
- NIO ES8
- Volkswagen E-Golf
- Tesla Model X
- Mitsubishi Outlander
- Renault Zoe
- Tesla Model S

Coming soon:



Volkswagen ID3
Start: Q2 2020



Porsche Taycan
Start: Q1 2020

AVL Series Battery Benchmarking Horizontal Comparison Example



- Comparison study of the following vehicle's battery systems -



Tesla Model 3



Chevrolet Bolt



Hyundai Kona

**Parameter
comparison**

**Vehicle
structure**


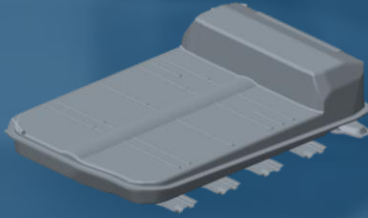
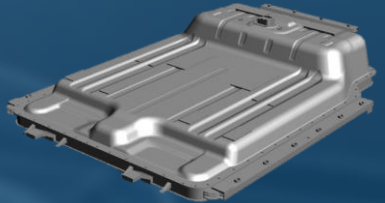
**Operation
robustness**

**DC Charge
strategy**

AVL Series Battery Benchmarking

COMPARED BATTERIES



	<i>Tesla Model 3 Long Range 2018</i>	<i>Chevrolet Bolt 2017</i>	<i>Hyundai Kona electric 150kW 2018</i>
<i>3D-Scan</i>			
<i>Battery Weight</i>	457 kg	435 kg	452 kg
<i>Battery Volume</i>	314 l	306 l	390 l
<i>Cell Type</i>	Cylindrical 2170	LGX N2.1 Pouch	LGY E63B Pouch
<i>Cell Capacity</i>	4,6 Ah	60,5 Ah	60 Ah
<i>Pack Specific Energy</i>	166 Wh/kg	138 Wh/kg	142 Wh/kg
<i>Pack Energy Density</i>	240 Wh/l	196 Wh/l	164 Wh/l

AVL Series Battery Benchmarking COMPARED BATTERIES

	<i>Tesla Model 3 Long Range 2018</i>	<i>Chevrolet Bolt 2017</i>	<i>Hyundai Kona electric 150kW 2018</i>
<i>Energy Nominal</i>	78 kWh	60 kWh	64 kWh
<i>Energy total C/3 25°C</i>	↓ 74,9 kWh	↑ 61,9 kWh	↑ 65,7 kWh
<i>Energy usable</i>	↑ 79,1 kWh	↓ 57,8 kWh	↓ 62,9 kWh
<i>Pack Specific Energy</i>	166 Wh/kg	138 Wh/kg	142 Wh/kg
<i>Specific Energy, usable</i>	173 Wh/kg	133 Wh/kg	139 Wh/kg
<i>Pack Energy Density</i>	240 Wh/l	196 Wh/l	164 Wh/l
<i>Energy Density, usable</i>	252 Wh/l	189 Wh/l	161 Wh/l
<i>Cell specific energy C/3, 25°C</i>	247 Wh/kg	287 Wh/kg	251 Wh/kg
<i>Cell energy density C/3, 25°C</i>	693 Wh/l	555 Wh/l	500 Wh/l

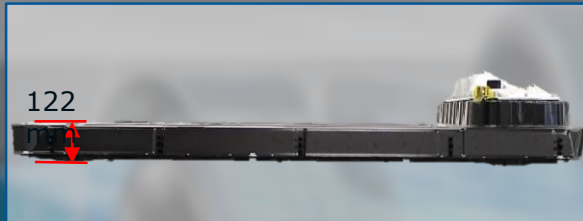


AVL Series Battery Benchmarking

Package efficiency



TESLA MODEL 3



CHEVROLET BOLT



HYUNDAI KONA



Energy Nominal	78 kWh	60 kWh	64 kWh
Battery Weight	469 kg	435 kg	452 kg
Pack weight efficiency cell weight/pack weight	64 %	51 %	57 %
Battery Volume	314 l*	306 l	390 l
Pack volume efficiency	33%	37%	33%

