Results of GM WtW-Study

at http://www.lbst.de/gm-wtw

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GM Well-to-Wheel Study - Consortium

Study commissioned by GM

- Well-to-Tank (Fuel) work conducted by L-B-Systemtechnik (LBST) with input from BP, ExxonMobil, Shell and TotalFinaElf
- Tank-to-Wheel (Vehicle) work performed by GM

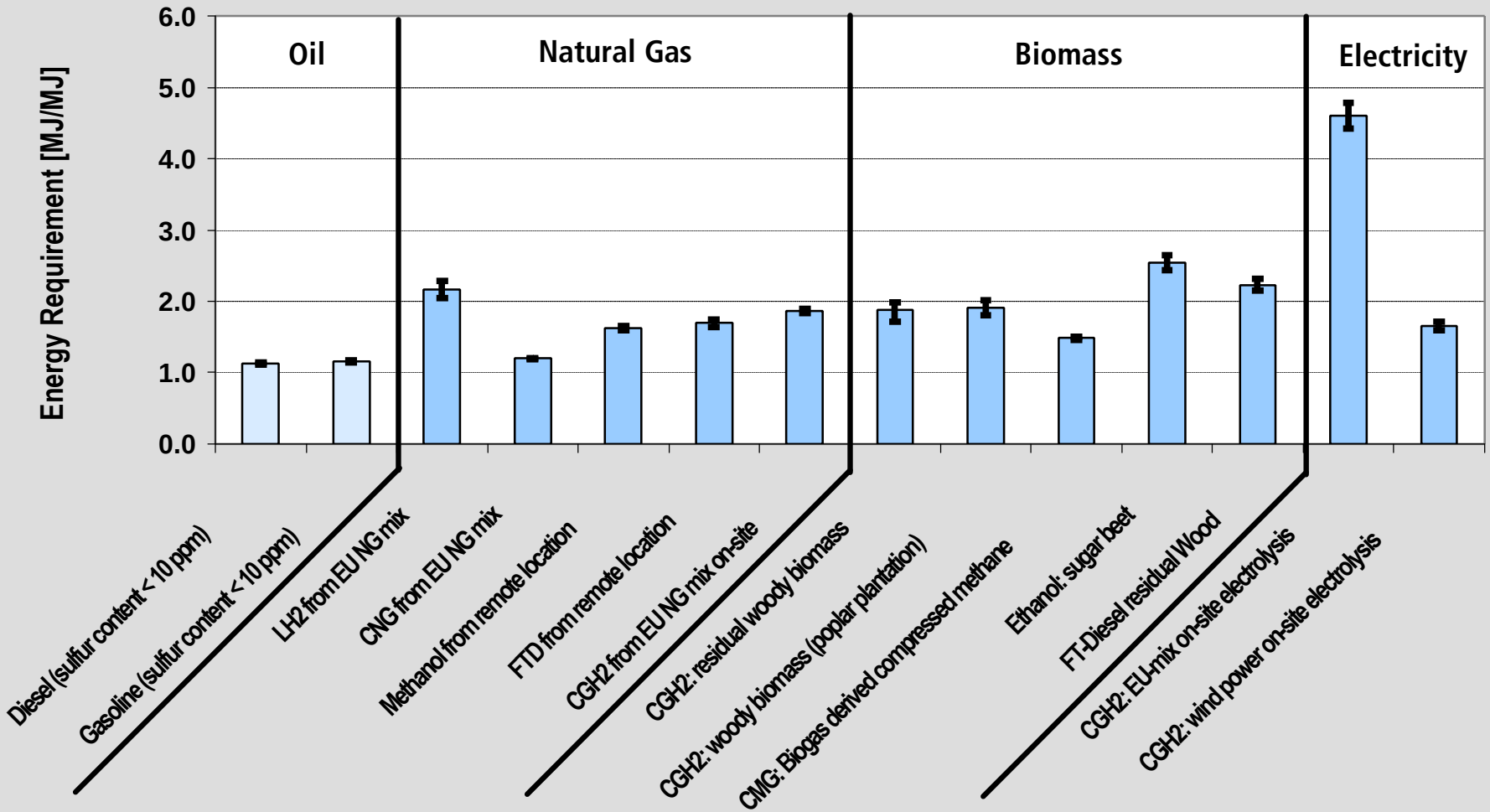
Considers 14 fuels (88 fuel “pathways”) and 22 conventional and advanced powertrain systems, targeted to 2010 timeframe

