

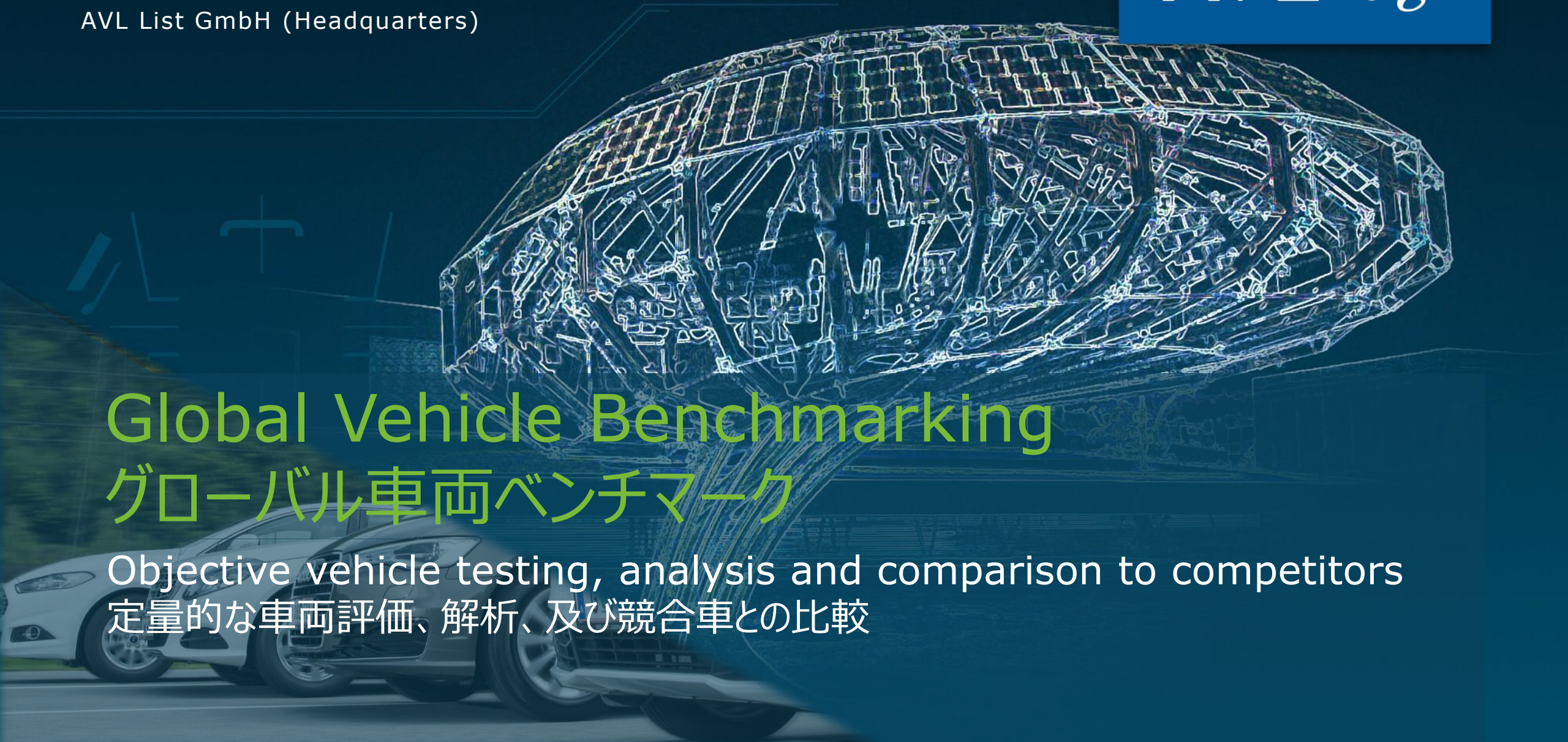
AVL List GmbH (Headquarters)



Global Vehicle Benchmarking

グローバル車両ベンチマーク

Objective vehicle testing, analysis and comparison to competitors
定量的な車両評価、解析、及び競合車との比較



Global AVL Network for Vehicle Benchmarking 車両ベンチマークにおけるAVLの国際ネットワーク



 **> 100**
new vehicles per year


 **> 500**
vehicles in database

 **> 60**
benchmarking staff

 **11**
global affiliates


cost efficient


customer individual


independent vehicle comparison


target setting

-  PERFORMANCE
-  DRIVEABILITY
-  HANDLING
-  RIDE COMFORT
-  SOUND/NVH
-  ADAS QUALITY
-  ENERGY CONSUMPTION
-  REAL WORLD DRIVING
-  ENERGY EFFICIENCY
-  DRIVING RESISTANCE
-  CHARGING EXPERIENCE

11 functional driving attributes
>1000 single criteria

Fun-to-Drive – Efficiency Balance

運転する楽しさと 高効率 のバランス



FUN-TO-DRIVE

EFFICIENCY



making **driving experiences** measurable and assessable

- PERFORMANCE
- DRIVEABILITY
- HANDLING
- RIDE COMFORT
- SOUND/NVH
- ADAS QUALITY

- ENERGY CONSUMPTION
- REAL WORLD DRIVING
- ENERGY EFFICIENCY
- DRIVING RESISTANCE
- CHARGING EXPERIENCE

Objective KPIs for all driving attributes
運転に関する指標全てについて定量的評価指標(KPI)を設定

Global Vehicle Benchmarking 国際車両ベンチマーク

Key aspects and process 鍵となる着眼点と業務プロセス



Why does it necessary to benchmark competitor vehicle? なぜ競合車両をベンチマークする必要がある?

Comparison to competition ✓

Characterization and Branding ✓

Defining potential for optimization ✓

Scouting technologies ✓

How does AVL do it? AVLはどうやってベンチマークを実施している?

Vehicle Instrumentation

Automatic Operation Mode Detection

Online Parameter Calculation

Instant Attributes Assessment

Vehicle Testing (test tracks and dynos)

Automatic Report Generation

Report – Highlights and improvement potential

- Vehicle Target Setting
- PERFORMANCE
 - DRIVEABILITY
 - HANDLING
 - RIDE COMFORT
 - SOUND/NVH
 - ADAS QUALITY
 - ENERGY CONSUMPTION
 - REAL WORLD DRIVING
 - ENERGY EFFICIENCY
 - DRIVING RESISTANCE
 - CHARGING EXPERIENCE

How long does it take? 時間はどれぐらい掛かる?



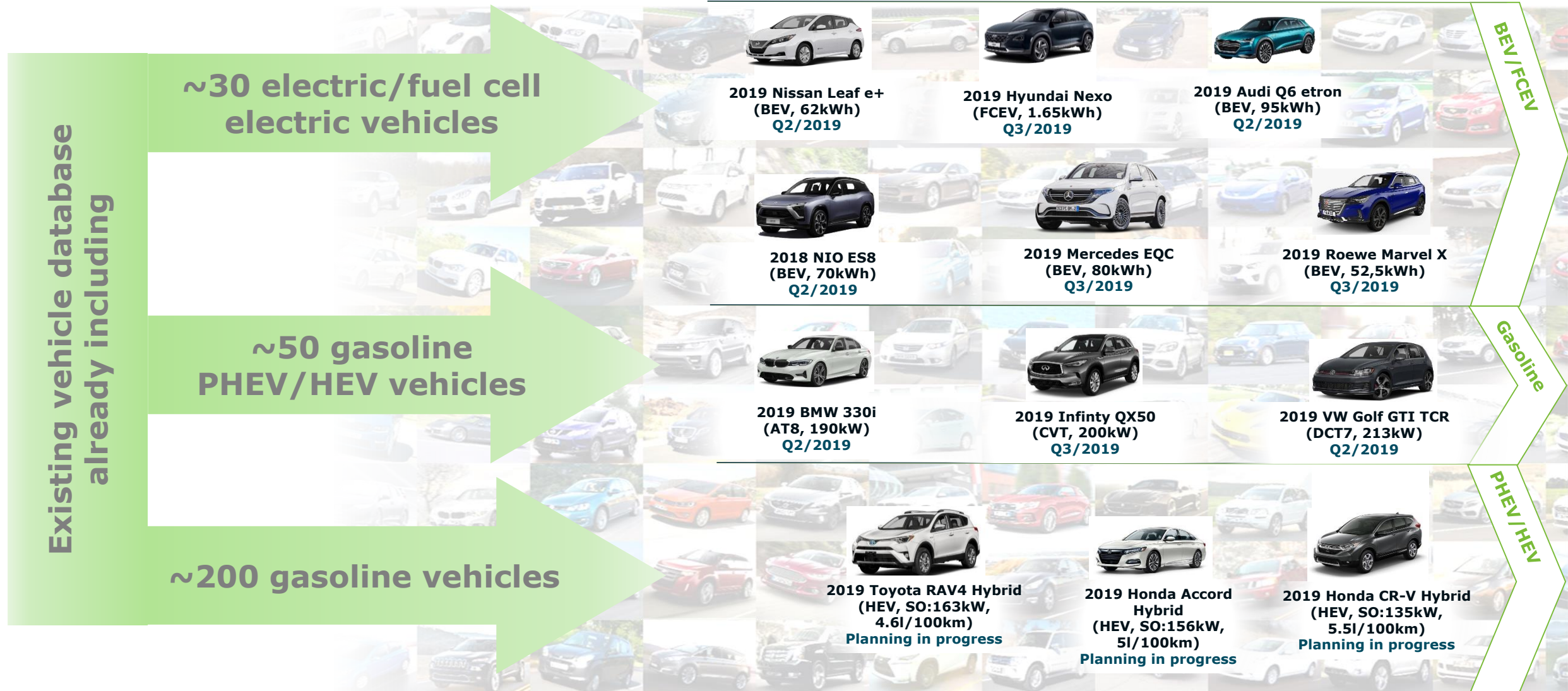
1. Instrumentation, data acquisition/testing and assessment: ~ 3-5 weeks
2. Customer report generation: ~ 3 weeks

計測準備・テスト・解析で3~5週間
顧客レポート作成で~3週間

What's new in AVL's data base? AVLのデータベース品揃えの最新ラインナップ(予定)?