* Excluding power conversion unit

AVL Series Battery Benchmarking

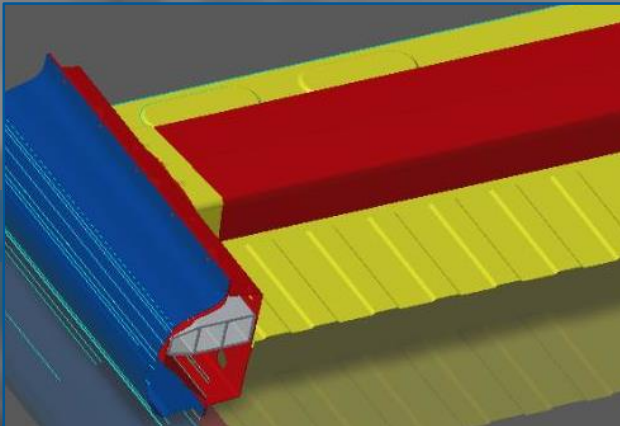
Deep-Dive Housing – vehicle structure



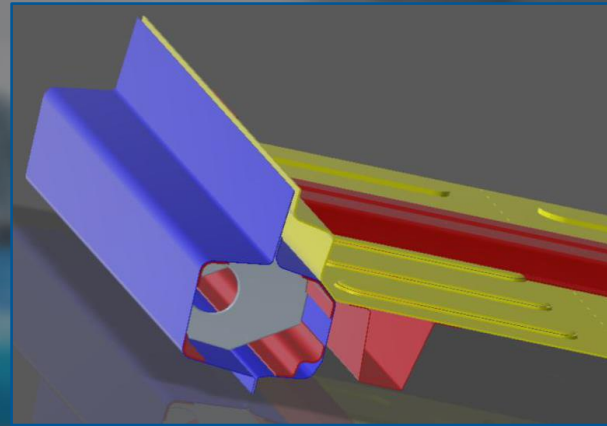
TESLA MODEL 3

CHEVROLET BOLT

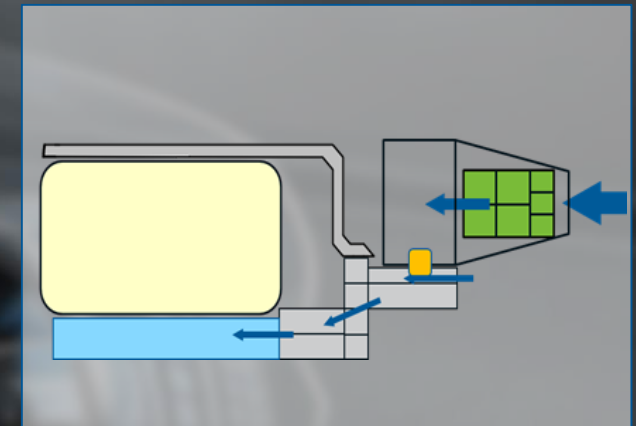
HYUNDAI KONA



Crash path in BIW



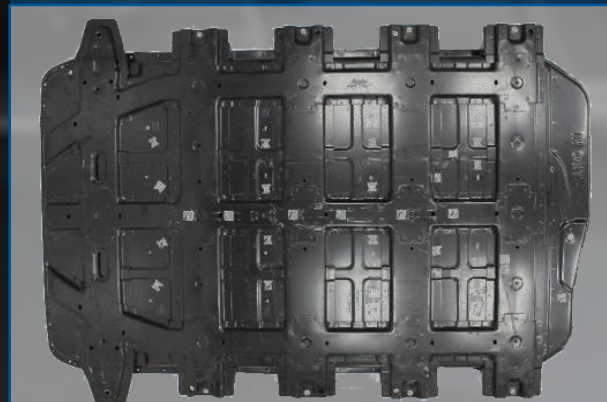
Crash path in pack



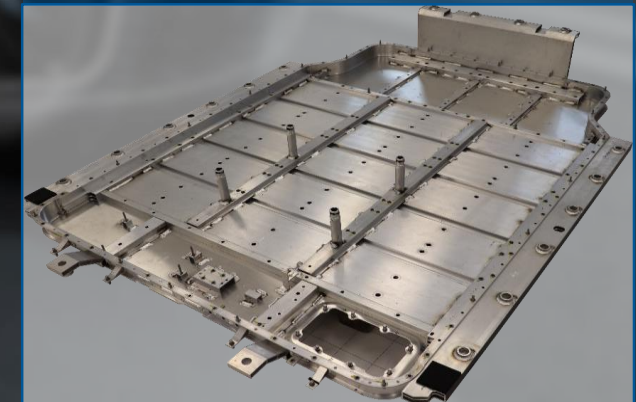
Crash path in pack



Al sheet & extrusion 54 kg



Sheet metal steel 65 kg



Al sheet & extrusion 68 kg

Crash Structure

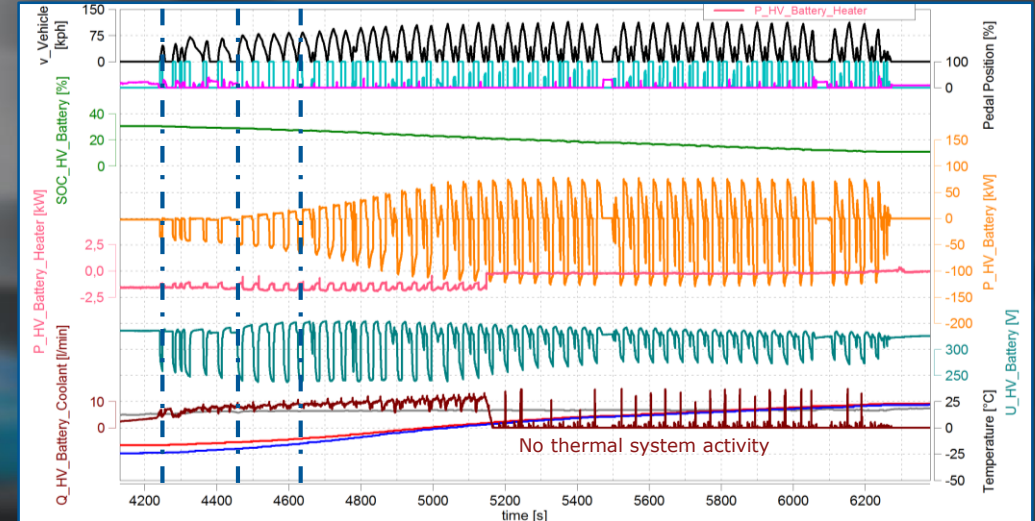
