IMPROVEMENTS OF FUEL CONSUMPTION & EFFICIENCY - **HYBRID PROPULSION VEHICLES (PART 1)**

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CARBON FOOTPRINT GAS EMISSIONS

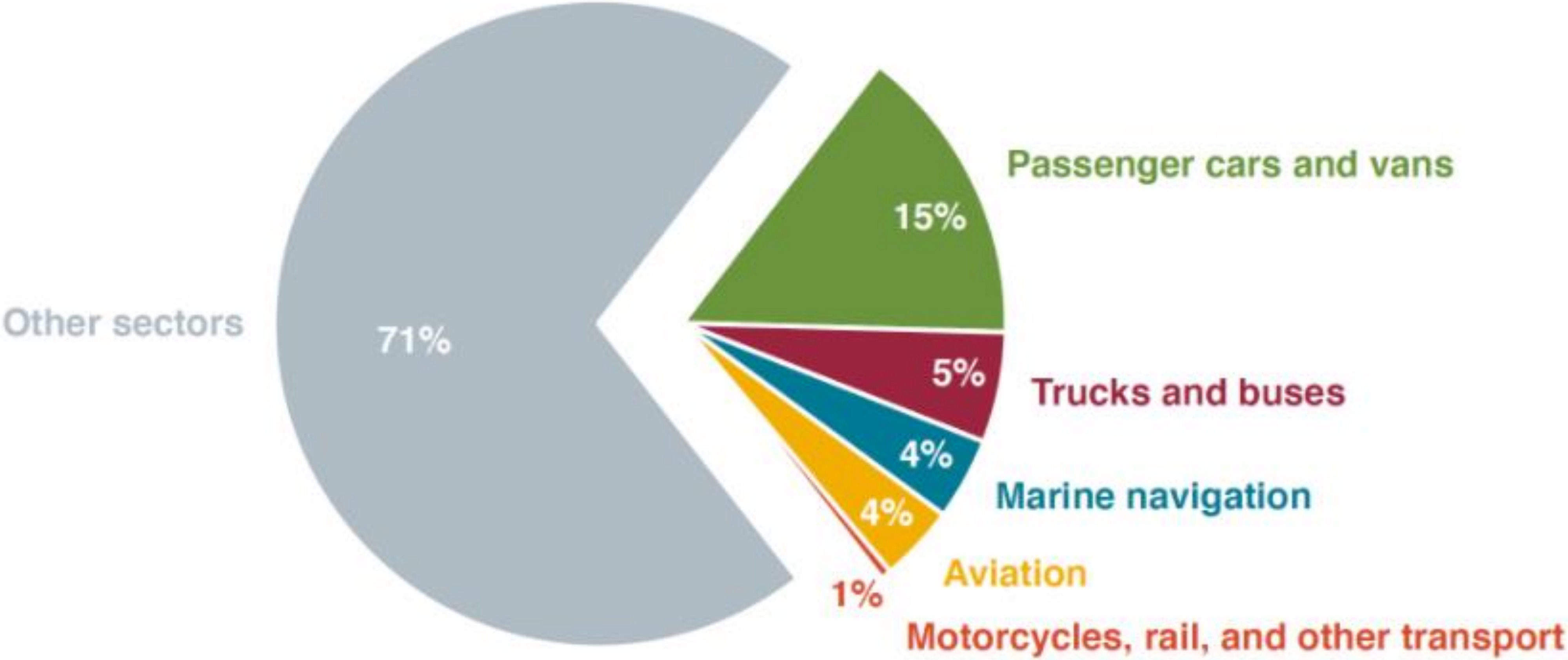


Figure 1. Share of EU-27 economy-wide greenhouse gas emissions in 2018 by transport subsector, including domestic and international components. Land use, land-use change, and forestry are included in the other sectors category.

AGENDA

EUROPEAN EMISSIONS STANDARDS

ENERGY CONSUMPTION ANALYSIS

BSFC / ENGINE MAP

DRIVING CYCLES

HYBRID CONFIGURATIONS

SERIES VS. PARALLEL

EURO 6

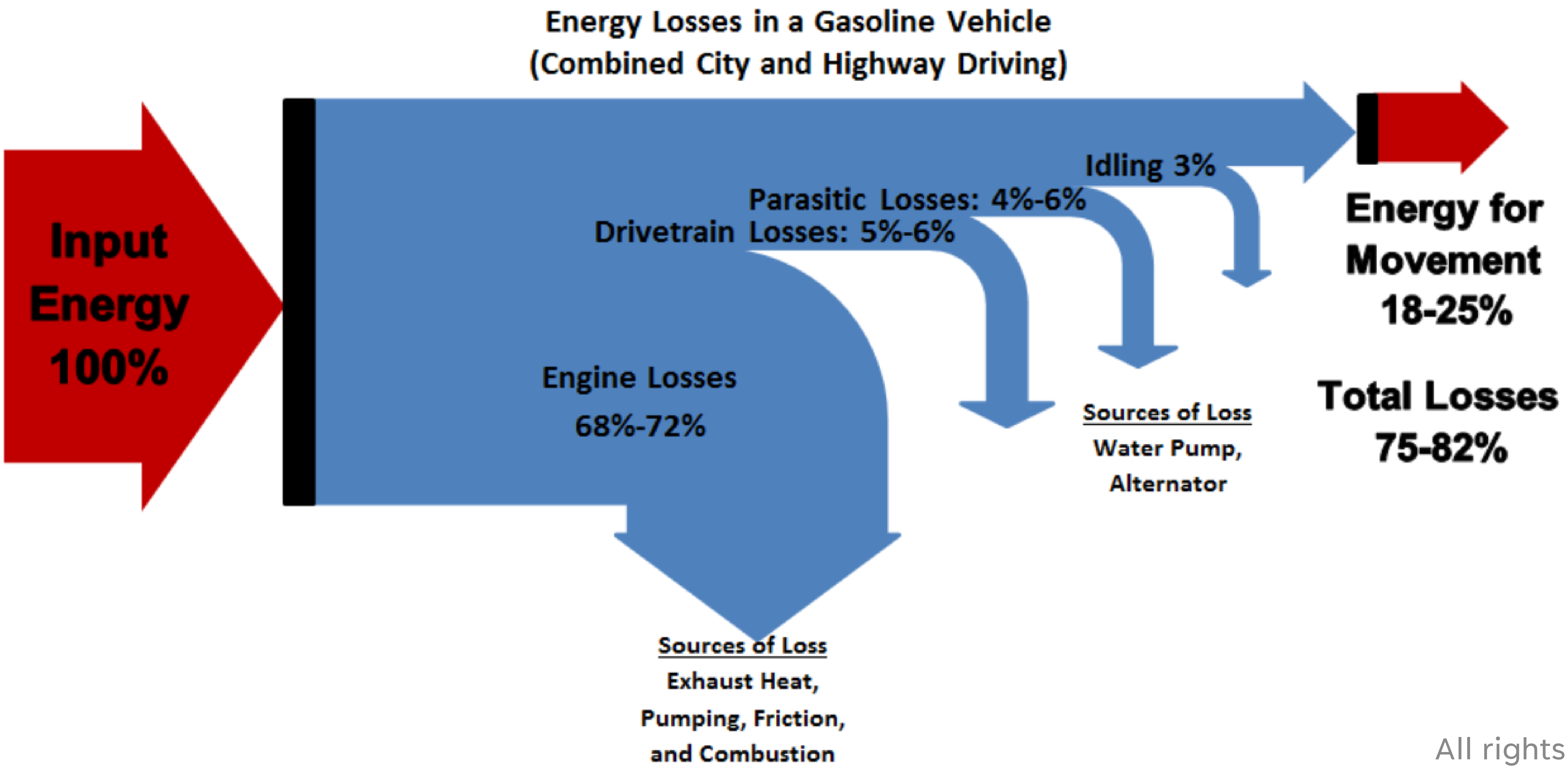
Euro 6 standards for petrol engines

•Carbon monoxide:	1.0g/km
•Total hydrocarbon :	0.10g/km
•Nonmethane hydrocarbon :	0.068g/km
•Nitrogen oxides:	0.06g/km
•Particulate matter:	0.005g/km
•CO_2 emissions	98g/km

Euro 6 standards for diesel engines

•Carbon monoxide:	0.50g/km
•Hydrocarbons and Nitrogen oxides:	0.17g/km
•Nitrogen oxides:	0.08g/km
•Particulate matter:	0.005g/km
•CO_2 emissions	98g/km

ENERGY CONSUMPTION ANALYSIS OF CONVENTIONAL VEHICLES



ENERGY CONSUMPTION ANALYSIS OF CONVENTIONAL VEHICLES

Source	Energy density [MJ/kg]
Lead acid batteries	0.0792
Nickel cadmium (NiCad) batteries	0.158
Lithium ion batteries	0.468
Lithium sulfur batteries	0.792
Methanol combustion	22.7
Ethanol combustion	30.5
Heating oil combustion	42.5
Diesel combustion	45.3
Gasoline combustion	45.8
n-Octane combustion	48.2
n-Butane combustion	49.6
Propane combustion	50.3
Methane combustion	55.5
Hydrogen combustion	142

ENERGY CONSUMPTION ANALYSIS OF CONVENTIONAL VEHICLES

$$1\ liter \cong 10\ km$$

$$\Rightarrow \quad \mathbf{1\ kg \cong 15\ km}$$

$$1\ liter \cong 700\ gr$$

$$1\ kwh \cong 5\ km$$

$$(200\ wh \cong 1\ km)$$

$$\Rightarrow \quad \mathbf{1\ kg \cong 1\ km}$$

$$200\ wh \cong 1\ kg$$

$$bsfc$$

Brake specific fuel consumption is a parameter that reflects the efficiency of a combustion engine which burns fuel and produces rotational power (at the shaft or crankshaft)

