Benchmarking the Highly-Efficient Toyota Yaris 1.5 Hybrid

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Today’s Presenters

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35 years of experience in Automotive Industry

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20 years of experience in Automotive Industry

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12 years of experience in Automotive Industry

Agenda

1 **About AVL**

2 **Objectives of Benchmark Investigations**

3 **Vehicle Attribute Benchmark**

4 **Engine Benchmark**

5 **Summary and Conclusions**

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Facts and Figures

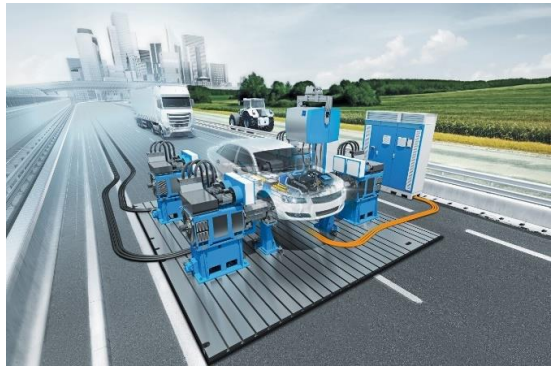
Global Footprint

Represented in 26 countries

45 Affiliates divided over 93 locations

45 Global Tech and Engineering Centers (including Resident Offices)

POWERTRAIN ENGINEERING SERVICES



INSTRUMENTATION AND TEST SYSTEMS

ADVANCED SIMULATION TECHNOLOGIES

1948

Founded

11,700

Employees Worldwide

12%

Of Turnover Invested in Inhouse R&D

70+

Years of Experience

68%

Engineers and Scientists

2,500

Granted Patents in Force

AVL Fields of Activities
Solutions for all Customer Segment


Passenger Cars


2 Wheelers


Racing


Construction


Agriculture


Commercial Vehicles


Locomotive


Marine


Power Plants

ENGINEERING

TESTING

SIMULATION

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Objectives of Benchmark Investigations

Benchmarking the Highly-Efficient Toyota Yaris Hybrid

The latest generation Yaris is the first model built on the **Toyota New Global Architecture (TNGA)** platform, which will provide the basis for all Toyota compact cars in the future. The new 1.5-litre three-cylinder engines feature highest thermal efficiency providing substantial fuel economy improvement.

For AVL´s benchmark investigations both sister models featuring **pure ICE** with MT6 transmission respectively a **Hybrid** powertrain have been tested and compared to each other.

Takeaways:

- Discover how the M15A-FXE engine obtains market-leading thermal efficiency within the hybrid powertrain in the new TNGA platform.
- Gain insight into Toyota's operating strategies for optimized fuel consumption.
- Learn about the complexity of integrated technologies for positive driver perception.
- Find out where the Toyota Yaris sits in its competitive landscape.
- Gain insight into AVL's benchmarking methodologies, services and solutions.

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3 **Vehicle Attribute Benchmark**

4 Engine Benchmark

5 Summary and Conclusions

Vehicle Attribute Benchmark

2021 Toyota Yaris Hybrid
DHE, 85 kW

vs.

2021 Toyota Yaris (ICE)
Conv. PT, 92 kW

Benchmarking in 13+ Functional Vehicle Attributes

Driving experience

- Performance
- Driveability
- Han
- Ride Comfort
- ADAS/AD Quality
- Traction Control Quality
- Vehicle Acoustics

Consumption / Efficiency

- Chassis Dyno Testing
- Real-World Drivin
- Vehicle E & C ption
- arging Experience
- Thermal Perf. & Eff.
- Driving Resistance and Dimensions, Space & Roominess

Vehicle Attribute Benchmark

2021 Toyota Yaris ICE and Hybrid – Main Specs (1/2)


			Yaris ICE		Yaris Hybrid
Vehicle	Market			Europe	
	Base Price	[€]	20.390		23.450
	Wheelbase	[mm]		2560	
	Length	[mm]		3940	
	Width excl. Mirrors	[mm]		1745	
	Height	[mm]		1500	
	Trunk Capacity	[l]		286	
	Trunk Capacity incl. Back Seats	[l]		768	
	Curb Weight	[kg]	1065		1151
	Gross Vehicle Weight	[kg]	1555		1615
	Payload	[kg]	900		900
	Number of Seats	[-]		5	
	0-100 kph acceleration time	[s]	9.0		9.7
	Top speed	[kph]	180		175
Chassis	Suspension front/rear			Coil/Coil	
	Brakes front/rear		Disc/Drum		Disc/Disc
	Tire Size		185/65 R15		205/45 R17
	Turning radius	[m]		10.4	

Vehicle Attribute Benchmark

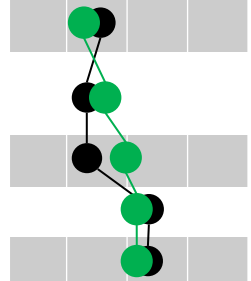
2021 Toyota Yaris ICE and Hybrid – Main Specs (2/2)


			Yaris ICE	Yaris Hybrid
Powertrain	Engine code	[-]	M15A-FKS	M15A-FXE
	Max. system power	[kW]	92	85
	Max. ICE power	[kW]	92@6600rpm	68@5500
	Max. electric power	[kW]	-	59
	Displacement / # of cylinders	[ccm] / [-]	1490 / 3	
	Compression ration	[-]	14.0:1	
	Fuel injection	[-]	Direct multipoint injection	Port injection
	Max. ICE torque	[Nm]	153	120
	Max. E-motor torque	[Nm]	-	141
	Battery capacity	[kWh]	-	0.9
	Transmission type	[-]	6-spd MT	CVT
	Emission class	[-]	Euro 6d / 1832AP	
	CO_2 emission (WLTP)	[g/km]	118	97
	Fuel Consumption Comb. (WLTP)	[l/100km]	5.0	4.3

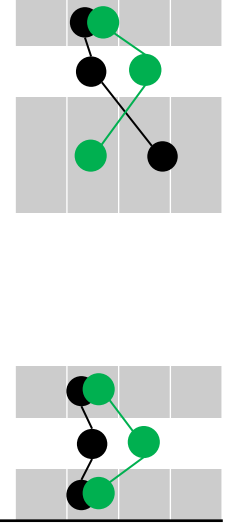
Vehicle Attribute Benchmark

Executive Results and Standing of 2021 Toyota Yaris ICE and Hybrid

	Yaris ICE	Yaris Hybrid	Standing
Performance			
0 to 100kph [s]	11.5	11.7	
Elasticities: 40 – 70 [kph]	5.5	5.0	
60 – 100 [kph]	10.5	9.8	
max. Acceleration level [m/s²]	3.5	4.1	
Top speed [kph]	180	175	
Curb weight [kg]	1065	1151	
Driveability DR … AVL-DRIVE Rating			
Drive away [DR]	6.7	7.6	
Acceleration [DR]	7.3	7.6	
Deceleration [DR]	7.2	7.2	
Tip in [DR]	7.6	7.7	
Tip out [DR]	8.0	9.0	
Gear shift [DR]	6.2	7.2	

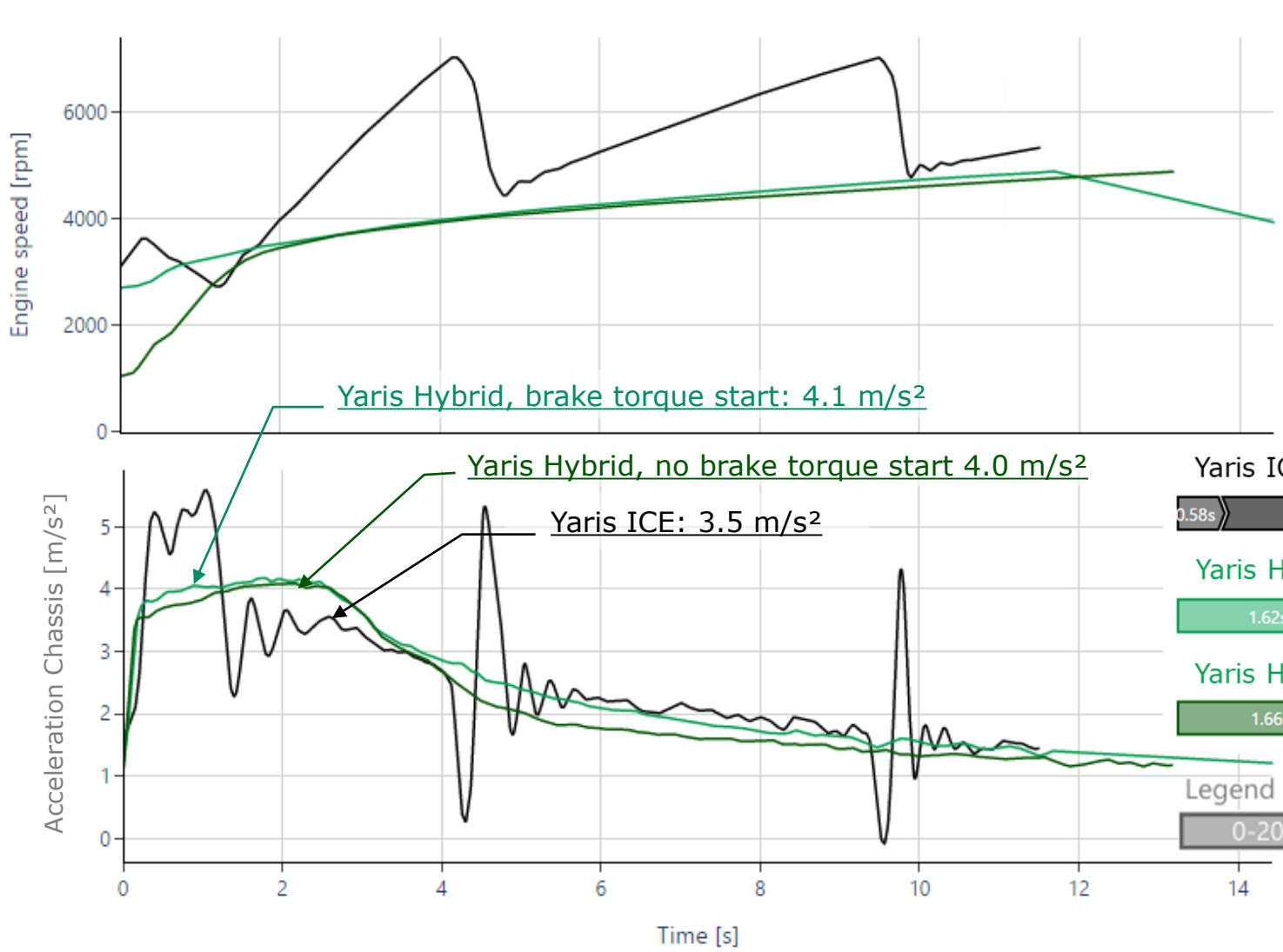


	Yaris ICE	Yaris Hybrid	Standing
Energy consumption & Range			
Fuel consumption WLTC [l/100km]	5.14	4.28	
CO_2 emissions RDE [g/km]	123	91	
Road load: A_0 [N]	62.70	113.0	
B_0 [N/kph]	0.970	0.467	
C_0 [N/kph²]	0.026	0.032	
Interior Sound Quality			
Interior sound quality at Full load acceleration			
Interior sound quality at Part load acceleration			
Interior sound quality at steady state conditions			



