



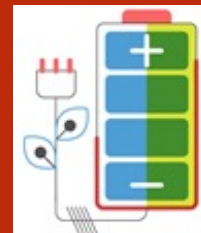
ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Dipartimento di Ingegneria dell'Energia Elettrica e
dell'Informazione "Guglielmo Marconi"

Fabbisogno energetico e impatto ambientale della mobilità nella transizione alla sostenibilità

Prof. Claudio Rossi

**CLUST-ER
MECH**
MECCATRONICA E MOTORISTICA



Value chain ERMES –
Emilia-Romagna Mobile
Electrification Systems

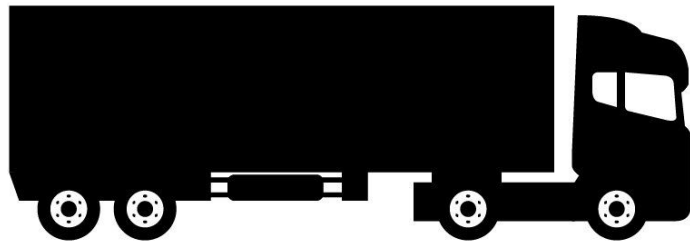
In regione Emilia Romagna i trasporti incidono per il 40.9% delle emissioni totali di CO2.

Automobili e veicoli commerciali leggeri



2.2 ton CO2 pro capite per anno

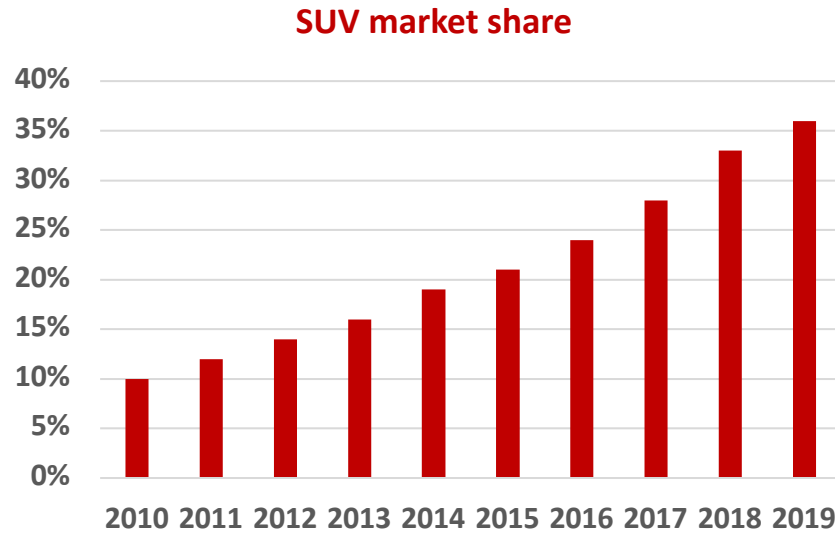
Autoveicoli pesanti



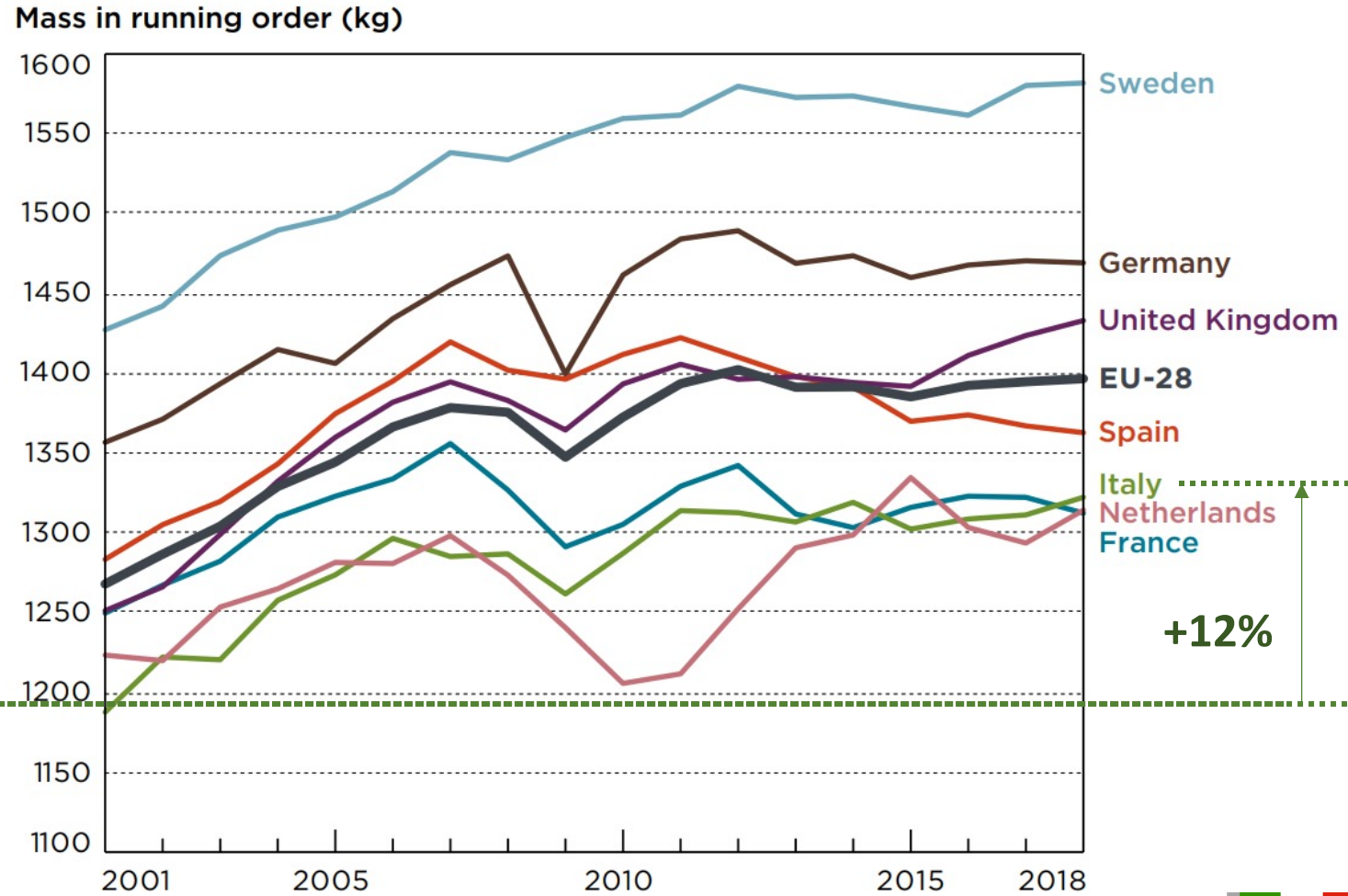
0.48 ton CO2 pro capite per anno



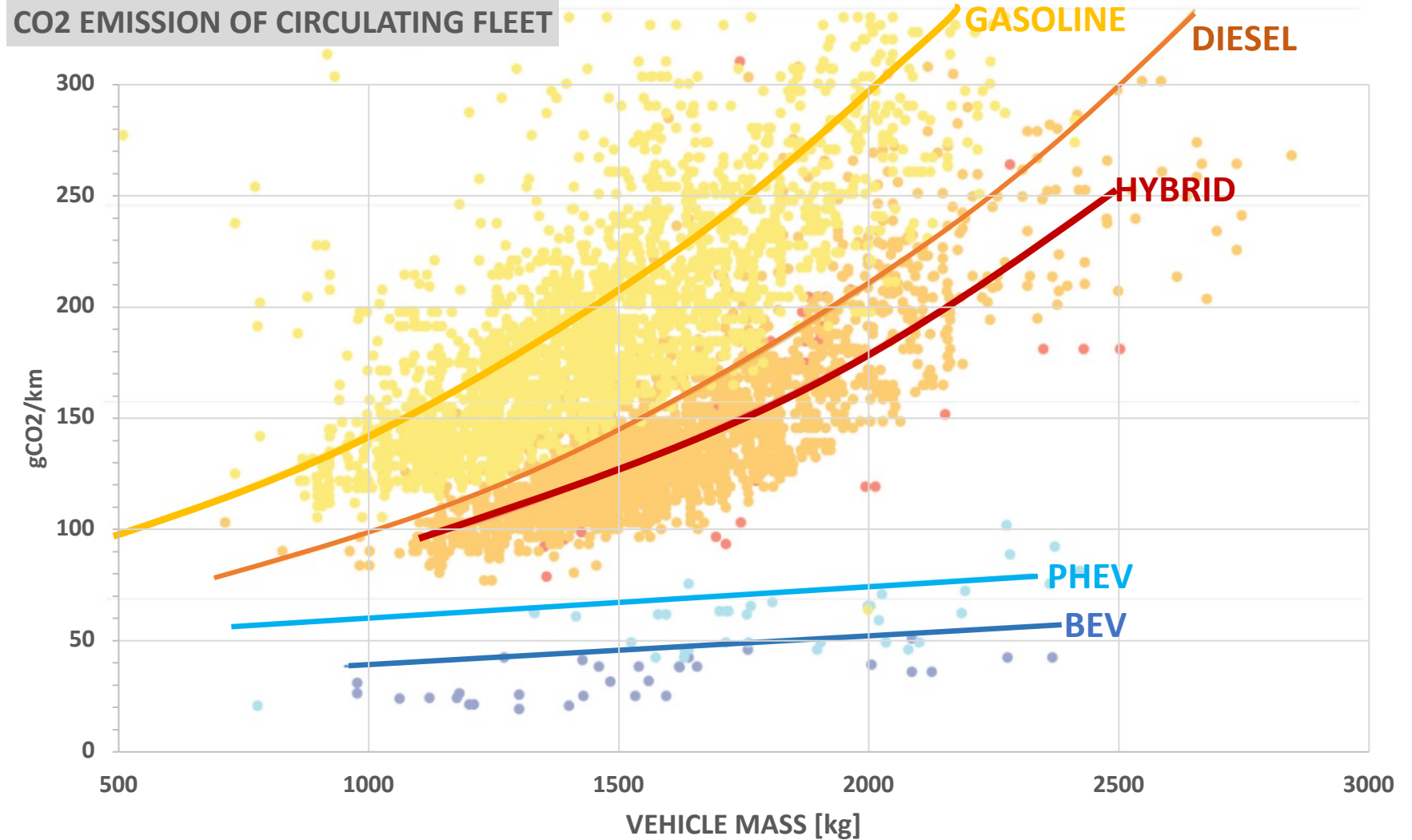
Massa del veicolo



Massa media delle auto immatricolate

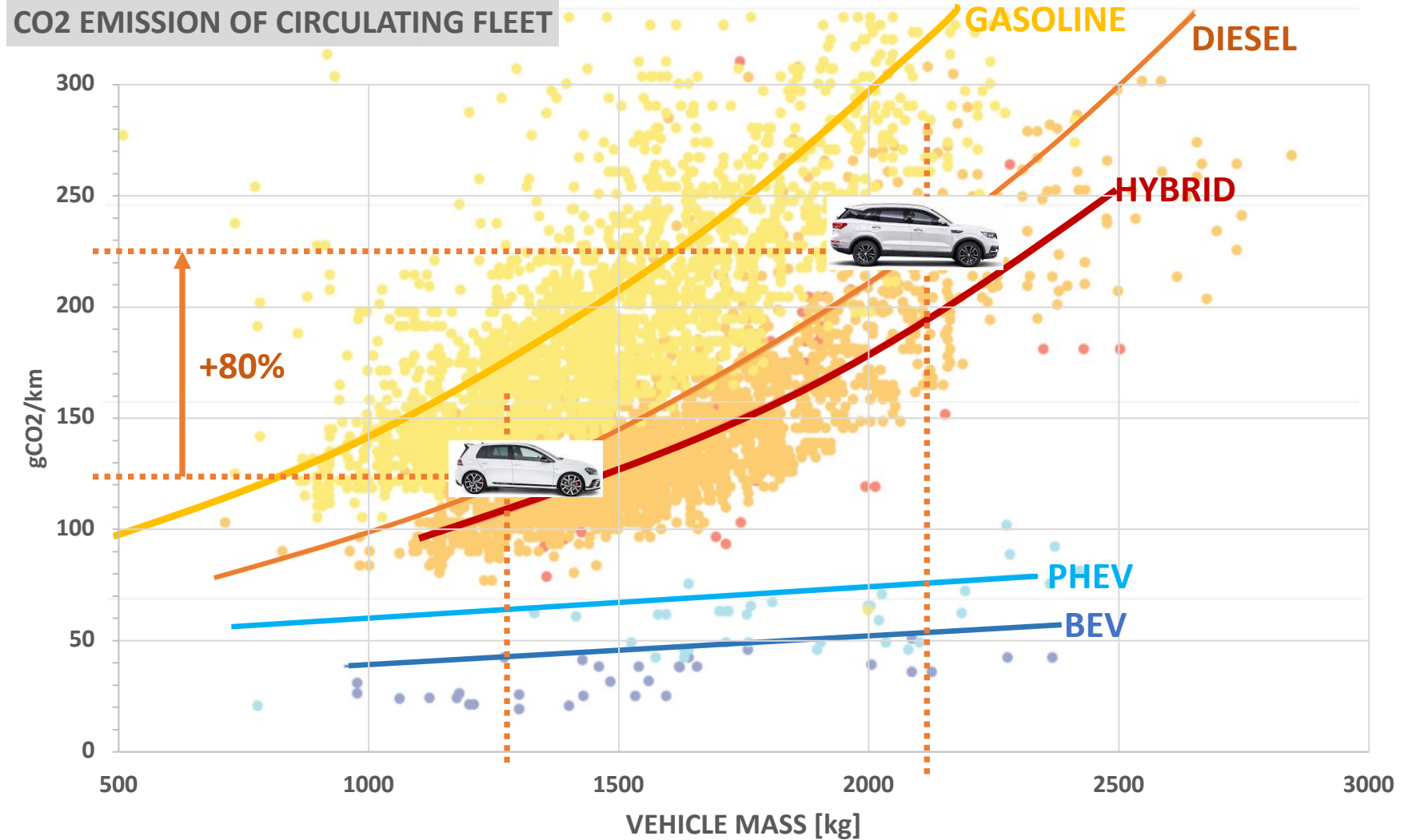


Car weight and fuel consumption

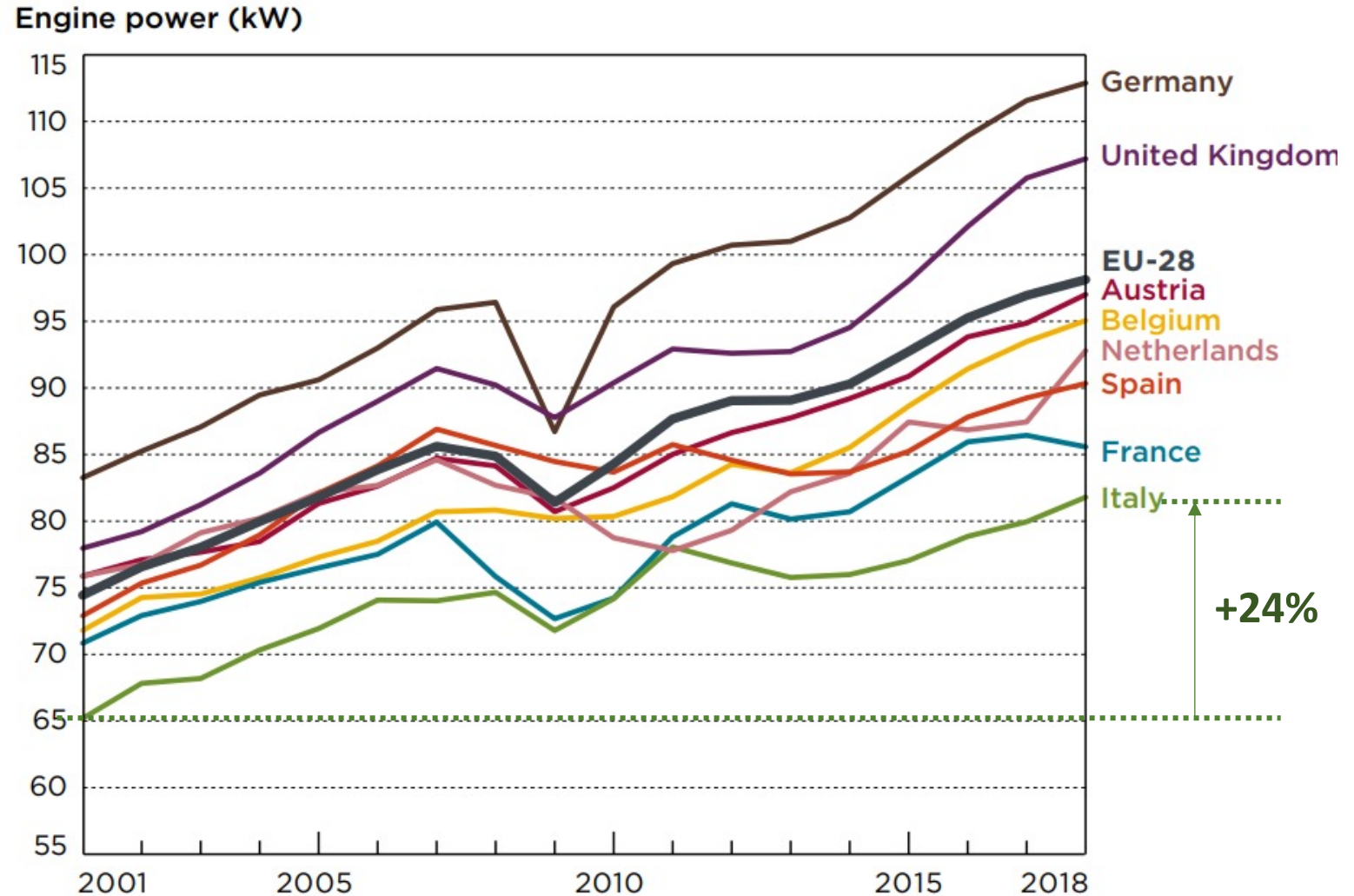


[Leonardo Paoli et al. «Fuel Consumption of Cars and Vans Tracking report — June 2020» IEA International Energy Agency](#)