*SO: system output



顧客要望の高い車両を中心に、毎年10台～がAVLベンチマーク対象車として選定される

Example case of vehicle benchmarking 車両ベンチマークの実事例

Example case of vehicle benchmarking 車両ベンチマークの実事例



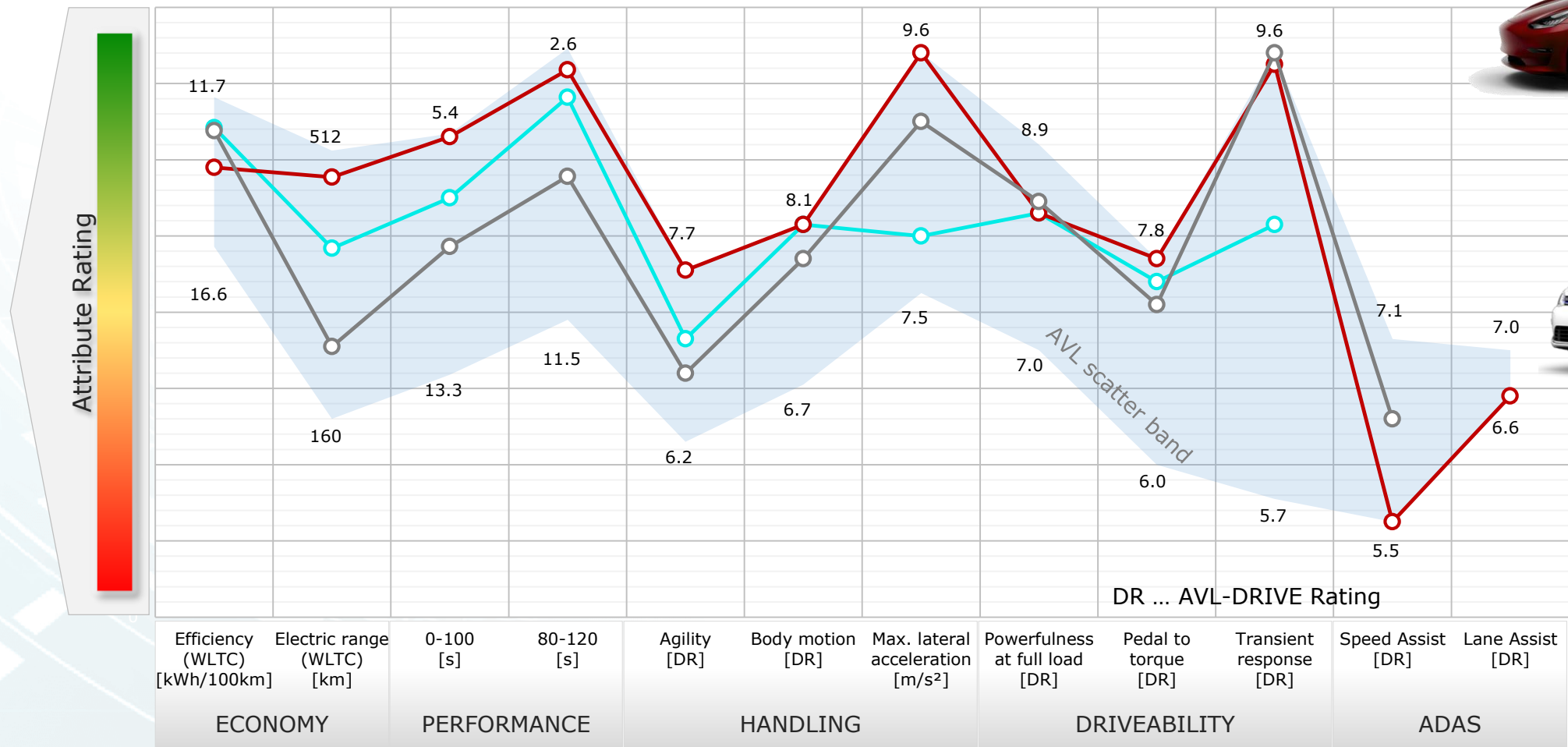
**Tesla Model 3
Long Range**



VW eGolf



Chevrolet Bolt



(in total more than 800 single criteria for driving attributes)

Example case of vehicle benchmarking 車両ベンチマークの実事例



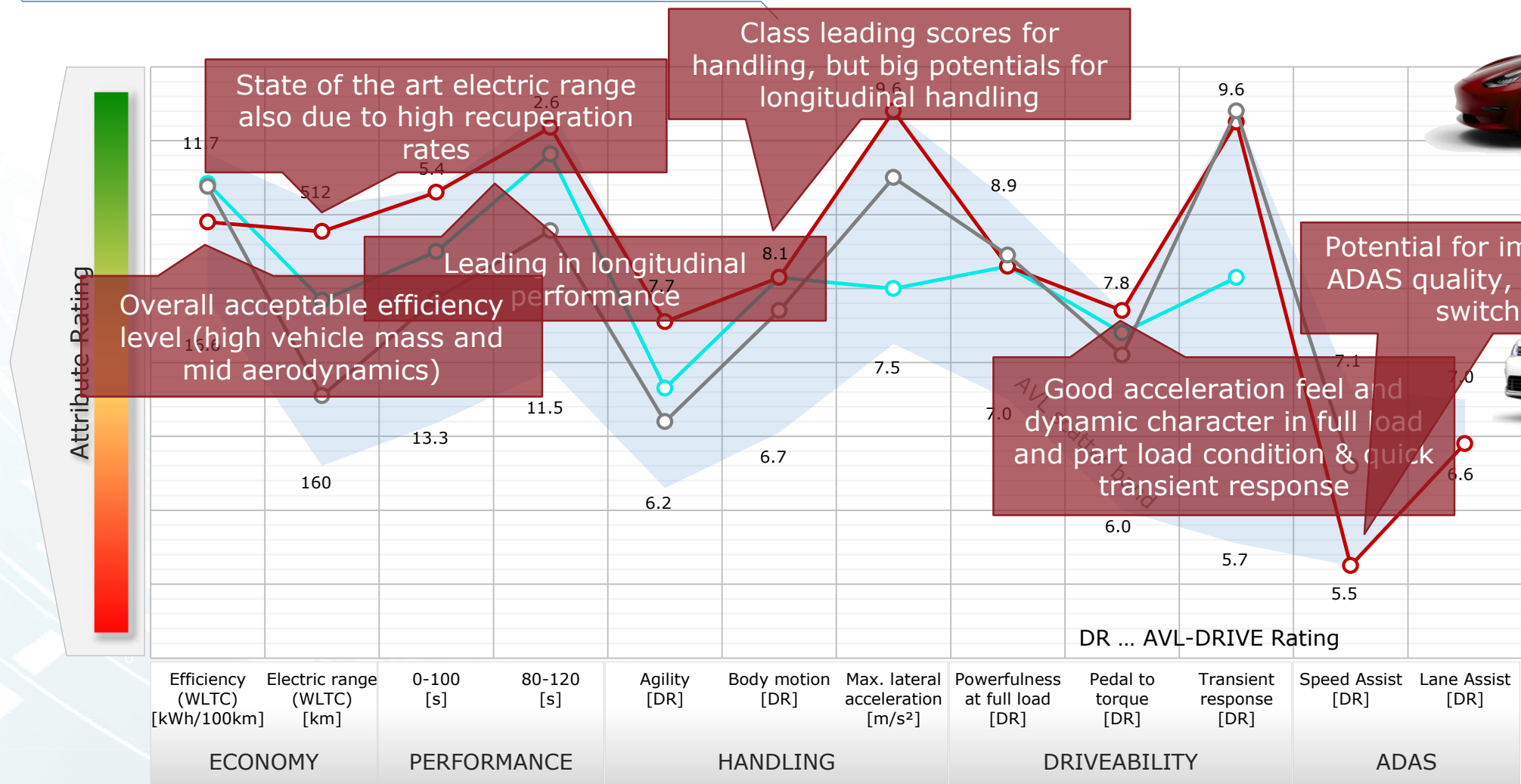
Tesla Model 3 Long Range



VW eGolf



Chevrolet Bolt



State of the art electric range also due to high recuperation rates

Class leading scores for handling, but big potentials for longitudinal handling

Overall acceptable efficiency level (high vehicle mass and mid aerodynamics)

Leading in longitudinal performance

Potential for improvements for ADAS quality, esp. due to TOF switch cut-out

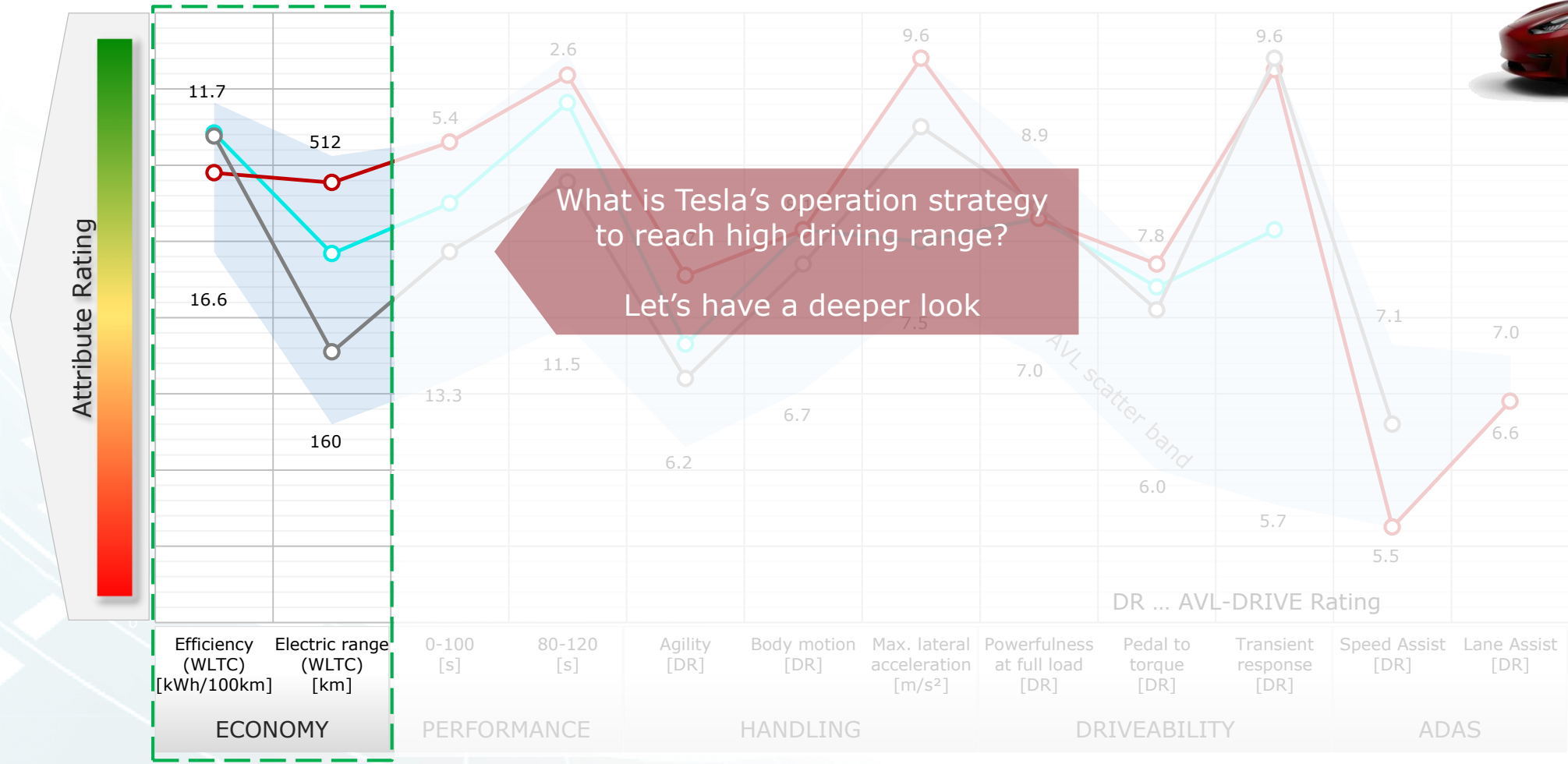
Good acceleration feel and dynamic character in full load and part load condition & quick transient response

(in total more than 800 single criteria for driving attributes)