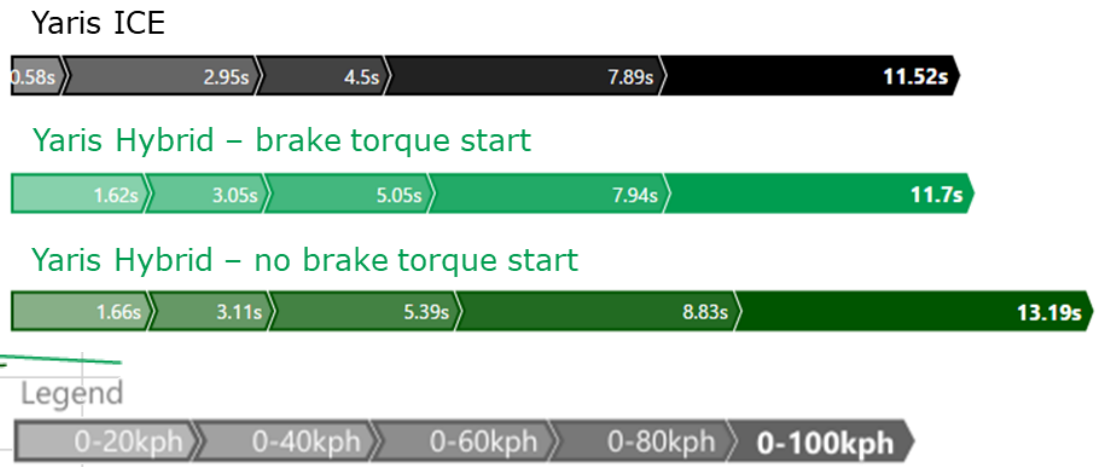
Vehicle Attribute Benchmark

Performance – Full Load From Standstill



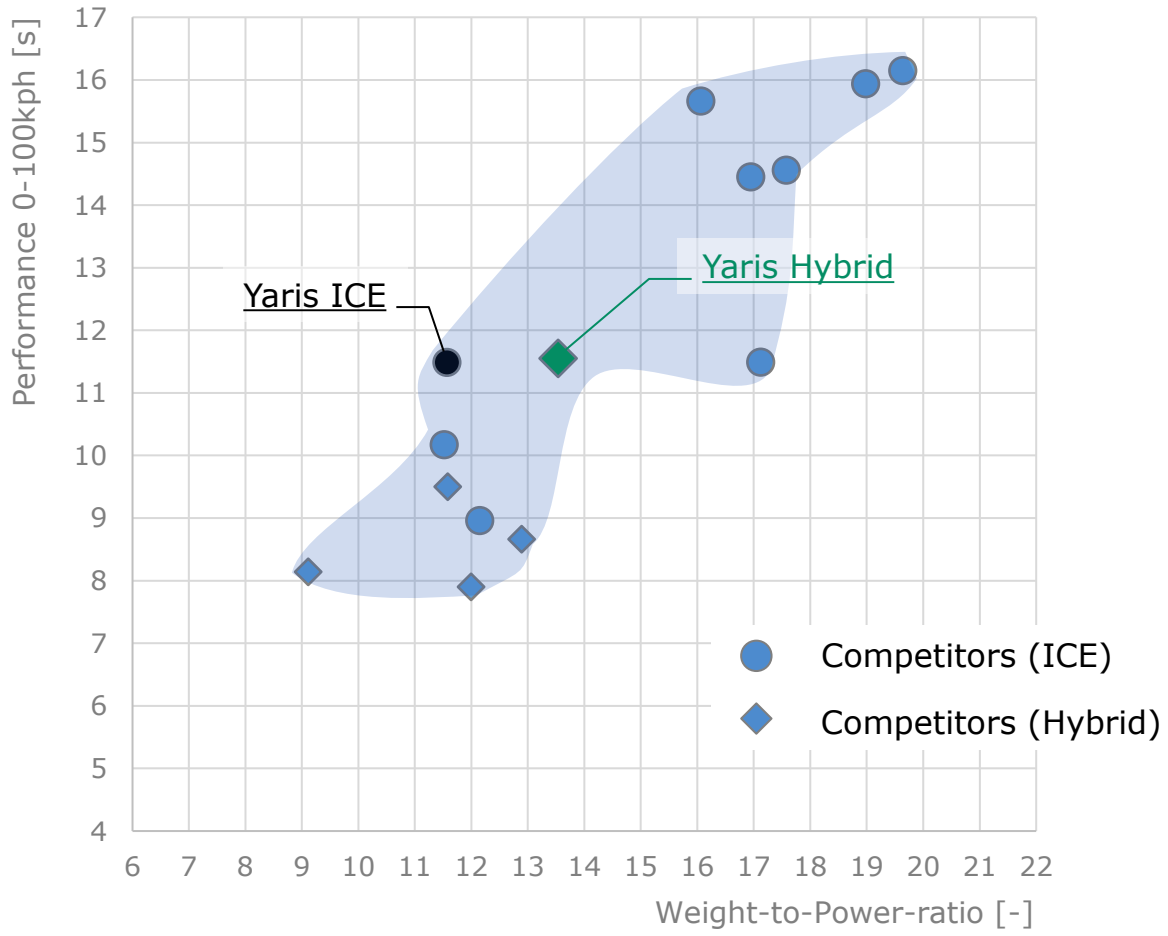
The **Yaris ICE** shows a relatively low initial acceleration level of 3.5 m/s² with quite a lot of wheel slip while upshifting from 1-2 and 2-3 gear. The sprint from 0 to 100 kph in 11.52 s doesn't meet the OEM's performance values of 9.0 s.

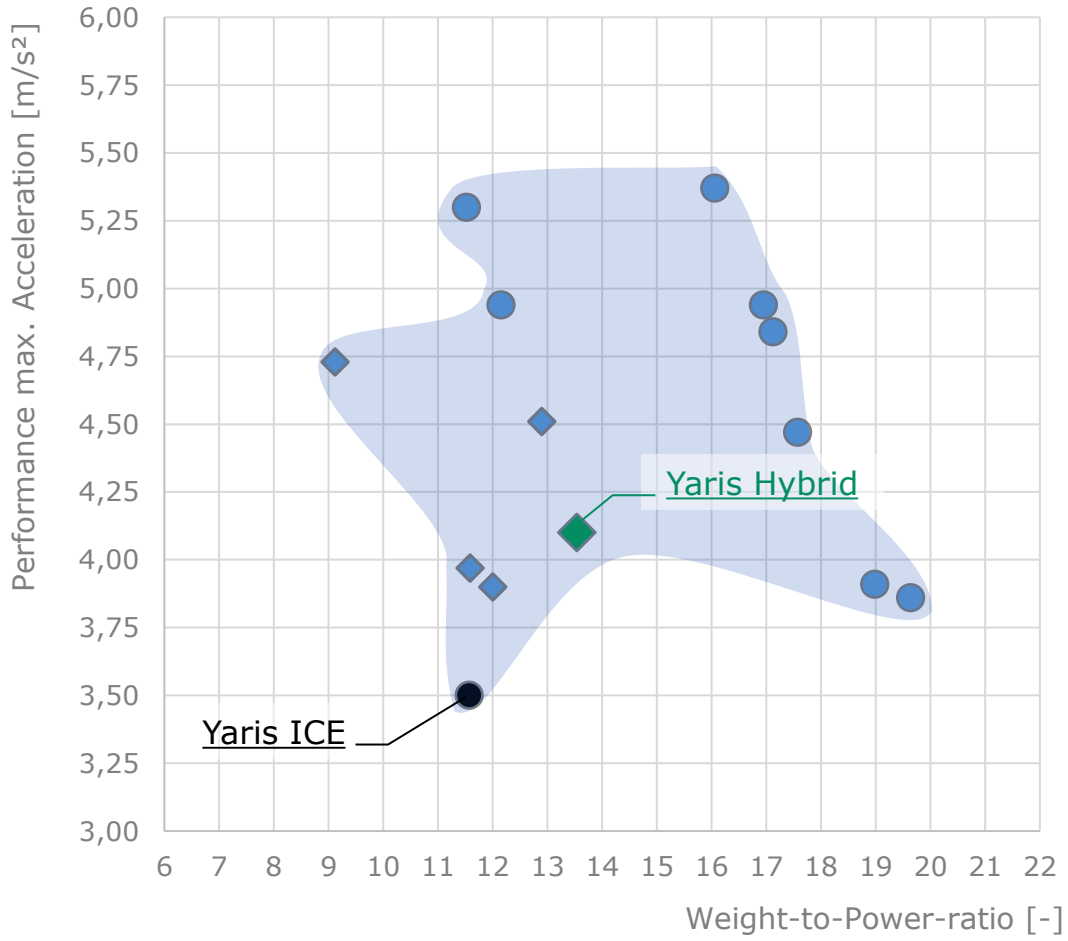
The **Yaris Hybrid** reaches 100 kph within 11.7 s only in brake torque start, but also fails to meet the OEM's published value of 9.7 s. A normal full load launch (w/o brake toque) shows a 0-100 kph duration of 13.19 s.