Potenza installata e accelerazione



[Leonardo Paoli et al. «Fuel Consumption of Cars and Vans Tracking report — June 2020» IEA International Energy Agency](#)

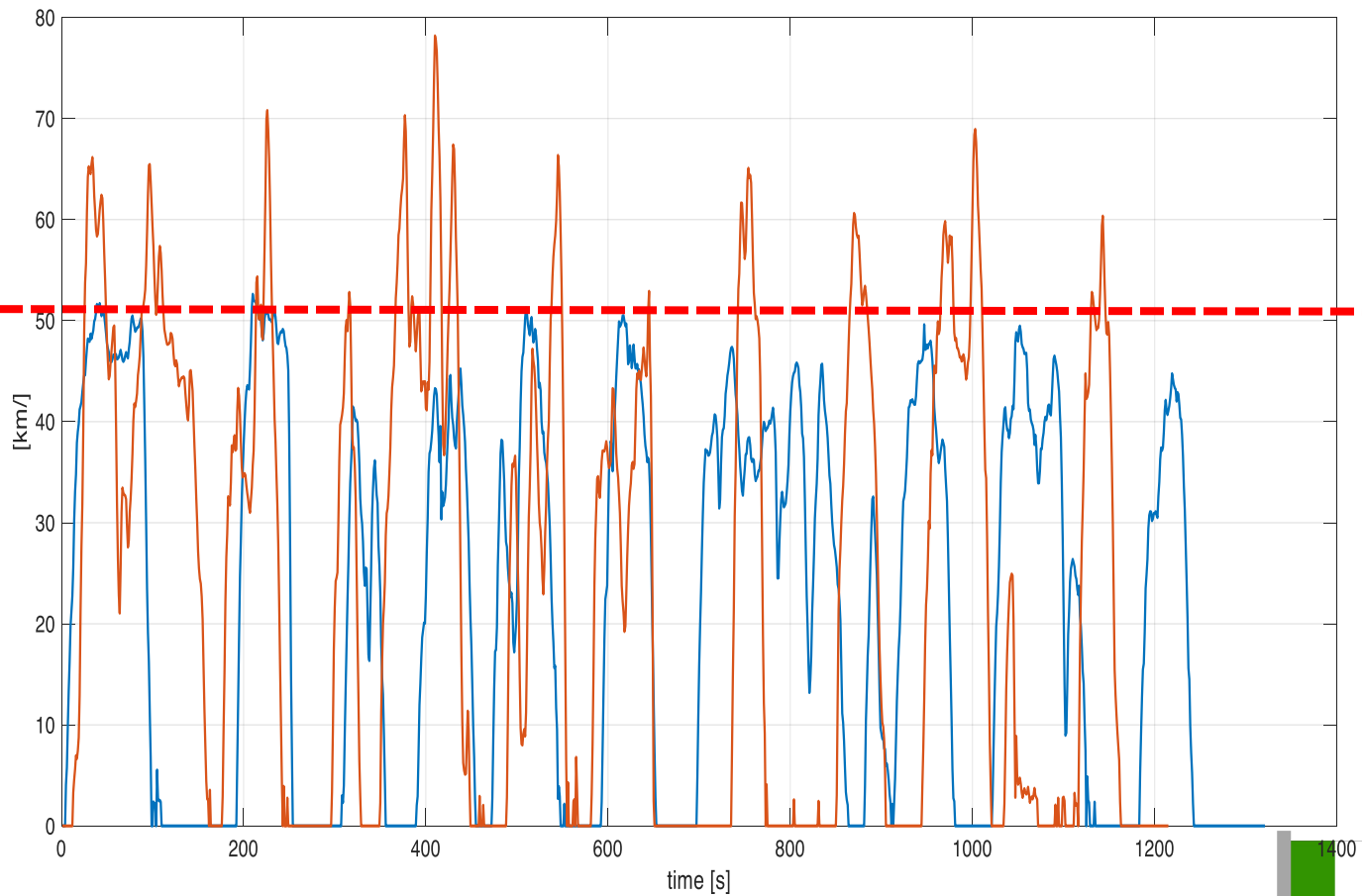
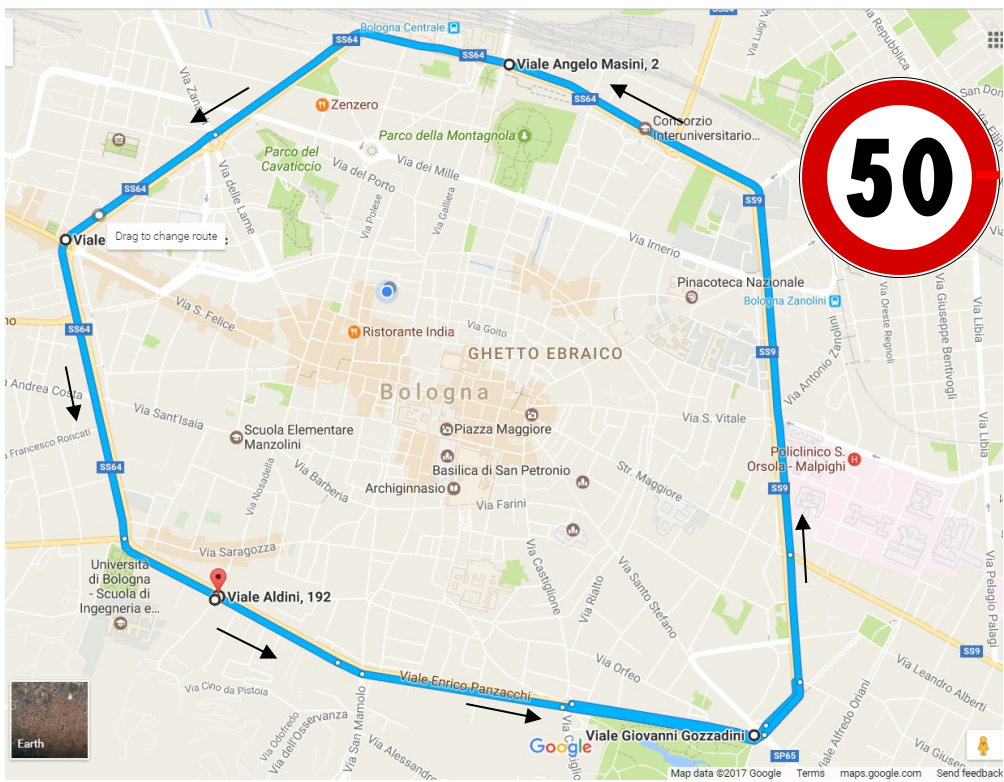
[Global Fuel Economy Initiative Vehicle Efficiency and Electrification: A Global Status Report](#)



Valutazione del fabbisogno energetico di un'auto di segmento B (es. VW Golf, Ford Focus, Peugeot 308, Fiat 500L)

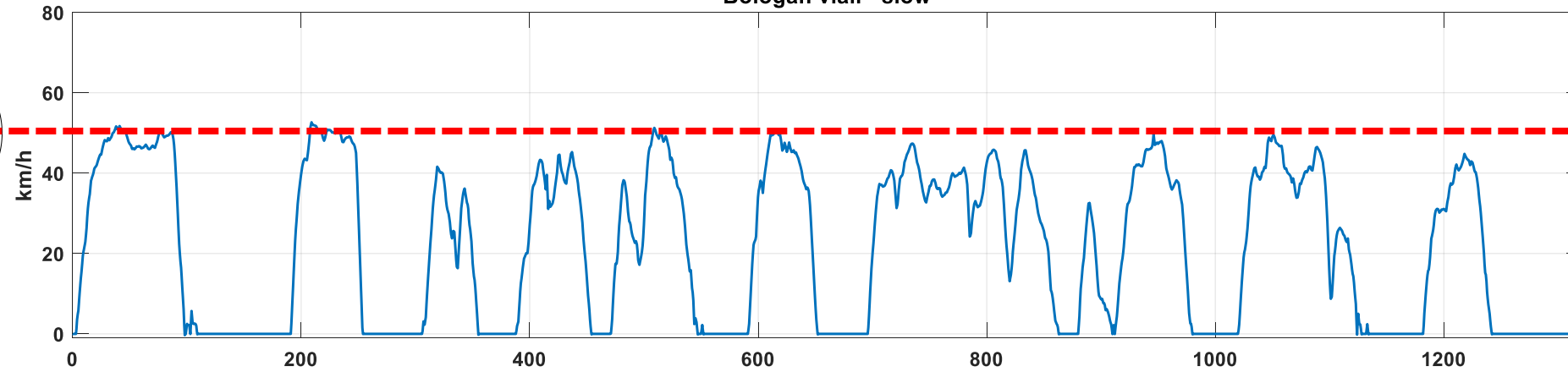
Allineato al traffico medio

Accelerazione controllata e velocità limitata ai 50km/h.