Example case of vehicle benchmarking 車両ベンチマークの実事例

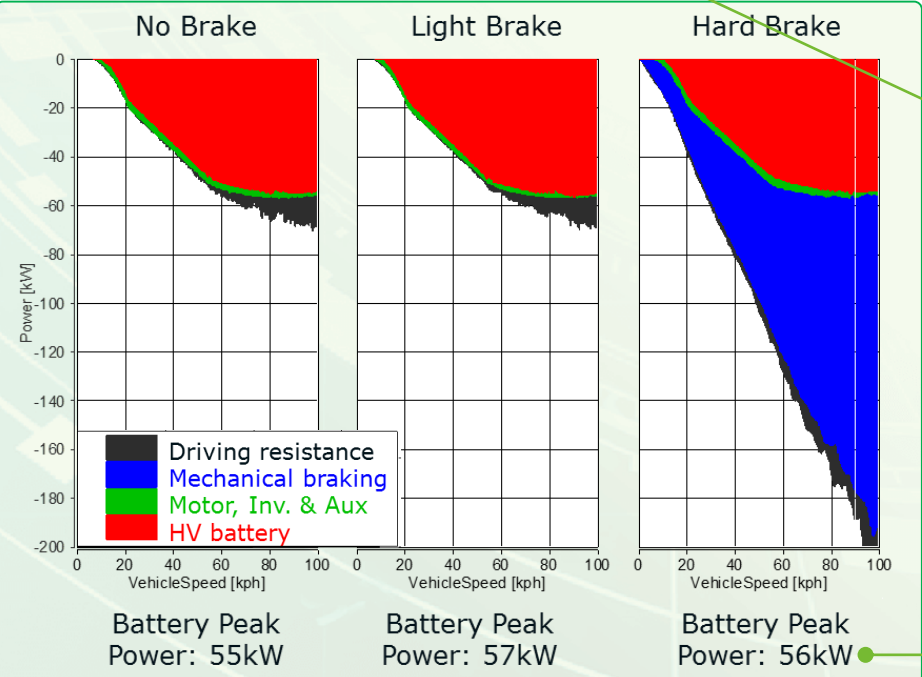
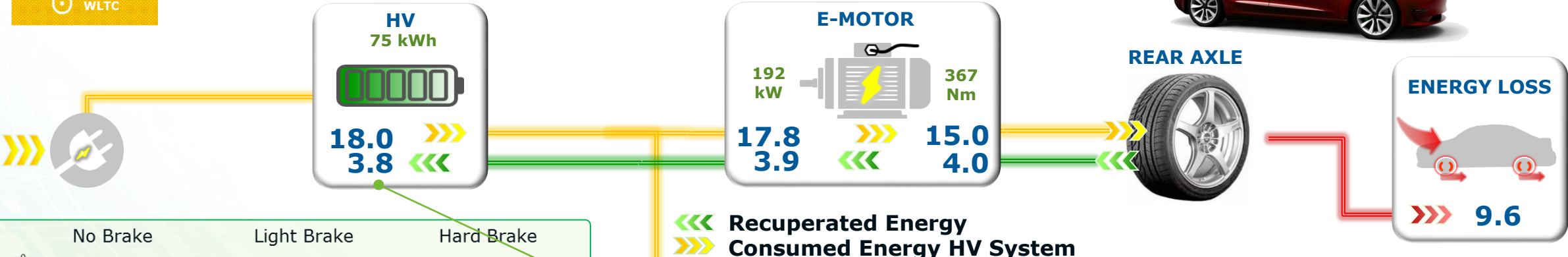


**Tesla Model 3
Long Range**



(in total more than 1000 single criteria for driving attributes)

Inside into Energy Management & Efficiency エネルギーマネジメントと高効率の内訳



<<< **Recuperated Energy**
>>> **Consumed Energy HV System**

AUX. LOAD

1.6

Recuperated energy: **3.8kWh/100km**
 Peak recuperation power in WLTC: **55kW**
 System potential for recuperation: **56kW**

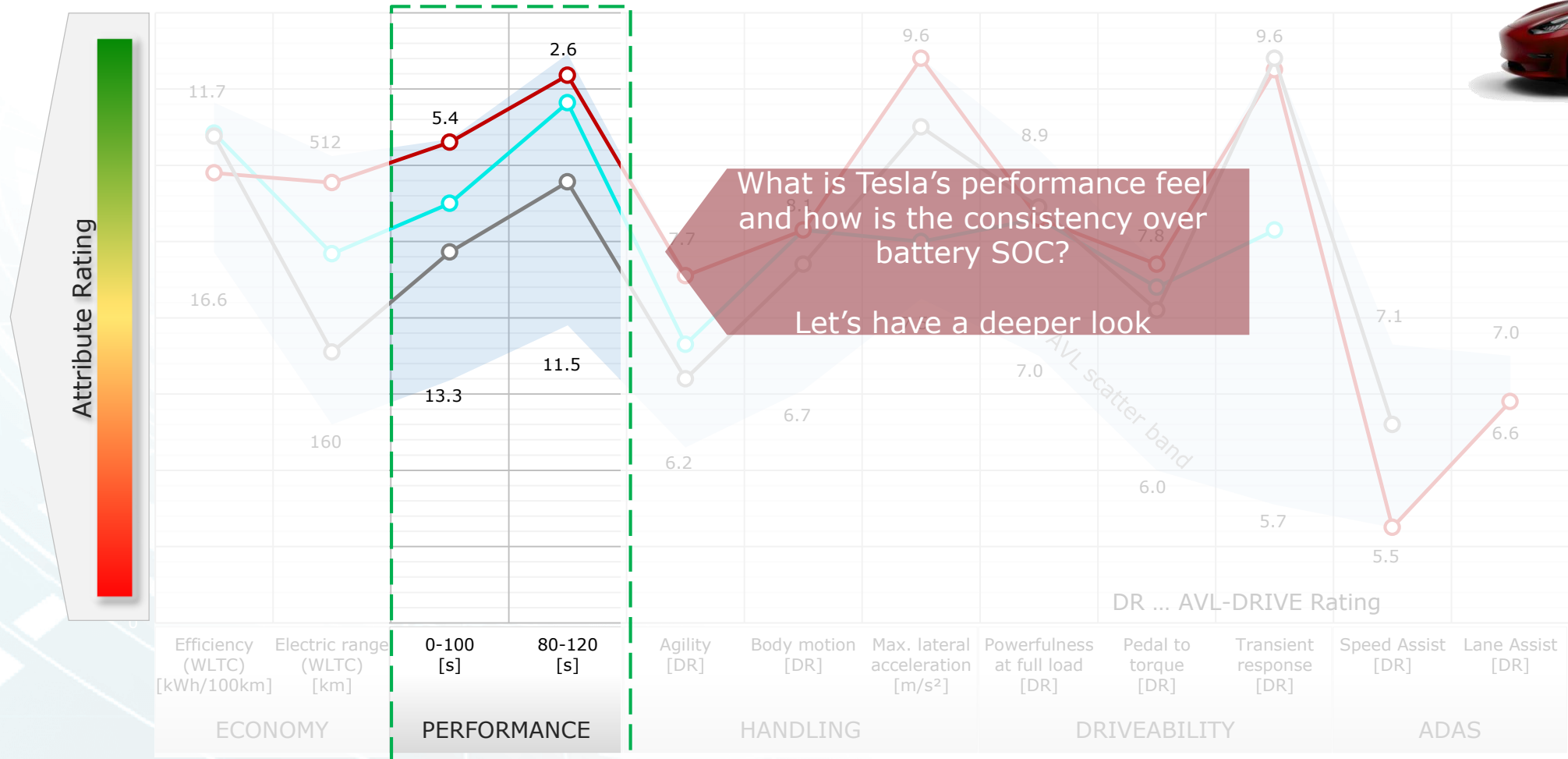
Units in kWh/100km

Full utilization of system capabilities for increased driving range

Example case of vehicle benchmarking 車両ベンチマークの実事例



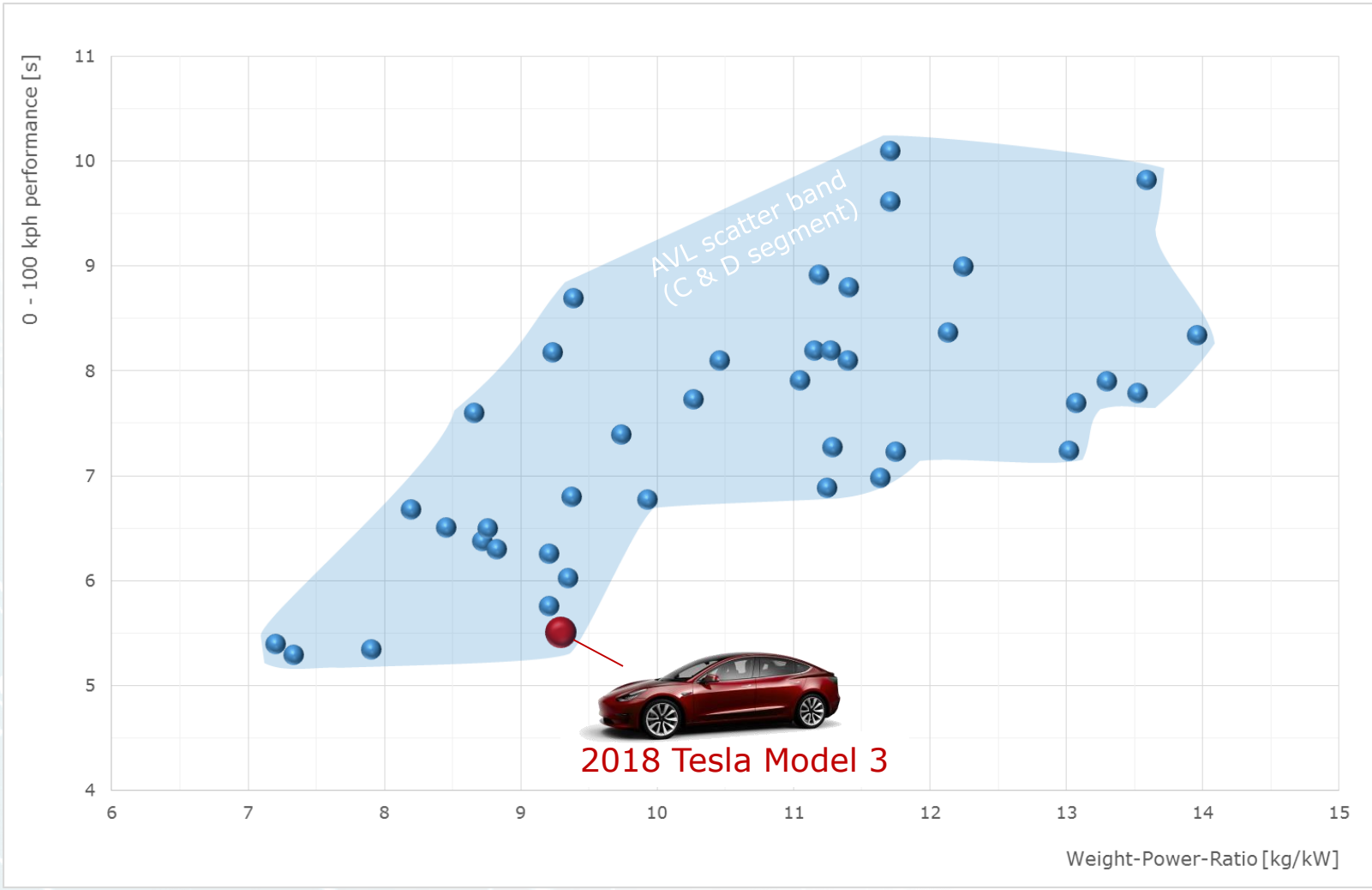
**Tesla Model 3
Long Range**



(in total more than 800 single criteria for driving attributes)

Performance – 0-100kph 0-100km/h加速性能

Competitive landscape 市場競争力の見通し



- The Model 3 shows excellent 0-100 kph acceleration considering the weight to power ratio
- It keeps up with models that have about a 20% better weight to power ratio and reaches the same acceleration time

Performance from standstill

静止状態からの車両性能(パフォーマンス)



