USING THE SYTECH ENGINE IN Range Extended Electric Vehicles;

- **Performance**
- **Simulation**
- **Durability**

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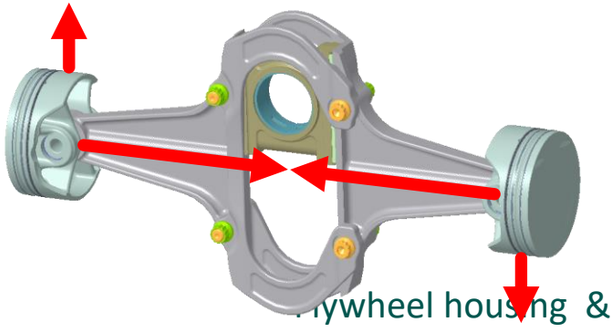
(paper016)

31st Aachen Colloquium Sustainable Mobility October 2022

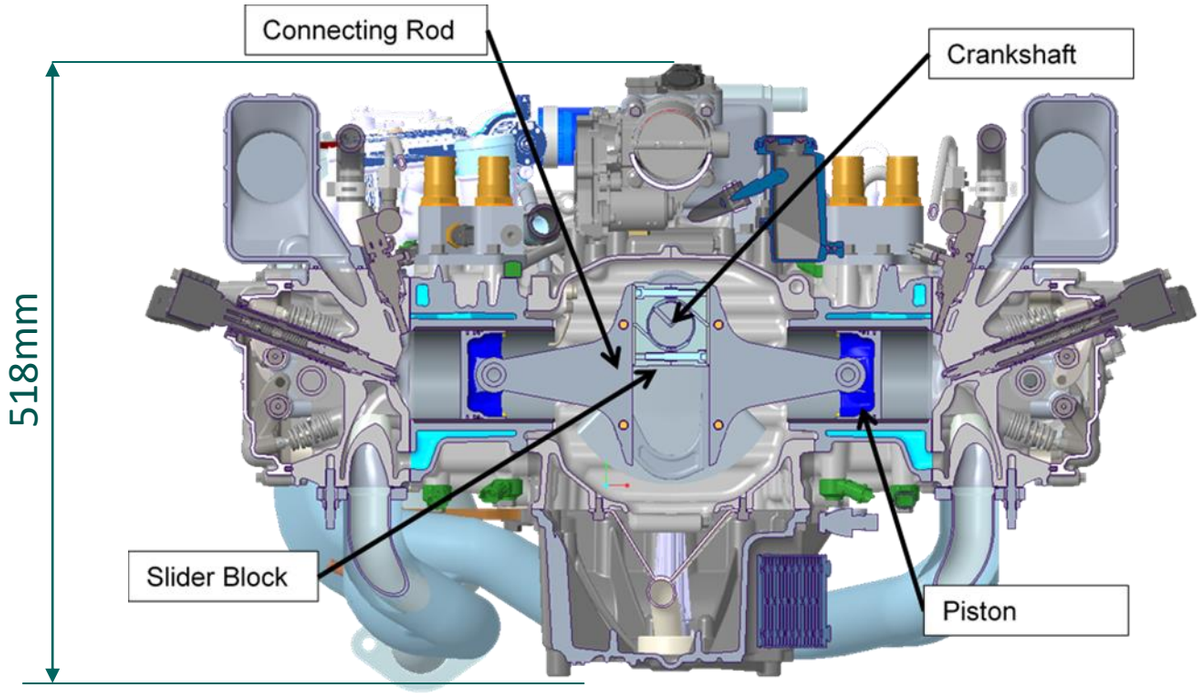
SYTECH S415-TC

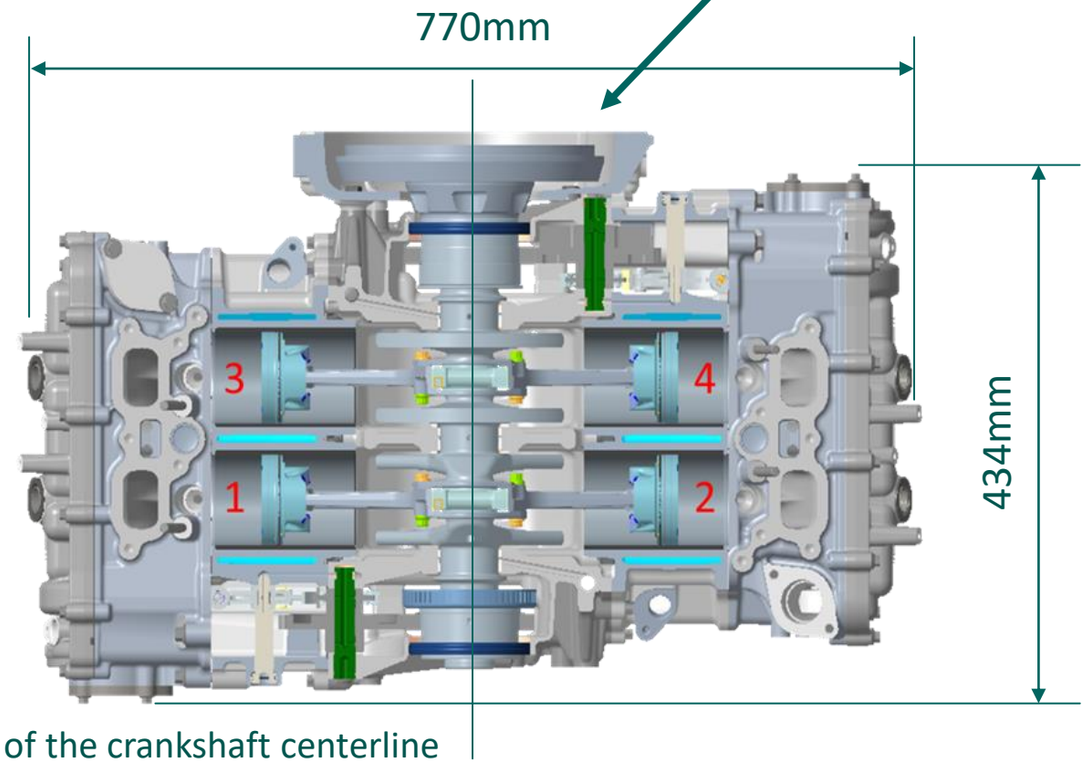
The SYTECH engine is an opposed cylinder engine with;

- Low NVH/minimal out of balance forces
- Low Centre of Gravity,
- High part commonality,
- Low cost,
- Light weight,
- Low Emissions with minimum technology



Flywheel housing & Crankshaft connection boss common front and rear

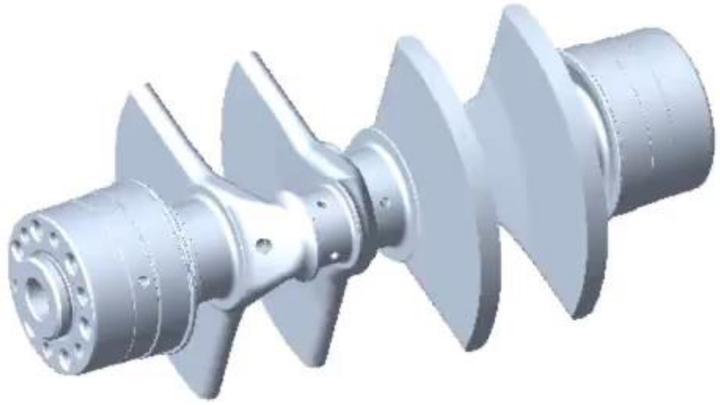




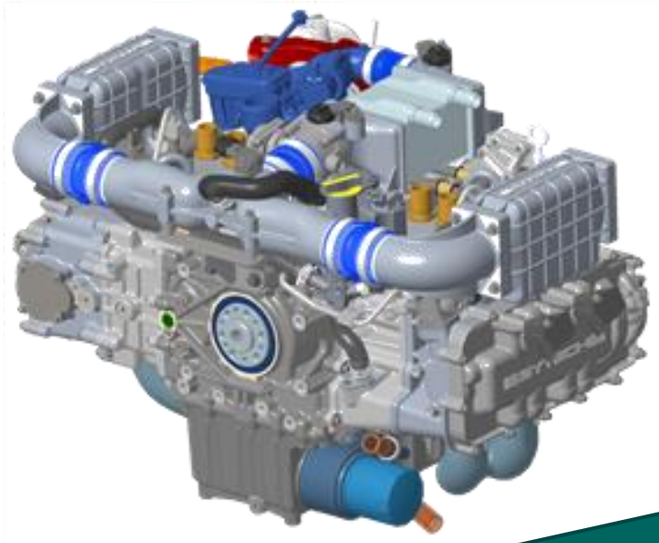
Engine parts are common either side of the crankshaft centerline (patent pending)