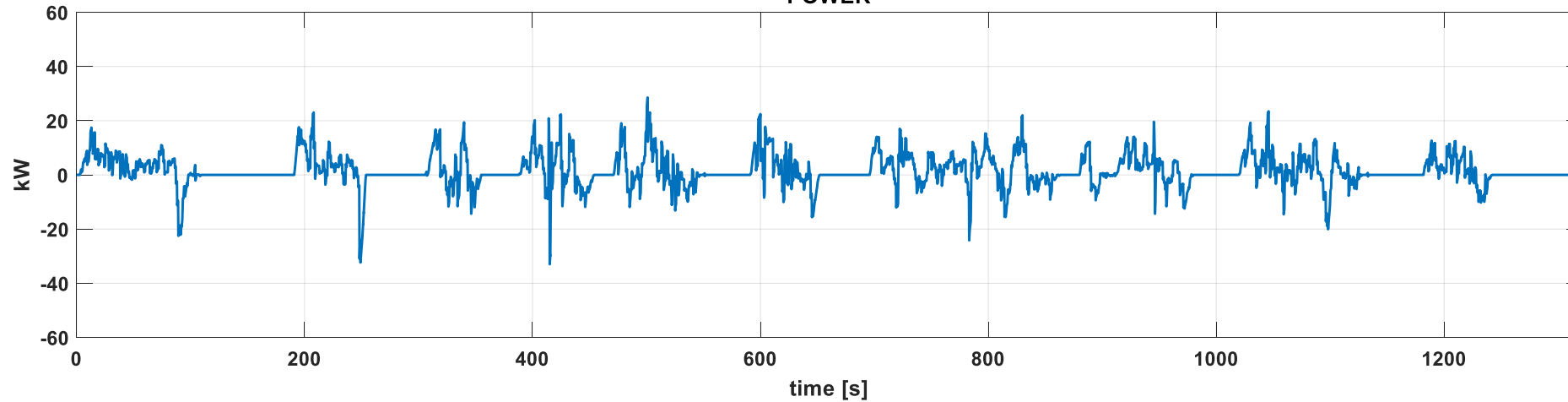


VIALI DI BOLOGNA. Velocità inferiore ai 50km/h.