Full load acceleration from Standstill

Weight: 1870 kg

Track: dry, 10 deg C

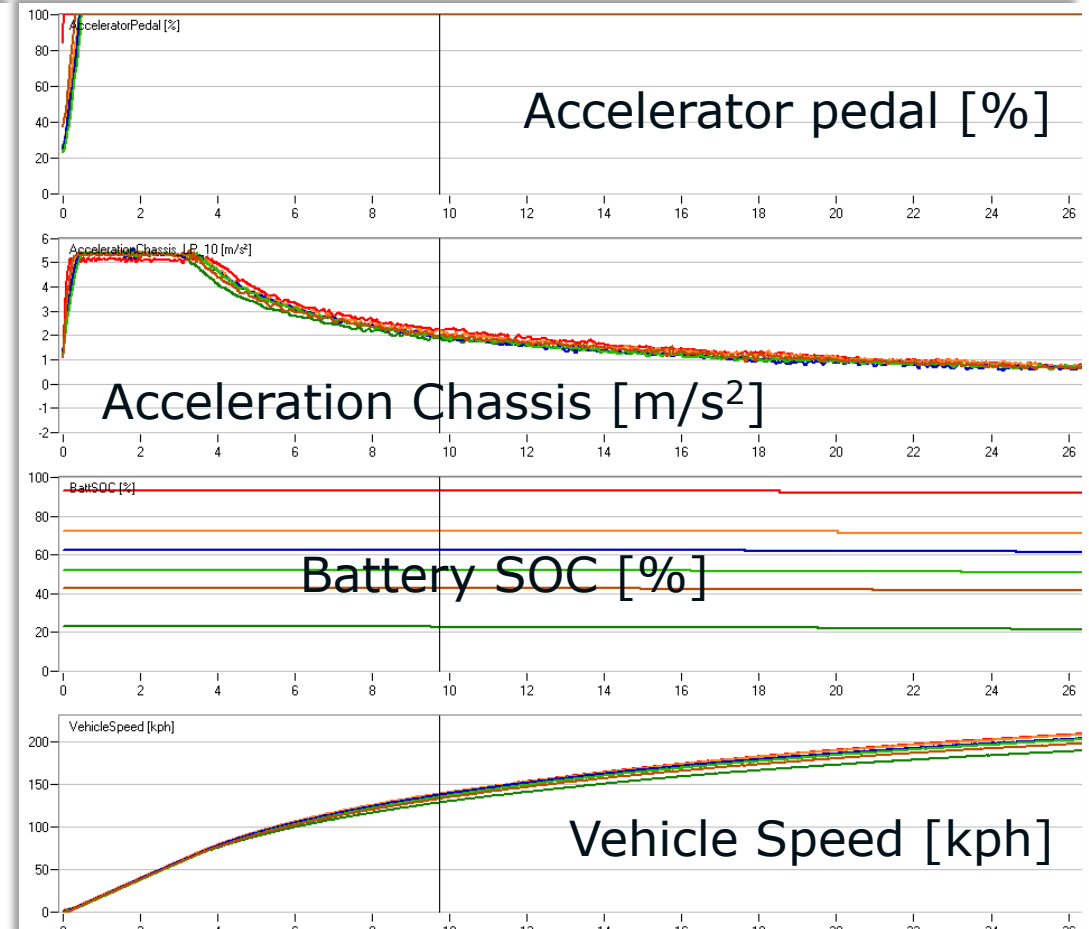
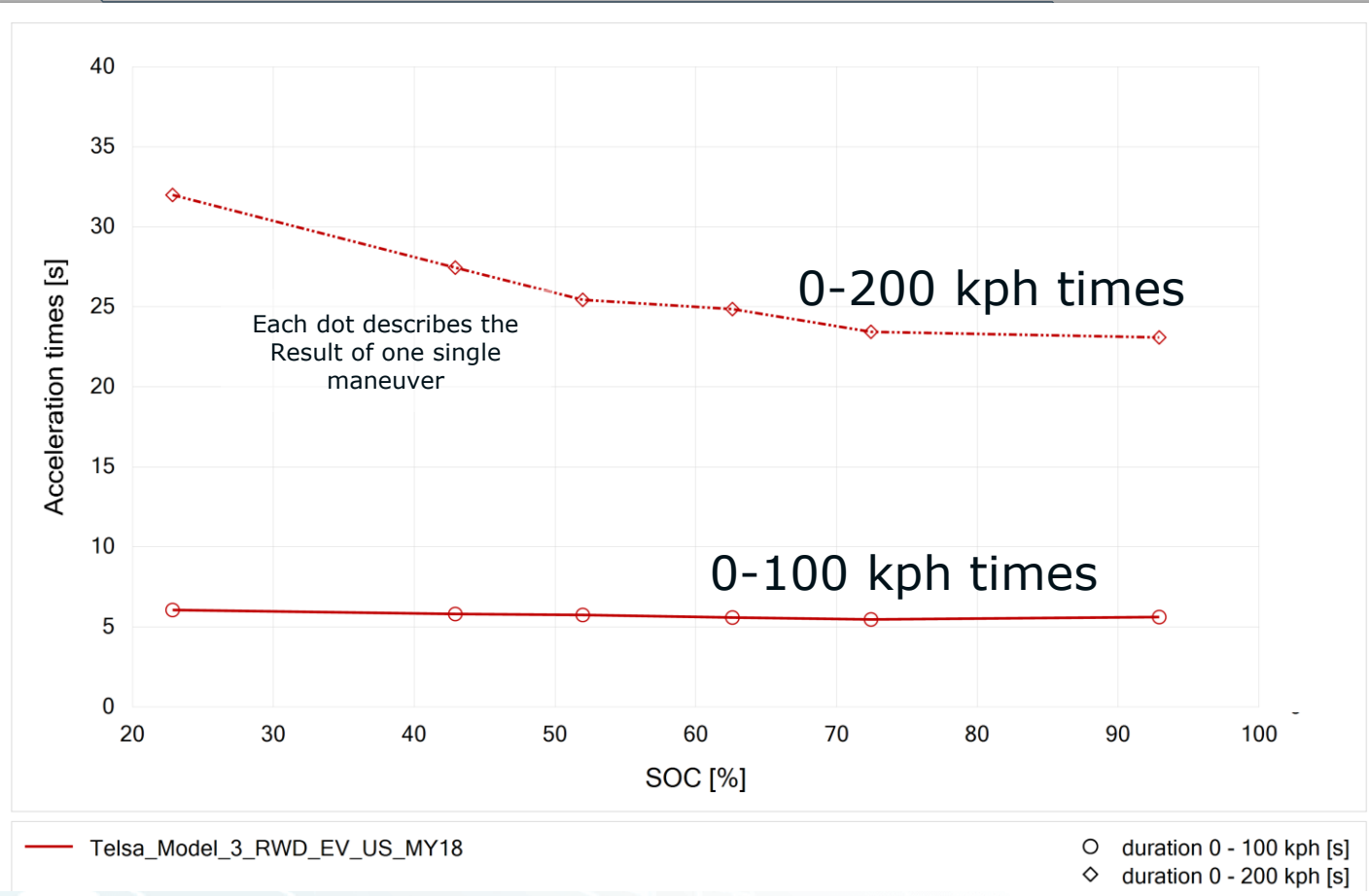
Mode:
Default (only one is available)

	Tesla Model 3 High SOC	Tesla Model 3 Low SOC	OEM data
0 to 40 kph	2.0 s	2.1 s	
0 to 80 kph	4.1 s	4.3 s	
0 to 100 kph	5.5 s	6.1 s	5.3 s
0 to 140 kph	9.9 s	11.9 s	
0 to 180 kph	17.5 s	22.6 s	
0 to 200 kph	23.4 s	32.0 s	
0 to 220 kph	32.2 s	48.9 s	
Initial acceleration [m/s ²]	5.4 m/s ²		
Standing quarter miles/ 400 m time	14.0 @ 163 kph		

• Tesla Model 3 misses the OEM data by 0.2 seconds. With low SOC the car performs significantly worse than with high SOC especially at speeds above 100 kph.



Performance Acceleration from standstill Dependency on SOC SOC依存の加速性能

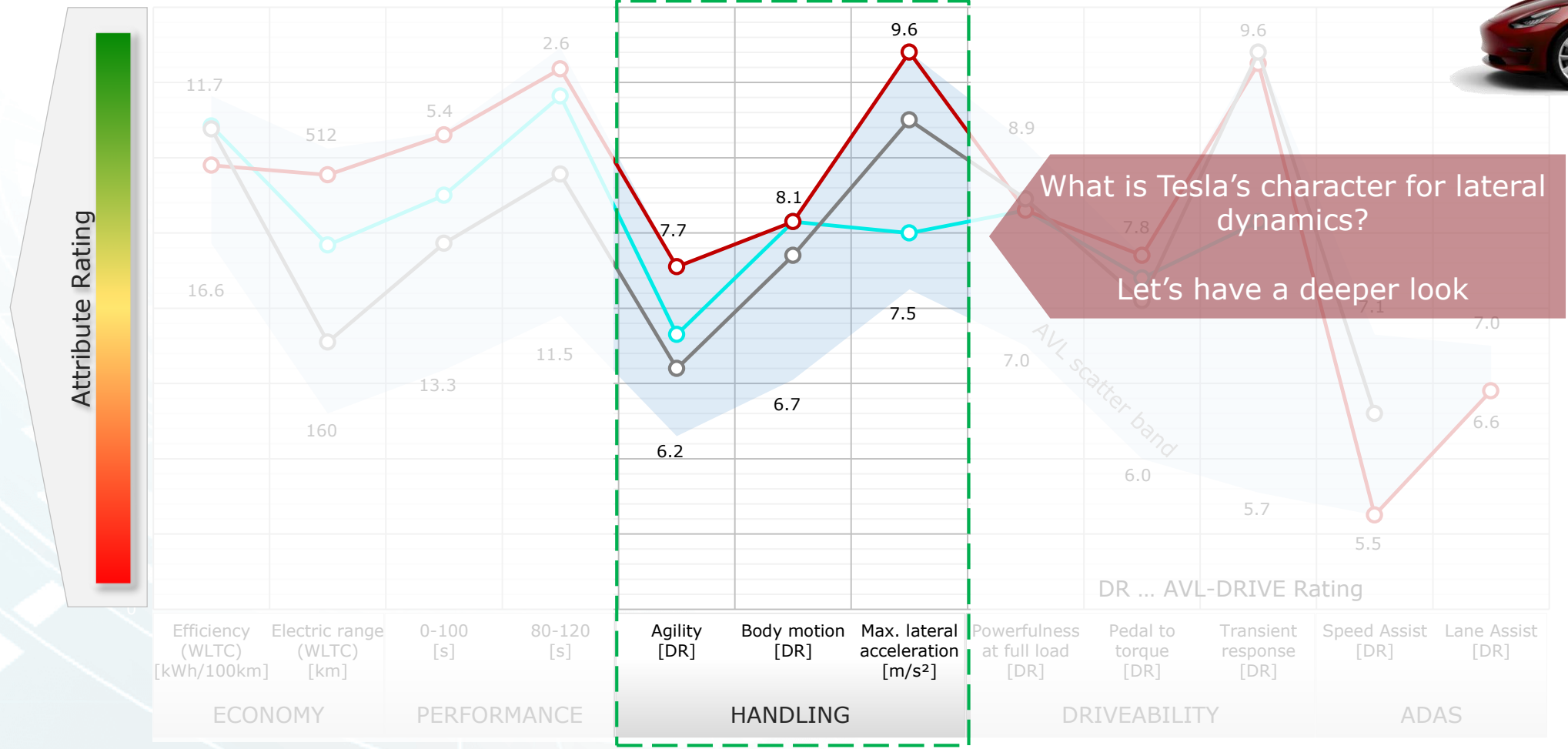


- The acceleration times to 100 kph stay consistent over the SOC range.
- Over 100 kph the difference between the SOC levels result in much different acceleration times.
- The lower the SOC the longer the 0-200 kph time. The car loses approximately 8 seconds between the fastest (Full SOC) and slowest times (20% SOC)