ICE MAP

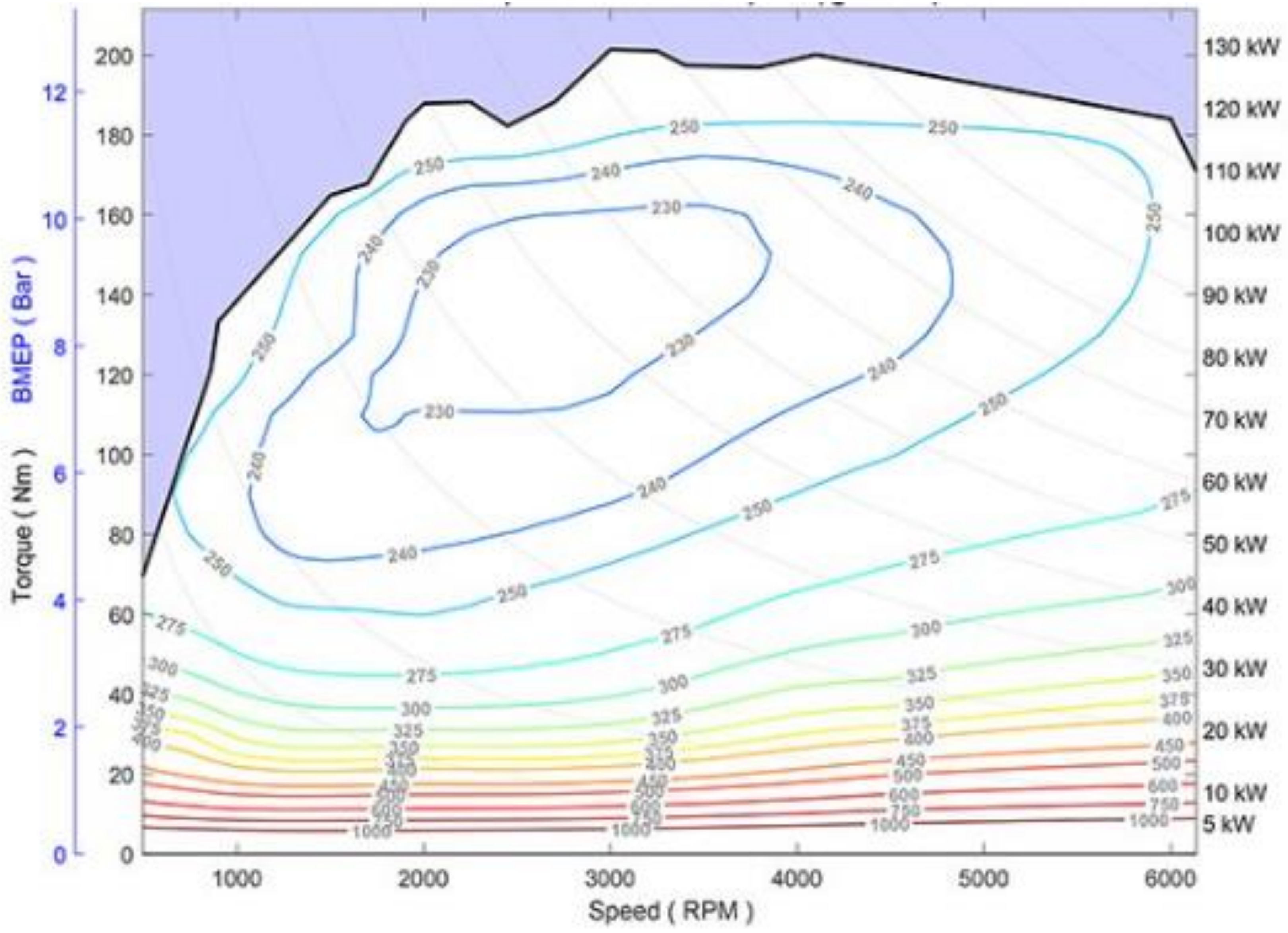


Fig. 3.6. Efficiency conto
with an EPA Tier 2 fuel.

ICE MAP - v increases at constant partial pressure

- ↑ f_mep
- ↑ η_{comb} (↑ *burning velocity*)
- ↑ h *(convection coefficient.)*
- ↑ *comb duration, deg*
- ↓ *heat losses/cycle*
- ↓ *pumping losses*

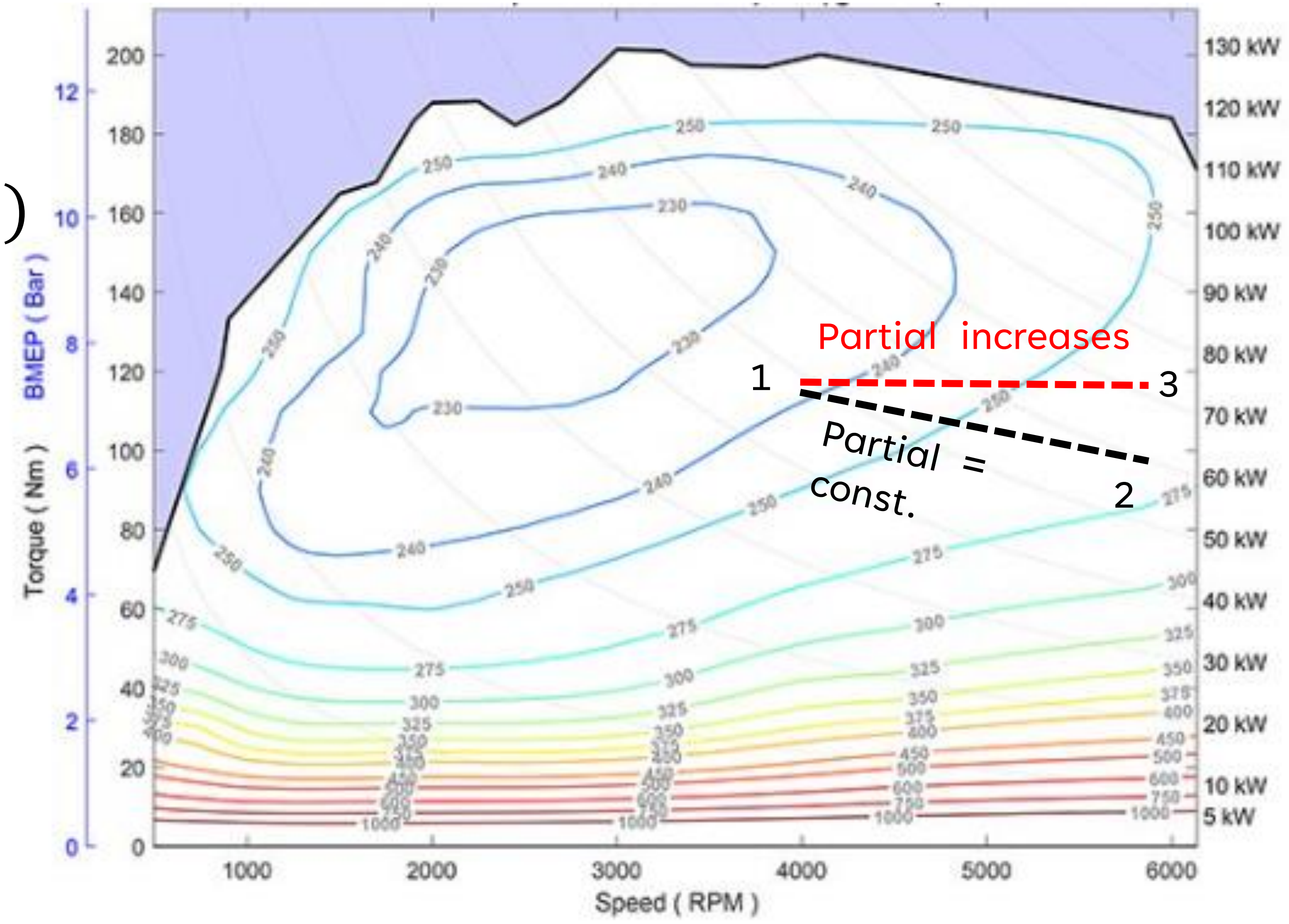


Fig. 3.6. Efficiency contours of Honda 1.5 L turbocharged engine when tested with an EPA Tier 2 fuel.

PARAMETERS AFFECT $\boldsymbol{bsfc}$

$$\boldsymbol{bsfc} = f\left(n_v, n_m, n_{comb}, w_{loss}, r_c, T, P, RH, ign, N, valve, \frac{A}{F} \ldots\right)$$

PARAMETERS AFFECT $\boldsymbol{bsfc}$

$$\boldsymbol{bsfc} = f\left(n_v, n_m, n_{comb}, w_{loss}, r_c, T, P, RH, ign, N, valve, \frac{A}{F} \ldots\right)$$

$$\frac{1}{bsfc \cdot E_{fuel}} \cdot 100\% = \%\ efficiency$$

$$\frac{1}{0.24\ kG/kWh \cdot 11.8\ kWh/kG} \cdot 100\% = 35\%$$

UDDS URBAN DYNAMOMETER DRIVING CYCLES

The cycle simulates an urban route of 7.5 mi (12.07 km) with frequent stops. The maximum speed is 56.7 mph (91.25 km/h) and the average speed is 19.6 mph (31.5 km/h).