Engine Assembly Overview

- Common Parts,
- Common tooling,
- Lower investment
- Lower cost
- More commonality



Engines based on the common family approach



S830
120-250kW
130-160kg

S415
60-110kW
95-110kg

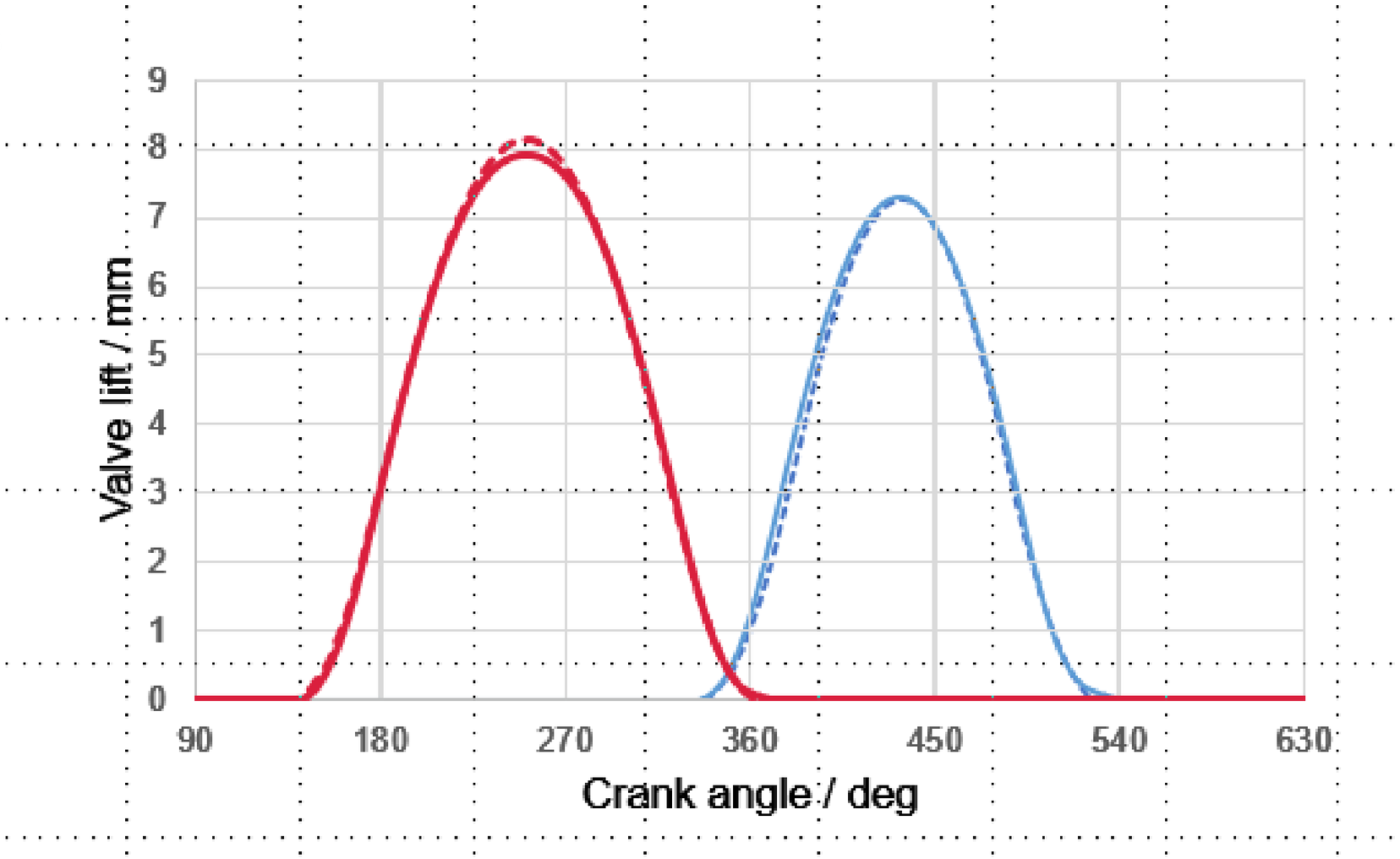
S208
30-50kW
40-55kg

Power can also be achieved by increased bore and stroke rather than additional cylinders