GM Well-to-Wheel Study - Well-to-Tank Pathways Analyzed

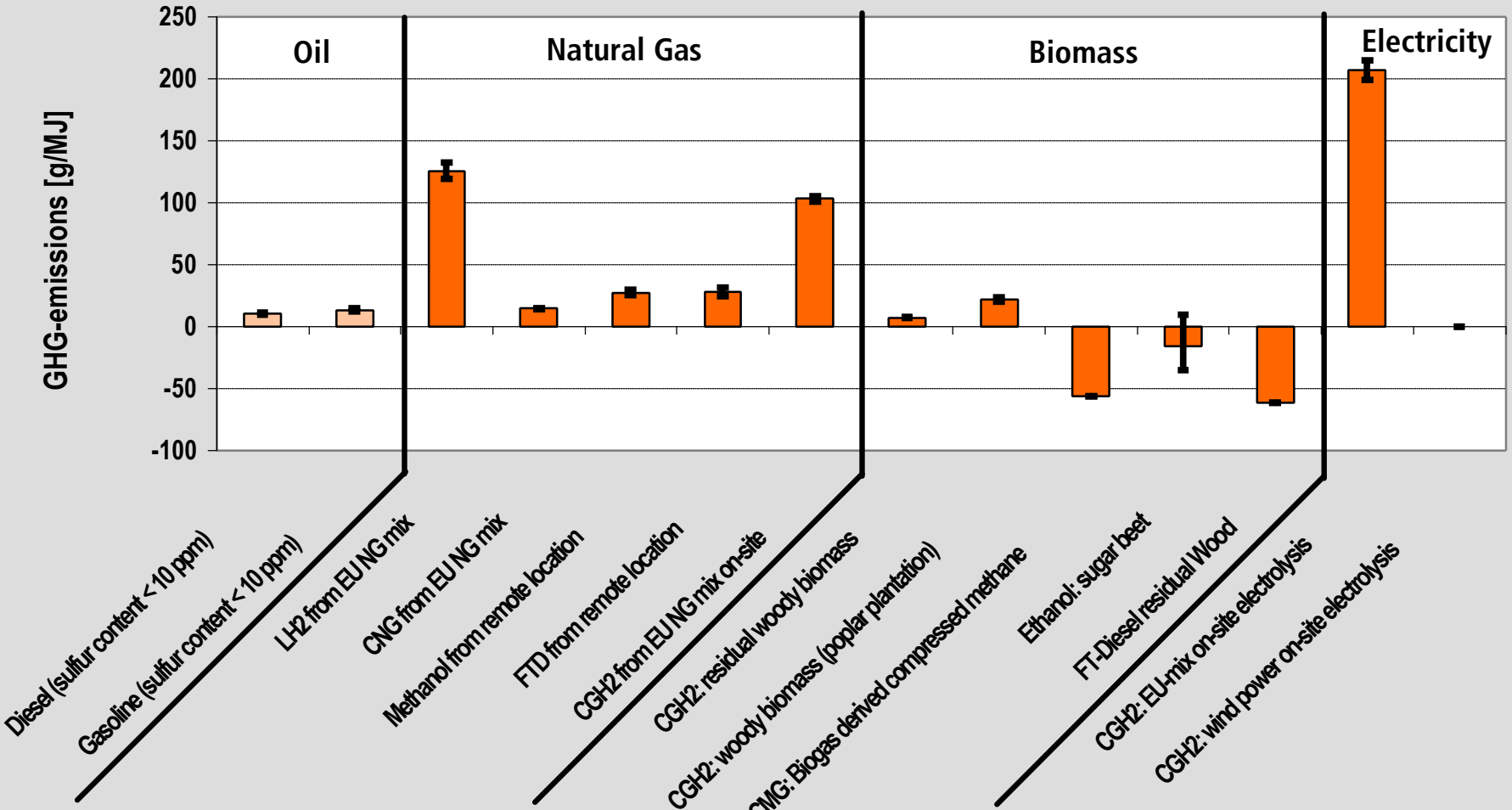
Feedstock →	Fuel
Oil-Based (3)	Gasoline, Diesel, Naphtha
Natural Gas-Based (10)	CNG, Methanol, Fischer-Tropsch Diesel and Naphtha (GTL), Compressed Hydrogen, Liquid Hydrogen
Electricity (7)	Electricity, Compressed Hydrogen, Liquid Hydrogen
Biomass-Based (12)	Compressed Hydrogen, Methanol, Ethanol, Hydrocarbon Liquids, CMG, Bio-ester, ETBE, MTBE
Total pathways examined:	32 [+ 56 variants]