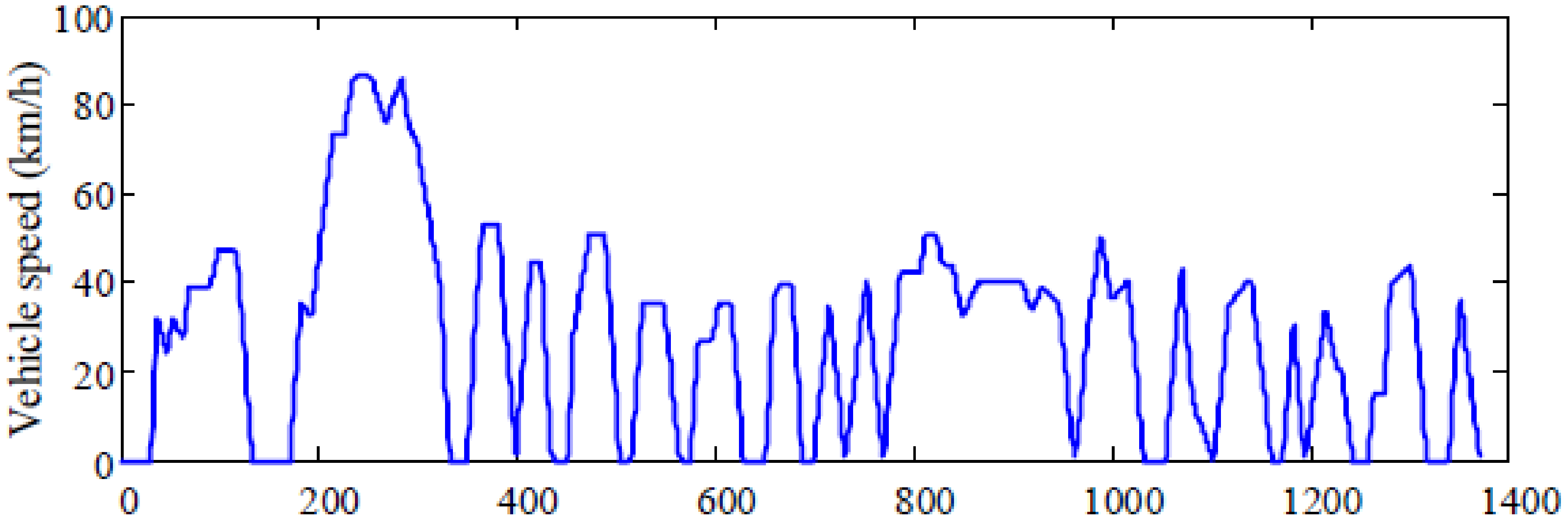


Figure 1.1 Speed profile of UDDS driving schedule

ICE MAP

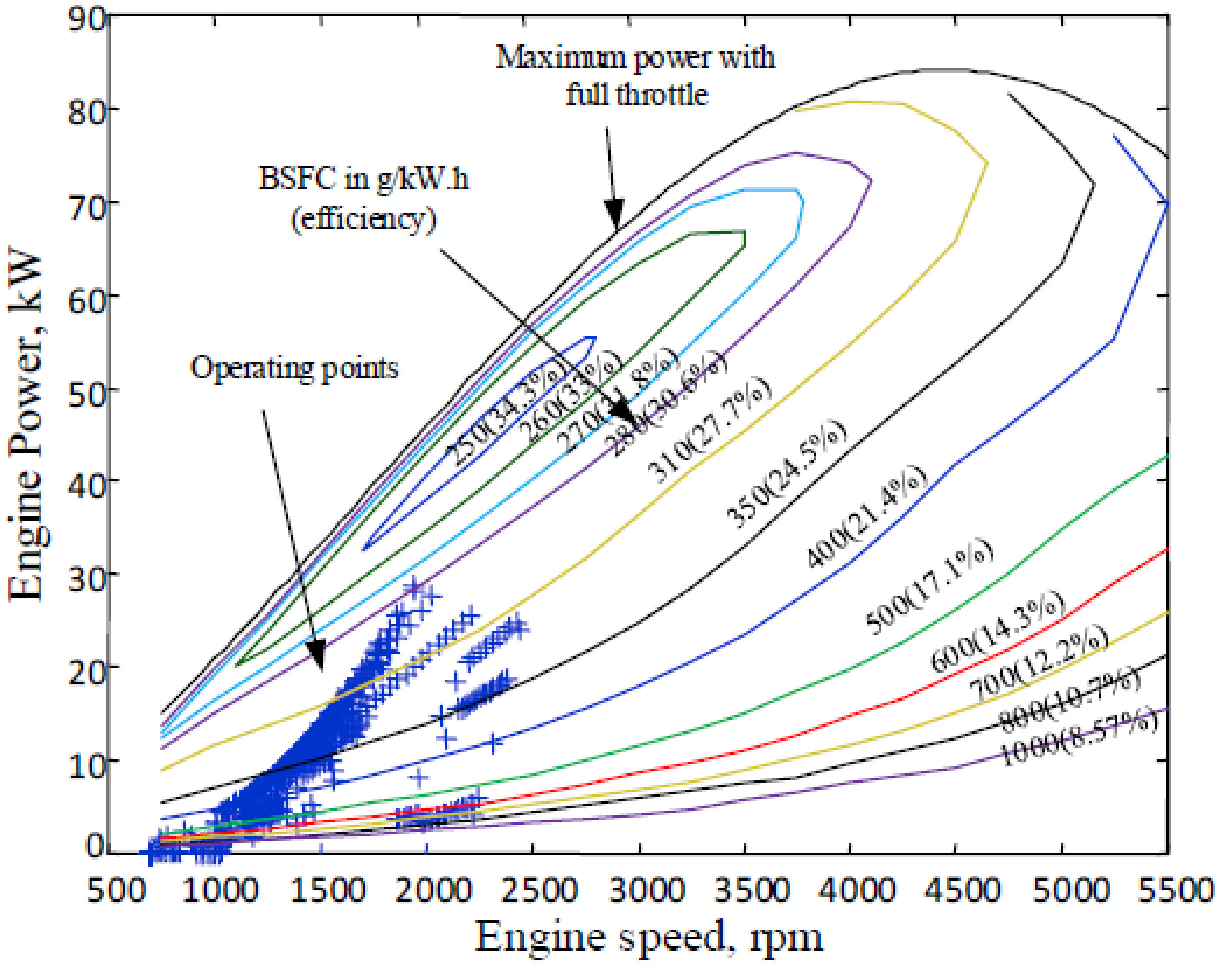
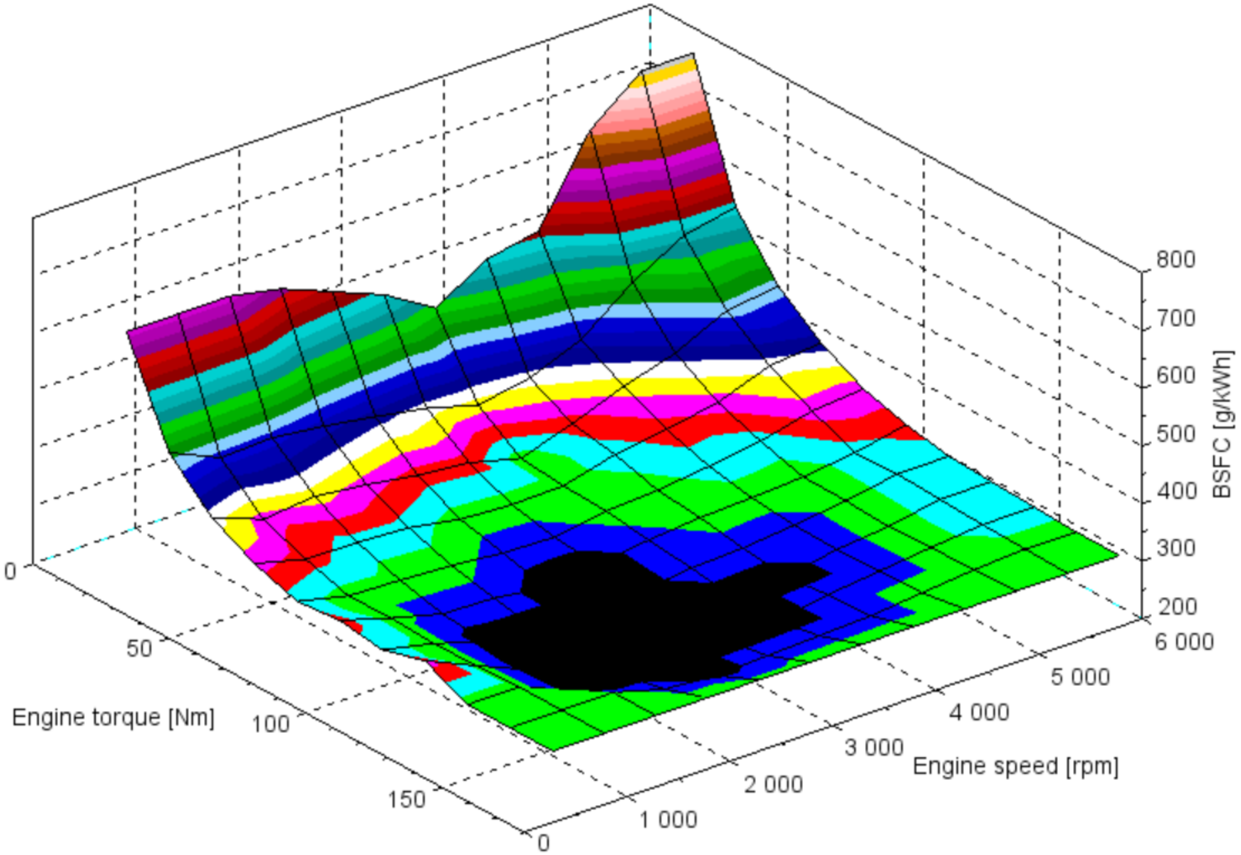
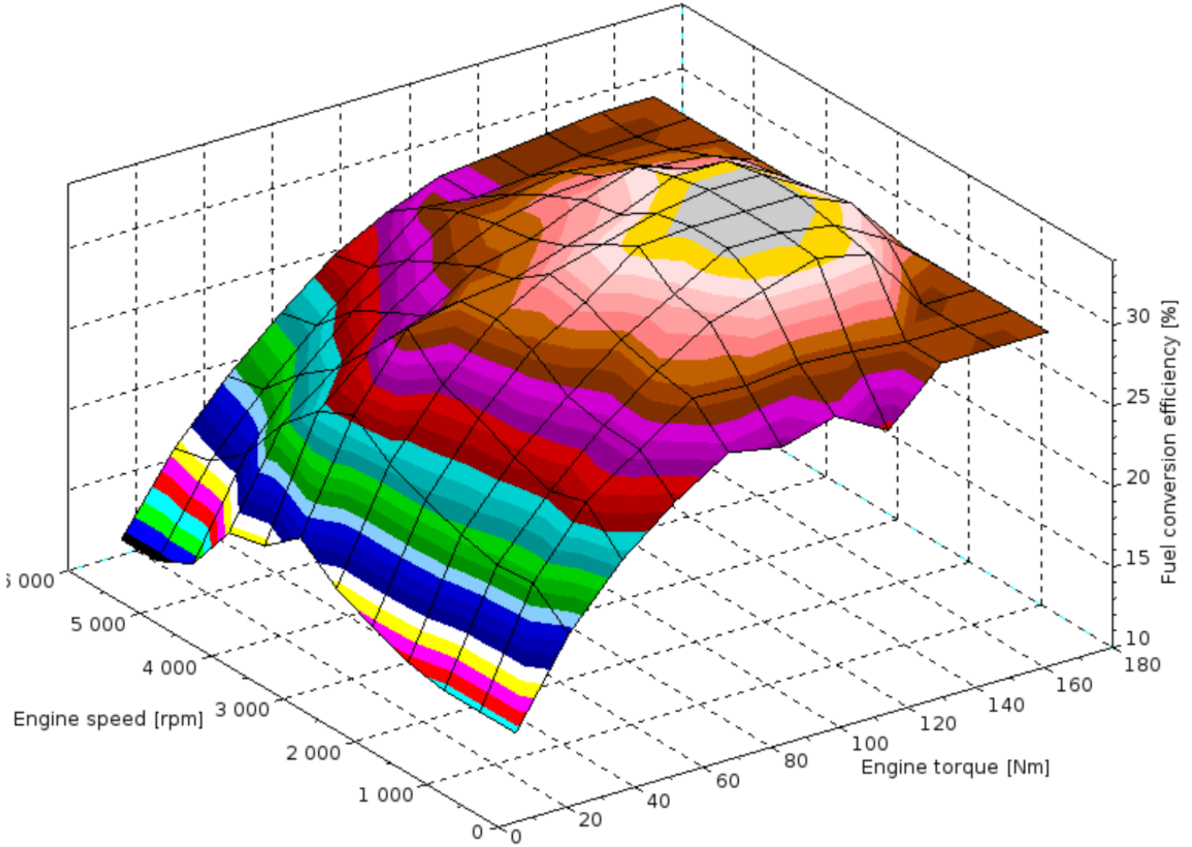
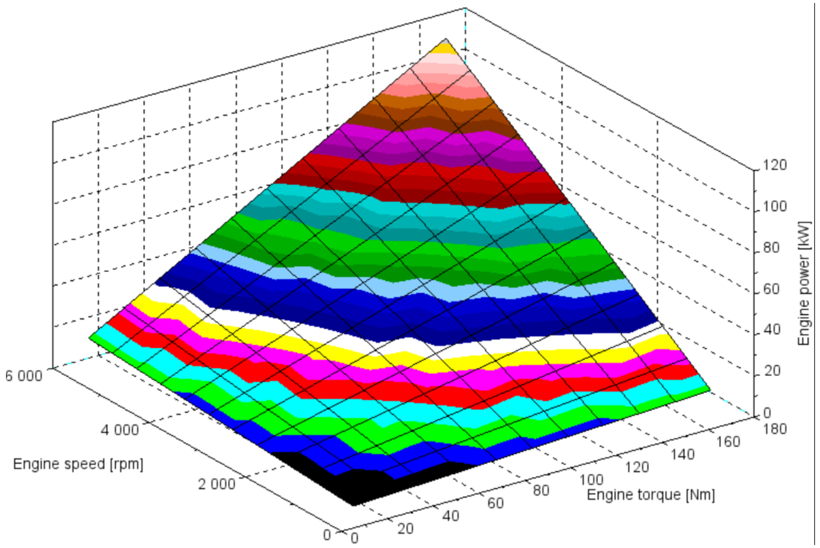