Battery Tray

AVL Series Battery Benchmarking Operation Robustness



- Low Temperature Performance -

CHEVROLET BOLT



*Preconditioned in cooling container / Test on test-track in ambient temperature (16°C)

Test Procedure

Full load acceleration repeating; high SoC; -30°C

Driving of sequenced full load accelerations with direct following decelerations with maximum recuperation at a high State of Charging

Results

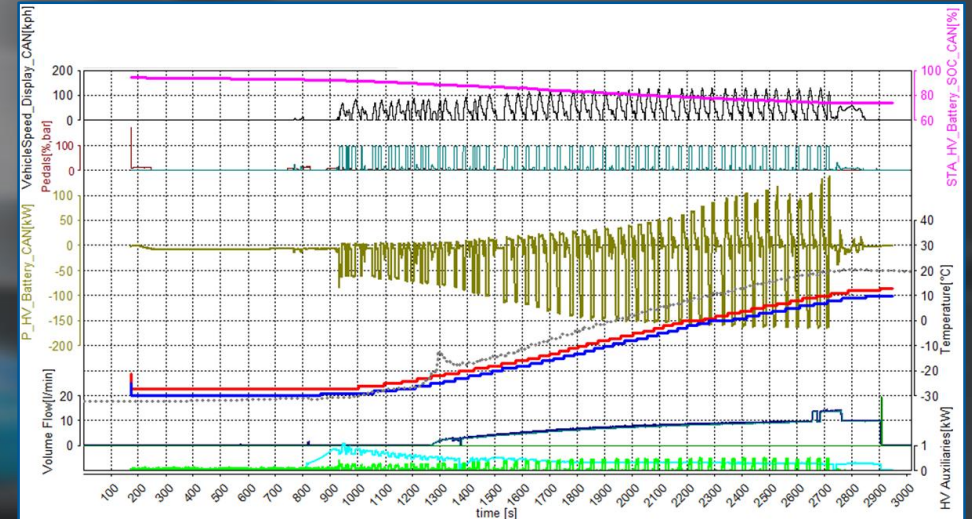
- Power at -20°C around 33% of normal
- Recuperation starts at -20°C
- No Operation under -24°C