Well-to-Tank

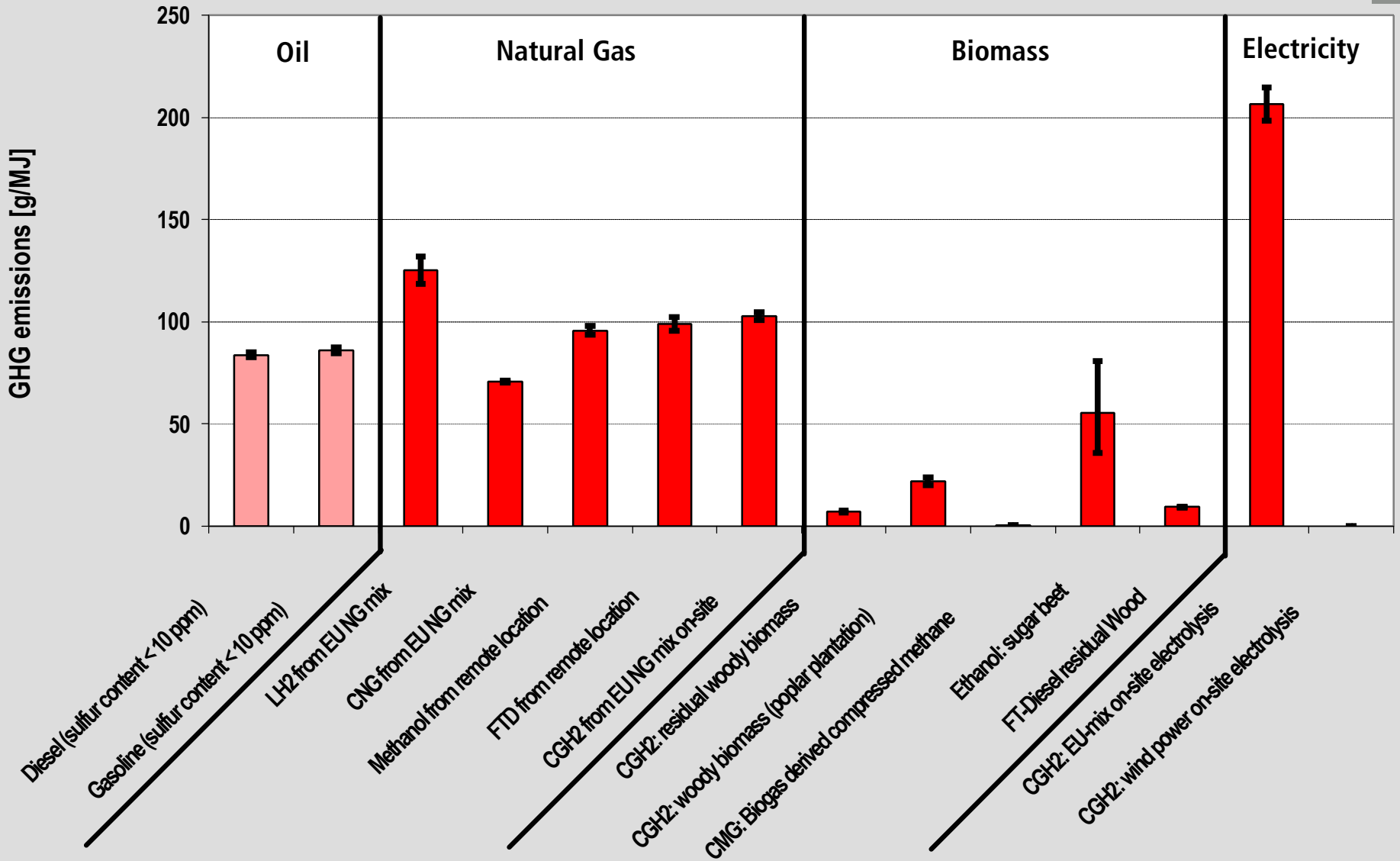
Energy Requirements: Well-to-Tank



GHG Emissions (CO_2 Equivalent): Well-to-Tank