Figure 1.3 Engine operation points under UDDS driving cycle


BSFC [g/kWh]
800
700
600
500
400
300
200
0
50
100
150
Engine torque [Nm]
0
1 000
2 000
3 000
4 000
5 000
6 000
Engine speed [rpm]


Fuel conversion efficiency [%]
30
25
20
15
10
Engine speed [rpm]
5 000
4 000
3 000
2 000
1 000
0
Engine torque [Nm]
0
20
40
60
80
100
120
140
160
180


Engine power [kW]
120
100
80
60
40
20
0
Engine speed [rpm]
6 000
4 000
2 000
0
Engine torque [Nm]
0
20
40
60
80
100
120
140
160
180

FIRST ELECTRIC VEHICLE

HYBRID CONFIGURATION

1. Series
2. Parallel
3. Series - Parallel

SYSTEM ARCHITECTURE OF SERIES HYBRID DRIVETRAIN

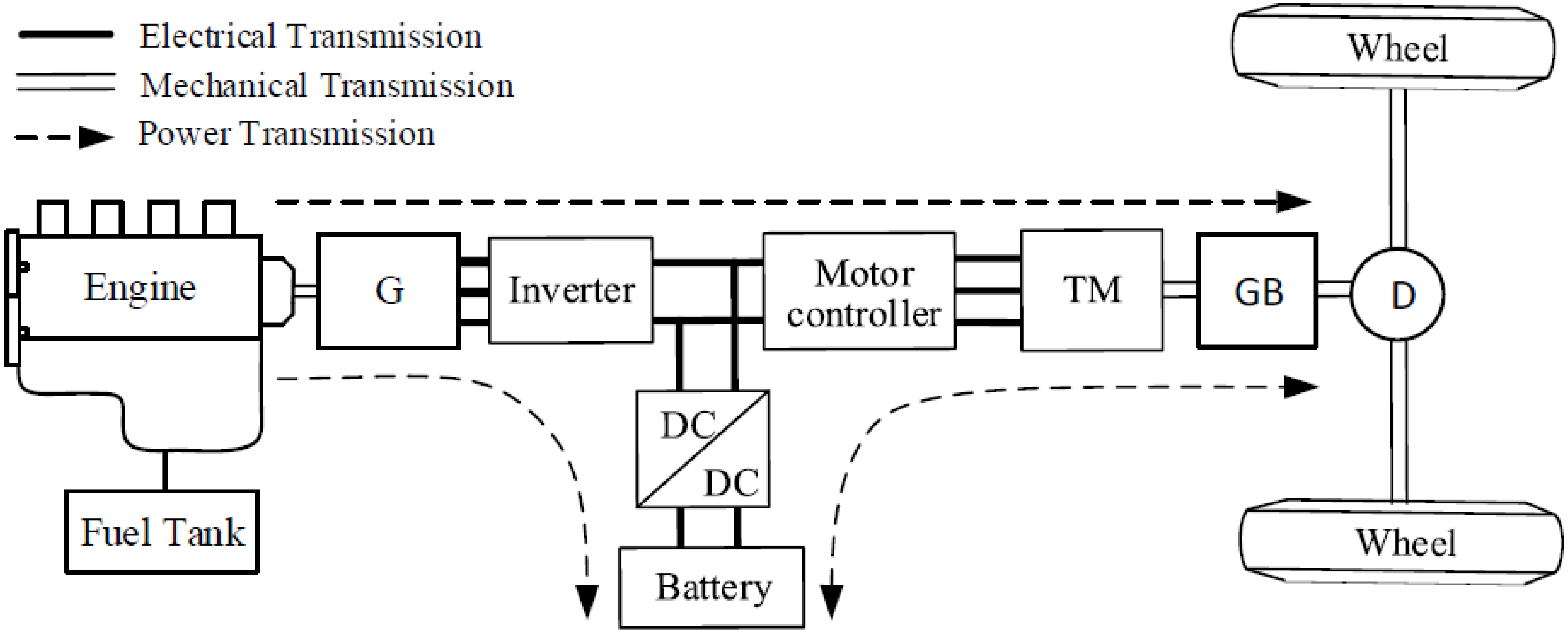


Figure 1.7 System architecture of series hybrid drivetrain

SYSTEM ARCHITECTURE OF SERIES HYBRID DRIVETRAIN

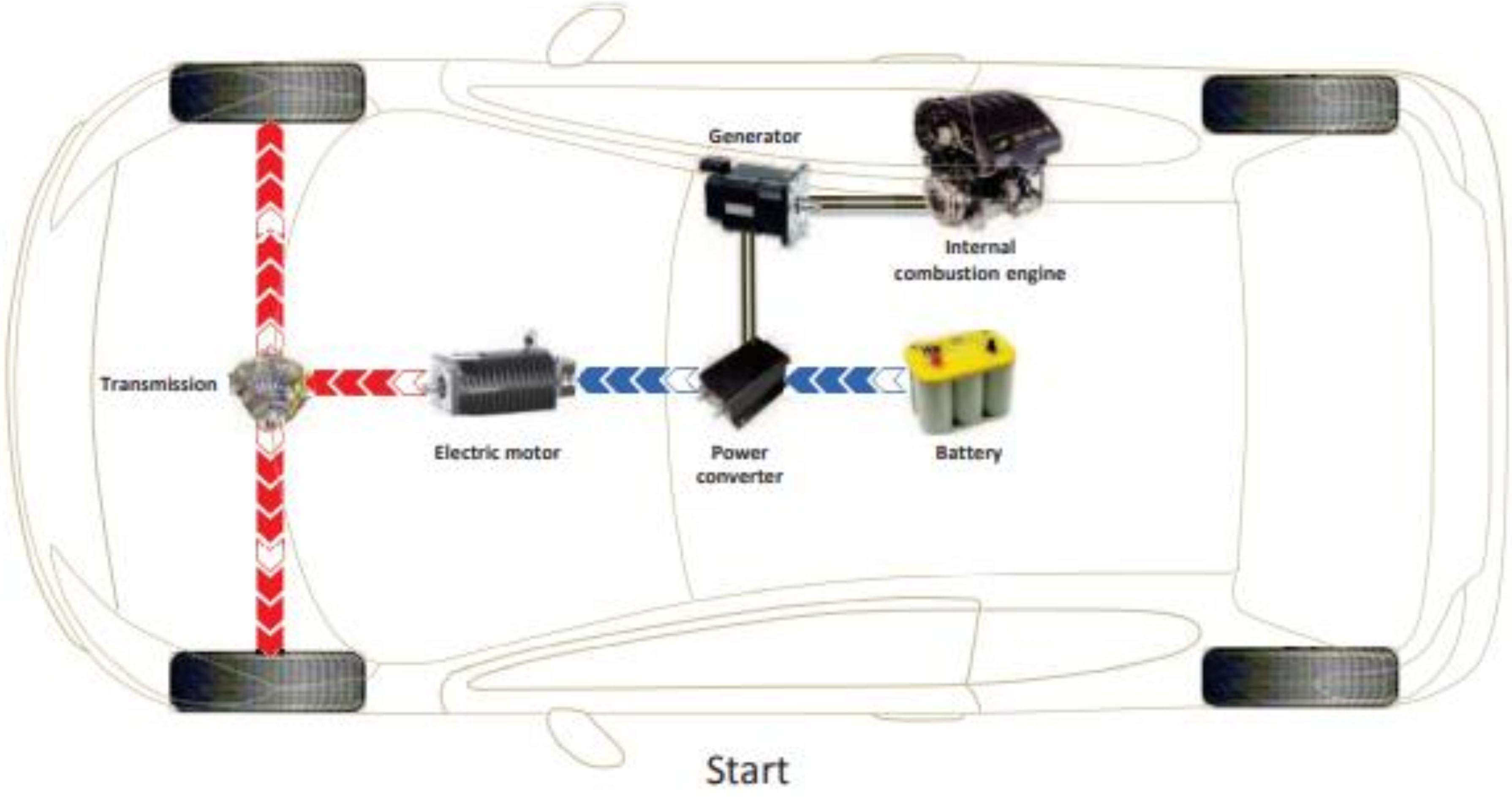


FIGURE 8. Series hybrid electric vehicle

SYSTEM ARCHITECTURE OF SERIES HYBRID DRIVETRAIN

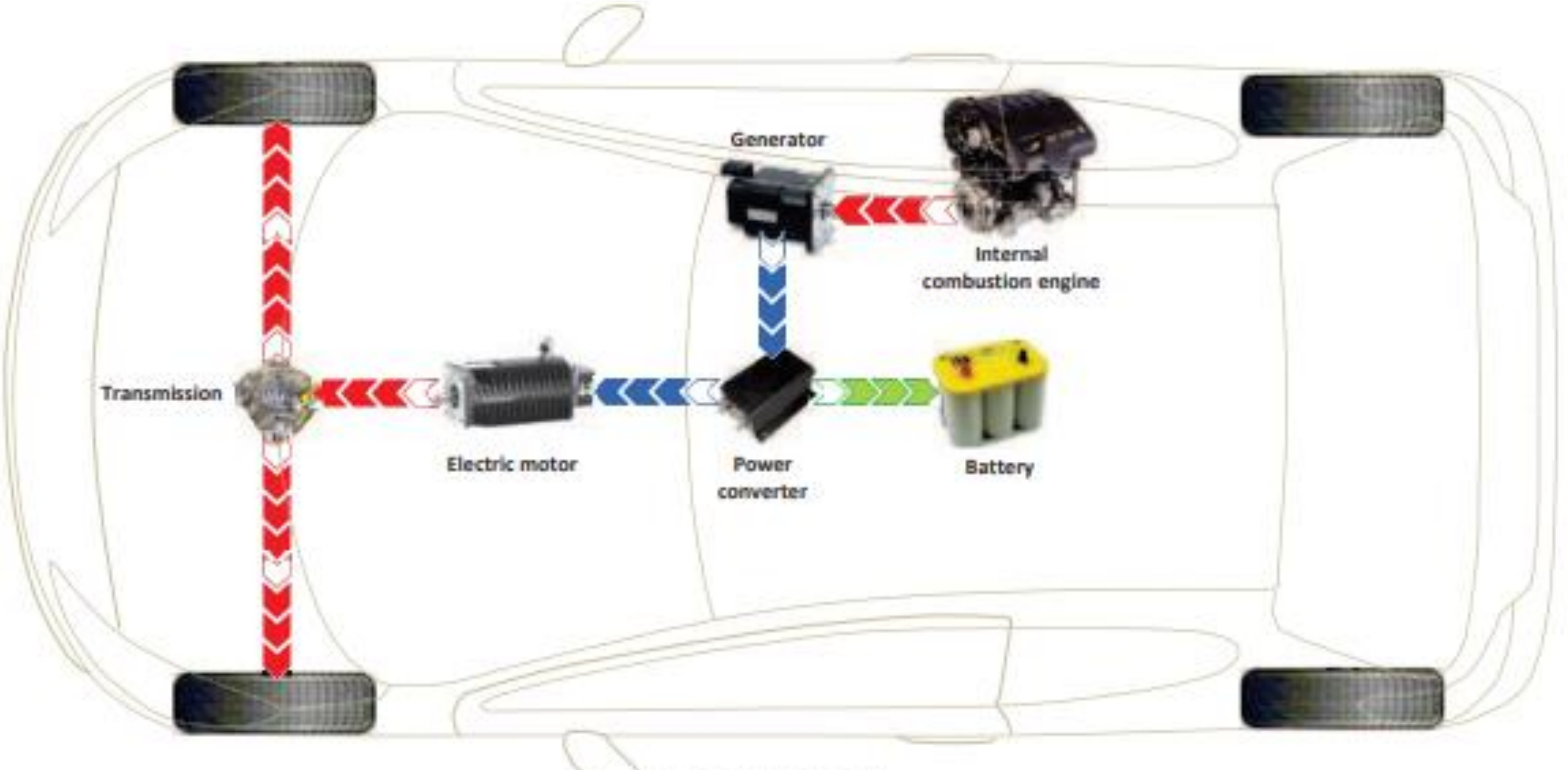


FIGURE 8. Series hybrid electric vehicle

SYSTEM ARCHITECTURE OF SERIES HYBRID DRIVETRAIN

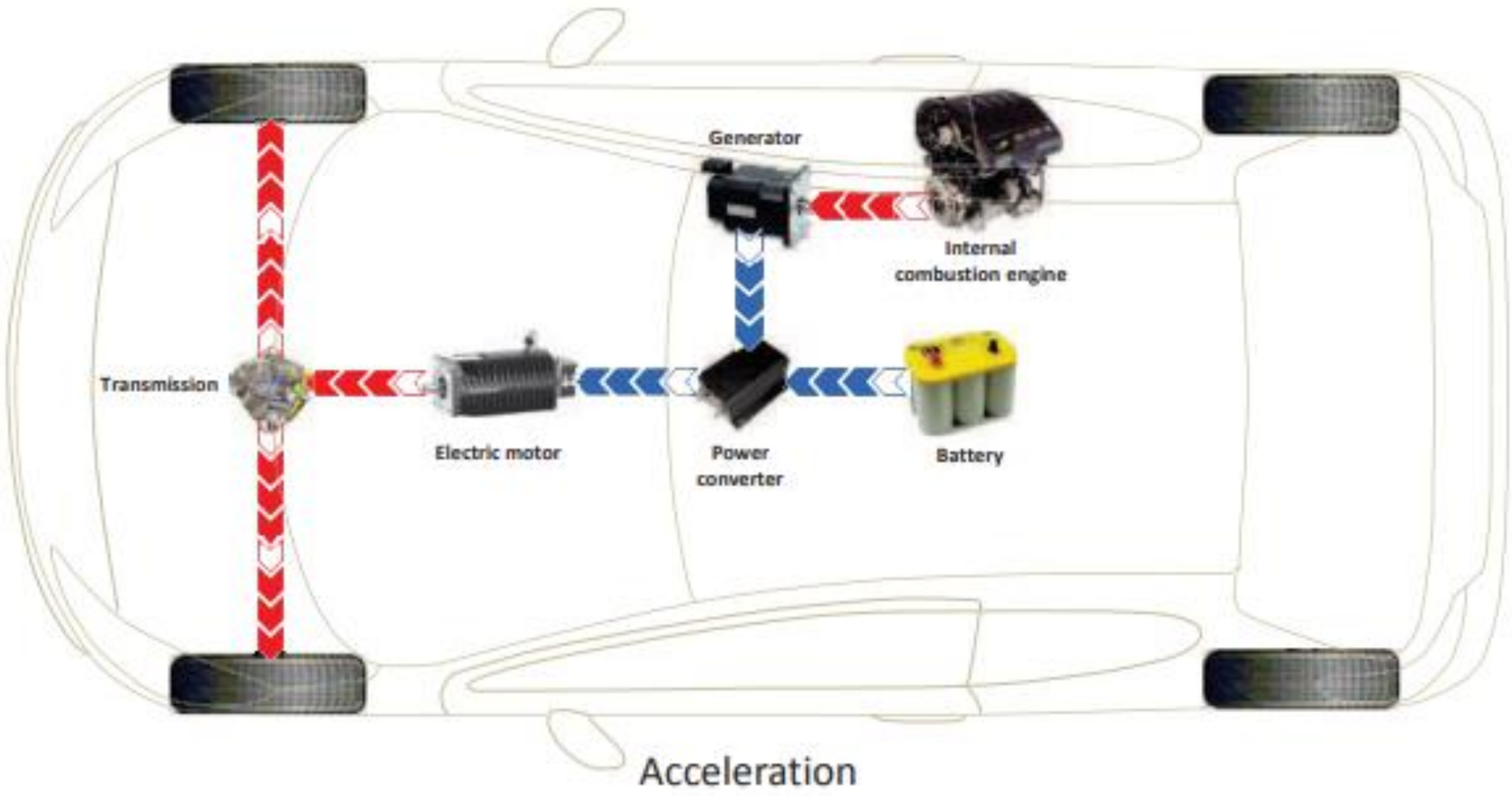


FIGURE 8. Series hybrid electric vehicle

SYSTEM ARCHITECTURE OF SERIES HYBRID DRIVETRAIN

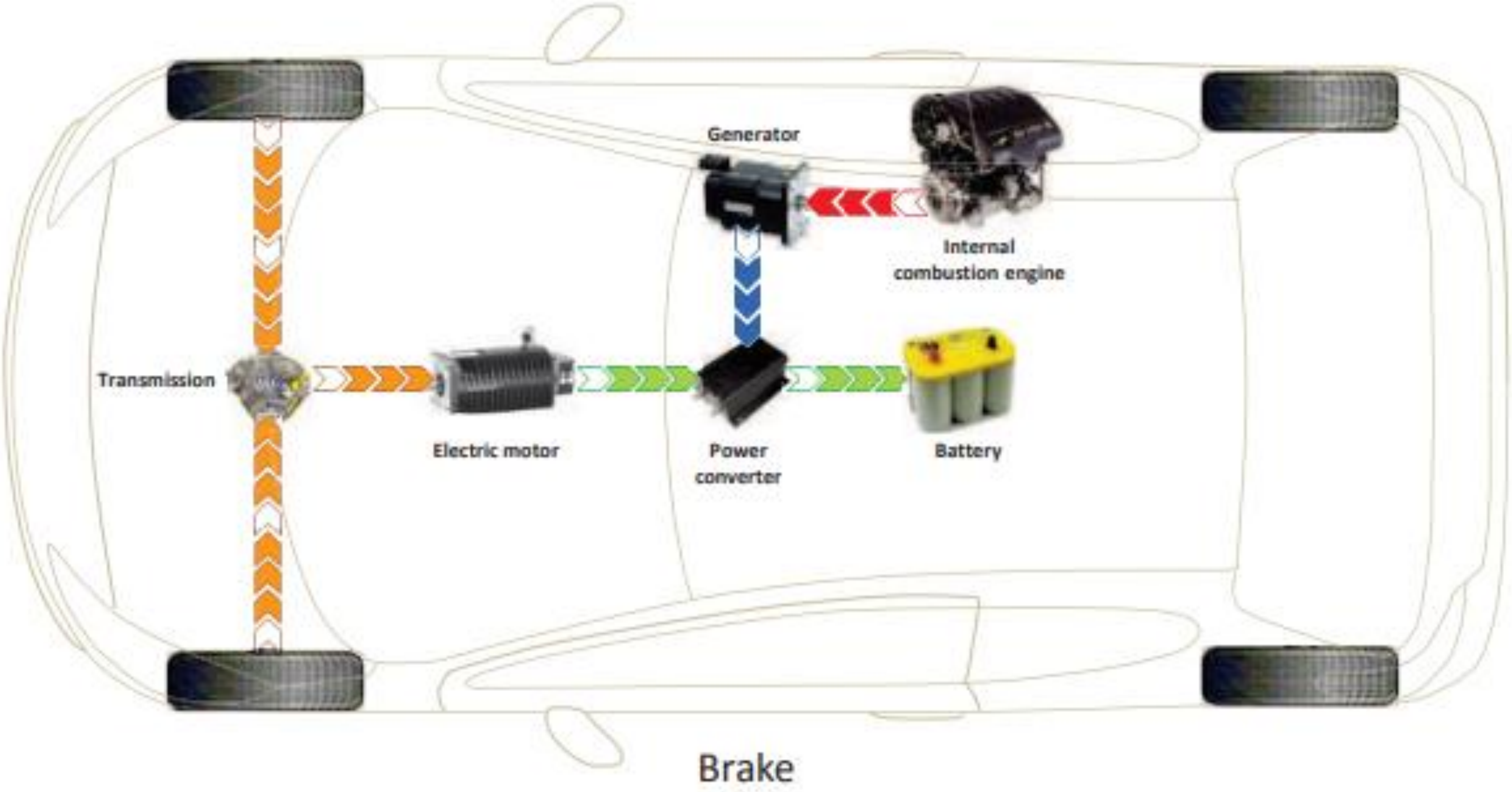