AVL Series Battery Benchmarking Operation Robustness



- Low Temperature Performance -

HYUNDAI KONA



*Preconditioned in cooling container / Test on test-track in ambient temperature (16°C)

Test Procedure

Full load acceleration repeating; high SoC; -30°C

Driving of sequenced full load accelerations with direct following decelerations with maximum recuperation at a high State of Charging

Results

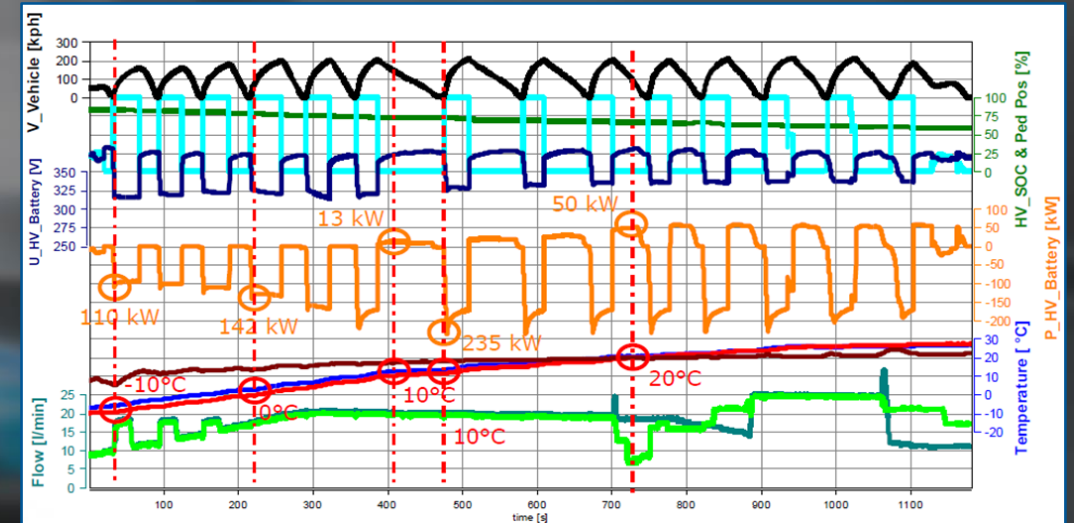
- Power at -20°C around 66% of normal
- Recuperation is 3% of normal
- More robust low temperature behavior

AVL Series Battery Benchmarking Operation Robustness



- Low Temperature Performance -

TESLA MODEL 3



Test Procedure

Full load acceleration repeating; high SoC; -10°C

- Same procedure as with the other two
- Preconditioning was not possible as battery was heated even in parking condition -> totally draining itself to shutdown

Results

- Power at -10°C around 45% of normal
- Recuperation activation starts at 10°C
- Discharge is 44% of normal