GHG Emissions (CO_2 Equivalent): Fuel Supply and Use



Tank-to-Wheel

GM Well-to-Wheel Study

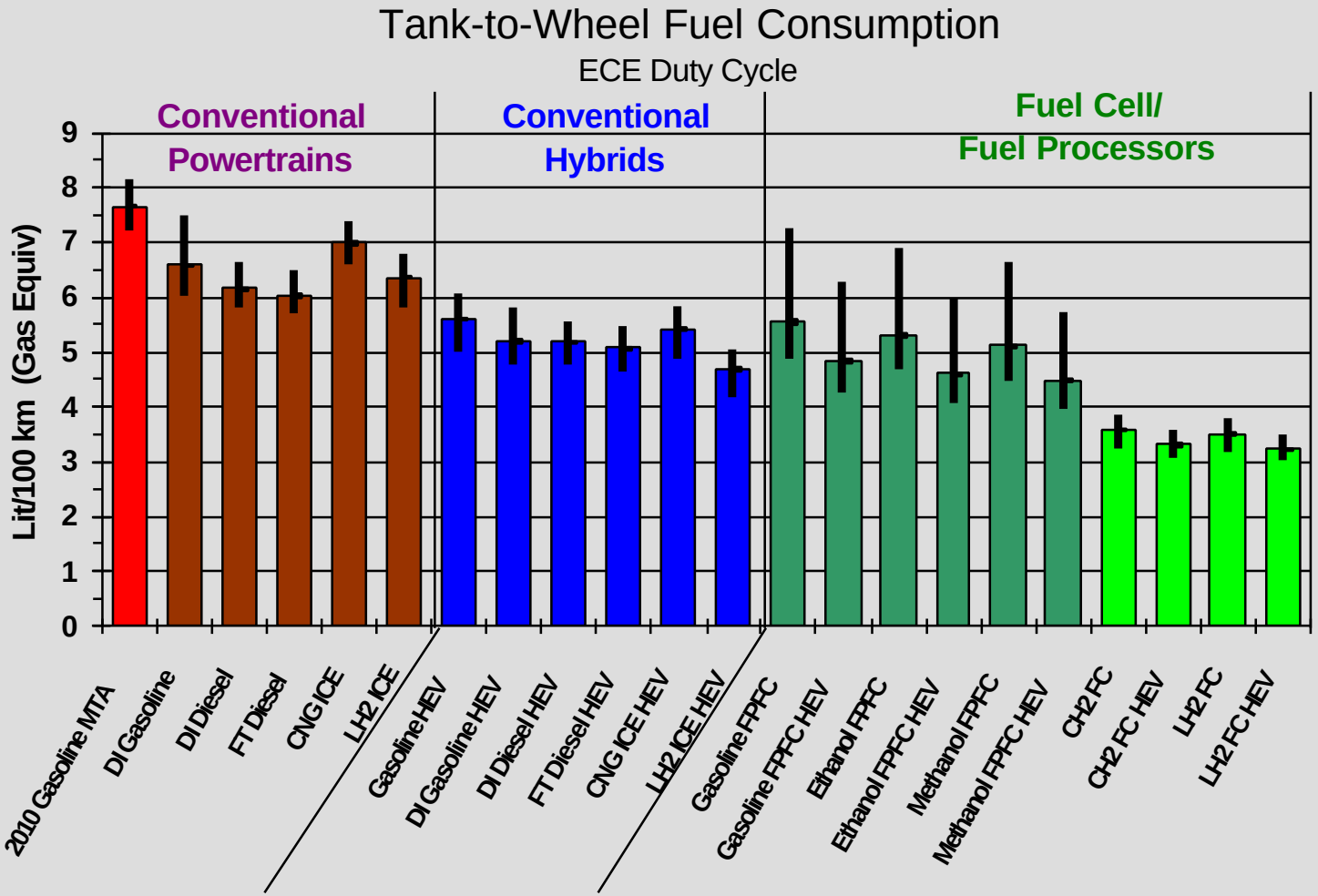
European Tank-to-Wheel Analysis (Vehicle Pathways)