FIGURE 8. Series hybrid electric vehicle

SYSTEM ARCHITECTURE OF PARALLEL HYBRID DRIVETRAIN

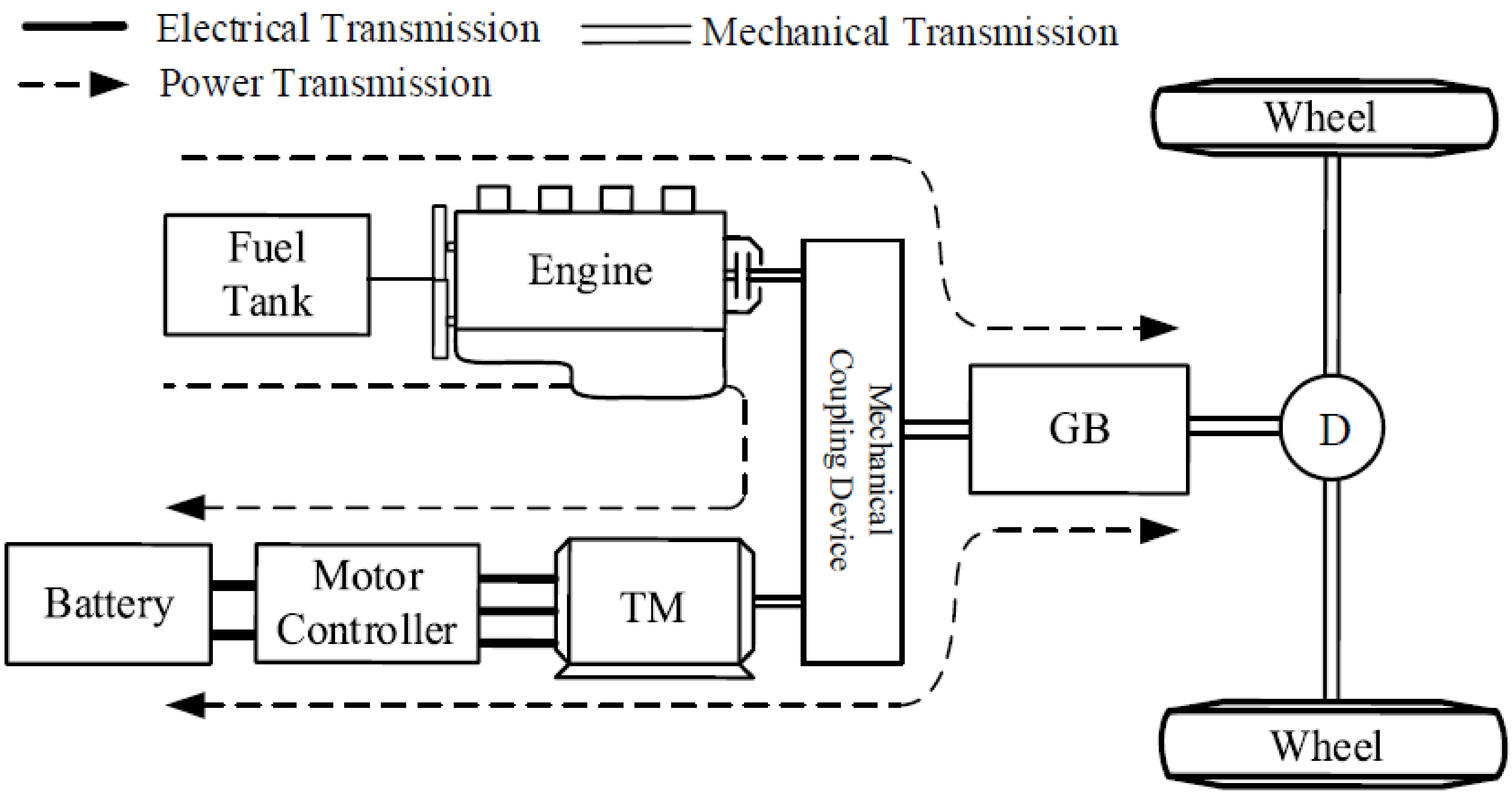


Figure 1.8 System architecture of parallel hybrid drivetrain

SYSTEM ARCHITECTURE OF PARALLEL HYBRID DRIVETRAIN

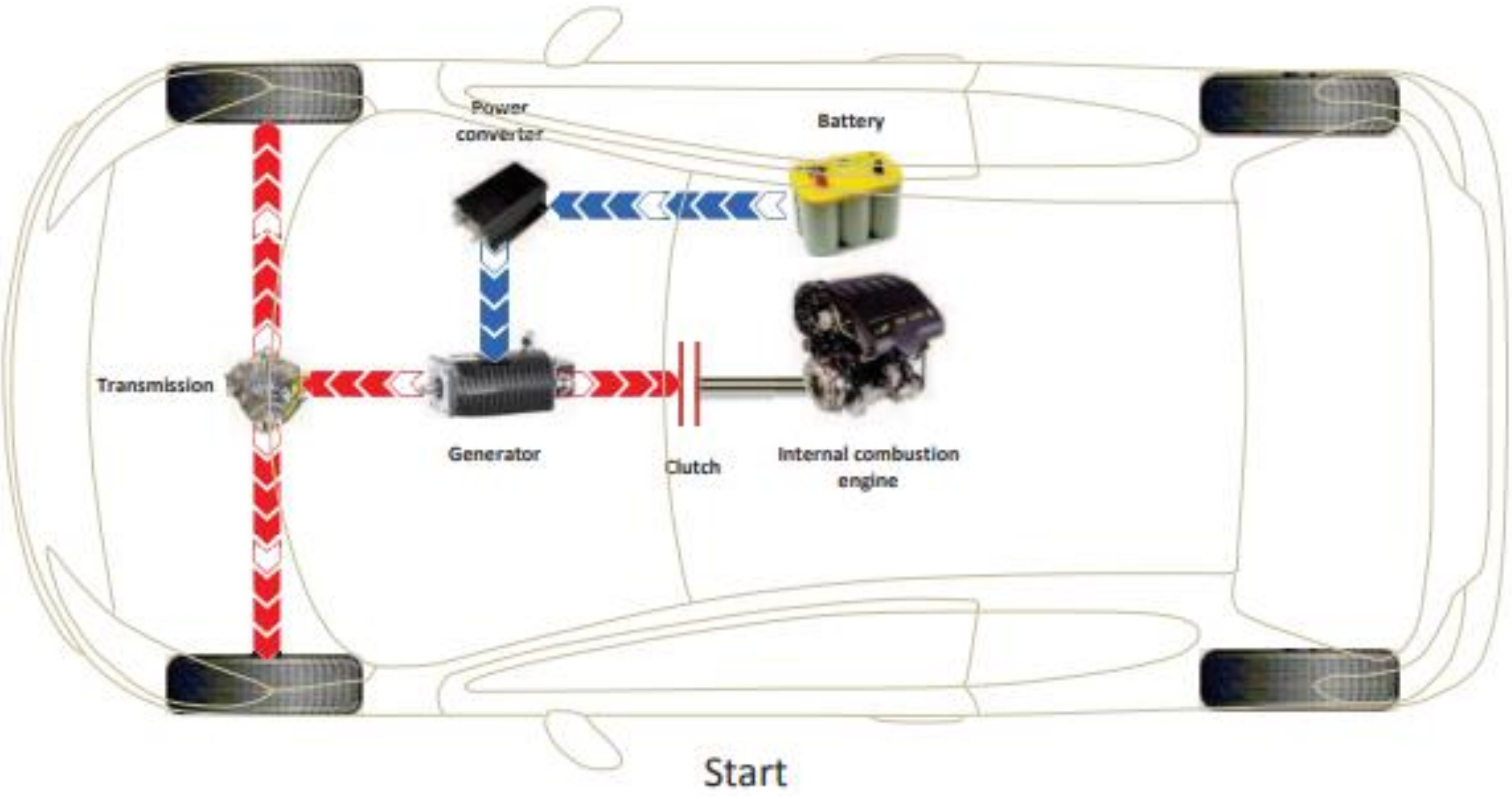


FIGURE 10. Parallel hybrid electric vehicle

SYSTEM ARCHITECTURE OF PARALLEL HYBRID DRIVETRAIN

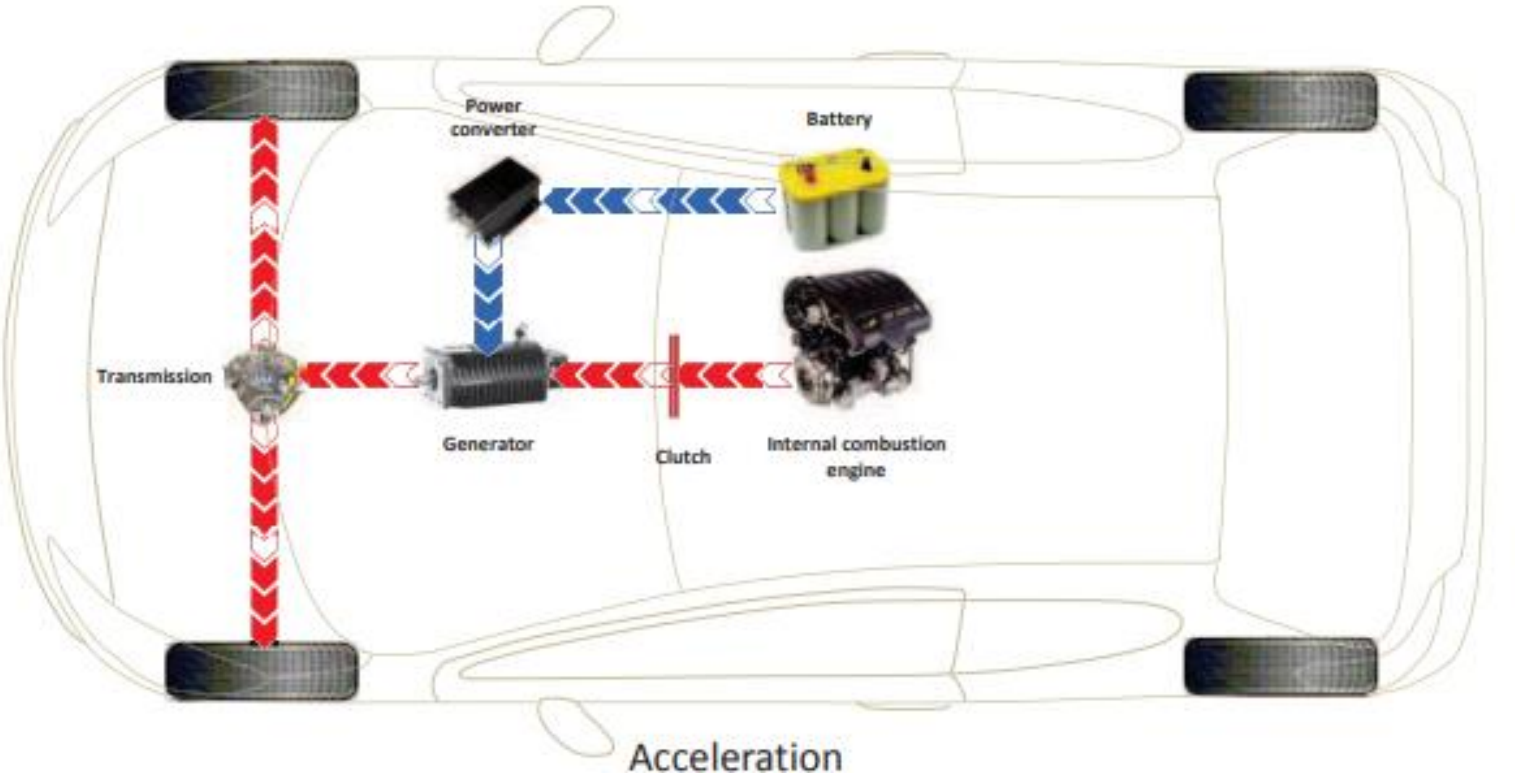


FIGURE 10. Parallel hybrid electric vehicle

SYSTEM ARCHITECTURE OF PARALLEL HYBRID DRIVETRAIN

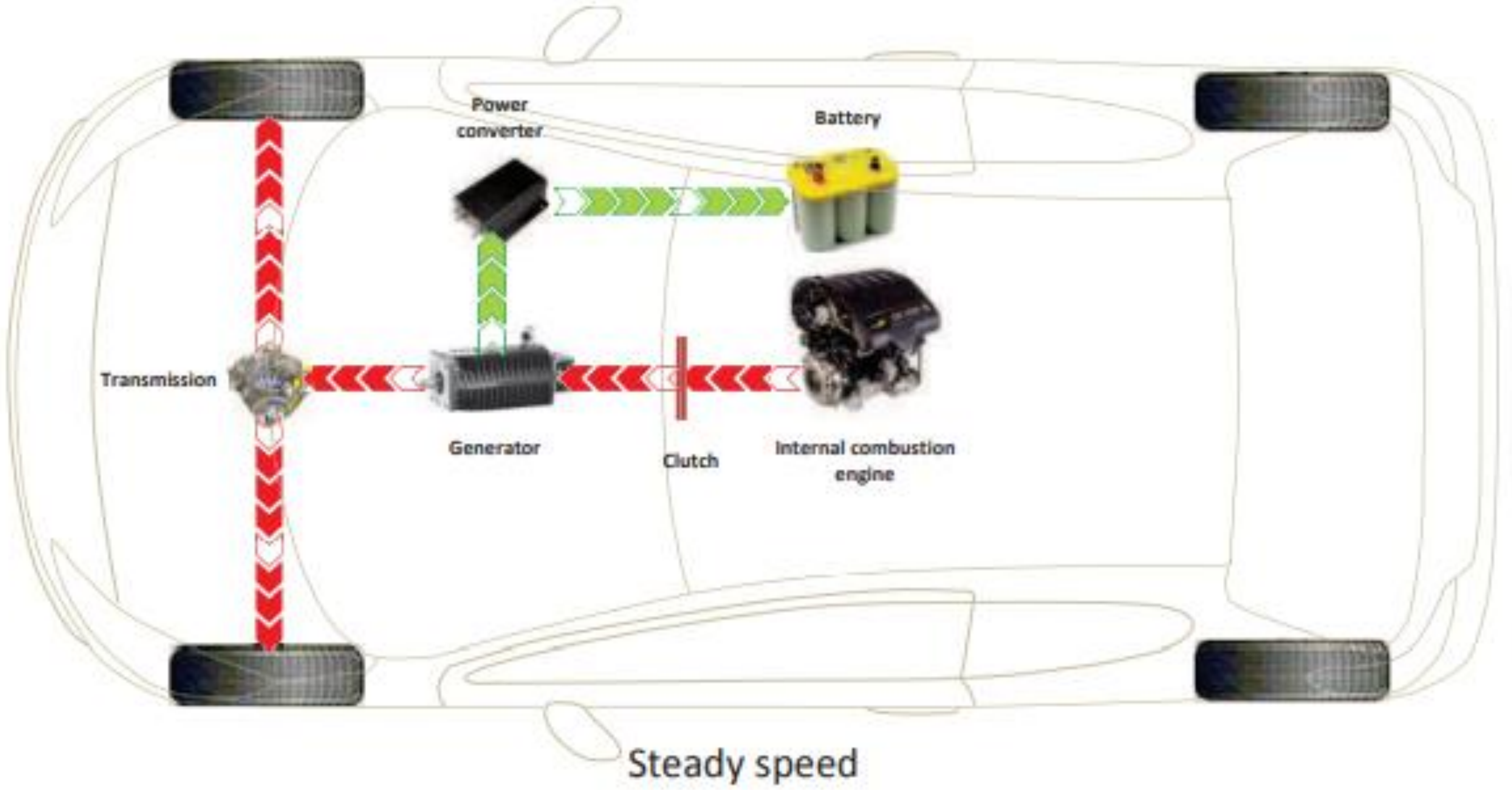


FIGURE 10. Parallel hybrid electric vehicle