Vehicle Attribute Benchmark

Performance – Standing in Competitive Landscape





Vehicle Attribute Benchmark

Driveability – Assessment of Driving Character

Drive Away

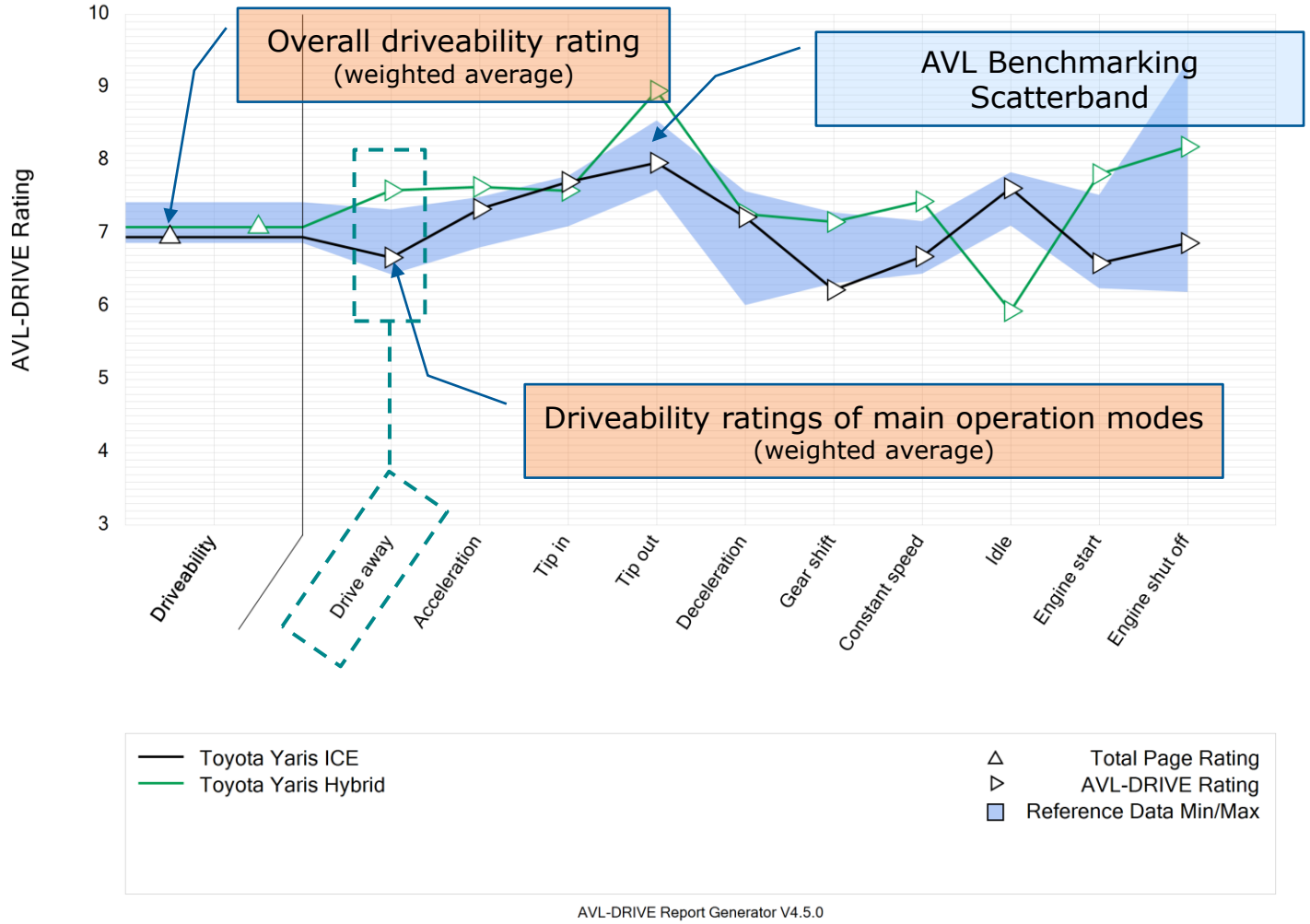
- **Yaris Hybrid:** Smooth drive away with sometimes the perception of a traction reduction and a little response issues at rolling start.
- **Yaris ICE:** Needs a skillful driver to avoid jerking at engagement point, especially at hill start.

Acceleration

- **Yaris Hybrid:** Smooth acceleration maneuvers and a good response and correlation at load increase.
- **Yaris ICE:** A little jerking at full load acceleration, a good response at load increase and a well distributed pedal map.

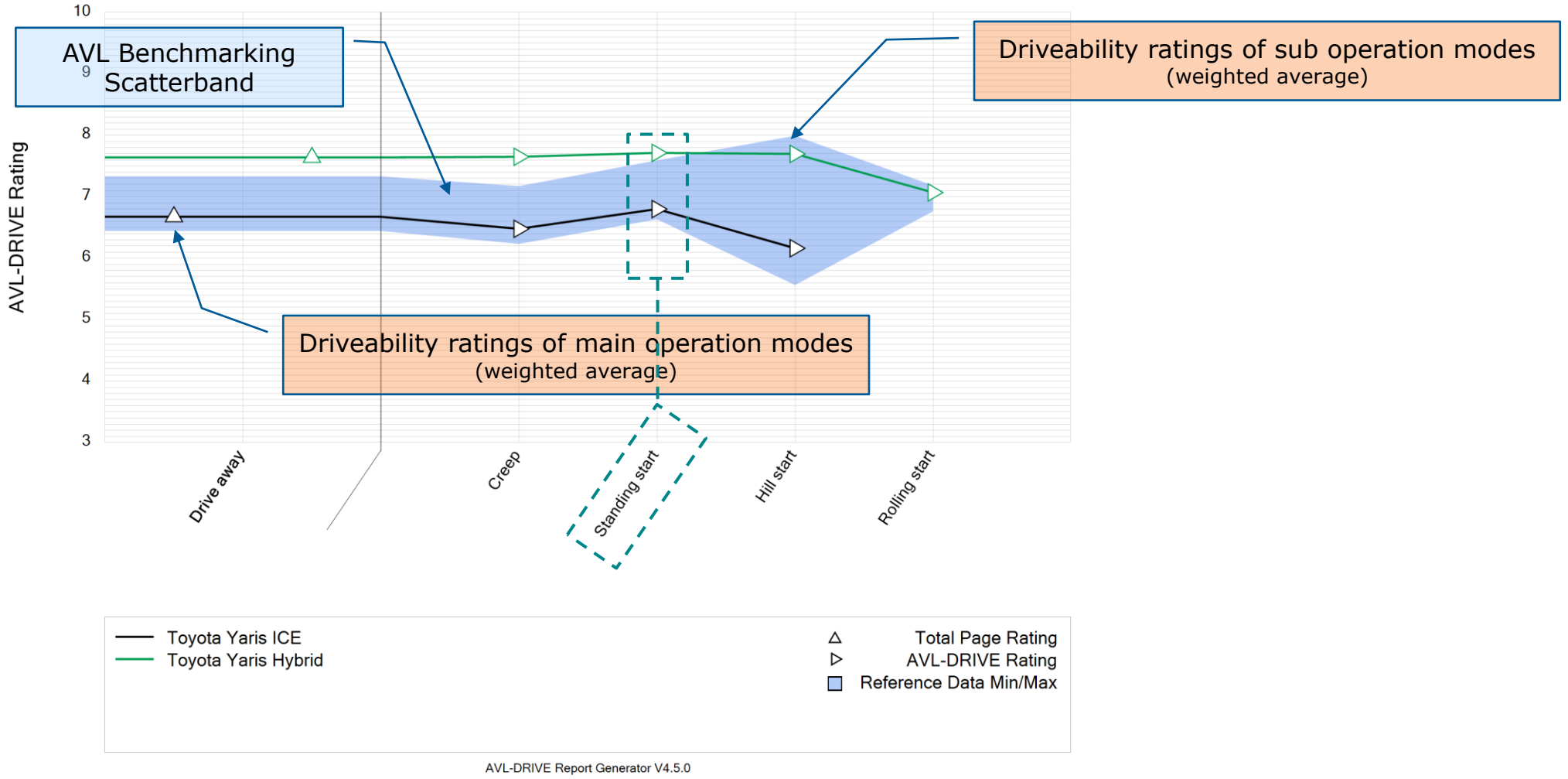
Tip In

- **Yaris Hybrid:** Very smooth and comfortable Tip Ins with sometimes a little ax increase delay.
- **Yaris ICE:** Good response with sometimes a very noticeable kick and acceleration disturbances.