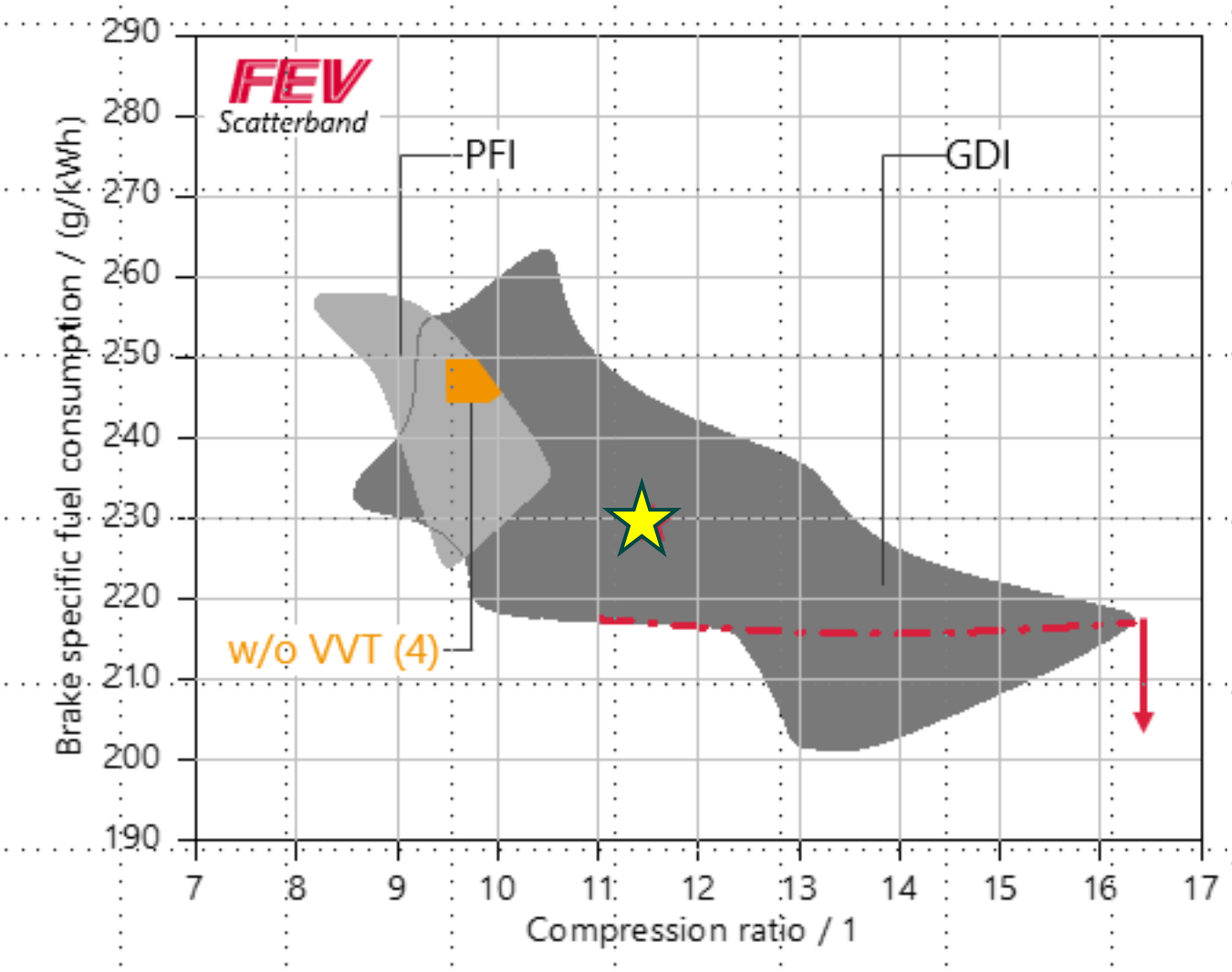
S415-TC ENGINE PERFORMANCE

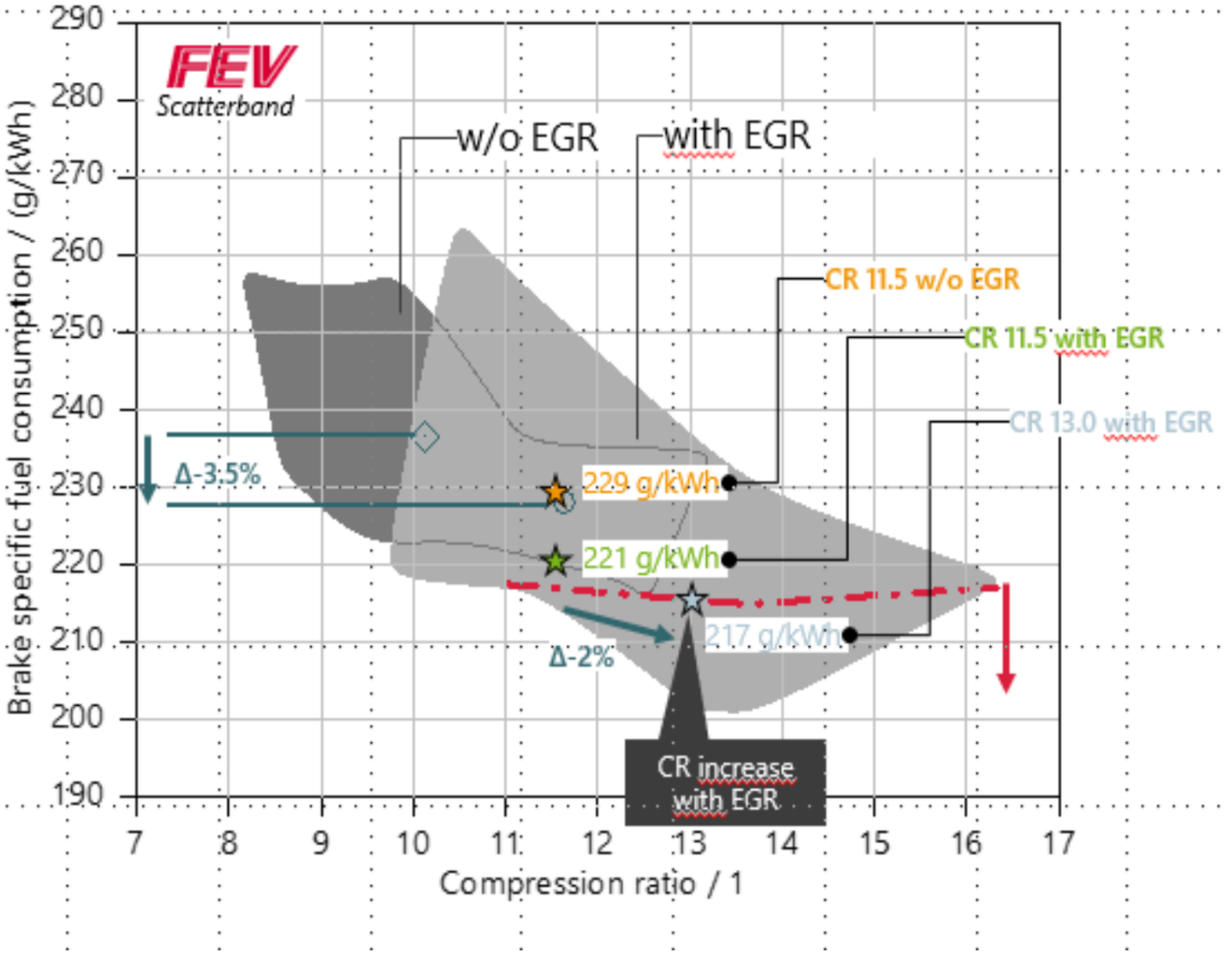
The S415-TC SYTECH engine has

- A capacity of 1.495L
- GDI
- Turbo with Intercooler
- Single overhead CAM
- 4 valves per cylinder
- Fixed valve timing
- No EGR
- 110kW at 4500RPM