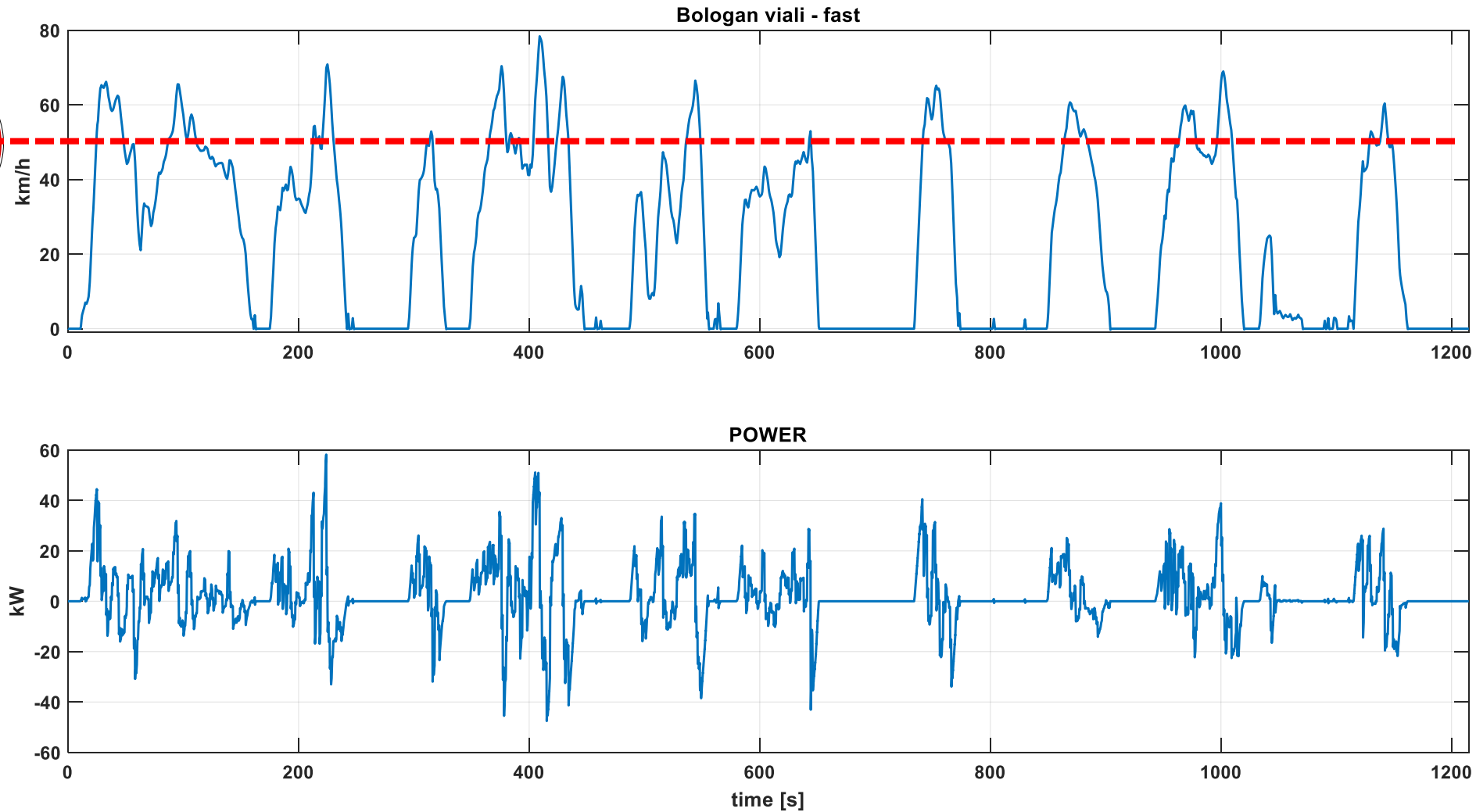
Bologan viali - slow



POWER

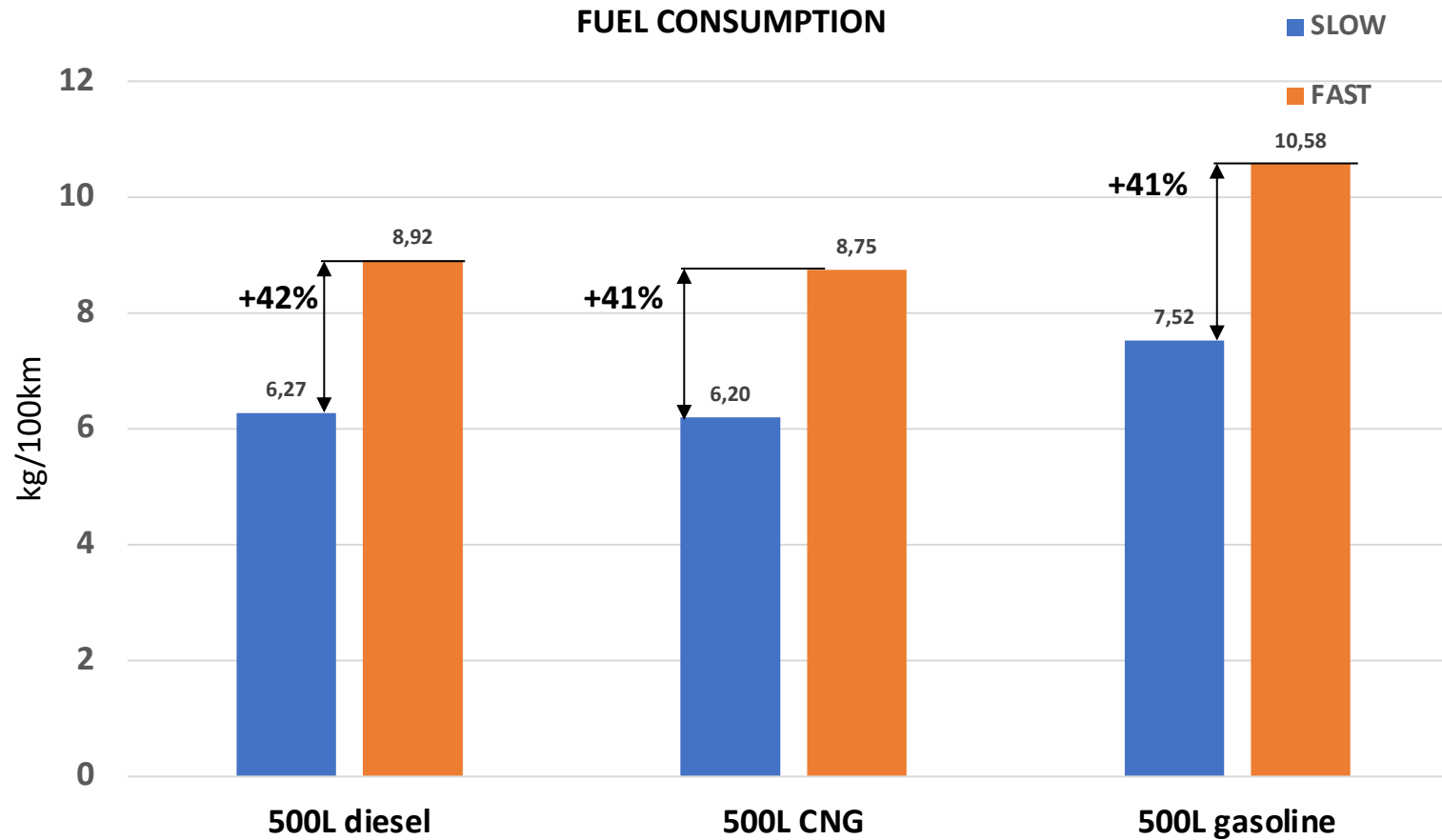


VIALI DI BOLOGNA. Velocità non limitata. Allineato al traffico medio

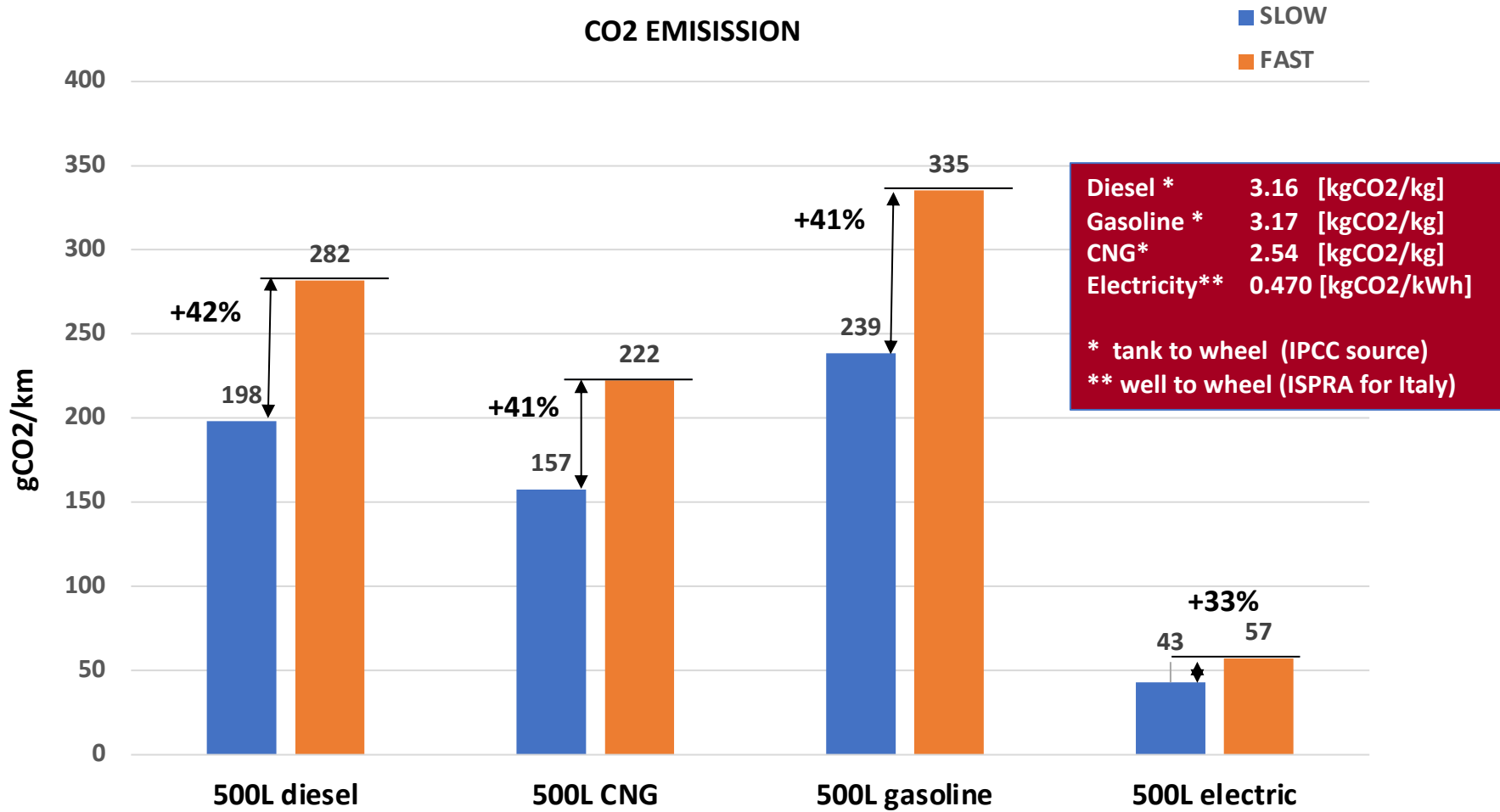


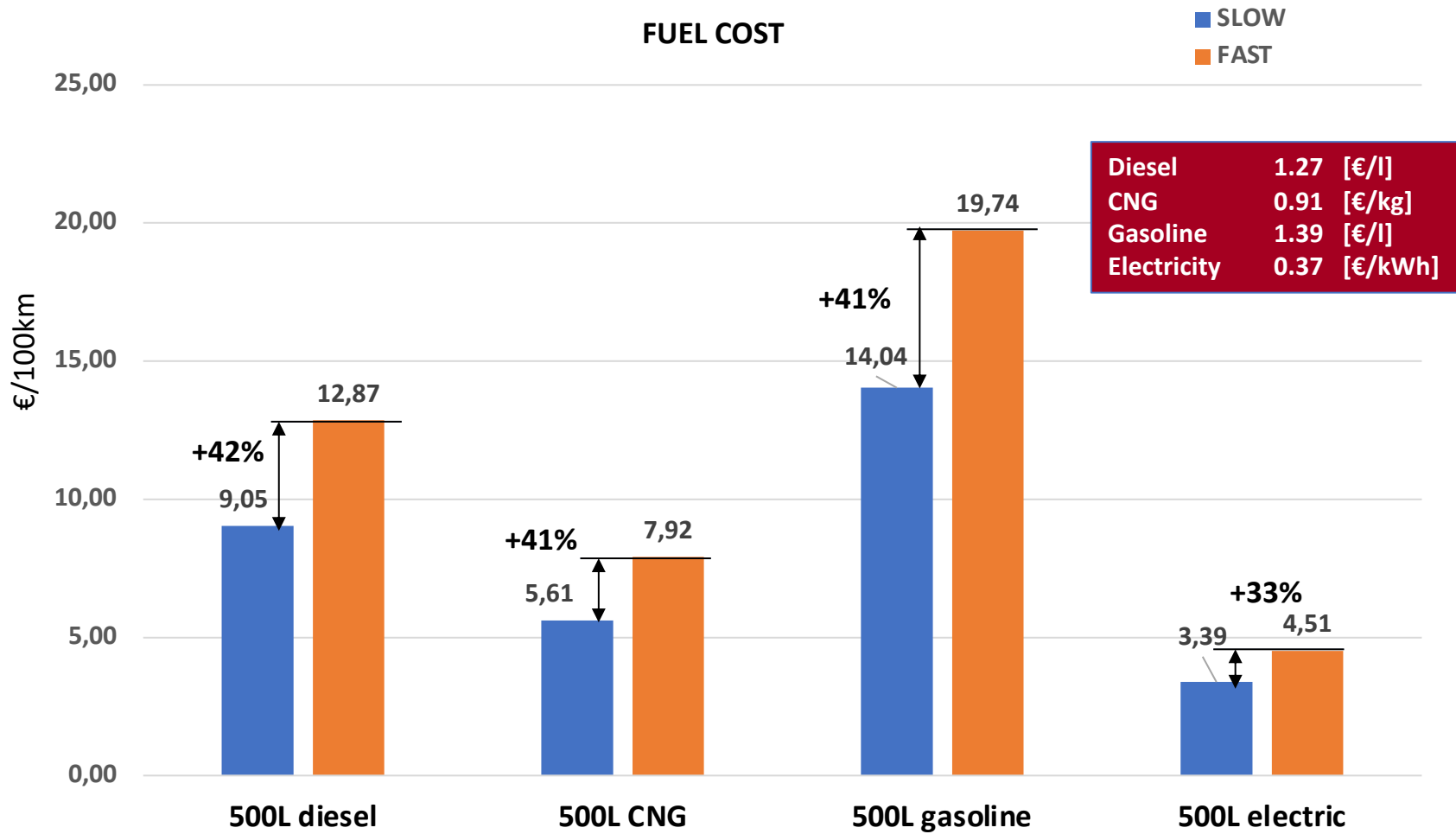
VIALI BOLOGNA		SLOW	FAST	Δ
Velocità massima	km/h	52.6	78.2	+49%
Massima accelerazione	m/s ²	1.95	2.72	+40%
Massima decelerazione	m/s ²	3.64	4.41	+21%
Distanza	m	7864	7918	-
Durata	' "	20'45''	19'20''	-7.3%
Velocità media	km/h	21.44	23.48	+9.5%
Velocità media in movimento	km/h	32.37	36.7	13.3%
Tempo fermo	%	33	36	+10%
Tempo accelerazione 0-50km/h	s	18	7.3	-60%
Potenza massima	kW	28.5	58.1	+103%
Potenza media positiva	kW	2.48	4.12	+57%
Consumo specifico alle ruote	Wh/km	116	175	+45%