Vehicle Attribute Benchmark

Driveability – Drive Away

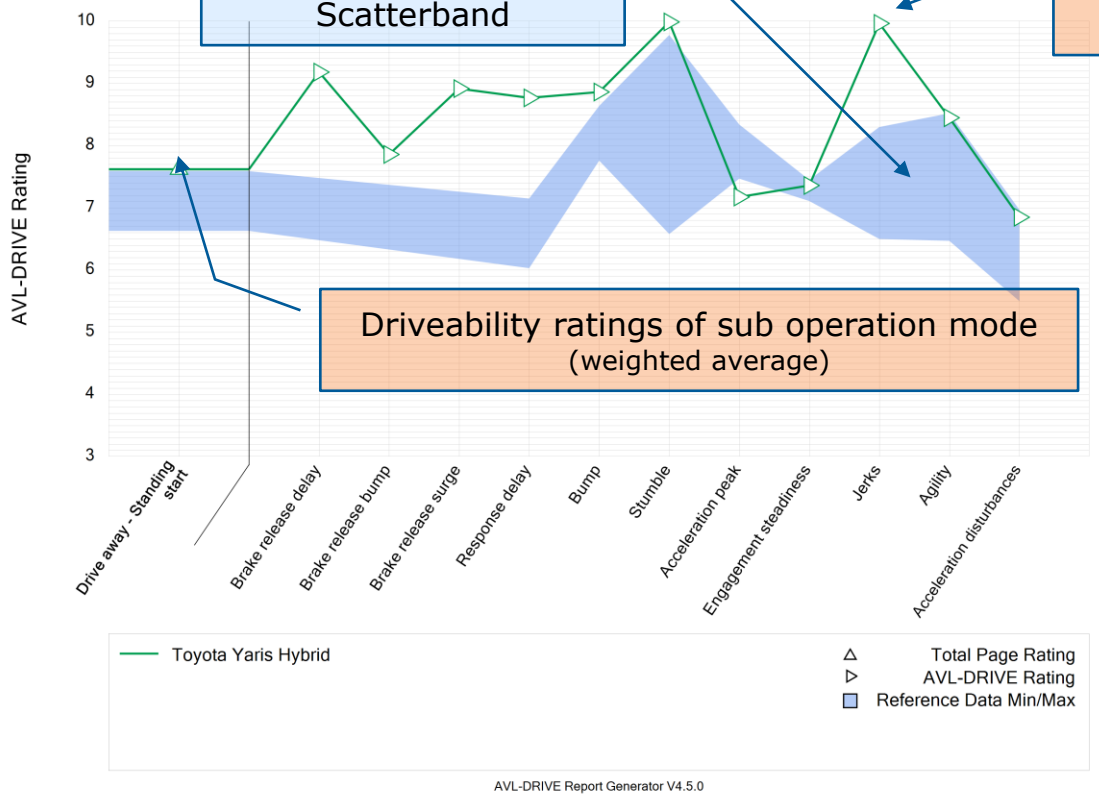


Vehicle Attribute Benchmark

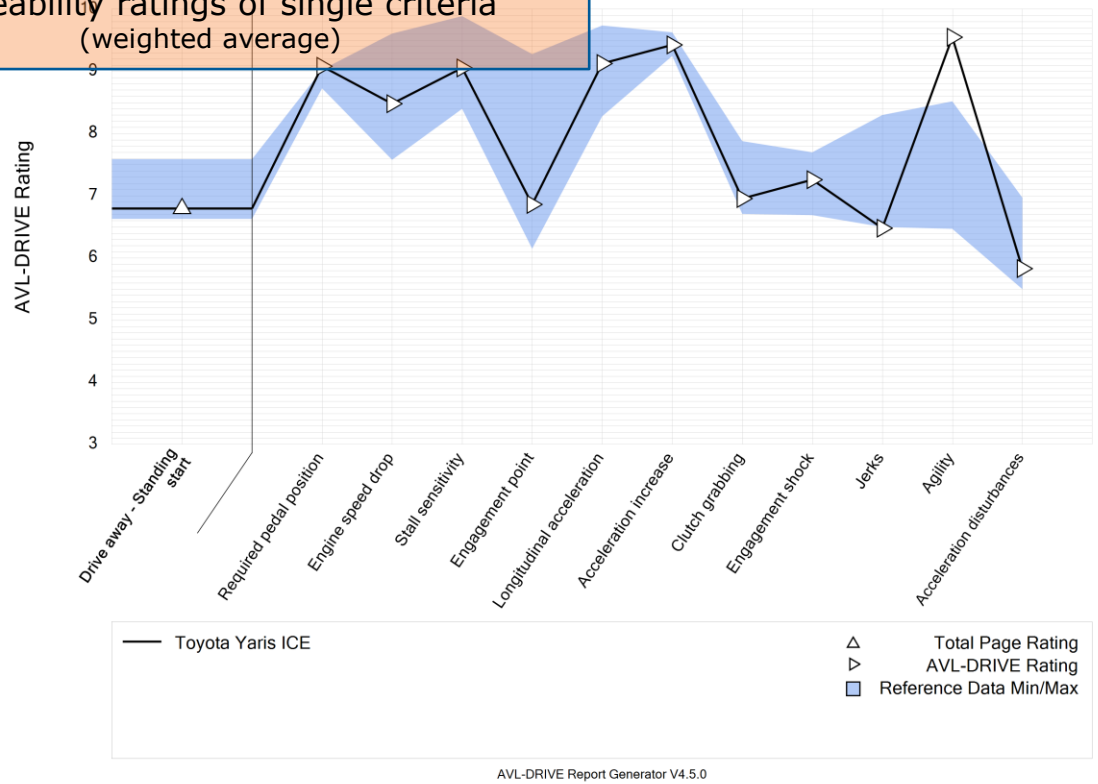
Driveability – Drive Away – Standing Start

AVL Benchmarking Scatterband

Driveability ratings of sub operation mode (weighted average)



Driveability ratings of single criteria (weighted average)



Yaris Hybrid:

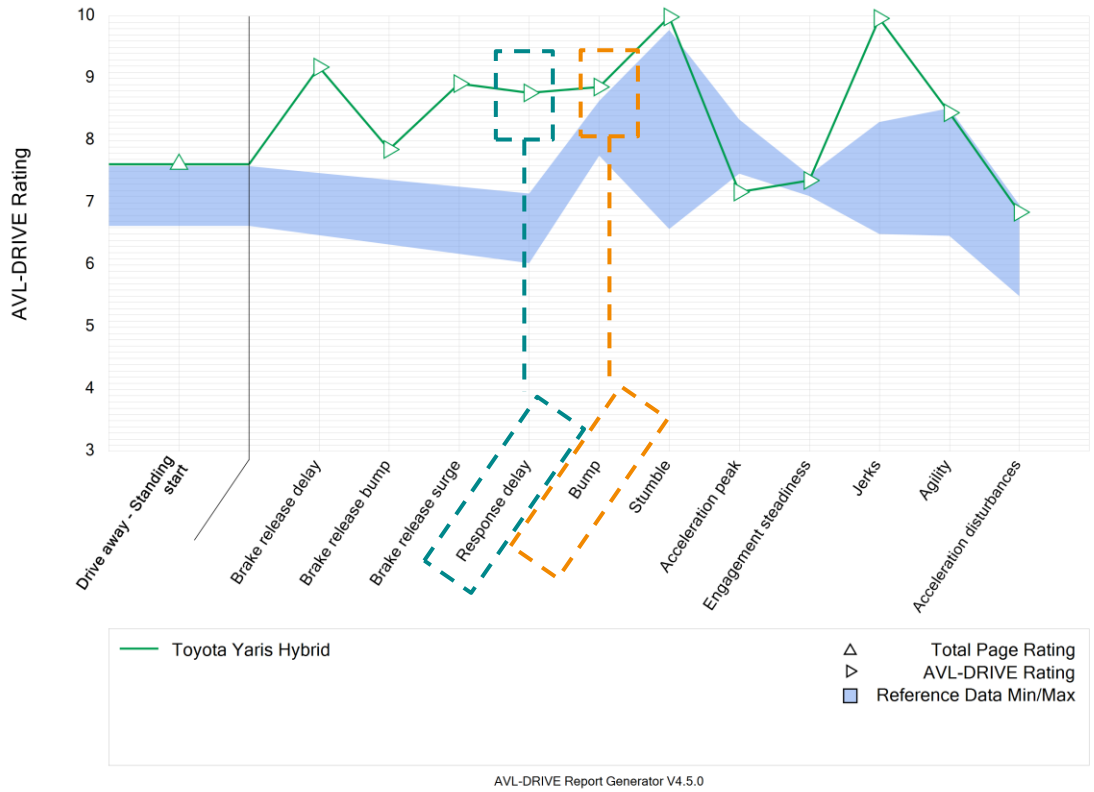
Very smooth drive away from standing start. With increasing pedal position drive away is getting more and more unsteady.

Yaris ICE:

The ICE nearly always reacts with a jerking behavior at drive away standing start.

Vehicle Attribute Benchmark

Driveability – Drive Away – Standing Start



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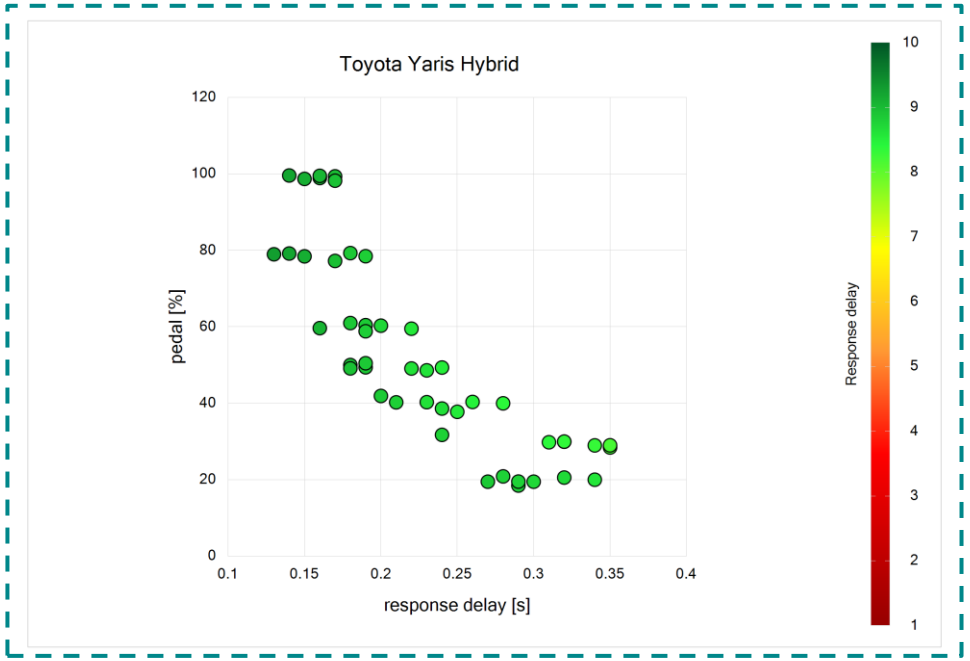
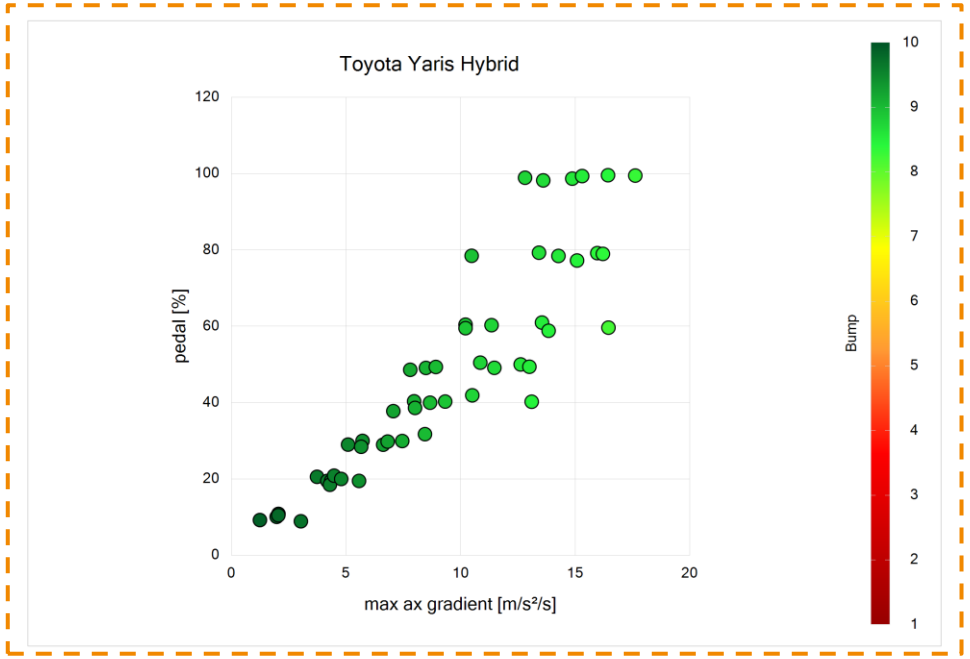
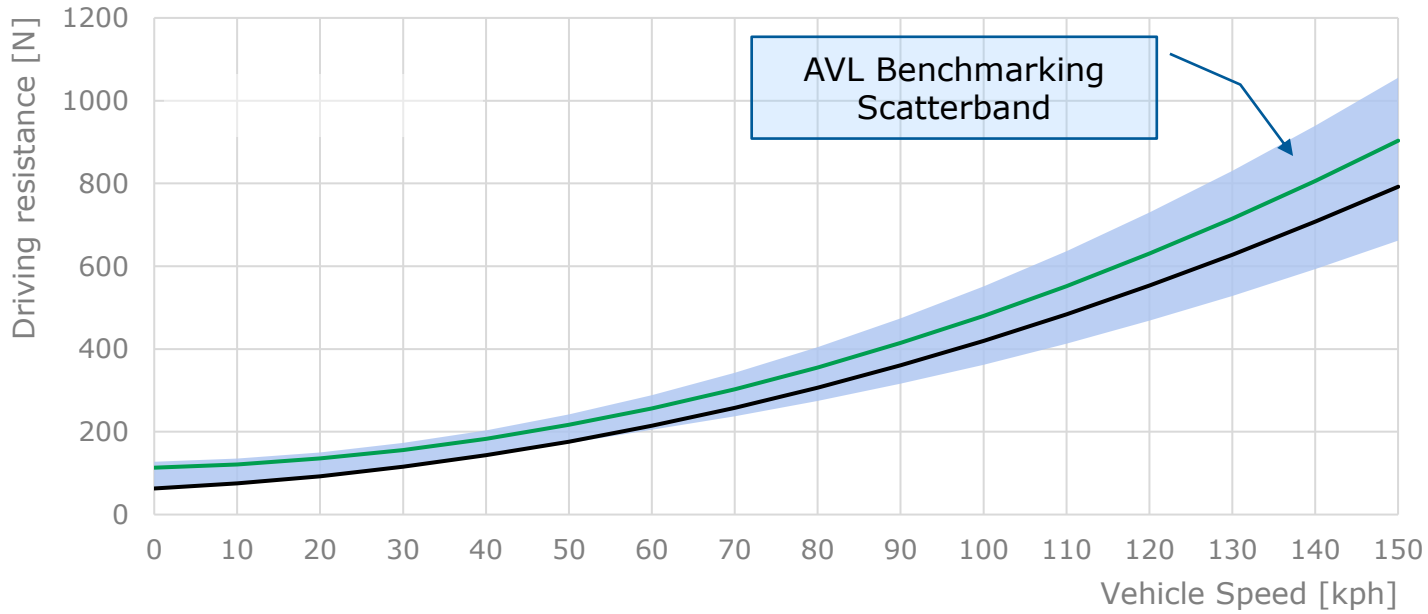