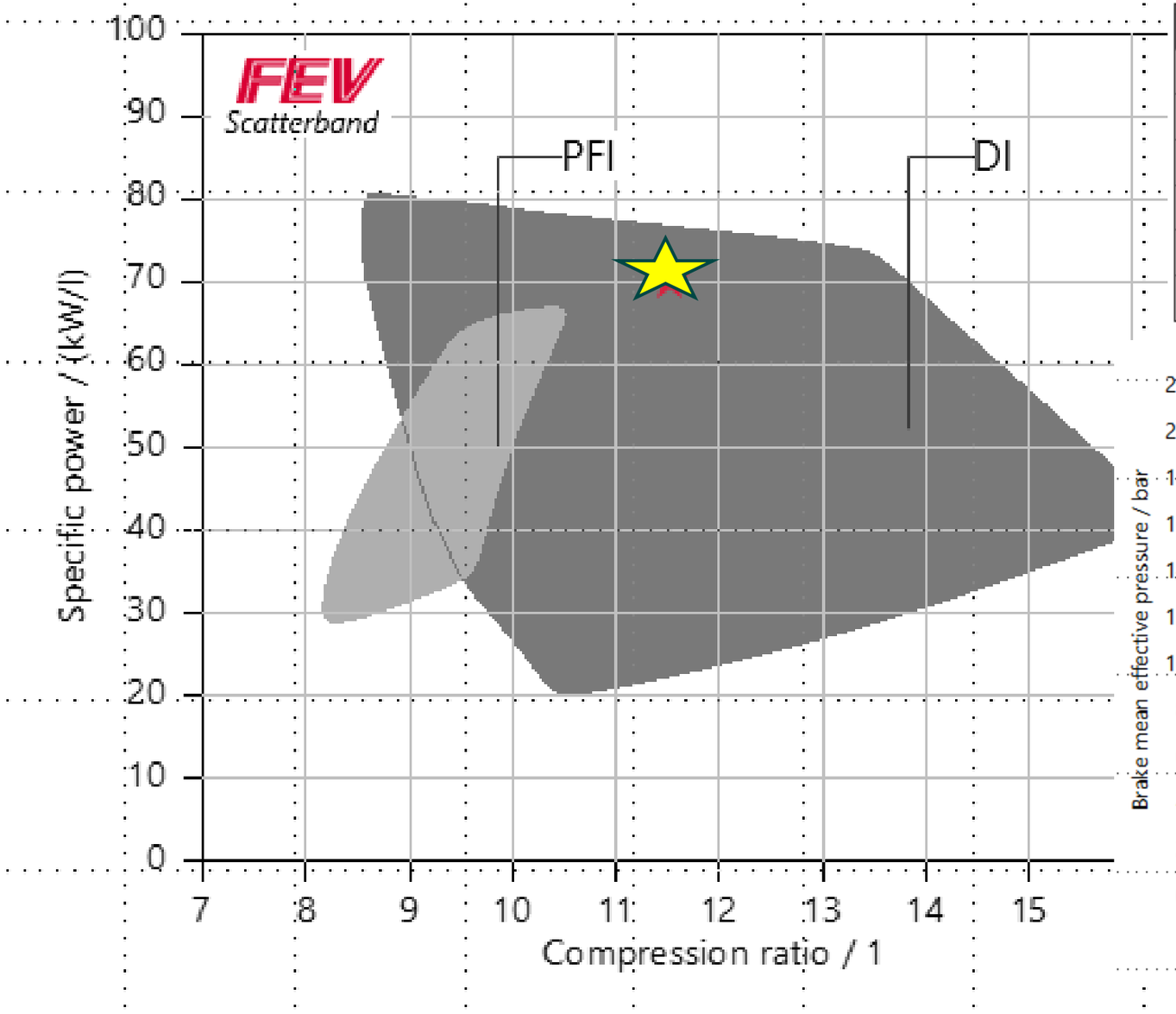


ENGINE PERFORMANCE
Addition of EGR provides an improvement of 3-5%

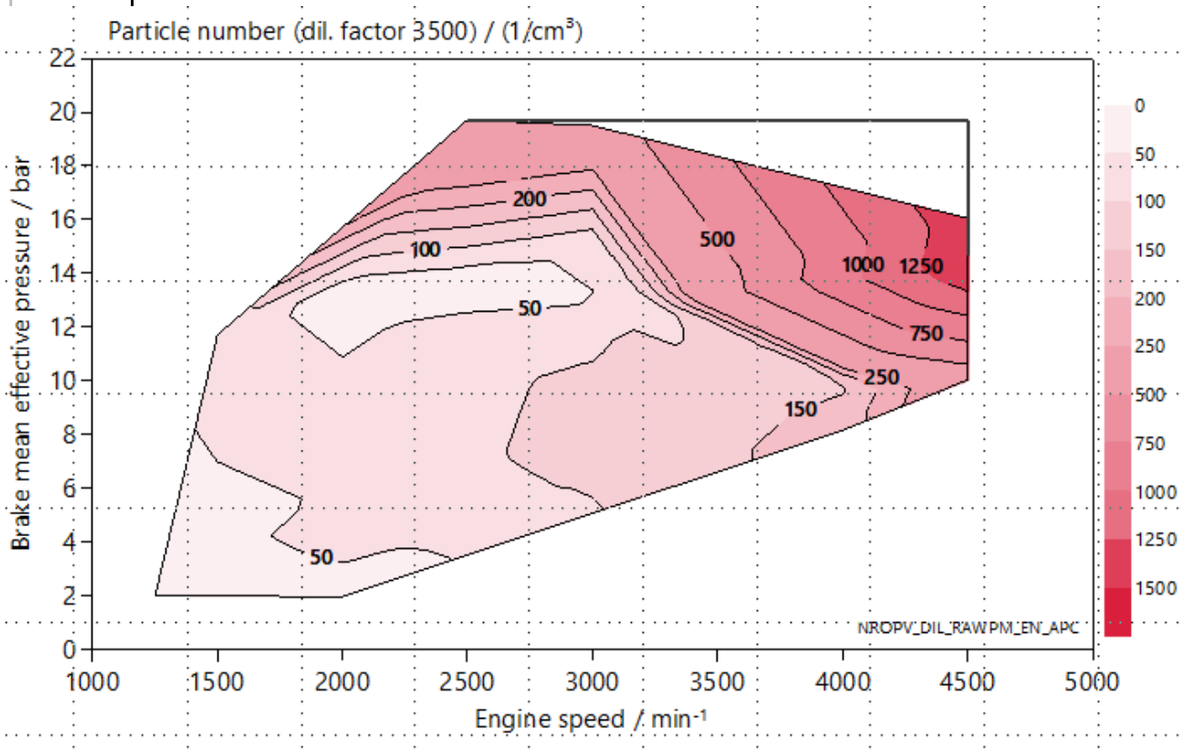




ENGINE PERFORMANCE

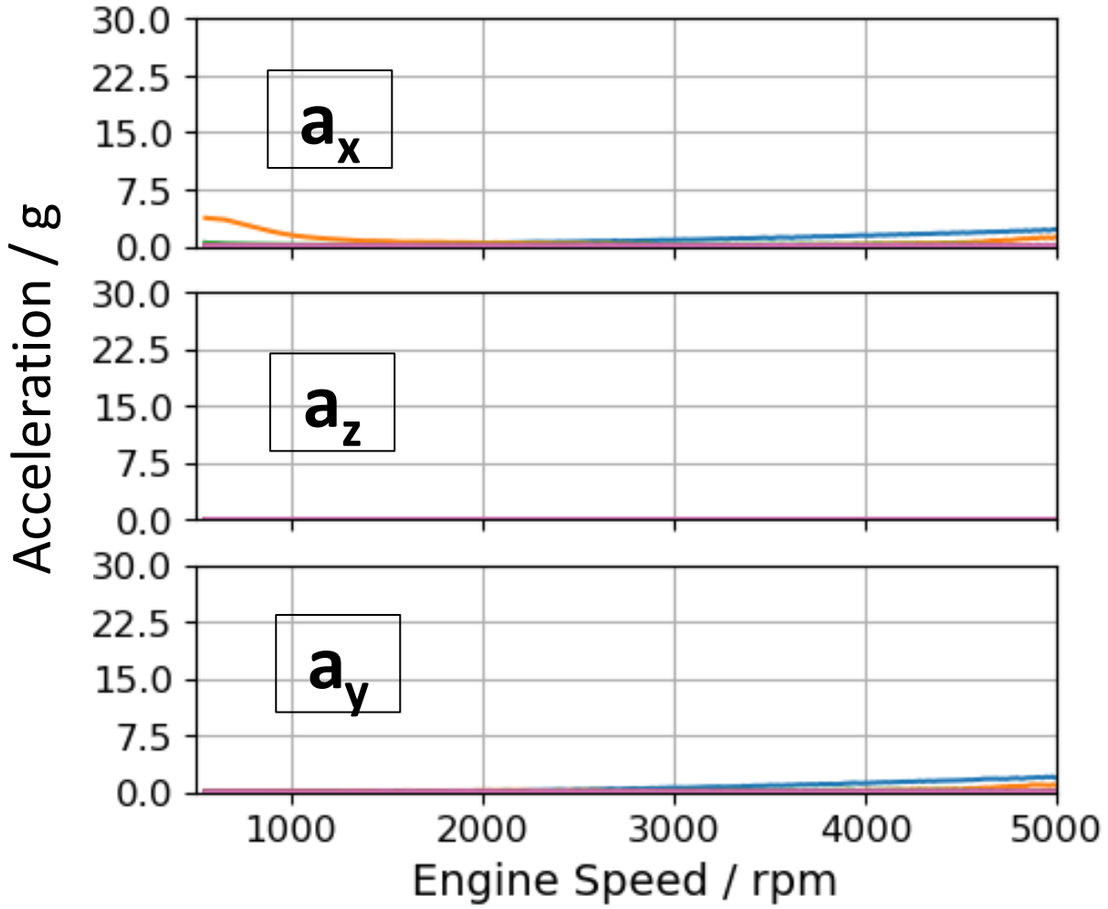


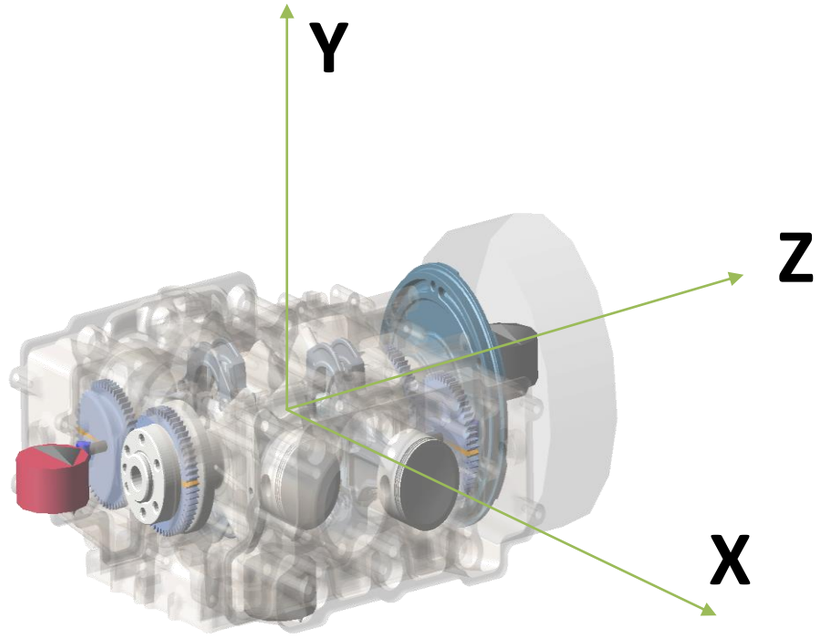
Performance values of SYTECH's S415B-TC engine	
Rated power @ 4500 rpm	110 kW
Peak torque @ 4500 rpm	234 Nm
Specific power output	73 kW/l
Minimum BSFC @ 3500RPM	≤ 229 g/kWh
Emission level	China 6b
Nominal fuel	RON 95



SYTECH S415B-TC Engine Balance