- Baseline vehicle: Opel Zafira
- Duty cycle: European Driving Cycle (EDC)
- All vehicle concepts modeled to meet same set of European customer performance requirements
- Technologies targeted for the 2010 time frame
  - Advanced IC engine and transmission technologies
  - Advanced vehicle level technologies
  - Hybrid system technologies
  - Fuel processor and fuel cell systems in hybrid and non-hybrid architectures

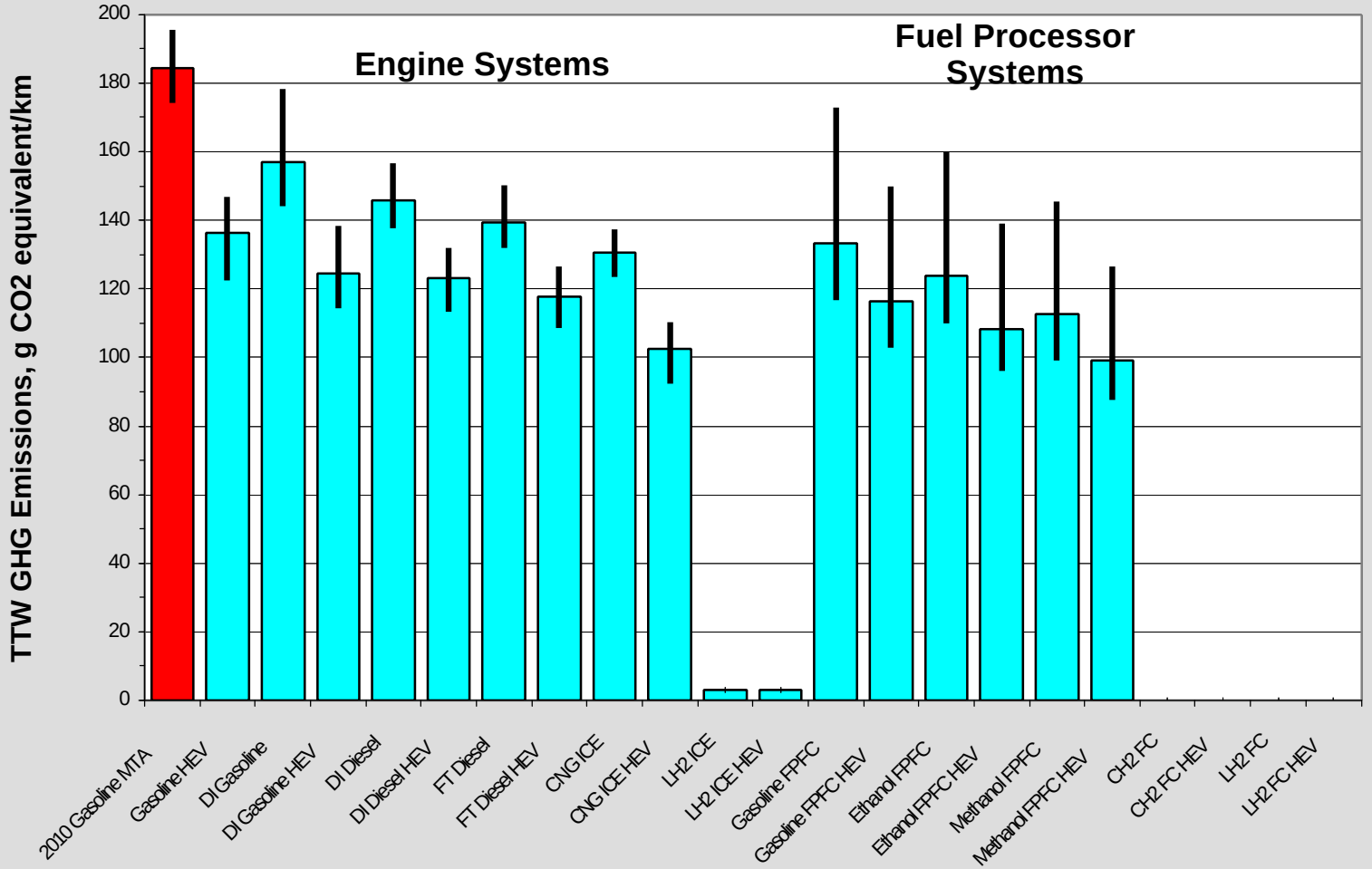
GM Well-to-Wheel Study - Powertrains

	IC Engine	IC Engine Hybrid	Fuel Cell Non-Hybrid	Fuel Cell Hybrid
Gasoline	X +Advanced Powertrain	X	X	X
Diesel	X	X		
FT Diesel	X	X		
CNG	X	X		
Methanol			X	X
Ethanol (E100)			X	X
Hydrogen	X	X	X	X