Vehicle Attribute Benchmark

Energy Management, Efficiency and Consumption – Driving Resistance



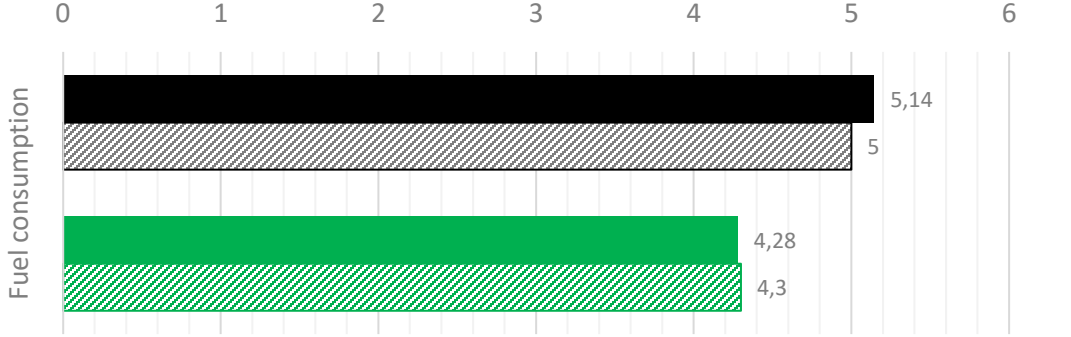
Driving resistance coefficients	**Yaris ICE**	**Yaris Hybrid**
A_0 [N]	62.7	113.0
B_0 [N/kph]	0.97	0.467
C_0 [N/kph²]	0.026	0.032

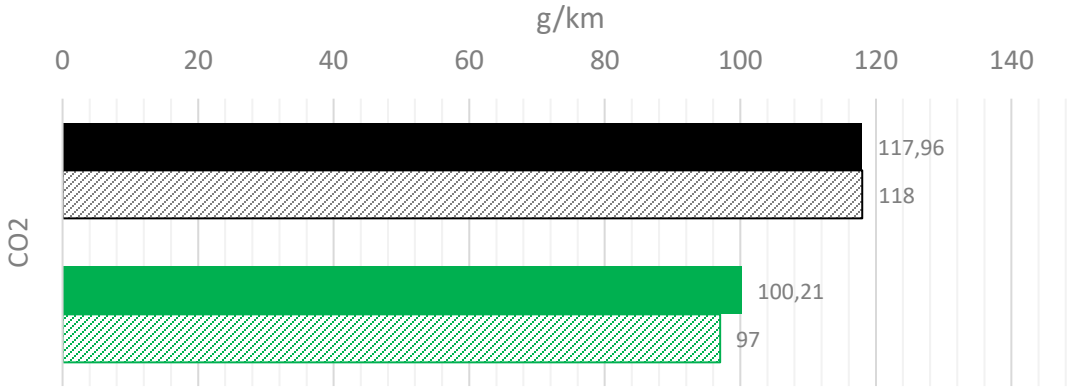
The **Yaris ICE** shows significant better driving resistance results than the **Hybrid** version, mainly influenced by vehicle mass, tire dimensions and of course the powertrain type itself.

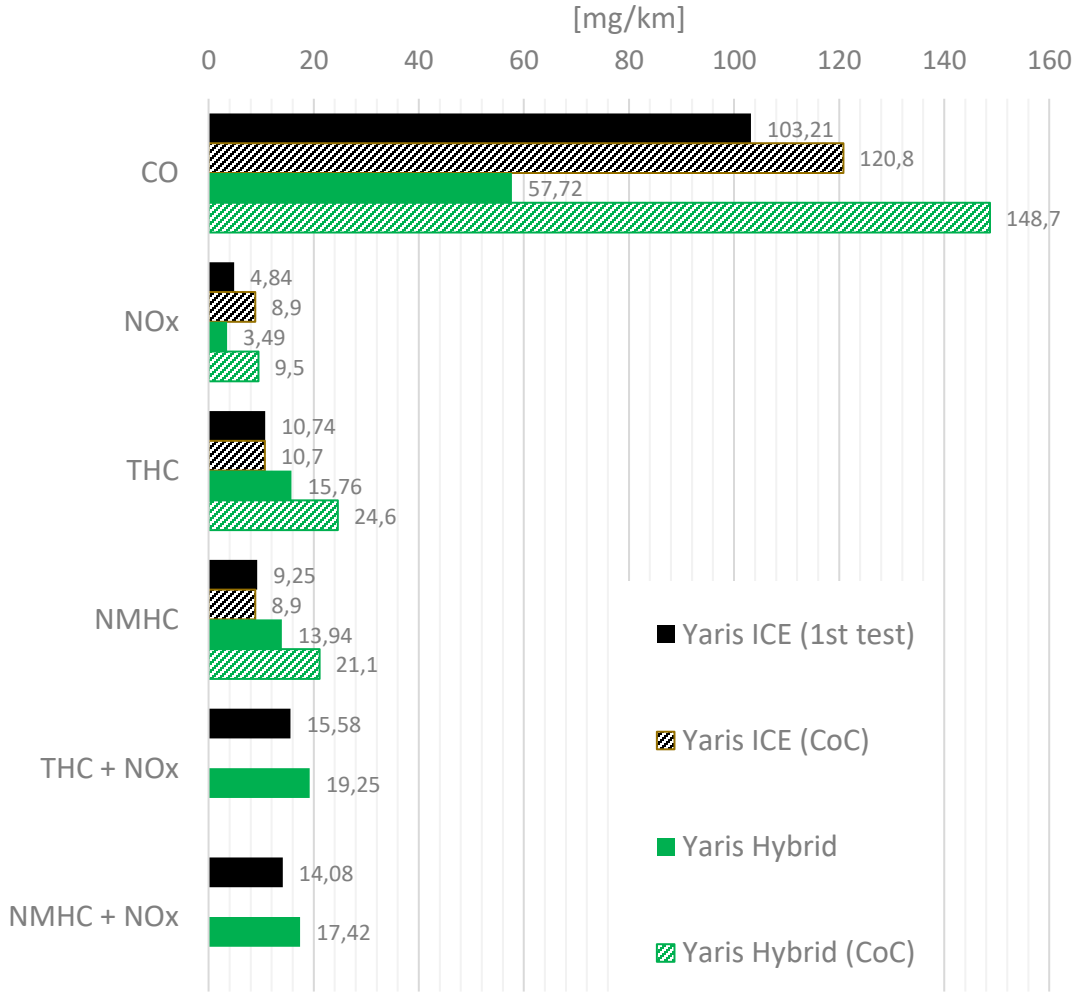
	Yaris ICE	**Yaris Hybrid**
Tire brand and type	Continental EcoContact6	Bridgestone Ecopia
Tire dimension	185/65 R15	205/45 R17
Tire pressure front/rear [bar]	2.3/2.2	2.3/2.2
Vehicle testing mass [kg]	1065	1151