50% crank, 50% Mass balance system

The S415-TC SYTECH engine shows low Imbalance with a combination of 50% crankshaft counterbalance coupled with 50% balance shaft compensation. Very low vertical forces are transmitted to the vehicle structure.
No free mass moments with no 1st order due to mass effects.



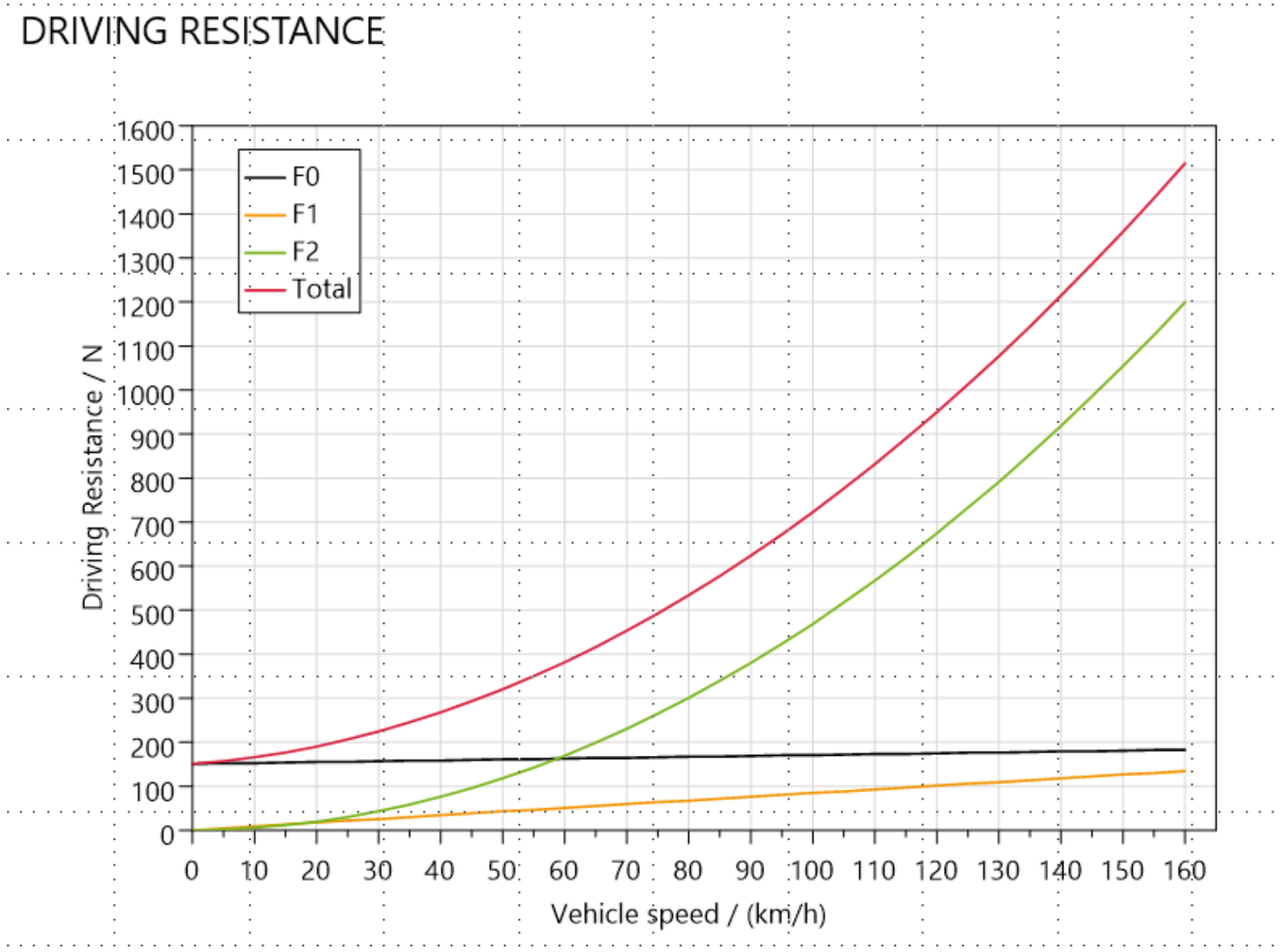


Ixx Ixy Ixz	2.48 X 10^5	-2.83 X 10^0	-1.99 X 10^2
Iyx Iyy Iyz	-2.83 X 10^0	3.32 X 10^5	3.01 X 10^0
Izx Izy Izz	-1.99 X 10^2	3.01 X 10^0	1.16 X 10^5