Car weight and fuel consumption

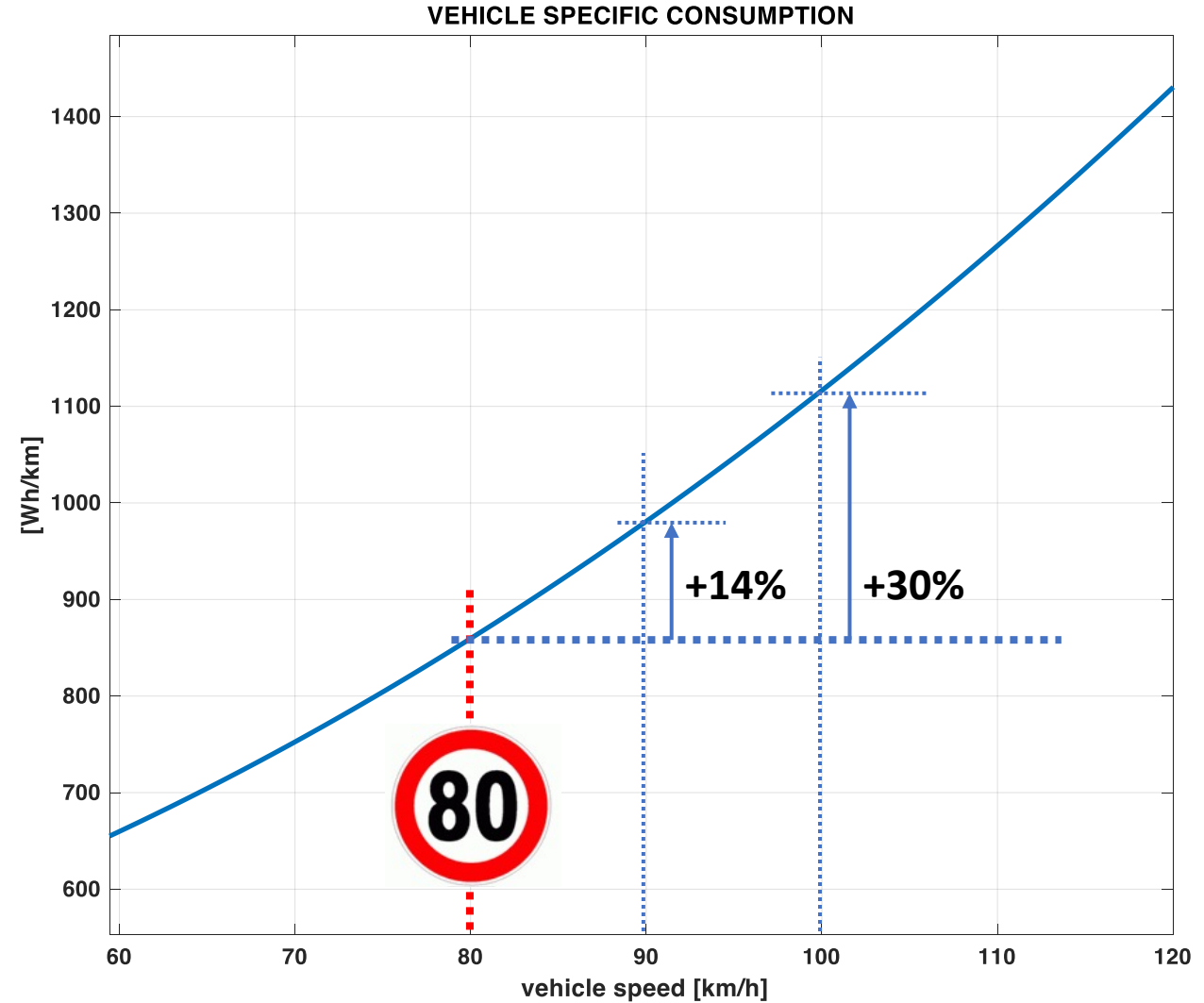




Autotreno

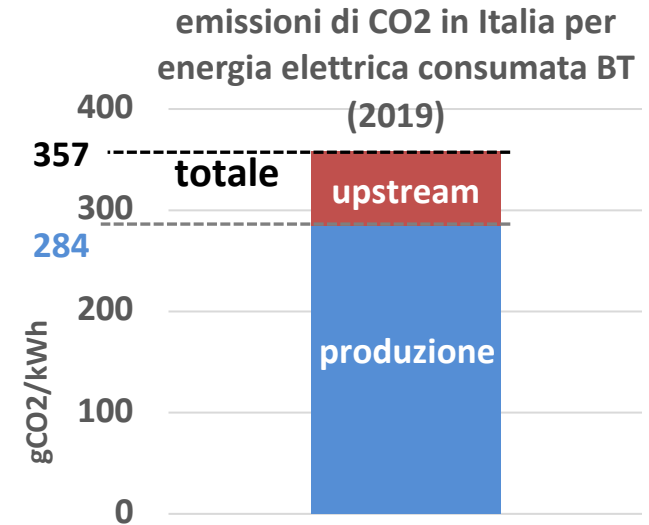
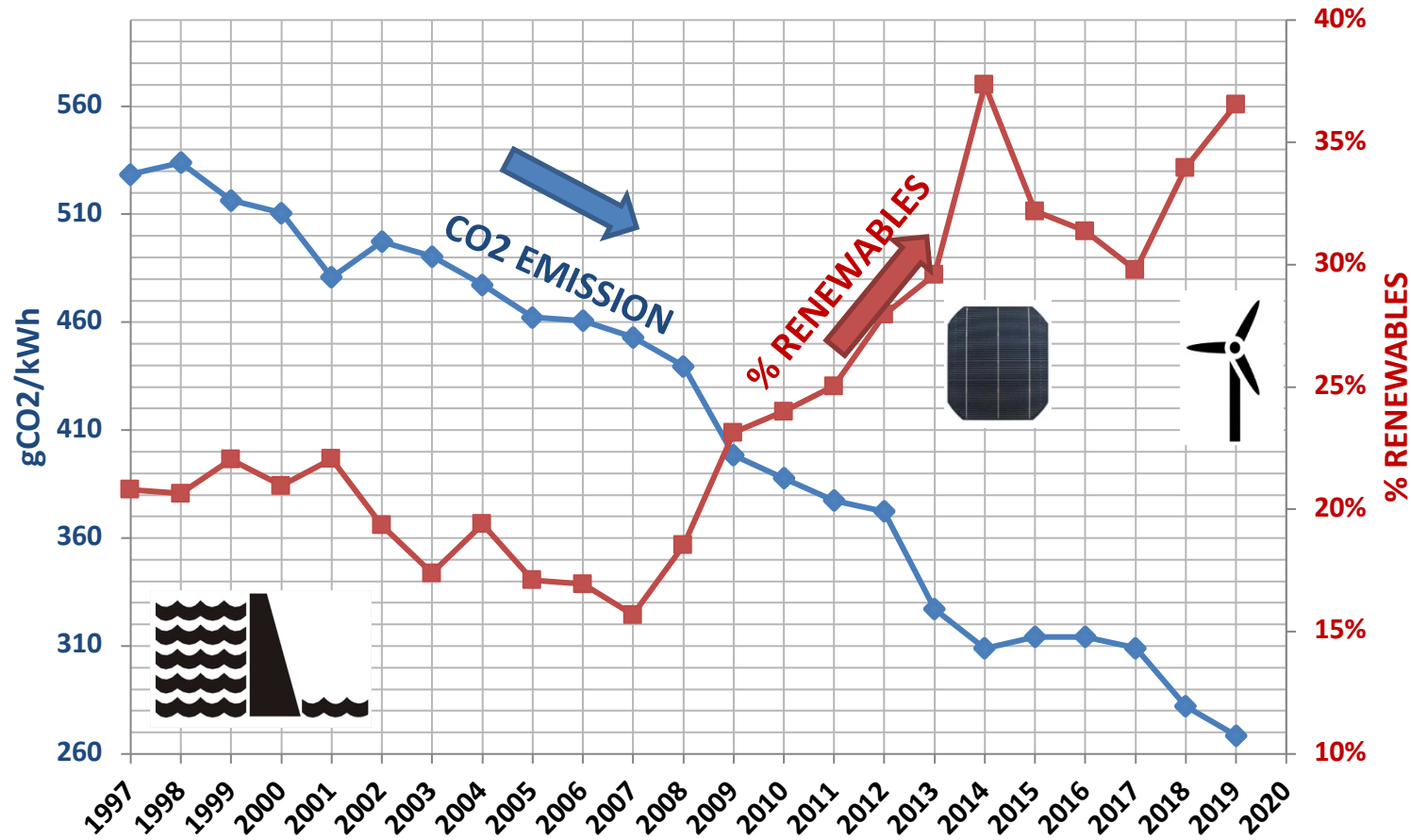
Massa: 26.9 ton

Velocità costante in autostrada



ITALY - electric energy production

Andamento della percentuale di energia elettrica prodotta in Italia da fonti rinnovabili (TERNA) e fattore di emissione della produzione di energia elettrica sul consumo (ISPRA).