SYSTEM ARCHITECTURE OF PARALLEL HYBRID DRIVETRAIN

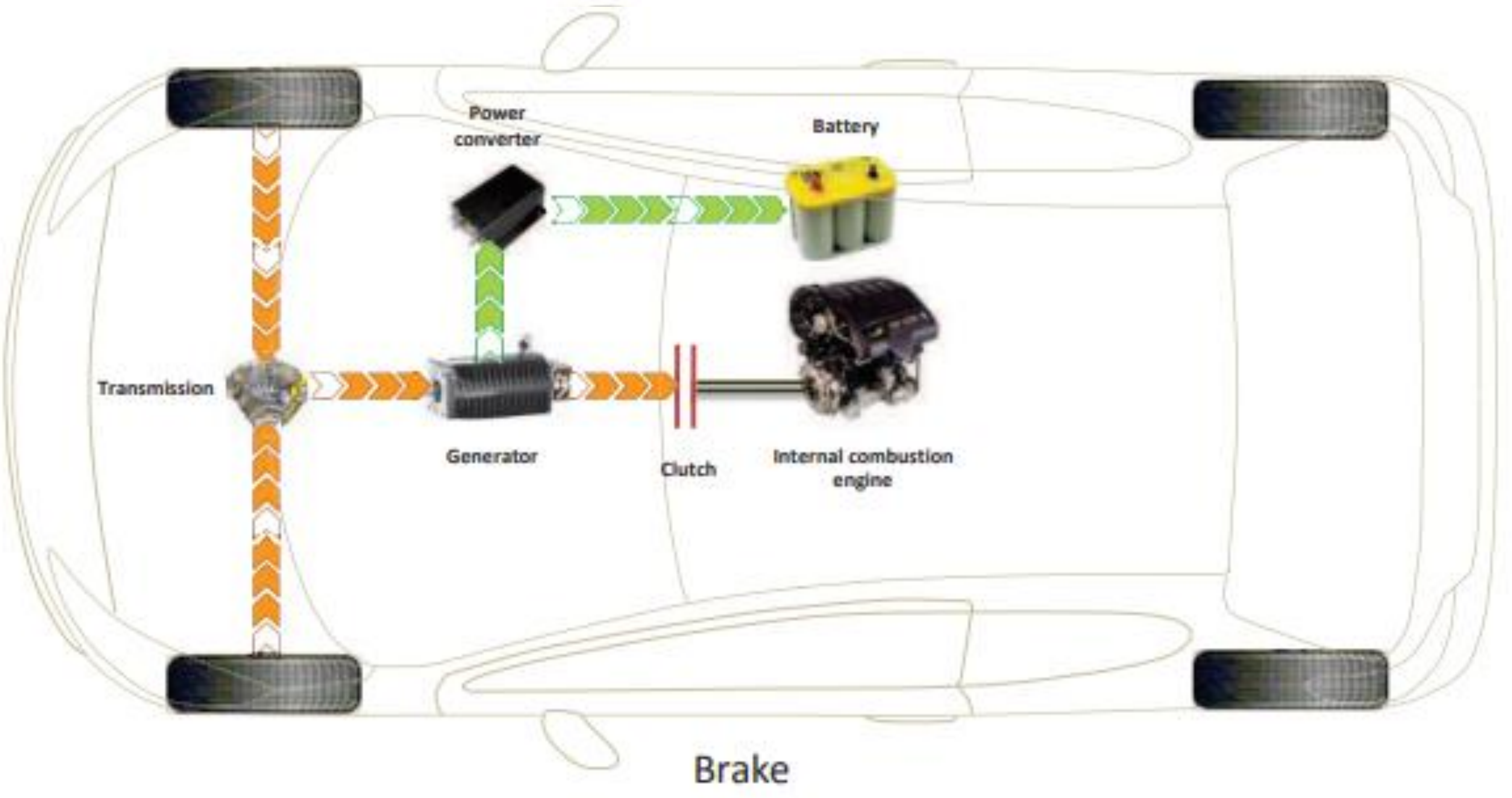


FIGURE 10. Parallel hybrid electric vehicle

SERIES VS. PARALLEL

	Pros	Cons
Series	Simple drive train	All 3 driving components (ICE, Generator, motor) need to be sized for long-distance high-speed driving
	ICE working point can be optimized	Cannot run with ICE only
	Control strategy has low constraints	Additional losses due to more components
Parallel	Good efficiency at low speed	The ICE may not always work at the best working point
	Better sizing	Complex mechanical parts
		Control strategy has more constraints