Example case of vehicle benchmarking 車両ベンチマークの実事例



Tesla Model 3 Long Range

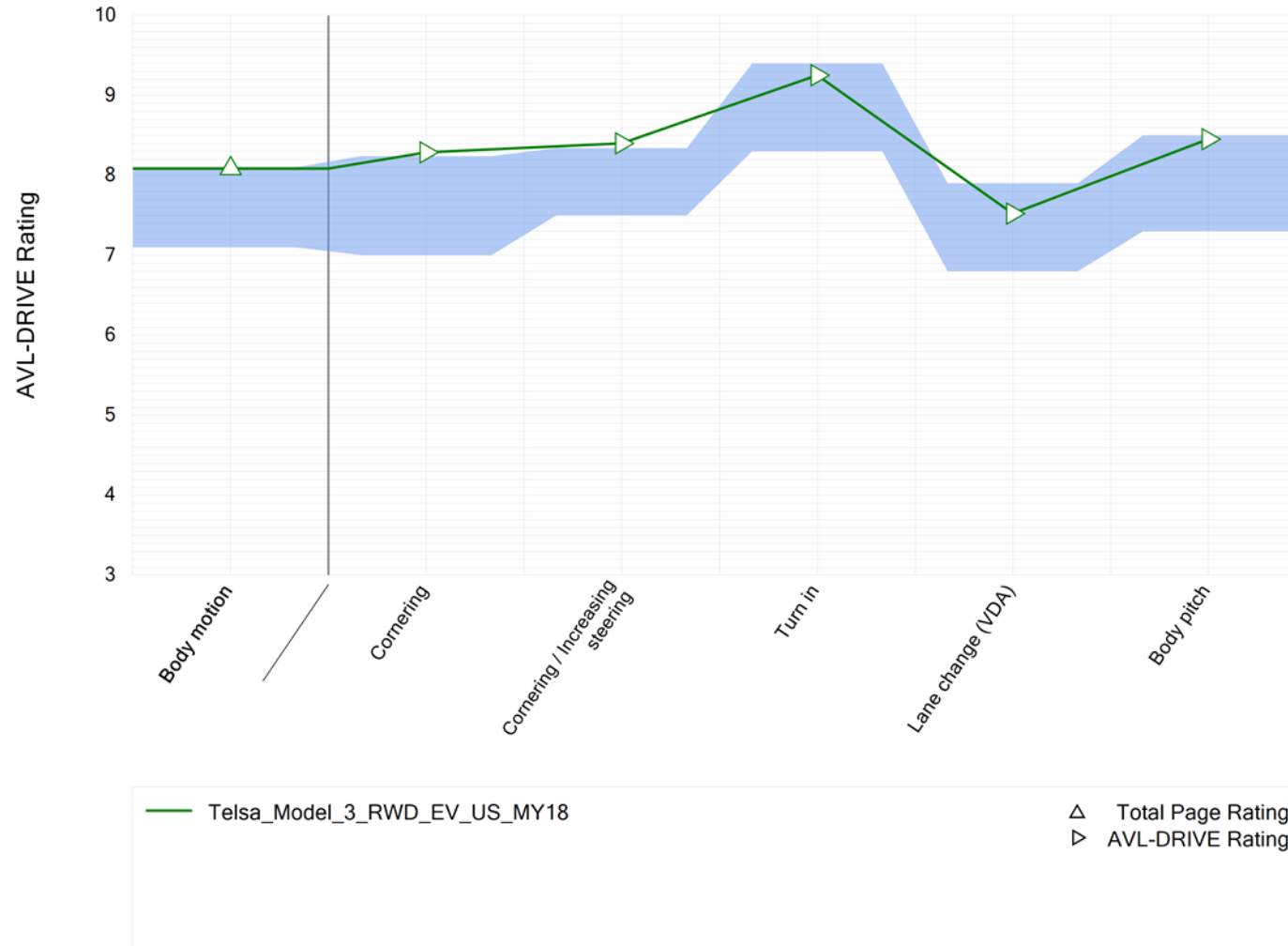


What is Tesla's character for lateral dynamics?
Let's have a deeper look

(in total more than 800 single criteria for driving attributes)

HANDLING EVALUATION ハンドリング評価

Body motion 車体の動きに関する評価



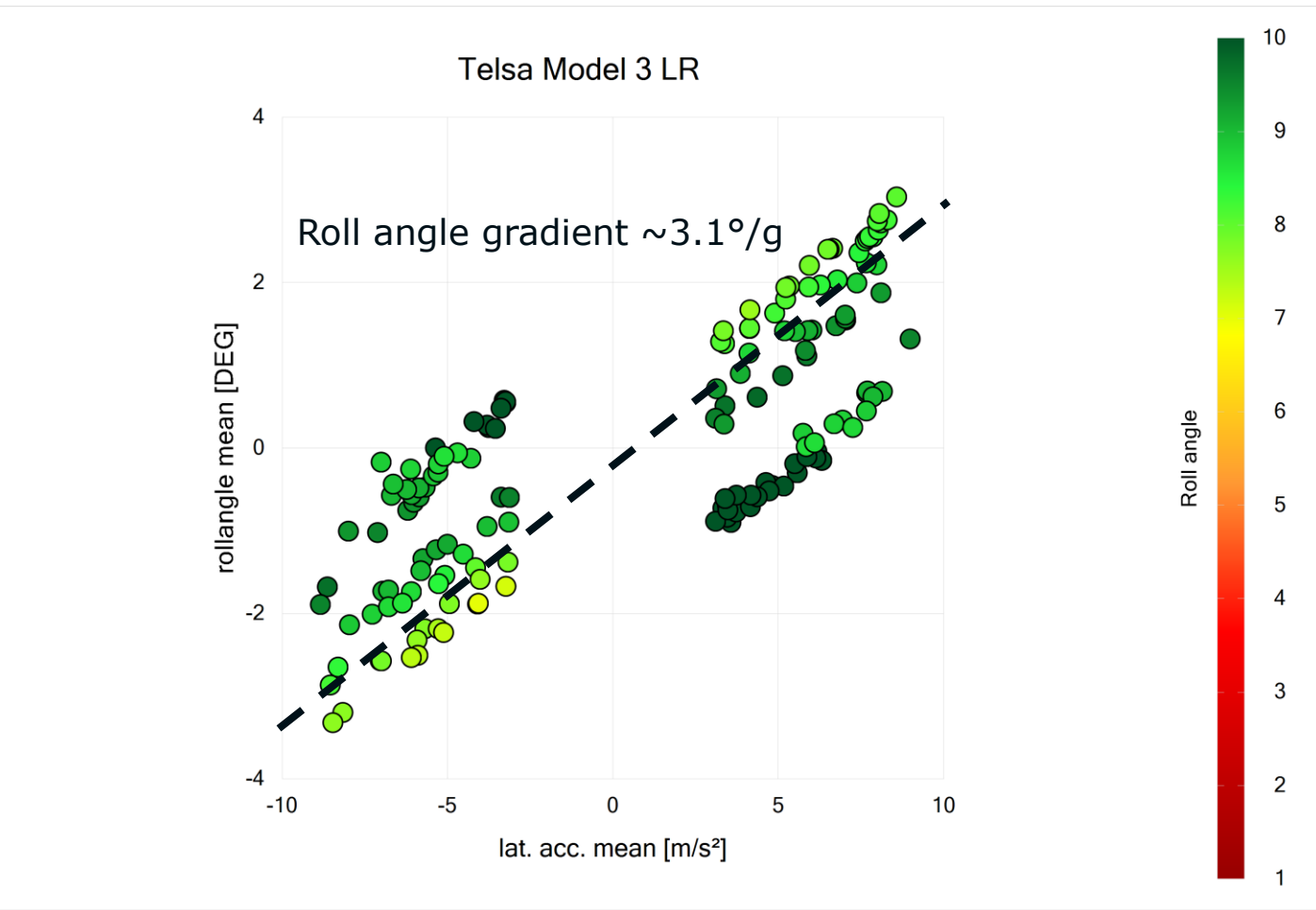
Operation Modes	Telsa Model 3 LR
	DR
Body motion	8.1
Cornering	8.3
- Roll angle	8.3
Cornering / Increasing steering	8.4
- Roll angle	8.4
- Roll characteristic	8.5
Turn in	9.3
- Roll dump	9.3
Lane change (VDA)	7.5
- Roll overshoot in 2nd lane	7.2
- Roll angle amplitude in 2nd lane	9.0
Body pitch	8.5
- Brake dive	8.5
- Accelerating squat	8.4

The main operation mode Body Motion rates the body motion of the vehicle in terms of pitch and roll.

This occurs due to lateral and longitudinal acceleration forces generated by accelerating, braking, or cornering.

HANDLING EVALUATION ハンドリング評価

Body motion – Cornering 車体の動き—特にコーナリングに関して



AVL-DRIVE Report Generator V4.1.0

Roll Angle and Roll Characteristic in cornering situations

The 3D plot shows the relation between roll angle and lateral acceleration.

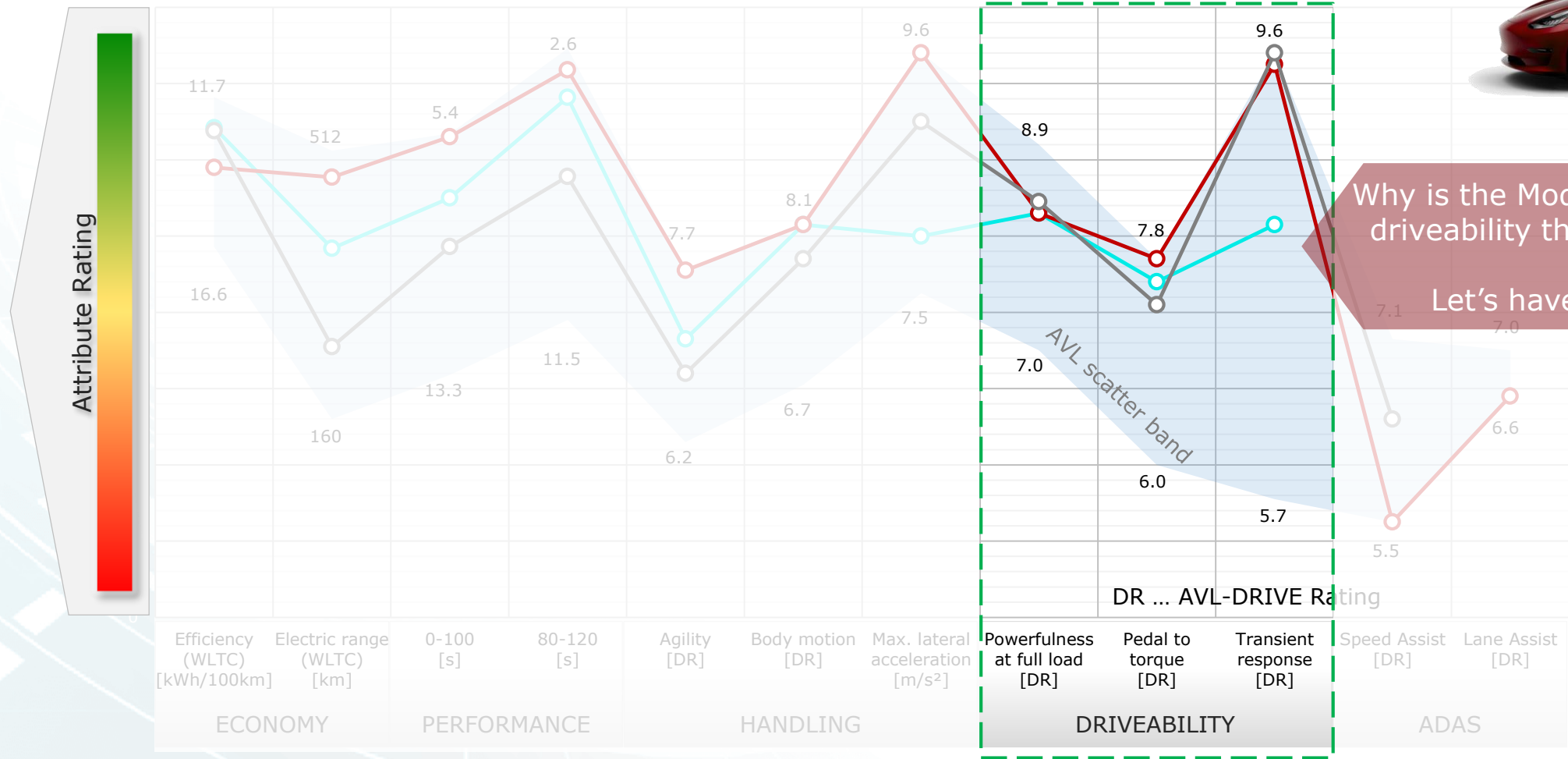
This relation is normally linear, which enables the calculation of a gradient.