Inertia Tensor in kg.mm^2

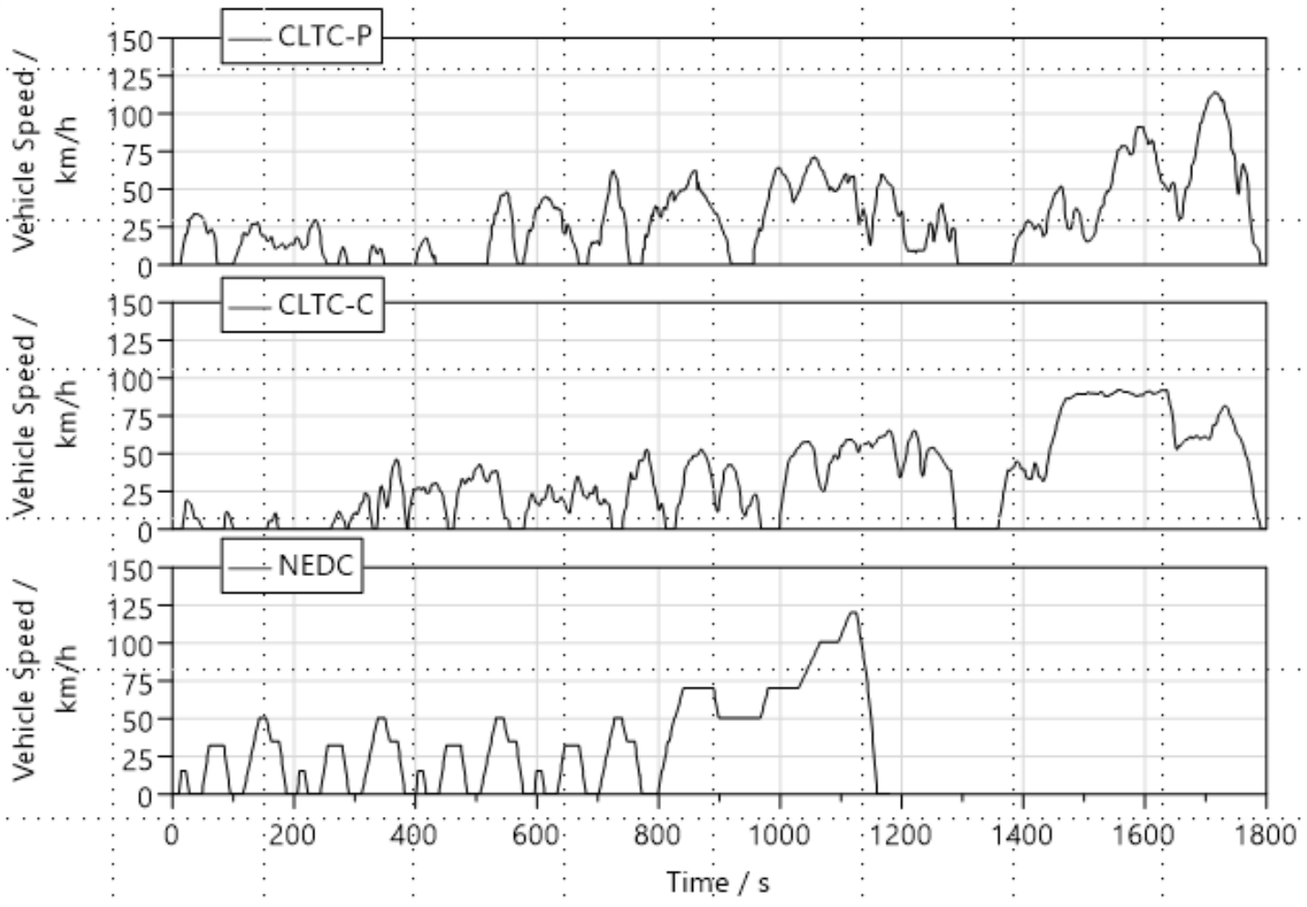
SYTECH S415B-TC Engine
Range Extender Vehicle Modelling with INPUT constraints

The SYTECH S415-TC engine was simulated in a range extender vehicle to determine the expected fuel economy and performance.



Cycle 1 Hybrid（CLTC & NEDC）		
Hybrid vehicle weight for cycle 1	**1580+100**	[kg]
Gross vehicle weight	**2027.5**	[kg]
Coast Down Coefficient F0 cycle 1	150.23	[N]
Coast Down Coefficient F1 cycle 1	0.8381	[N/(kph)]
Coast Down Coefficient F2 cycle 1	0.0468	[N/(kph)^2]
Vehicle mass used for coast-down recording	1915	[kg]

Comparison of the different test cycles shows that CLTC-C and CLTC-P have similar average acceleration and deceleration figures



	CLTC-P	CLTC-C	NEDC
Distance	14.48 km	16.43 km	10.93 km
Average speed (excl. stops)	37.18 km/h	41.25 km/h	43.1 km/h
Maximum speed	114 km/h	92 km/h	120 km/h
Average acceleration	0.45 m/s²	0.47 m/s²	0.506 m/s²
Maximum acceleration	1.47 m/s²	1.36 m/s²	1.042 m/s²
Average deceleration	-0.49 m/s²	-0.48 m/s²	-
Maximum deceleration	-1.47 m/s²	-1.39 m/s²	-

A combined CLTC cycle was used with a minimum SOC of 15%.

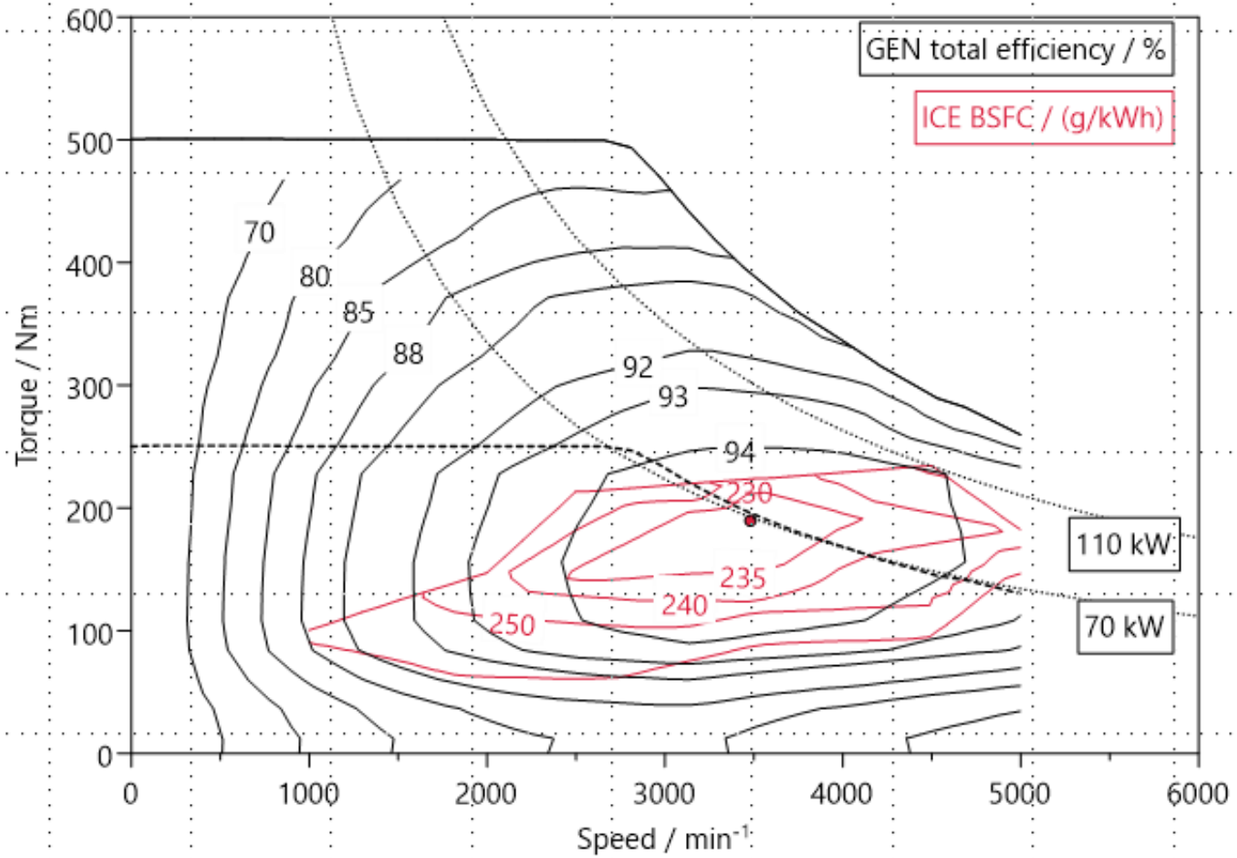
SYTECH S415B-TC Engine
Range Extender Vehicle Modelling

Performance scenario	Target	Further definitions	Required wheel power	Required mech. generator power
0 – 100 km/h acceleration	9 s	▪ Fully charged battery		
AER	100 - 200 km	▪ Fully charged battery		
Top speed	**150 km/h**	▪ **Discharged battery** ▪ **For min. 5 min**	▪ Calculation based on provided coast down data and vehicle weight ▪ Result: **56 kW**	▪ Assumptions: Efficiency EM = 90 %, Efficiency GEN = 90 %, 0.6 kW electrical auxiliary load ▪ Result: **70 kW continuously**
Gradeability 1: Max. speed at 4 % grade	120 km/h	▪ Discharged battery ▪ Not mandatory		
Gradeability 2: Max. speed at 30 % grade	**20 km/h**	▪ **Discharged battery** ▪ **For min. 60 s or 1 km**	▪ Calculation based on provided coast down data and vehicle weight ▪ Result: **33 kW**	▪ Assumptions: Efficiency EM = 90 %, Efficiency GEN = 90 %, 0.6 kW electrical auxiliary load ▪ Result: **41 kW**