AVL Series Battery Benchmarking

WARM UP

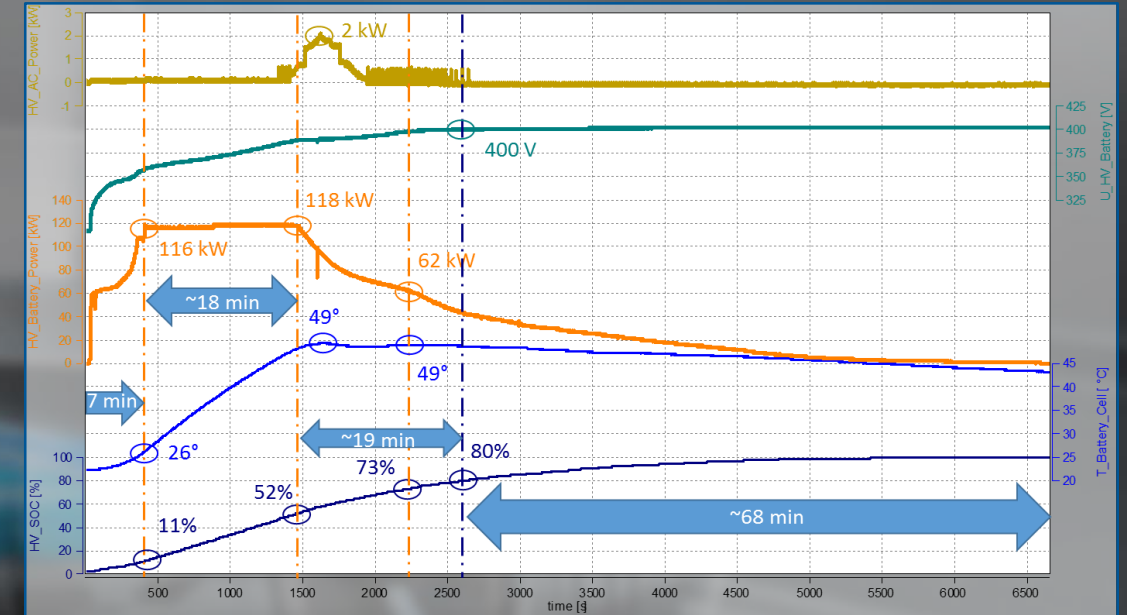


		<i>Tesla Model 3 Long Range 2018</i>	<i>Chevrolet Bolt 2017</i>	<i>Hyundai Kona electric 2018</i>
Performance	Battery Heating	~2 kw (e-Drive waste heat during standstill)	~1,9 kW (PTC heater)	2,5 kW (possible e-Drive waste heat)
	Power at -20°C (Tesla -10°C)	N/A (45% @ -10°C)	33%	66%
Thermal	Battery Temperature (Start of Operation)	-20°C	-24°C	-29°C
	Battery Temperature (End of Discharge Derating)	>10°C	0°C	>3°C
Electrical	Recuperation Power at -5°C	0 kW	50 kW	40 kW
	Recuperation Power at 0°C	0 kW	62 kW	80 kW

AVL Series Battery Benchmarking DC CHARGE STRATEGY



TESLA MODEL 3



Test Procedure

Charging after overnight parking

Voltage nominal was 350V

Results

- ~87 kW mean (119 kW peak)
- Full charge power up to 380V
- Active battery cooling in a small window
- Power derating voltage guided