Vehicle Attribute Benchmark

Energy Management, Efficiency and Consumption – WLTC Testing

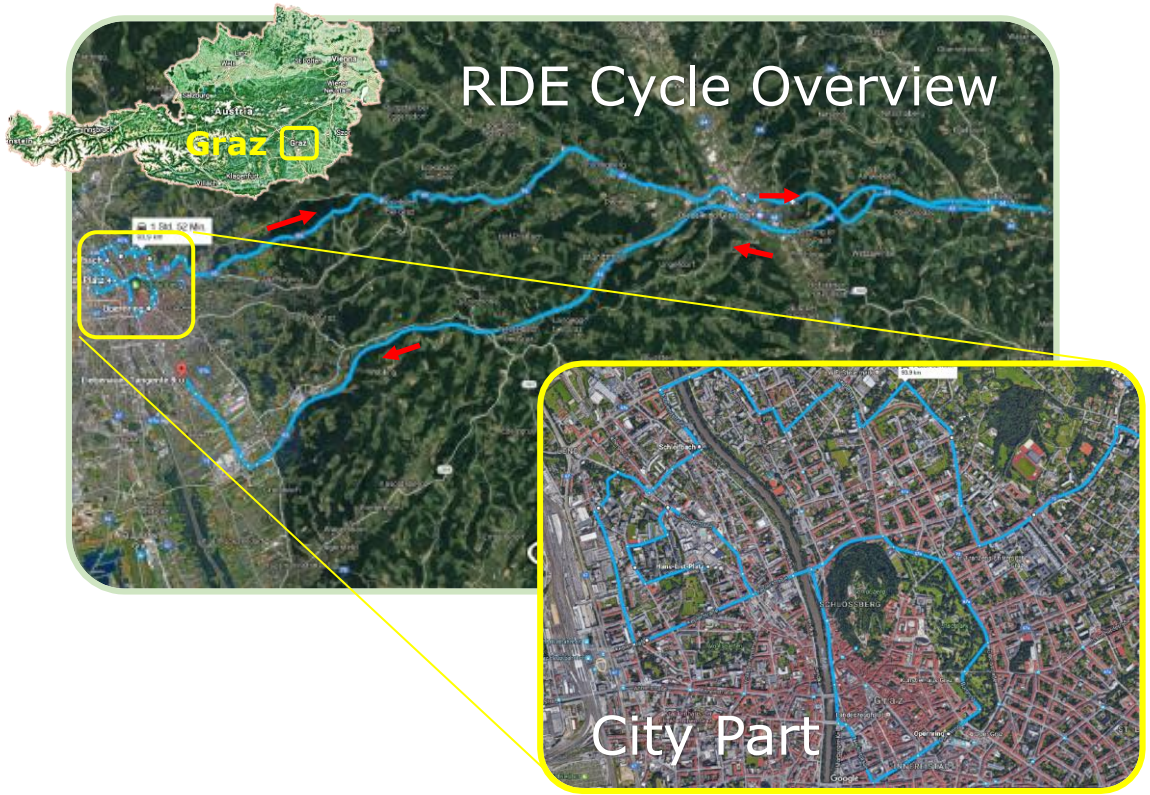


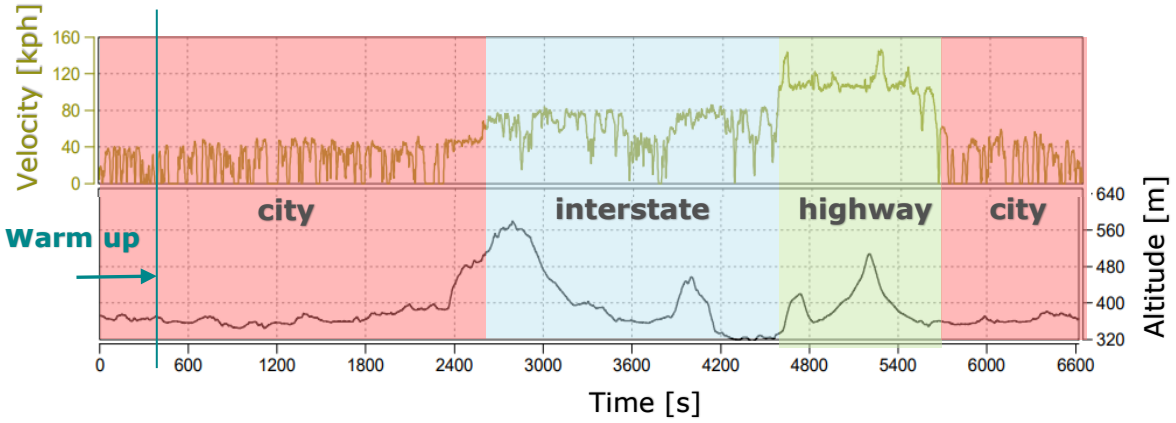


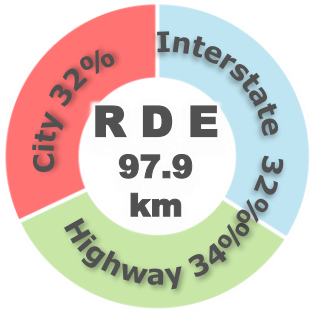


Vehicle Attribute Benchmark

Energy Management, Efficiency and Consumption – Real-World Driving (Total Trip)



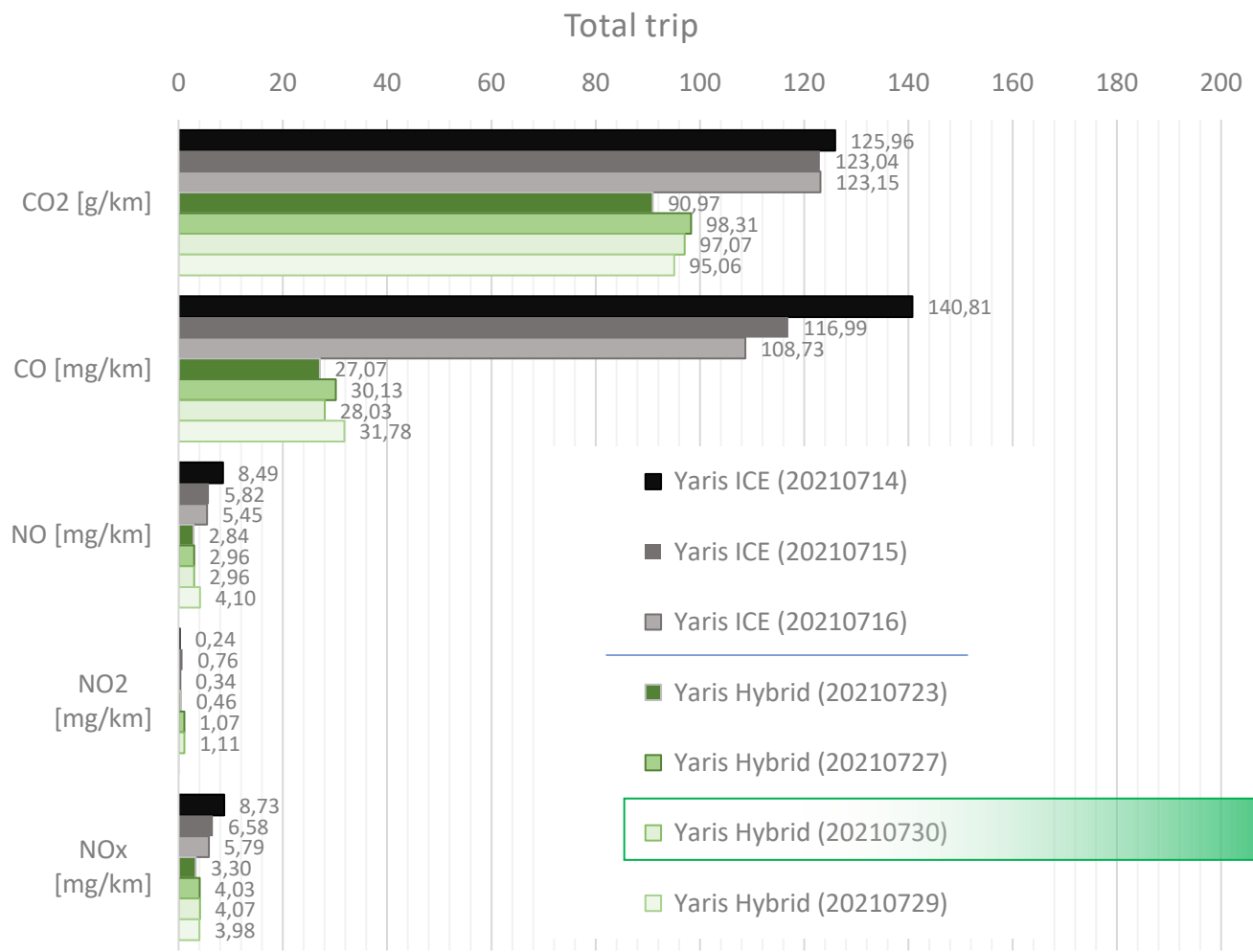




Ambient temp.	25[°C]
Settings	A/C auto 22°C, headlights on

Vehicle Attribute Benchmark

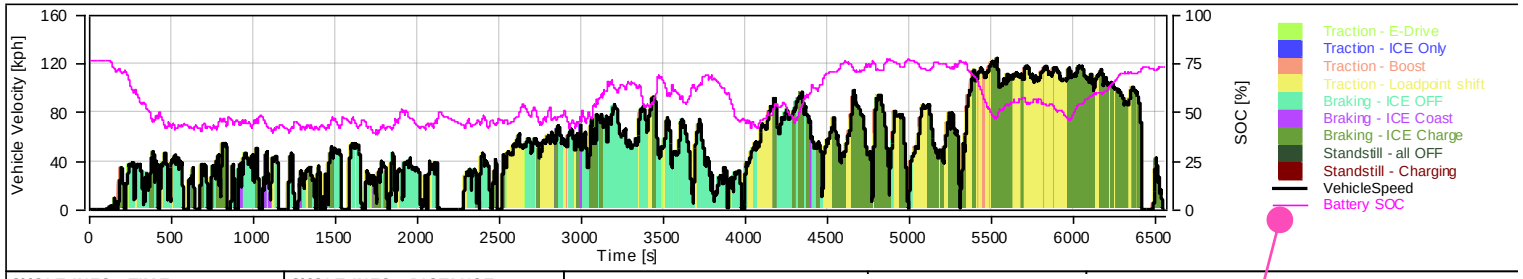
Energy Management, Efficiency and Consumption – Real-World Driving (Total Trip)



Example given for Eco mode, moderate driving style. Insights into the operation strategy.

Vehicle Attribute Benchmark

Energy Management, Efficiency and Consumption – Operation Strategy Analysis



CYCLE INFO - TIME

Total Time	6567 s	
Time Without Standstill	5835 s	
Standstill Time	733 s	
0-50kph	3437 s	52.3 %
50-90kph	2023 s	30.8 %
>90kph	1108 s	16.9 %

CYCLE INFO - DISTANCE

Total Distance	93.1 km	
0-50kph	23.0 km	24.7 %
50-90kph	37.2 km	39.9 %
>90kph	32.9 km	35.4 %

Eco mode,
moderate driving style

Keep SOC level >38 %

High share of pure EV driving

ICE efficiency increase by load point moving

Decals are used for recuperation

Battery Analysis

BATTERY SOC

start	76.5 %
end	74.0 %
max	77.4 %
min	38.7 %
swing	38.7 %

Energy Throughput

Batt. IN	2.29 kWh
Batt OUT	-2.24 kWh
Delta	0.05 kWh

CHARGING

	ABSOLUTE	PERCENTUAL
Driving, EM only	0.01 kWh	0.2 %
Driving, ICE only	0.00 kWh	0.0 %
Driving, Boost	0.00 kWh	0.0 %
Driving, Loadpoint shift	1.12 kWh	48.8 %
Braking, ICE off	0.89 kWh	39.0 %
Braking, ICE coast	0.06 kWh	2.8 %
Braking, ICE charge	0.21 kWh	9.1 %
Standstill, all off	0.00 kWh	0.0 %
Standstill, charge	0.00 kWh	0.0 %

DISCHARGING

	ABSOLUTE	PERCENTUAL
Driving, EM only	-1.35 kWh	60.2 %
Driving, ICE only	0.00 kWh	0.0 %
Driving, Boost	-0.70 kWh	31.3 %
Driving, Loadpoint shift	0.00 kWh	0.0 %
Braking, ICE off	-0.04 kWh	1.6 %
Braking, ICE coast	-0.00 kWh	0.0 %
Braking, ICE charge	-0.01 kWh	0.5 %
Standstill, all off	-0.13 kWh	5.9 %
Standstill, charge	-0.01 kWh	0.4 %

Operation Mode Analysis - Time

TIME ANALYSIS

	ABSOLUTE	PERCENTUAL
Driving, EM only	1511 s	23.0 %
Driving, ICE only	0 s	0.0 %
Driving, Boost	1217 s	18.5 %
Driving, Loadpoint shift	1630 s	24.8 %
Braking, ICE off	1000 s	15.2 %
Braking, ICE coast	86 s	1.3 %
Braking, ICE charge	375 s	5.7 %
Standstill, all off	654 s	10.0 %
Standstill, charge	94 s	1.4 %

DISTANCE ANALYSIS

	ABSOLUTE	PERCENTUAL
Driving, EM only	17.0 km	18.3 %
Driving, ICE only	0.0 km	0.0 %
Driving, Boost	24.9 km	26.7 %
Driving, Loadpoint shift	29.7 km	31.9 %
Braking, ICE off	12.0 km	12.9 %
Braking, ICE coast	2.0 km	2.1 %
Braking, ICE charge	7.6 km	8.1 %
Standstill, all off	0.0 km	0.0 %
Standstill, charge	0.0 km	0.0 %

Basic Drivability

ACTIVE RUN TIMES

ICE	3353 s
MG2	5073 s

COAST TIMES

ADDITIONAL ANALYSIS

ICE Start Count	106 -
ICE Runtime per start	33 s

Wheel Energy Analysis

Driving	-13.77 kWh
Recuperation	1.78 kWh

RECUPERATION ENERGY FLOW

Wheel	1.78 kWh
HV Batt.	1.08 kWh

Vehicle Attribute Benchmark

2021 Toyota Yaris Hybrid
DHE, 85 kW

vs.