ISPRA. Fattori di emissione per la produzione e il consumo di energia elettrica in Italia
[Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles](#)



CAR MANUFACTURING

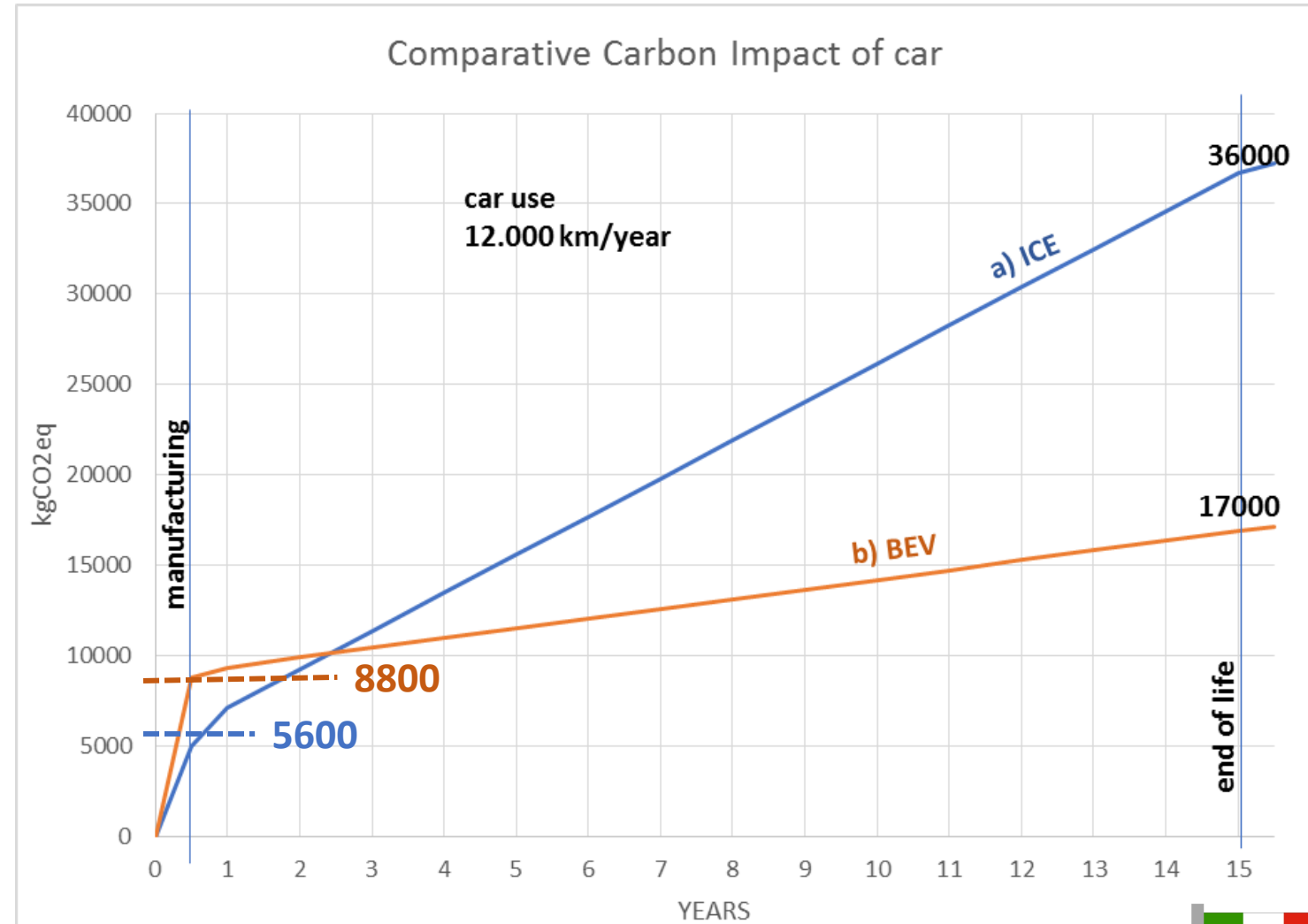
Carbon Intensity of thermal car manufacturing. Official data released by manufacturers	
Car	Carbon Intensity [kgCO ₂ _{eq}]
Audi A6 3.0 diesel TDI quattro S tronic (y2017)	11.000
Audi A4 1.8 gasoline TFSI (y2015)	6800
WV Golf IV, 1.4 l gasoline 55 kW(y2003)	6400
Alfa Romeo Giulia 2.2 diesel 180 HP (y2016)	6095
WV Golf VI 1.2 gasoline TSI BlueMotion (y2010)	5460
Renault New MeganeIV diesel dCi 110 (y2016)	5402
<i>Estimated average EU mid-size gasoline car</i>	5600

Carbon Intensity electric car manufacturing	
Car	Carbon Intensity [kgCO ₂ _{eq}]
Nissan LEAF	8100
Volkswagen e-up! BL24E1 (y2017)	6426
<i>Estimated average EU mid-size BEV</i>	8800