AVL Series Battery Benchmarking

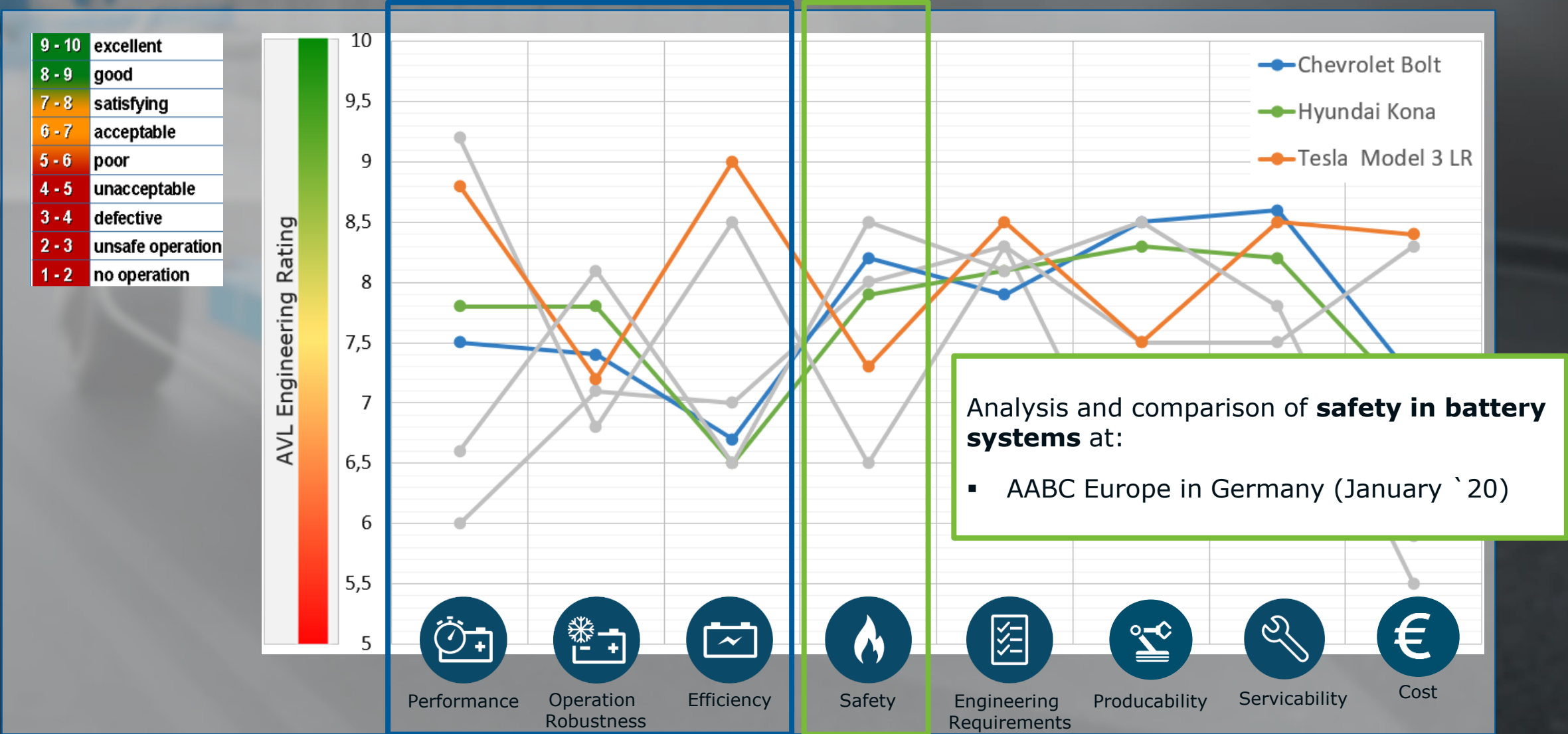
DC CHARGE STRATEGY

- Tesla outruns the market greatly also due to vehicle efficiency -



		<i>Tesla Model 3 Long Range 2018</i>	<i>Chevrolet Bolt 2017</i>	<i>Hyundai Kona electric 2018</i>
Performance	Battery Cooling during Charging	Active	Active	Active
	Charge Time until 80% SoC	44 min	1 h 25 min	1 h 03 min
	Avg. Charge Speed (WLTP normalized)	8,9 km/min	4,1 km/min	4,9 km/min
Thermal	Battery Temp. START	23°C	32°C	20°C
	Battery Temp. END	43°C	25°C	31°C
Electrical	MAX Charge Power	119 kW	55 kW	65 kW
	MEAN Charge Power until 80% SoC	87 kW	40 kW	45 kW

AVL Series Battery Benchmarking Scatterband - Conclusion



AVL Series Battery Benchmarking

LATEST BENCHMARKED VEHICLES



Audi e-Tron Quattro



Hyundai Kona



JLR iPace



Tesla Model 3

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- Tesla Model S

Coming soon:



Volkswagen ID3

Start: Q2 2020



Porsche Taycan

Start: Q1 2020

AVL Benchmarking (Vehicle, System & Component): Porsche Taycan 800V Powertrain



AVL performs **vehicle and component benchmarks** based on **AVL's proven benchmarking processes**.

Core values:

- Objective assessment and comparison of vehicle and component attributes.
- Transparent identification and analysis of strengths and improvement potentials.
- Comparison to AVL's vehicle and component benchmark database.

All packages as bundle
or stand-alone available

Vehicle	Battery	E-Drive
Deep dive analysis of vehicle & powertrain functionality on test track and chassis dno		
Handling (Lateral Dynamics)	Component performance tests	
Efficiency and charging	Teardown analysis and engineering evaluation	
Performance & Driveability	Cost analysis including assembly evaluation	
ADAS	Cell analysis	Efficiency analysis
NVH & AVAS	Safety / Abuse tests	Material analysis

Source Picture: Porsche.com



First **results** available **in Q1-2020**. Order now and **be ahead of the market!**



Thank You



www.avl.com

MORE INFORMATION AND
COOPERATION OPPORTUNITIES:

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