Roll angle gradient: $\sim 3.1^\circ/g$

Example case of vehicle benchmarking 車両ベンチマークの実事例



**Tesla Model 3
Long Range**



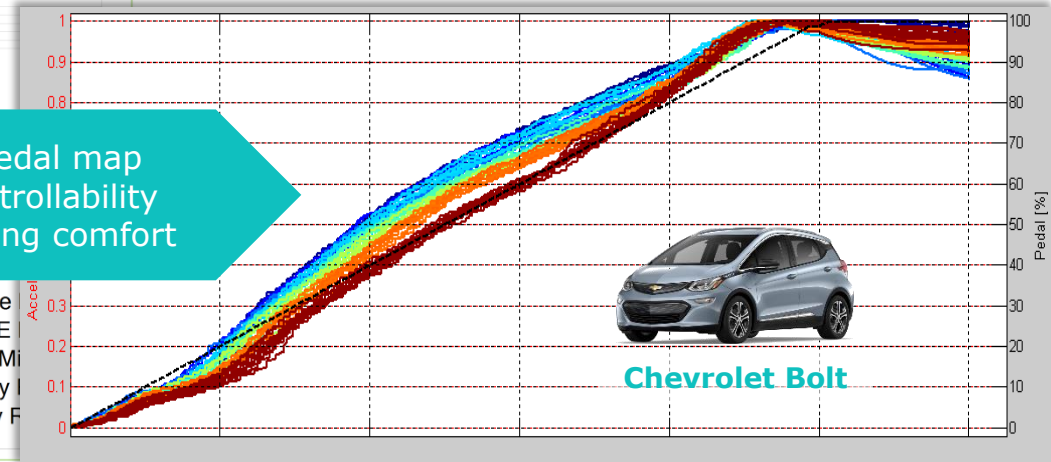
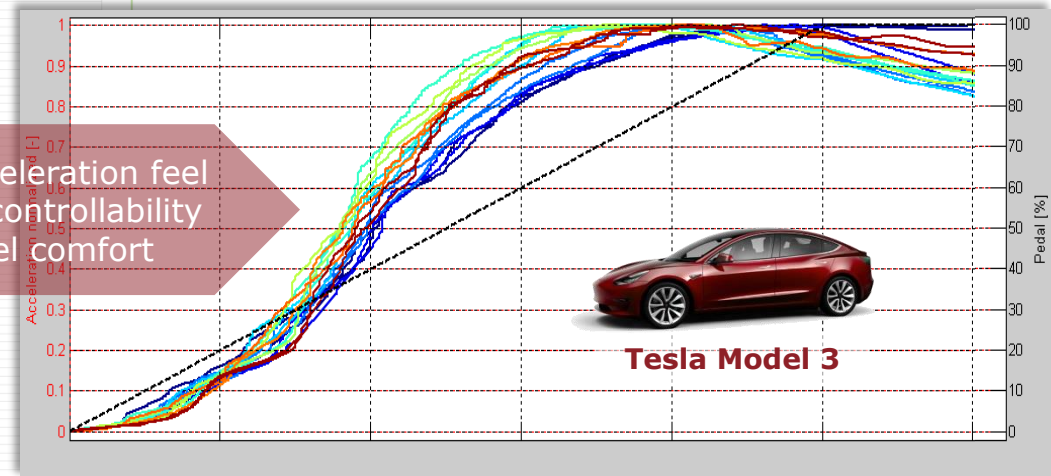
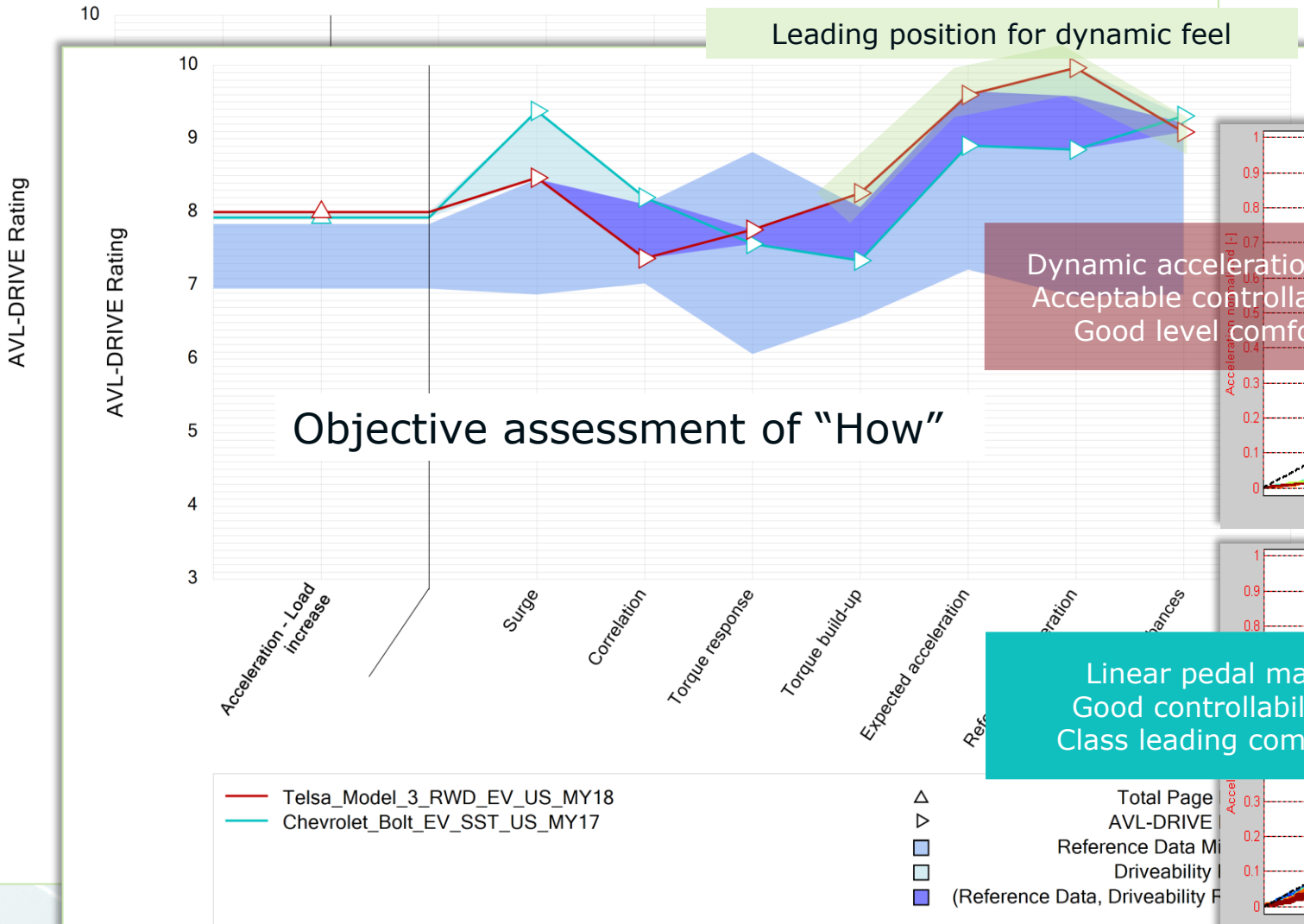
Why is the Model 3 better rated for driveability than the competitor?
Let's have a deeper look

(in total more than 800 single criteria for driving attributes)

Linking drivers perception to physical data 運転者の認知と、物理的データの相関



Deep understanding of "Why",
based on measurement data
describing **driving characteristics**



Dynamic acceleration feel
Acceptable controllability
Good level comfort

Linear pedal map
Good controllability
Class leading comfort

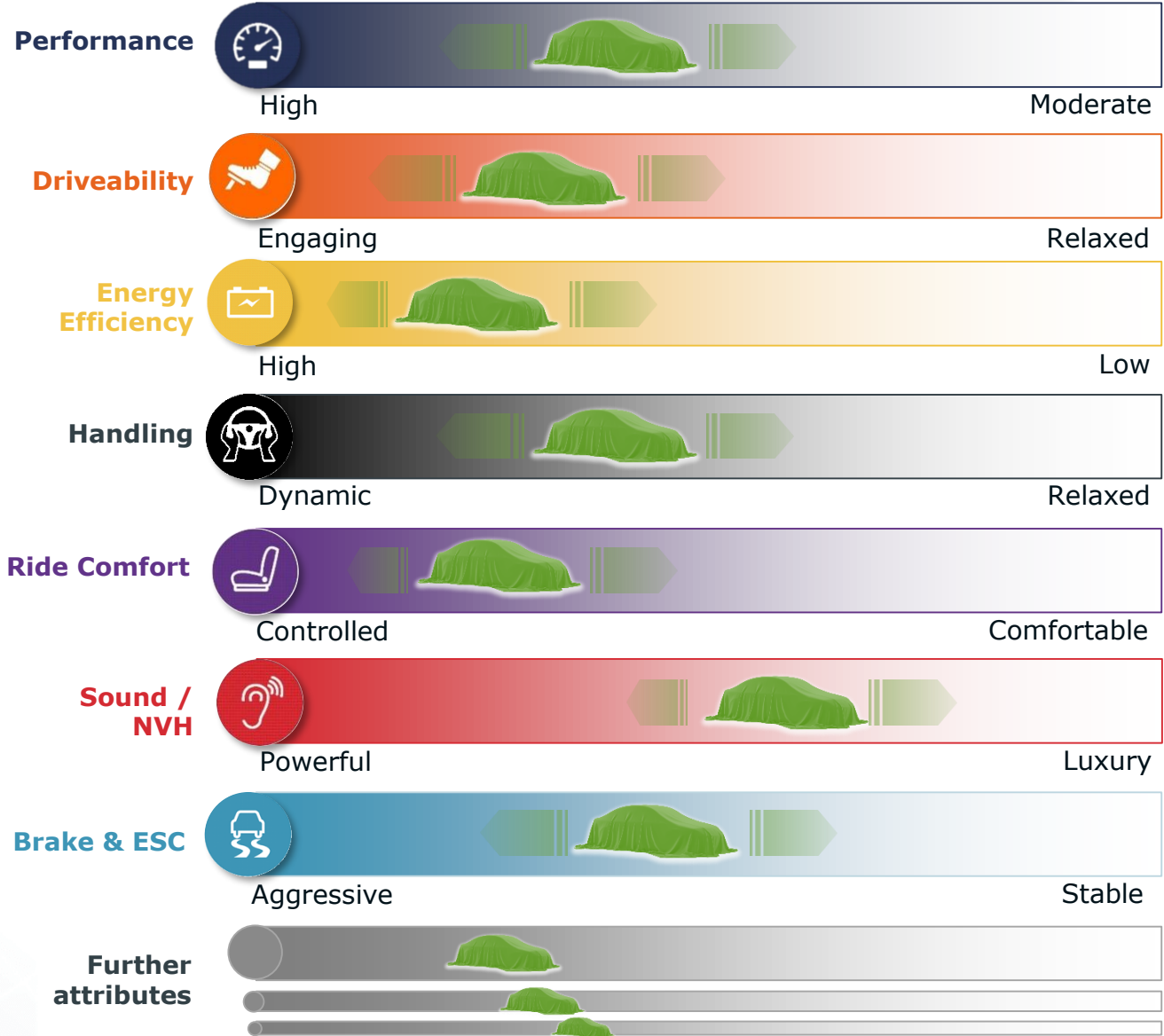
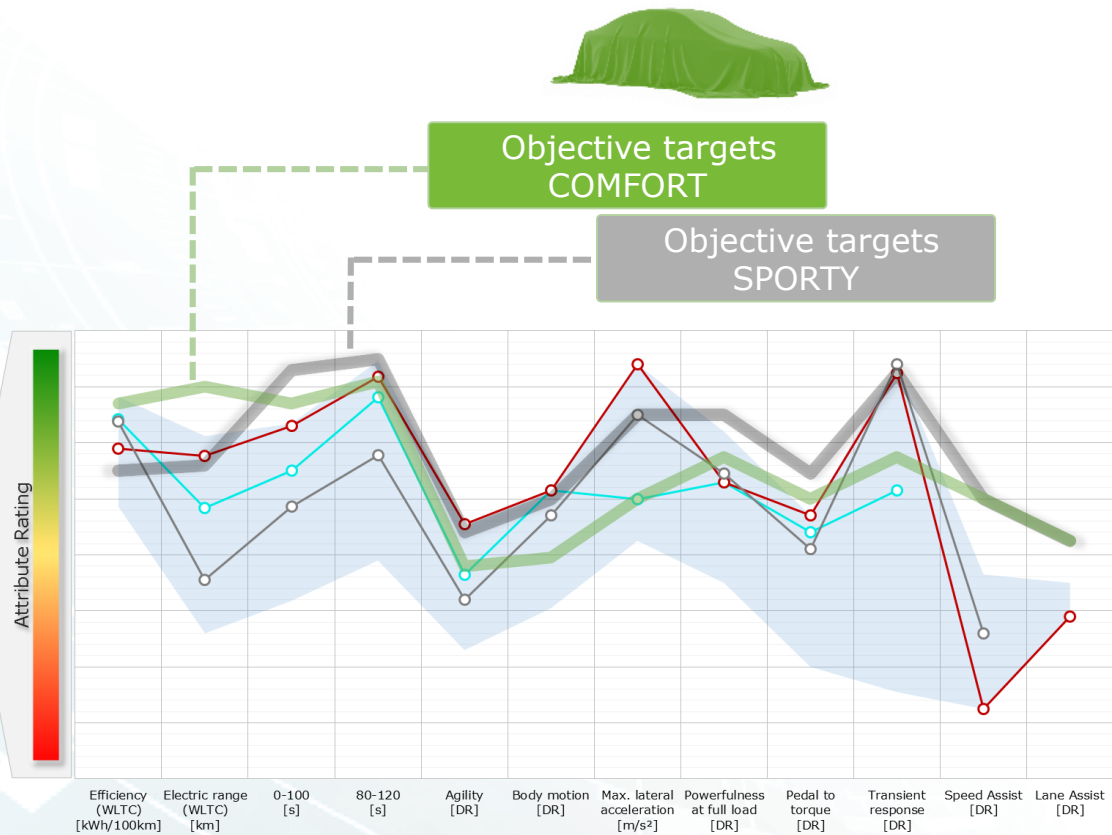
— Tesla_Model_3_RWD_EV_US_MY18
 — Chevrolet_Bolt_EV_SST_US_MY17
 ▲ Reference Data (Driveability F)
 ▼ Reference Data (Driveability F)
 ■ Reference Data (Driveability F)
 □ Reference Data (Driveability F)