2021 Toyota Yaris (ICE)
Conv. PT, 92 kW

2021 Renault Clio e-tech
DHT, 103 kW

> 450

PC vehicles in database

all main vehicle segments
From small PC to SUVs, Pick-ups and LCV

> 30

new vehicles per year

> 13

Vehicle attributes

cost efficient

reuse and resell of existing benchmark data

More on
https://app.avl.com/benchmarking-program

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4 **Engine Benchmark**

5 Summary and Conclusions

About the Engine
Main Hybrid Engine Attributes

3-cylinder NA engine
with 68 kW max. power

High stroke to bore ratio
s/b = 1.21

High compression ratio
CR = 14

EGR system

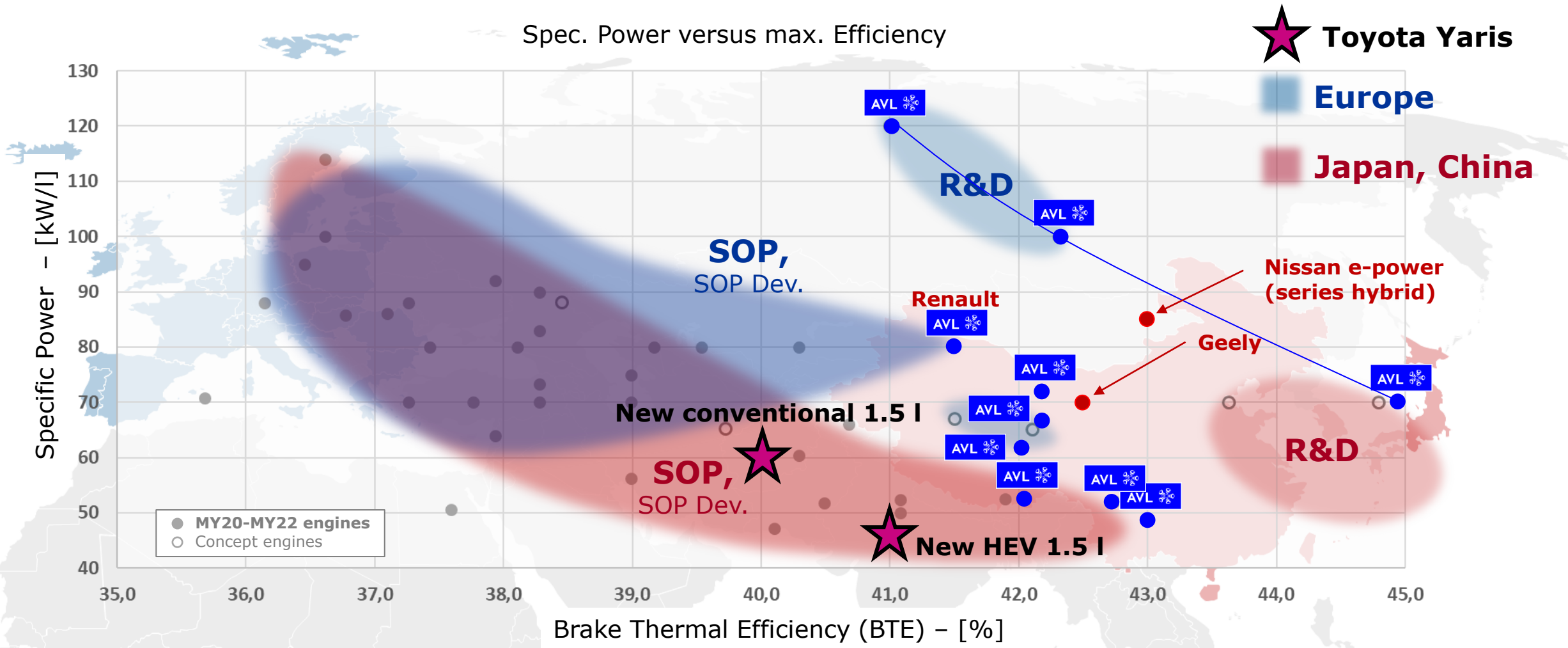
Low friction

How does the thermal efficiency of the new Toyota Yaris hybrid engine look compared to other engines?

How the new Toyota hybrid engine obtains market-leading thermal efficiency?

How AVL did the benchmarking of the new Toyota engine?

Gasoline Engine Development Trends
EUROPE vs. ASIA



Key Features
For Highest Thermal Efficiency

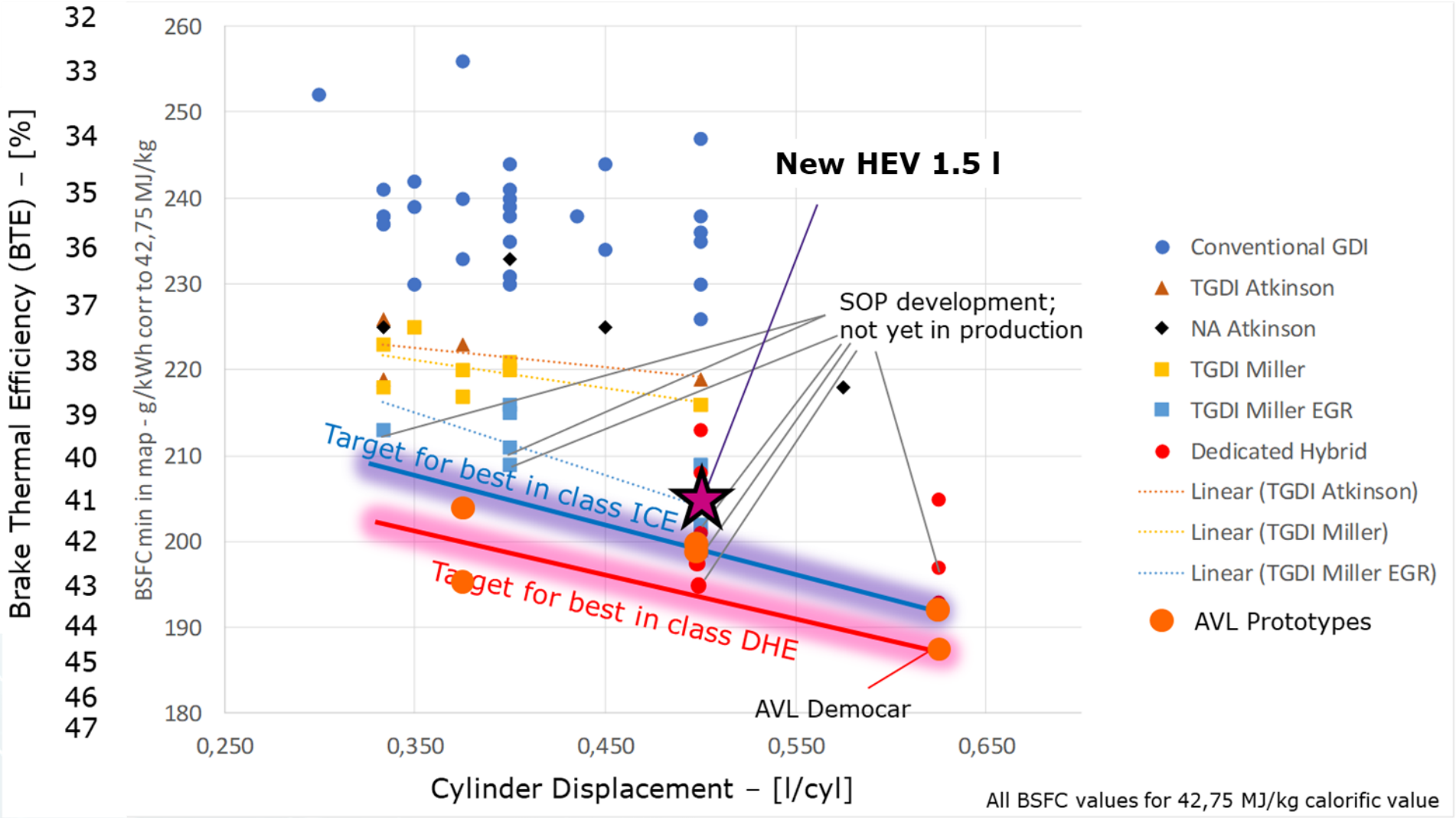
Combustion system

- 3-cylinder (0.5 l/cylinder)
- High CR (CR = 14)
- Stroke to bore: s/b = 1.21
- High EGR rates
- Atkinson cycle
- High tumble ports
- Volumetric efficiency improvement