GENERATOR SIZING

The generator is designed for a continuous power of 70 kW, which is required for 150 km/h vehicle speed

GENERATOR FOR SYTECH 110 KW 4-CYLINDER TC ENGINE PROPOSED BY FEV

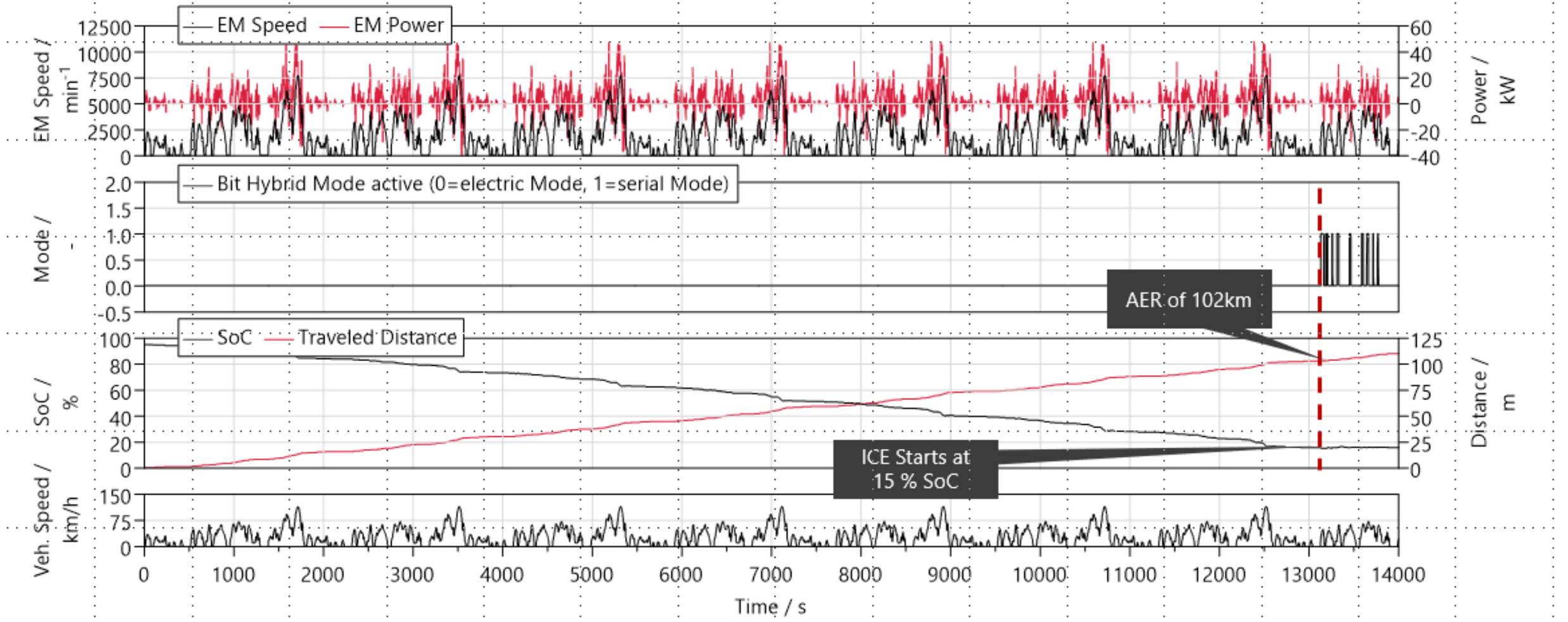


DESCRIPTION

- Consideration of PMSM electric machine
- Approximate generator design with focus on power requirement and optimal match of generator and ICE efficiency. For a detailed definition of all generator specifications, a more detailed analysis would be required
- Assumption of 50 % continuous torque to peak torque ratio (typical for PMSM machines)
- With this layout, the generator can provide just enough electrical power continuously, so that the vehicle can run 150 km/h continuously
- This generator layout is considered for the simulation study

CLTC-P charge depletion simulation results in an all-electric range of 102 km

CLTC-P PERFORMED 8 TIMES



Calculation of combined fuel consumption for investigated vehicle – ICE firstly started in 1st phase of 8th CLTC-P

CHARGE DEPLETION MODE

CHARGE SUSTAINING MODE

SIMULATION RESULTS	CLTC-P 1			CLTC-P 2			CLTC-P 3			CLTC-P 4			CLTC-P 5			CLTC-P 6			CLTC-P 7			CLTC-P 8			CLTC-P 10		
Phase j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	28	29	30
Distance d_j	2.5	5.9	6.1	2.5	5.9	6.1	2.5	5.9	6.1	2.5	5.9	6.1	2.5	5.9	6.1	2.5	5.9	6.1	2.5	5.9	6.1	2.5	5.9	6.1	2.5	5.9	6.1
Fuel cons./ (l/100km)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	4.8	6.9	4.1	5.1	6.7

STABILIZATION

FUEL CONSUMPTION CHARGE SUSTAINING MODE:

$$\frac{4.138\ \text{L/100KM} \times 2.453\ \text{KM} + 5.061\ \text{L/100KM} \times 5.906\ \text{KM} + 6.686\ \text{L/100KM} \times 6.123\ \text{KM}}{2.453\ \text{KM} + 5.906\ \text{KM} + 6.123\ \text{KM}} = 5.592\ \text{L/100KM}$$

FUEL CONSUMPTION CHARGE DEPLETION MODE:

$$\frac{0.00568 \times 4.046\ \text{L/100KM} + 0.01278 \times 4.857\ \text{L/100KM} + 0.01207 \times 6.932\ \text{L/100KM}}{0.8257} = 0.204\ \text{L/100KM}$$

COMBINED FUEL CONSUMPTION:

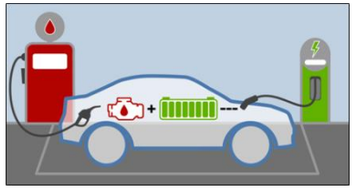
$FC_{COMBINED} = (1 - UF_{CYCLE}) \times FC_{CS} + UF_{CYCLE} \times FC_{CD} = 1.14\ \text{L/100KM}$

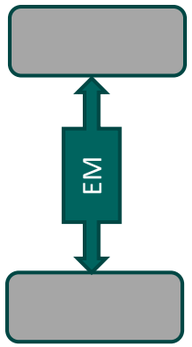
WITH: $UF_{CYCLE} = 0.8257$

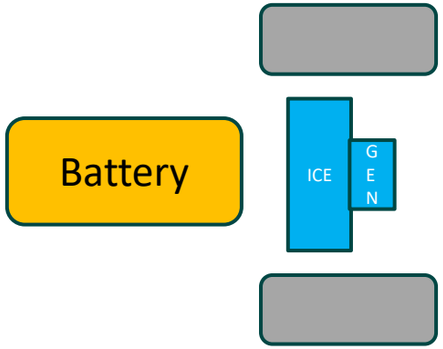
PHASE 24

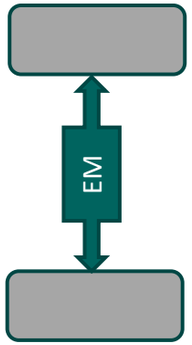
VEHICLE INSTALLATION OPTIONS

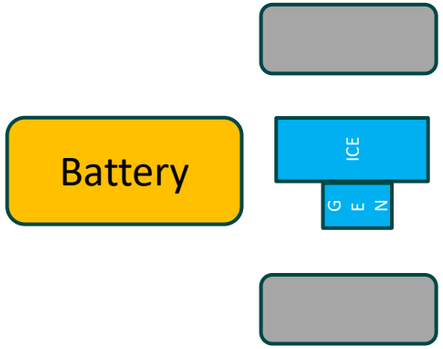
- The shape and size of the SYTECH engine package means that it can be placed in areas of the vehicle that other engines cannot.