Target setting and Requirement engineering

目標設定と要求工学

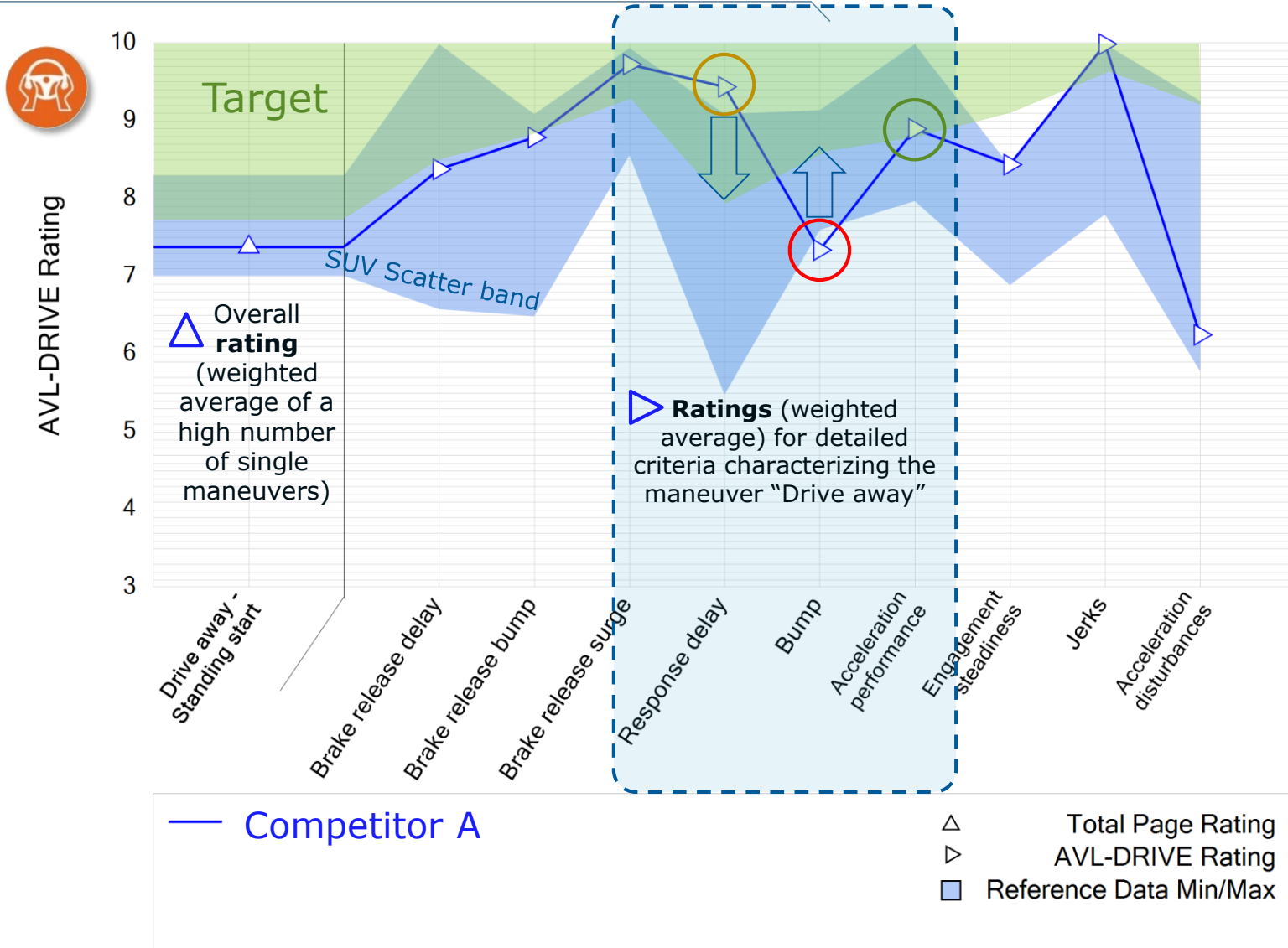
Customer Market Profile and Target List

顧客の市場プロフィールと目標(値)一覧



Driveability - Drive away 全開加速時のドライバビリティ

Detailed assessment criteria for „Drive away - Standing start“



Overall competitor character

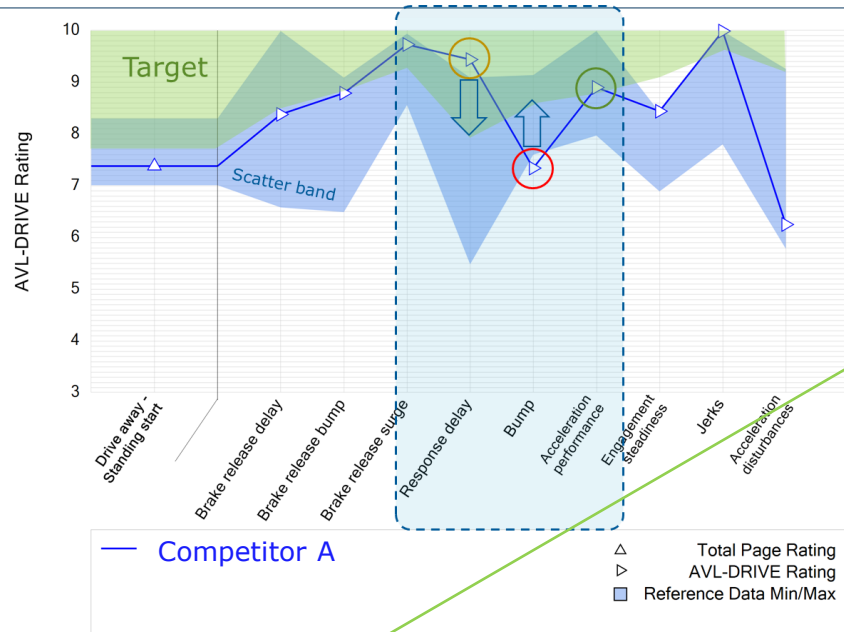
- best in class ratings for response delay
- excellent ratings for jerks for all events
- lowest rating for bump at standing start (7.3) indicates a more dynamic oriented vehicle calibration

Target

high demand for driving comfort
 → Still good response rating, but high scores for comfort relevant criteria, esp. "Bump" (max. gradient of longitudinal acceleration)

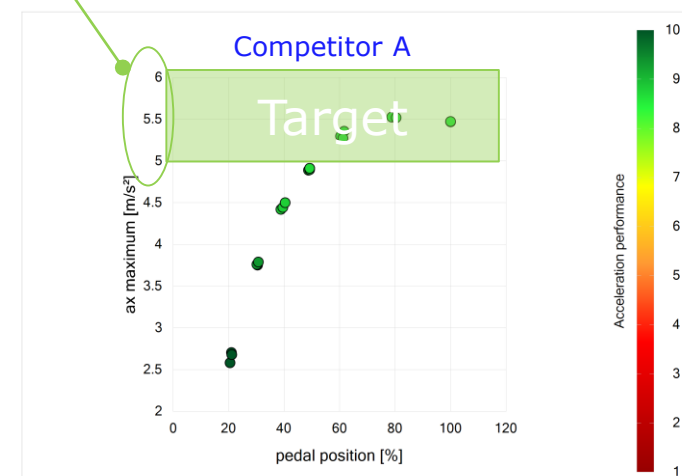
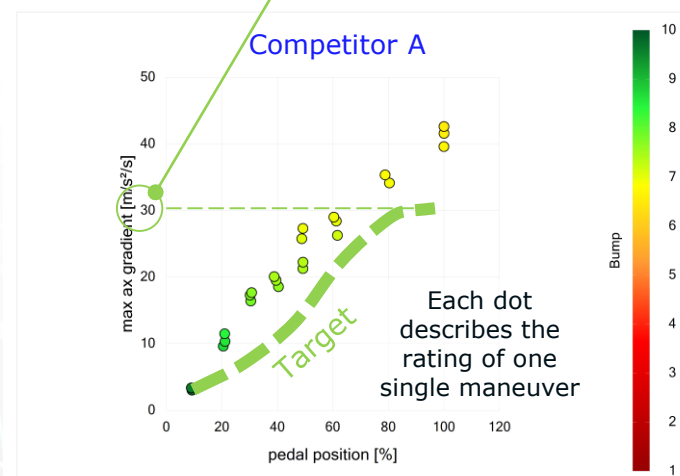
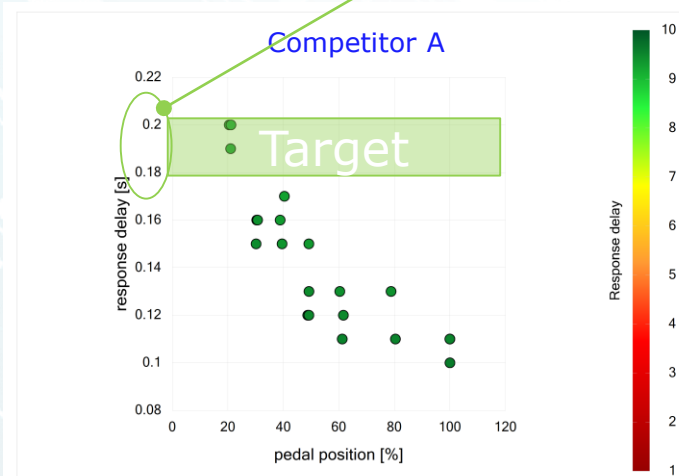
Drive away 全開加速