GM Well-to-Wheel Study - TTW Fuel Consumption



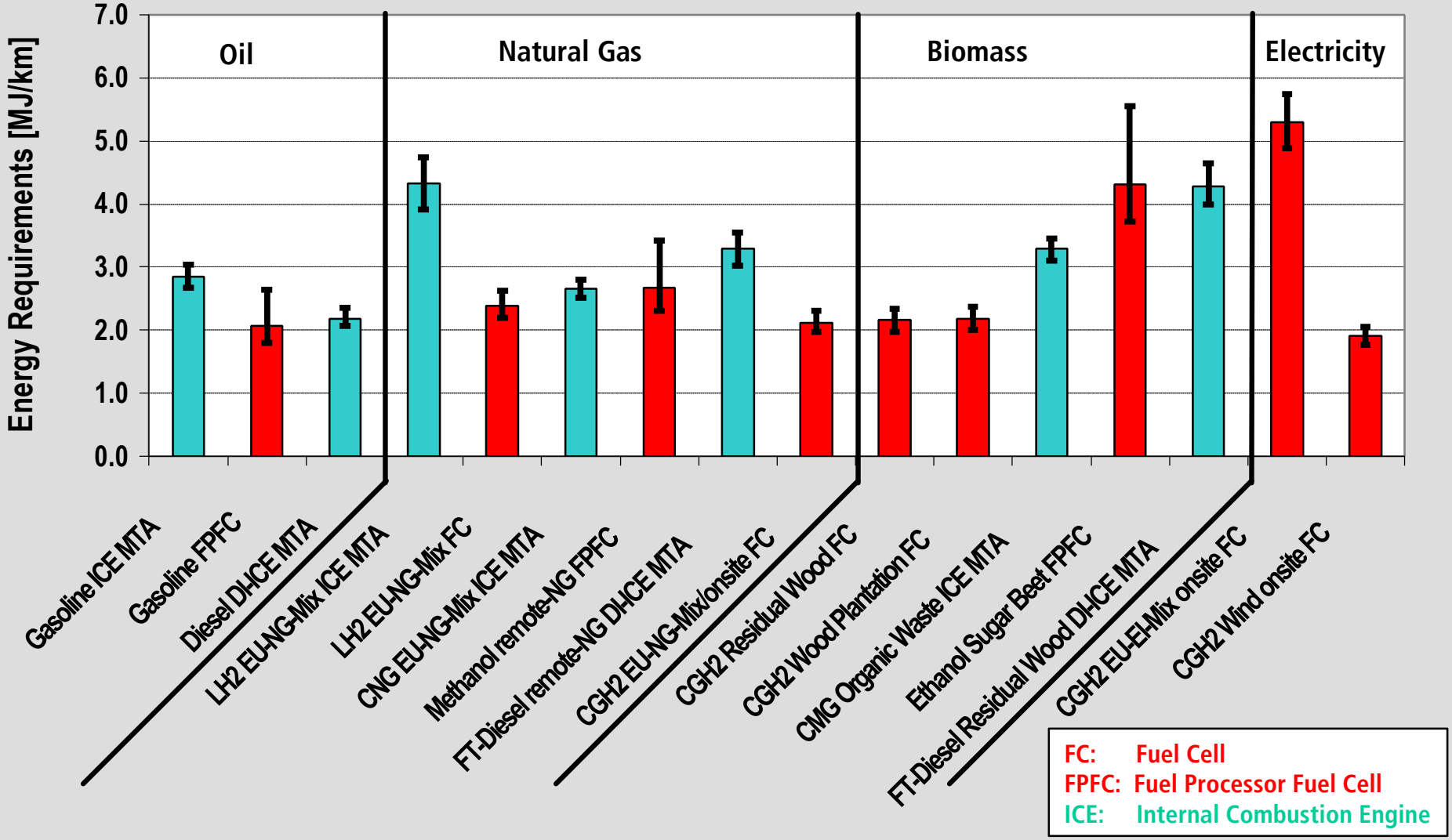
GM Well-to-Wheel Study - TTW GHG Emissions