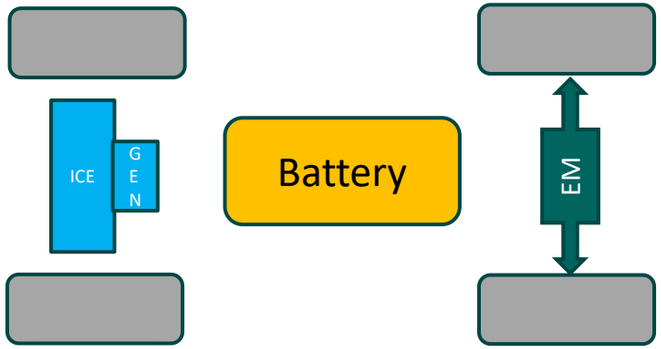


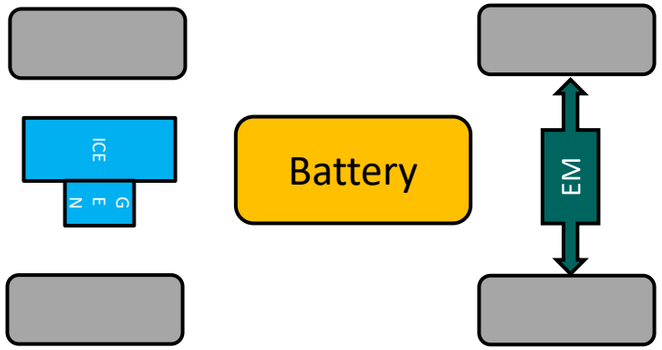


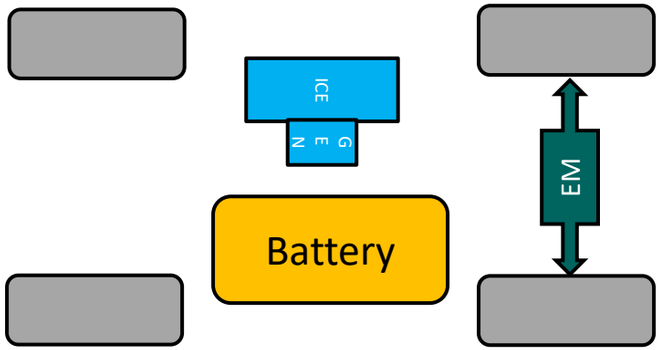












Low centre of gravity improves lateral and dynamic stability of the vehicle
Perfect for MOOSE test conditions

ALTERNATIVE FUEL READINESS

POWER COMPARISON OF THE SYTECH ENGINE RUNNING ON ALTERNATIVE FUELS TO GASOLINE

If a fuel other than Gasoline is used in the SYTECH engine, a difference in maximum power can be expected.
The table below shows the predicted engine power of alternative fuels compared with gasoline SYTECH engines.

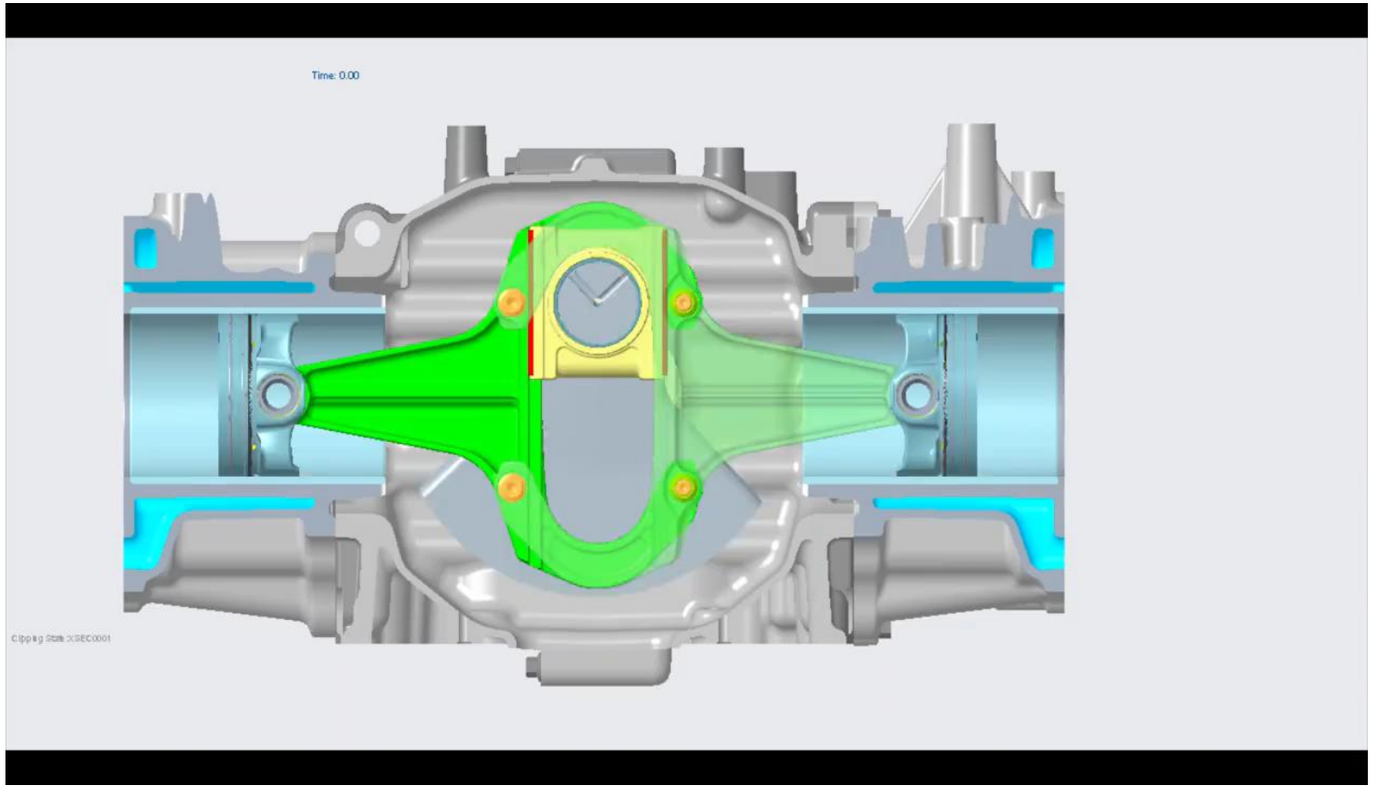
PREDICTED POWER (kW)						
GASOLINE SYTECH ENGINES		HYDROGEN (LP gas)[a]	HYDROGEN (HP gas)[b]	LPG (liquid)[c]	LPG (gas)[d]	CNG (gas)[e]
S415TC (DI)	**110**	90	121	108	98	93
S415NA (MPFI)	**60**	50	68*	65	56	54
S208TC (DI)	**50**	41	55	49	45	43
S208NA (MPFI)	**27**	23	31*	29	25	24

ASSUMPTIONS: Assume no design change of the gasoline engine, i.e. gasoline compression ratio.

[a] Low pressure Hydrogen gas MPFI
[b] High pressure Hydrogen gas DI, (* Hydrogen DI conversion on a MPFI engine)
[C] Liquid propane injection MPFI
[d] Gas propane injection MPFI
[e] Compressed natural gas MPFI

Summary and Conclusion

- The new S415B-TC engine is well-suited to Range Extended Vehicles and uses many common parts across the family of engines to reduce Parts costs, Tooling costs, Manufacturing costs, Assembly tooling.
- The SYTECH engine has very good NVH with no 1st order vibration.
- Due to its dimensions, the SYTECH engine can be fitted to vehicles in many positions
- The SYTECH engine performs better than many of its competitors and with the addition of VVT, EGR and other technologies, the SYTECH engine performance can be further improved



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Thank You!