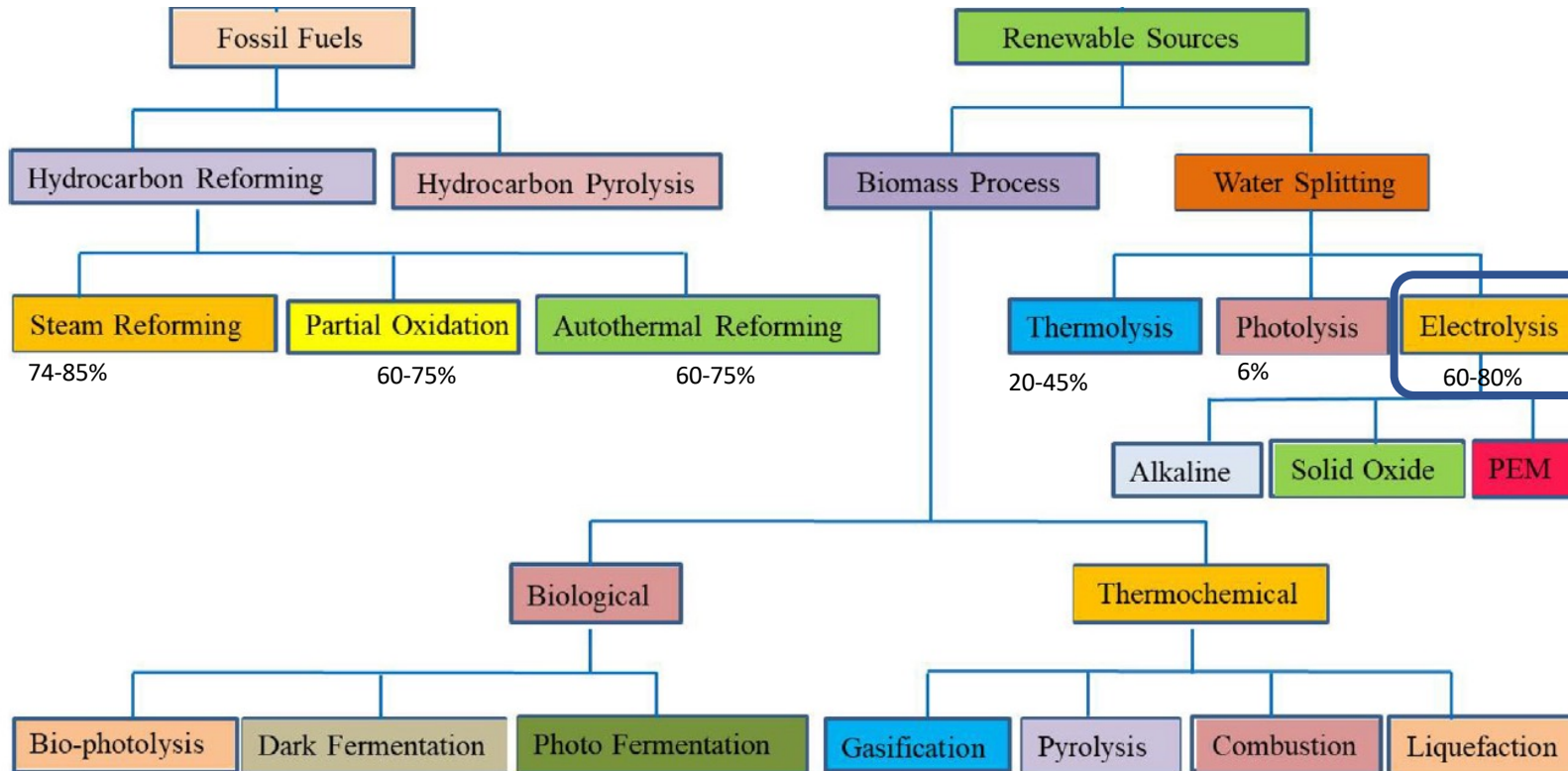
CAR USE Well to Wheel - WTW

Thermal car : 176 gCO₂/km

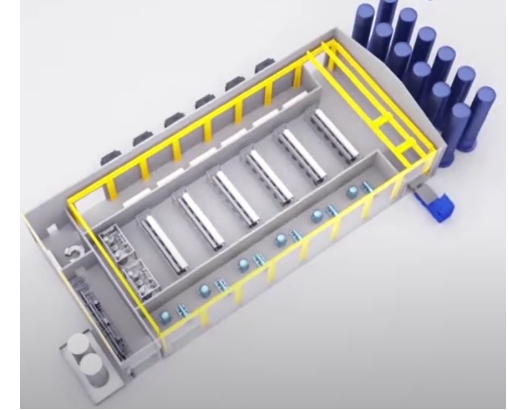
Electric car : 42 gCO₂/km



Electrolizer classification



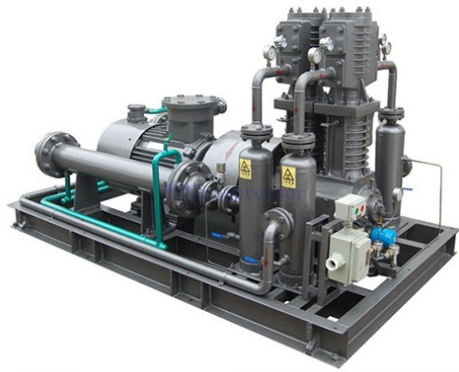
AREVA H2GEN (best in class 2020)



SPECIFICATION	VALUE
Power rating	10MW (5unit x 2.5 MW each)
Production	2250 Nm3/h (5 unit x 450Nm3/unit 202 kg/h (5 unit x40kg/h)
Storage	30000 Nm3 @35 bar (13h production)
System efficiency	40 kWh/kg 77% LHV
CAPEX	~ 3 M€
Production cost (energy only)	4€/kg @ energy cost 0.1 €/kWh
TCO	~ 4.5 €/kg
lifetime	8000h
CO2 (Italian energy mix)	16 kgCO2/kg
State	Preliminary design /scale demonstrator

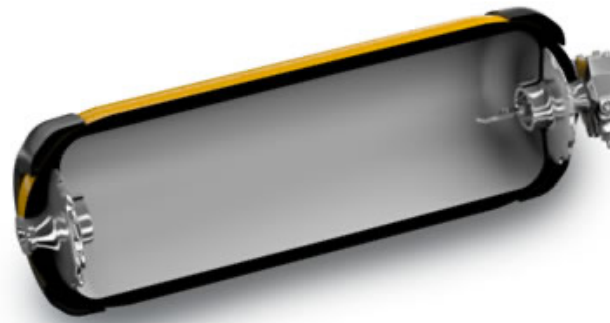
COMPRESSION

SPECIFICATION For 1000kg/day refueling station [1]	unit	350 bar	700 bar	Liquid para LH2
Starting pressure	bar	20	20	20
Starting temperature	°C	25	25	25
Theoretical energy (isothermally)	kWh/kg	1.05	1.36	3.9
Overpressure	bar	440	880	/
Pre-cooling	°C	/	-40	/
Energy use	kWh/kg	2.23	3.0	10
Energy use	%	7	9	30



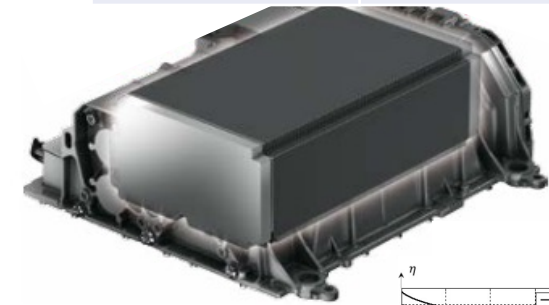
TANK

SPECIFICATION	VALUE [2]
application	Toyota Mirai
Pressure	700 bar
Vessels volume	122,4 l in 2 units (60 l. ant, 62,4 l post)
Gravimetric density	5,7% mass
Approx H2 capacity	5 kg
Technology	Type IV - Full carbon fiber

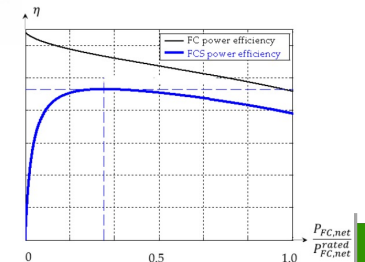


FUEL CELL SYSTEM

SPECIFICATION	VALUE
product	Toyota Mirai
Max. power	114 kW
Number of cells	370
Volume power density	3.1 kW/l
Mass power density	2 kW/kg
Cell voltage	260-370 V
MAX efficiency	45%
Fuel efficiency	15 kWh/kg



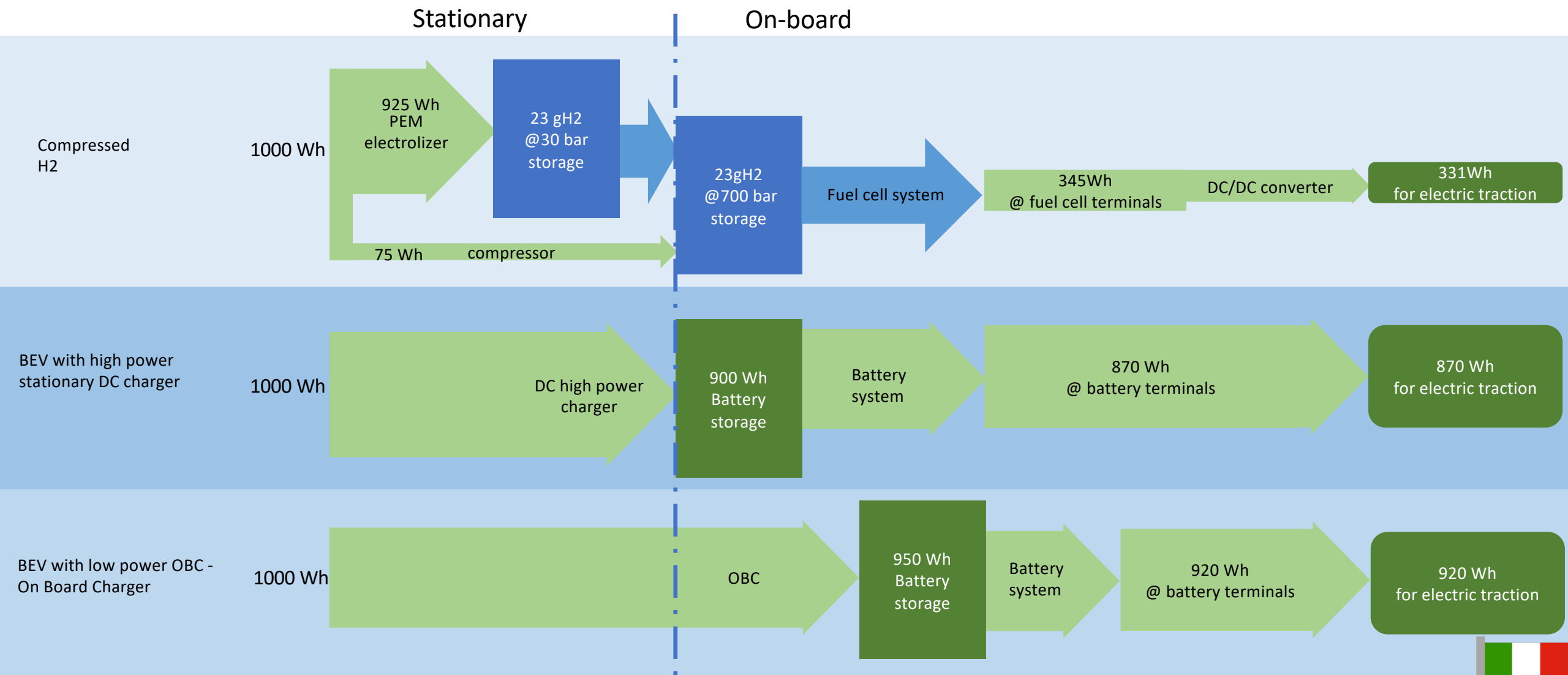
45%



[1] DOE Hydrogen and Fuel Cells Program Record

[2] Barthélémy, H HYDROGEN STORAGE – INDUSTRIAL PROSPECTIVES

Hydrogen vs. electric



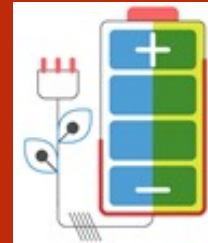


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