Low friction

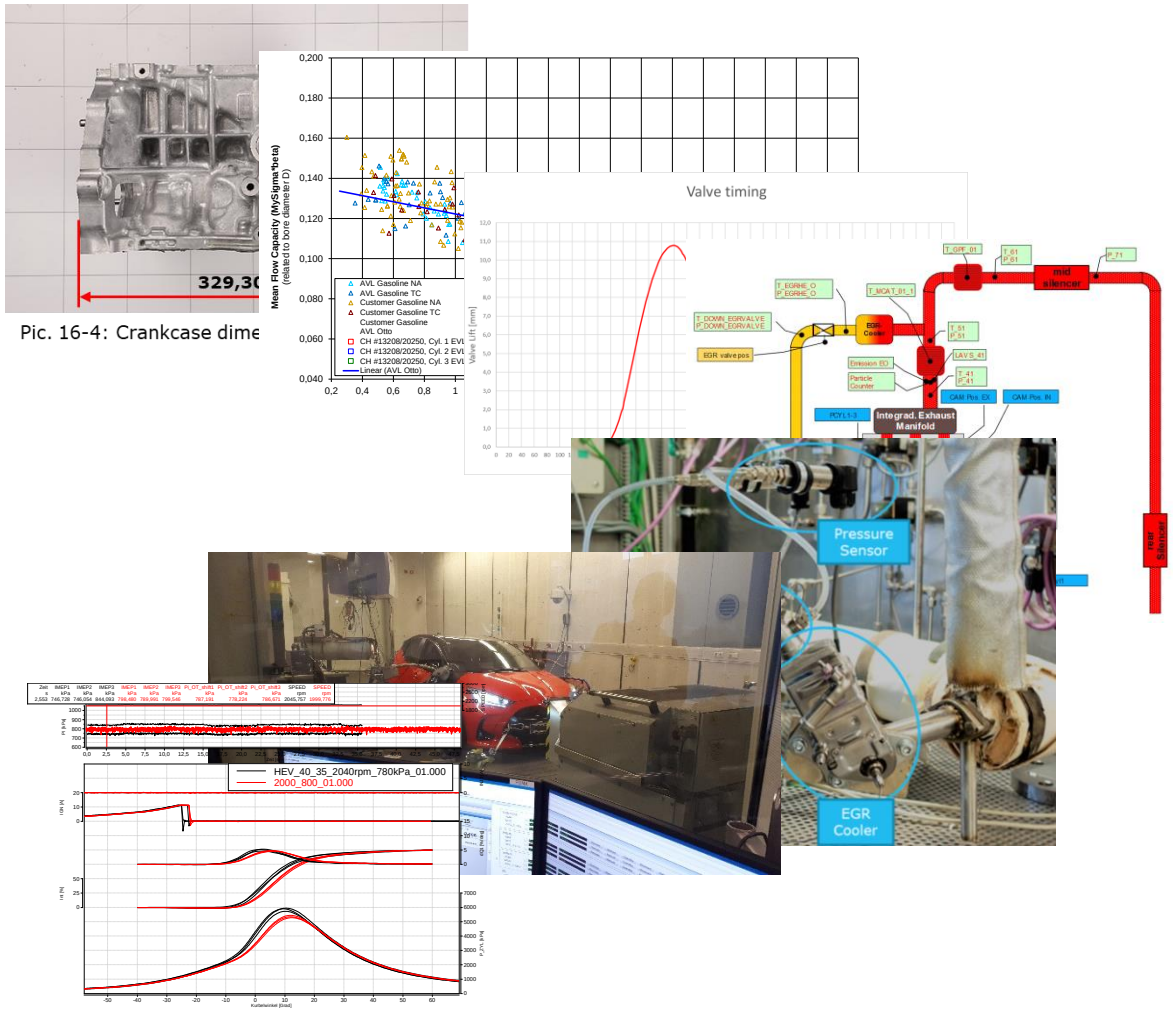
- No balance shaft for hybrid engine
- Bearing design optimization
- Piston oil ring tension reduction to 15 N
- PFI injection system
- Electric cam phaser on intake side
- Electric coolant pump
- Very low oil viscosity 0W8 oil

Sweetspot BSFC – Lambda = 1
AVL Scatterband



Hybrid Engine Benchmark
Methodology / Workflow

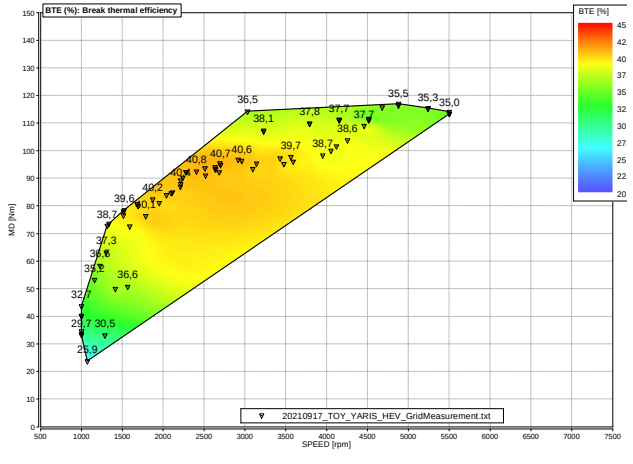
- Design benchmark
- Port flow measurement
  and comparison to AVL scatterband
- Valve lift curve measurement
- Full instrumentation
  Fuel mass flow measurement in vehicle, Emission, lambda, p, T, indication, electric signals, CAN
- EGR rate determination
- Measurements on chassis dyno and road
  stationary engine mapping, cycle measurement
- Combustion assessment (indication system)

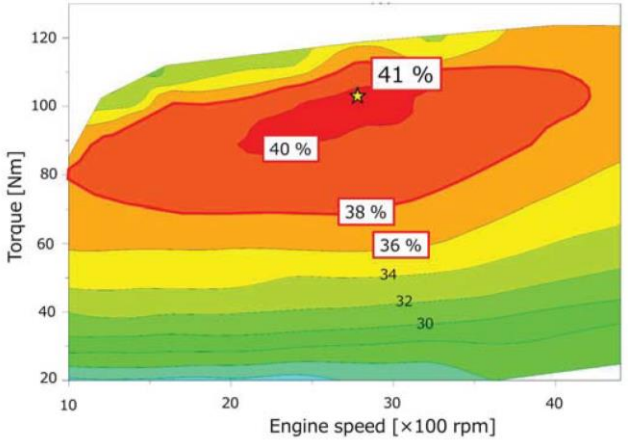


Engine Efficiency and Performance

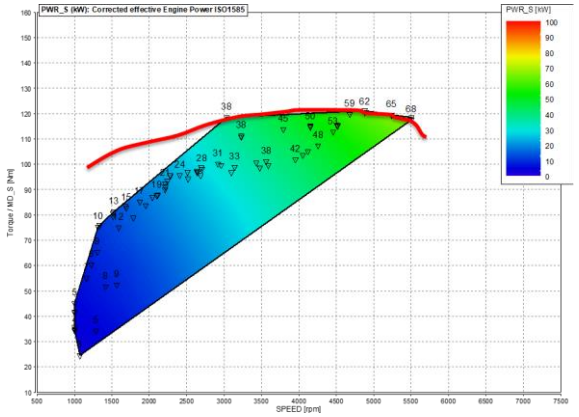
Chassis Dyno Measurements

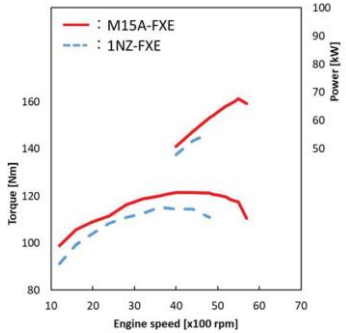
Fuel consumption 41 % brake thermal efficiency





Engine power 68 kW





WLTC	CVS	CoC paper	SOC start
Unit	*l/100km*	*l/100km*	*%*
WLTC_09082021	4,28	4,3	21,6
WLTC_291021	4,22	4,3	46

Source: Hironori Kitadani, Ryo Kaneda, Satoshi Mizoguchi, Yoshitsugu Shinohara, Jun Takeuchi Toyota Motor Corporation, Toyota, Japan; The new 1.5 L gasoline engine from the TNGA* series *Toyota New Global Architecture

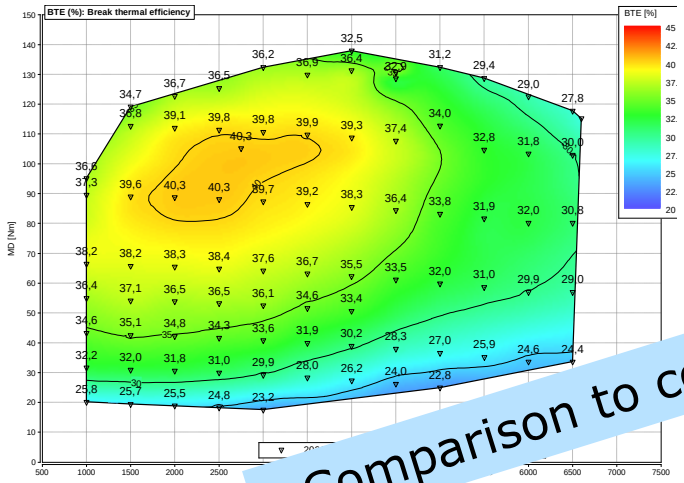
Comparison to New Conventional Engine

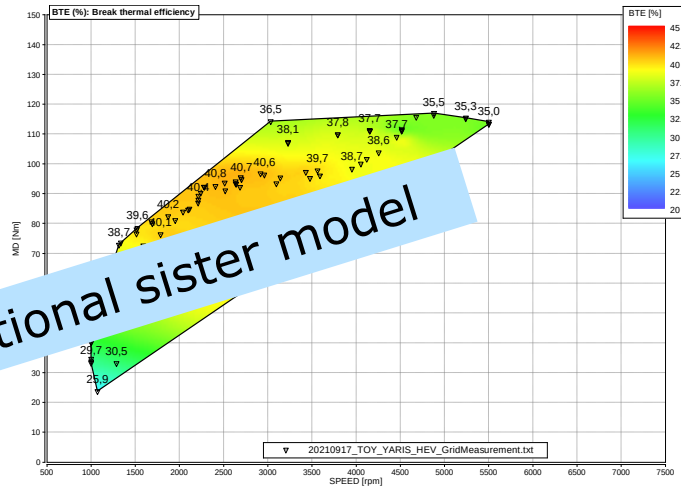
Chassis Dyno Measurements

M15A-FKS / ICEV:

M15A-FXE / HEV:

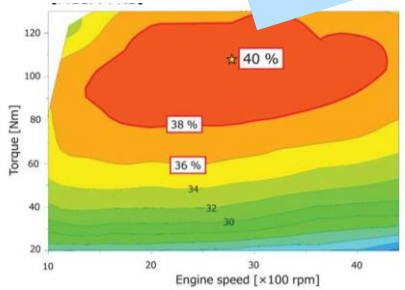
Bemchmark

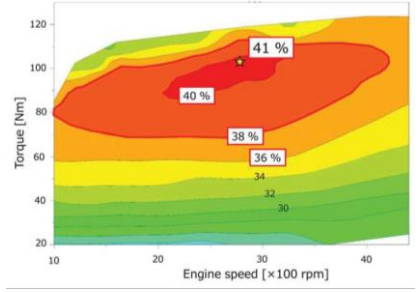




Comparison to conventional sister model

Publication





Break Thermal Efficiency

Toyota M15A-FKS:

- Toyota M15A-FKS showing maximum BTE of ~40 % (40,3 %).
- That's correlating good with the published result from Toyota.

Toyota M15A-FXE:

- Toyota M15A-FXE showing maximum BTE of ~41 % (40,8 %).
- That's correlating good with the published result from Toyota.

Source: Hironori Kitadani, Ryo Kaneda, Satoshi Mizoguchi, Yoshitsugu Shinohara, Jun Takeuchi Toyota Motor Corporation, Toyota, Japan; The new 1.5 L gasoline engine from the TNGA* series *Toyota New Global Architecture

Agenda

1 About AVL

2 Objectives of Benchmark Investigations

3 Vehicle Attribute Benchmark

4 Engine Benchmark

5 **Summary and Conclusions**

Summary and Conclusions

Market

- More than half million units of Yaris 1.5 are produced every year, mostly as hybrid
- Even ICE-Stop has been announced by several OEM, the trend for highly efficient ICE is still going on

Vehicle

- Overall comfort focused character
- Good differentiation between driving modes
- Operation strategies use full system potential to optimize driving excitement and fuel efficiency

Engine

- Engine is consistently developed for hybrid powertrain
- Engine provides highest thermal efficiency
- Engine is consistently operated along best efficiency curve

Q & A

Benchmarking Toyota Yaris 1.5 Hybrid

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