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Vehicle Feature	Series/Parallel	Parallel	Series
Vehicle mass (Kg)	1450	1450	1450
Rolling coefficient	0.01	0.01	0.01
Drag coefficient	0.25	0.25	0.25
Vehicle front area (m^2)	2.3	2.3	2.3
Wheel radius (m)	0.3	0.3	0.3
Differential gear ratio	3.45	10.8	8
Differential efficiency	0.97	0.97	0.97
Gear efficiency	0.95	0.95	0.95
Air density (kg/m^3)	1.22	1.22	1.22
ICE power (kW)	72	72	40
ICE maximum torque (Nm)	142	142	79
MG2 maximum torque (Nm)	163	163	230
MG2 base speed (rpm)	3000	3000	3000
MG2 maximum speed (rpm)	17,000	17,000	12,000
MG1 maximum torque (Nm)	43	-	400
MG1 base speed (rpm)	5000	-	1750
MG1 maximum speed (rpm)	1000	-	5500
DC-link voltage (V)	650	650	650

Missions	Average Speed (km/h)	Maximum Speed (km/h)	Length (km)	Time (min)	Change of Altitude (m)
US06	78	130	13	10	-
UDDS	31	90	12	23	-
HWFET	78	90	16.5	13	-
Urban	24	57	11.4	25	-
Fast-urban	27	68	22	52	62
Extra-urban 1	45	80	36	50	300
Mountain mission 1	48	85	24	30	500
Extra-urban 2	62	96	57	55	190
Mountain mission 2	51	90	60	70	710
Highway-mountain	87	125	480	330	1700

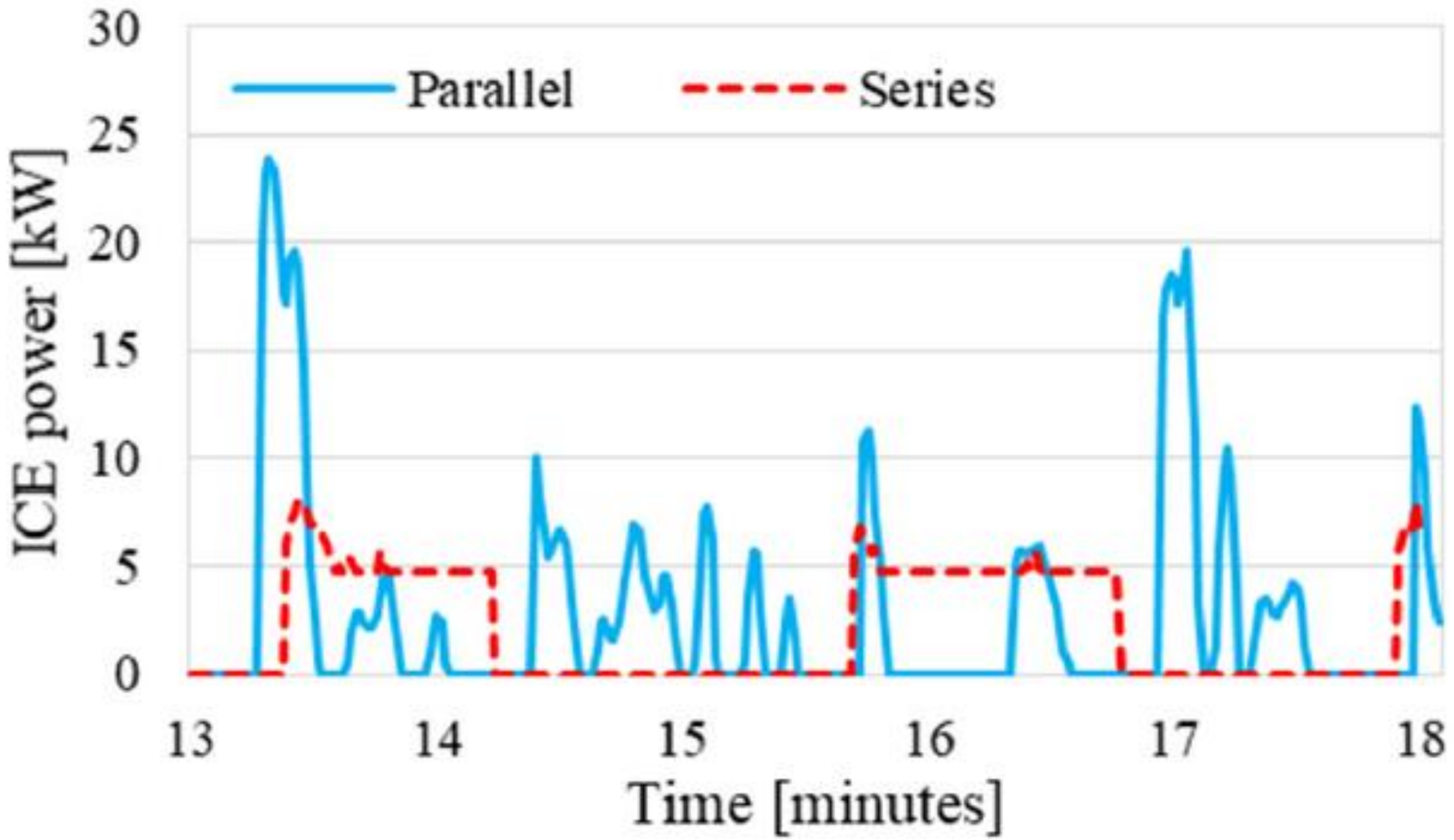

Figure 27. ICE power profile, comparison between parallel and series architectures (Urban).

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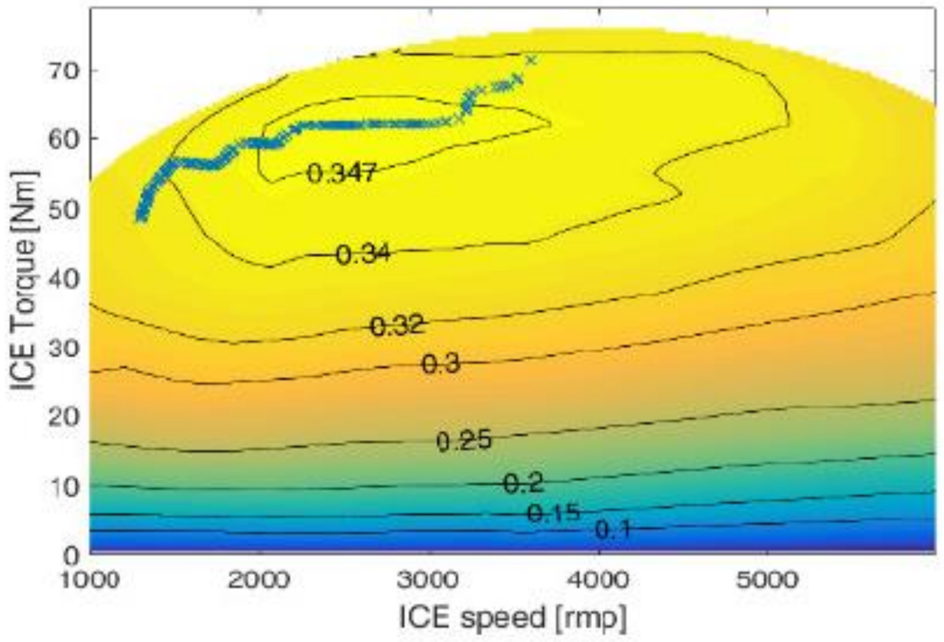

Figure 28. Series architecture: ICE working points.

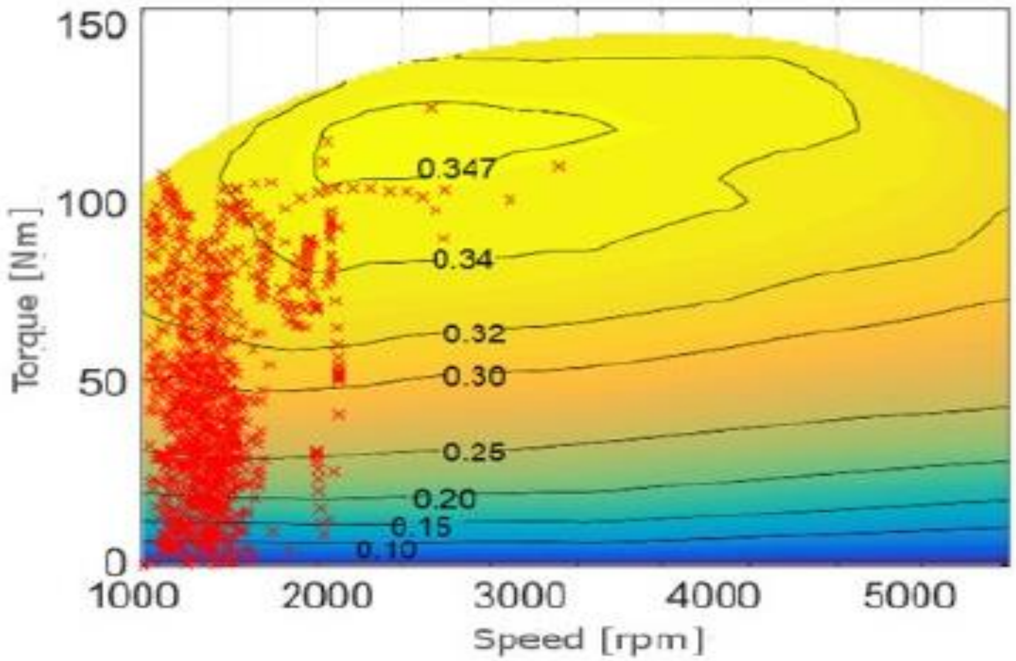

Figure 29. parallel architecture

Thank you