Target setting and requirement engineering 目標設定と要求工学



From vehicle targets to system requirements
 Component specification and selection according to

- Transient response characteristic
- Max torque build-up gradient
- Max torque level



Charging experience 充電性能

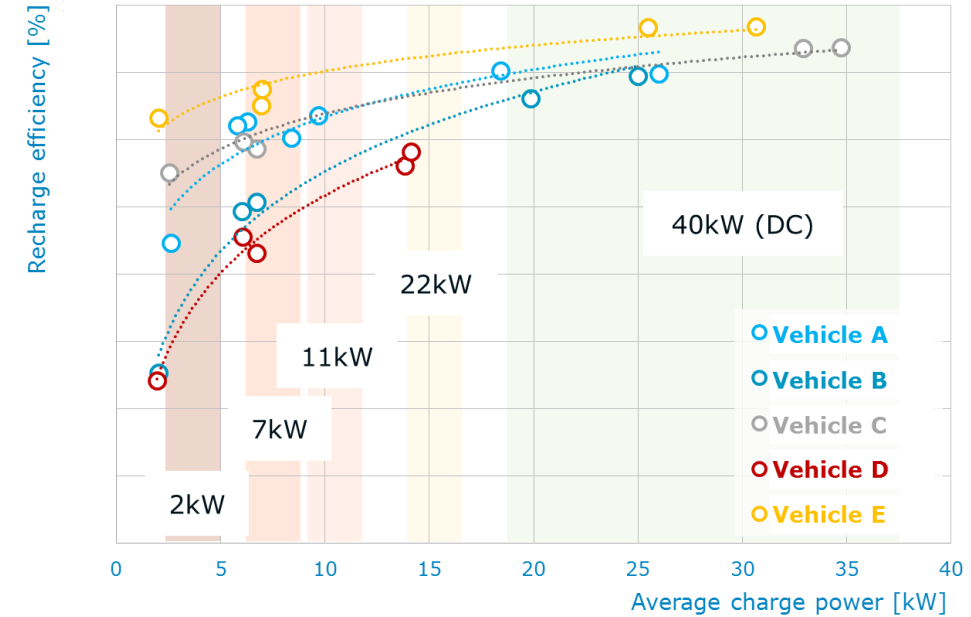
An additional aspect in vehicle benchmarking of electrified vehicles
電気自動車(Battery EV)に関する車両ベンチマークの新しい指標

Charging experience Benchmarking

充電性能ベンチマーク



Charging time	Power supply	Voltage	Max current
6–8 hours	Single phase - 3.3 kW	230 VAC	16 A
2–3 hours	Three phase - 10 kW	400 VAC	16 A
3–4 hours	Single phase - 7 kW	230 VAC	32 A
1–2 hours	Three phase - 24 kW	400 VAC	32 A
20–30 minutes	Three phase - 43 kW	400 VAC	63 A
20–30 minutes	Direct current - 50 kW	400 - 500 VDC	100 - 125 A



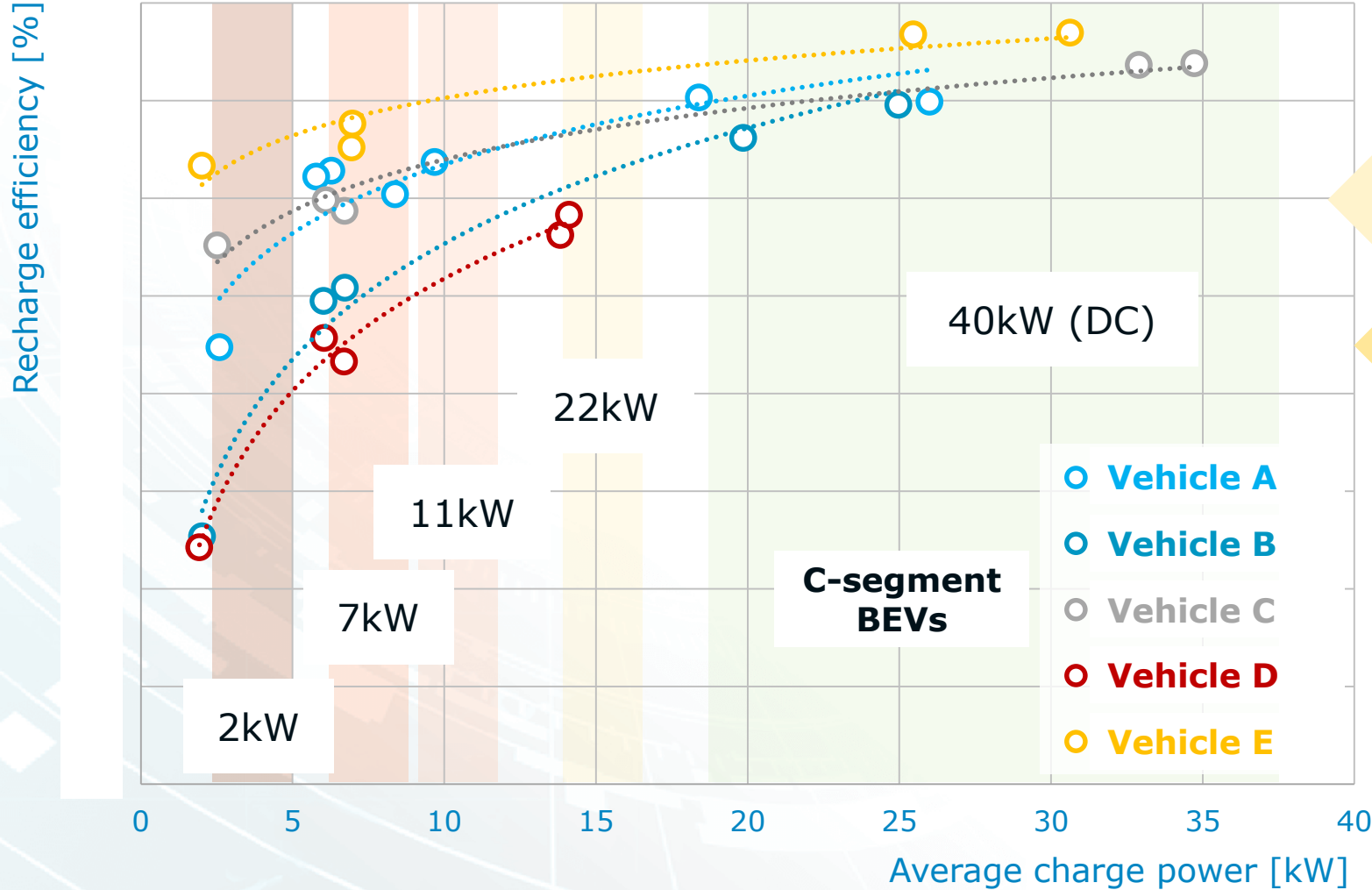
Project with fast charging and Chassis Dyno Tests

Influence of battery temperature to charging performance

Charging performance and efficiency in different power classes

Comparison of ELECTRIC VEHICLES with focus on customer usability

Charging efficiency 充電効率



Models have different charging concepts

Charging efficiency is almost independent from battery temp

Charging efficiency strongly depends on charging power

Charging power is heavily impacting charging duration

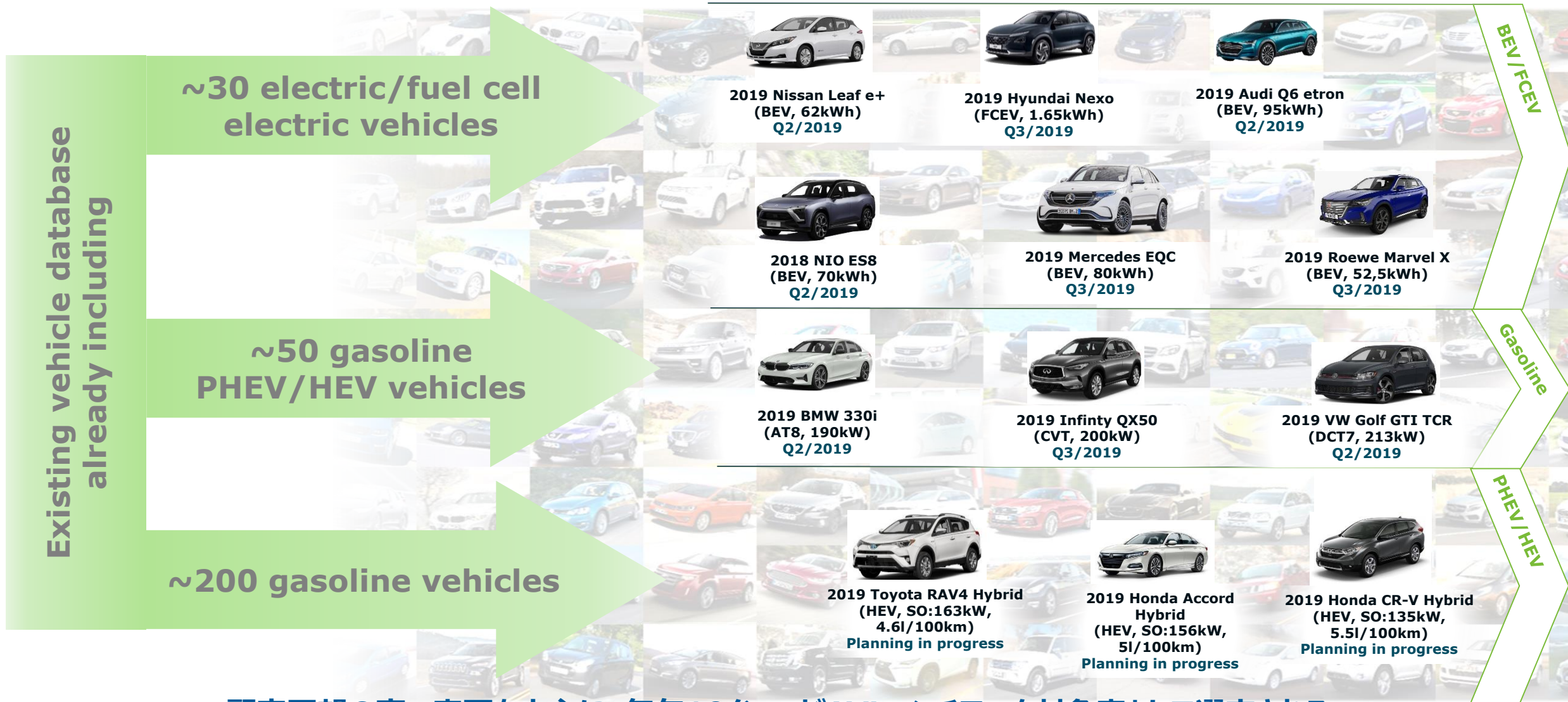
What's new in AVL's data base?

AVLのデータベース品揃えの最新ラインナップ(予定)?

What's new in AVL's data base? AVLのデータベース品揃えの最新ラインナップ(予定)?



*SO: system output



顧客要望の高い車両を中心に、毎年10台～がAVLベンチマーク対象車として選定される

What's new in AVL's data base? AVLのデータベース品揃えの最新ラインナップ(予定)?



*SO: system output

Existing vehicle database
already including

弊社AVLのベンチマークプログラムにご興味があるお客様は是非、
弊社営業担当にお問い合わせください

- どんな車両がAVLデータベースにラインナップされている (今後の予定)?
- ○○という着眼点のデータのみ(一部切り分け)が欲しいが、可能か?
- 予算管理の関係上 すぐに成果が欲しい・・・可能か?
- 新しい車両を企画している、ベンチマークをどう生かすべきか?
→別資料 Vehicle Concept Engineering も是非ご覧ください

BEV / FCEV

Gasoline

PHEV / HEV

顧客要望の高い車両を中心に、毎年10台～ がAVLベンチマーク対象車として選定される

Thank You



www.avl.com