Well-to-Wheel

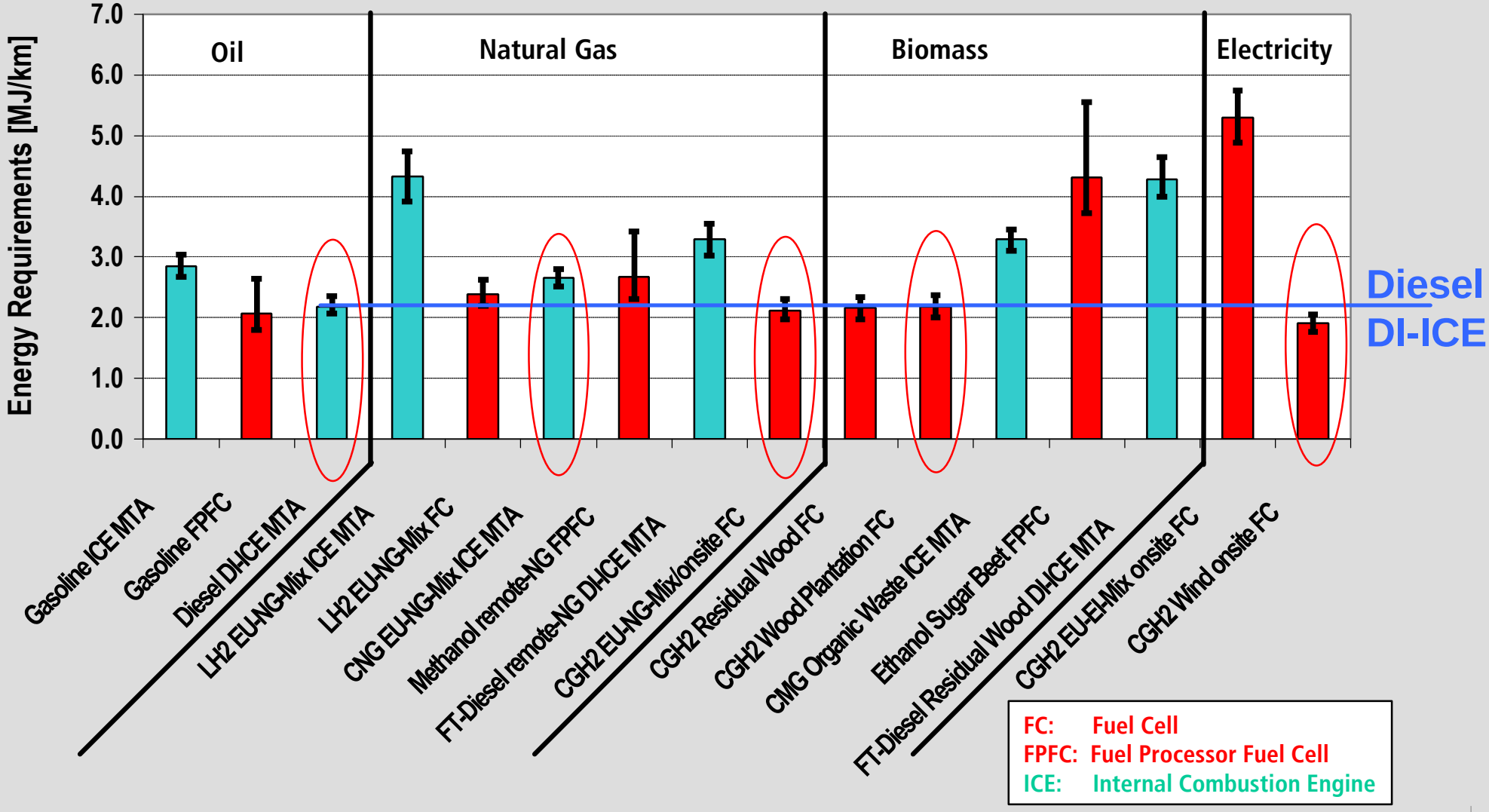
Energy Requirements: Well-to-Wheel

Vehicle: Opel Zafira



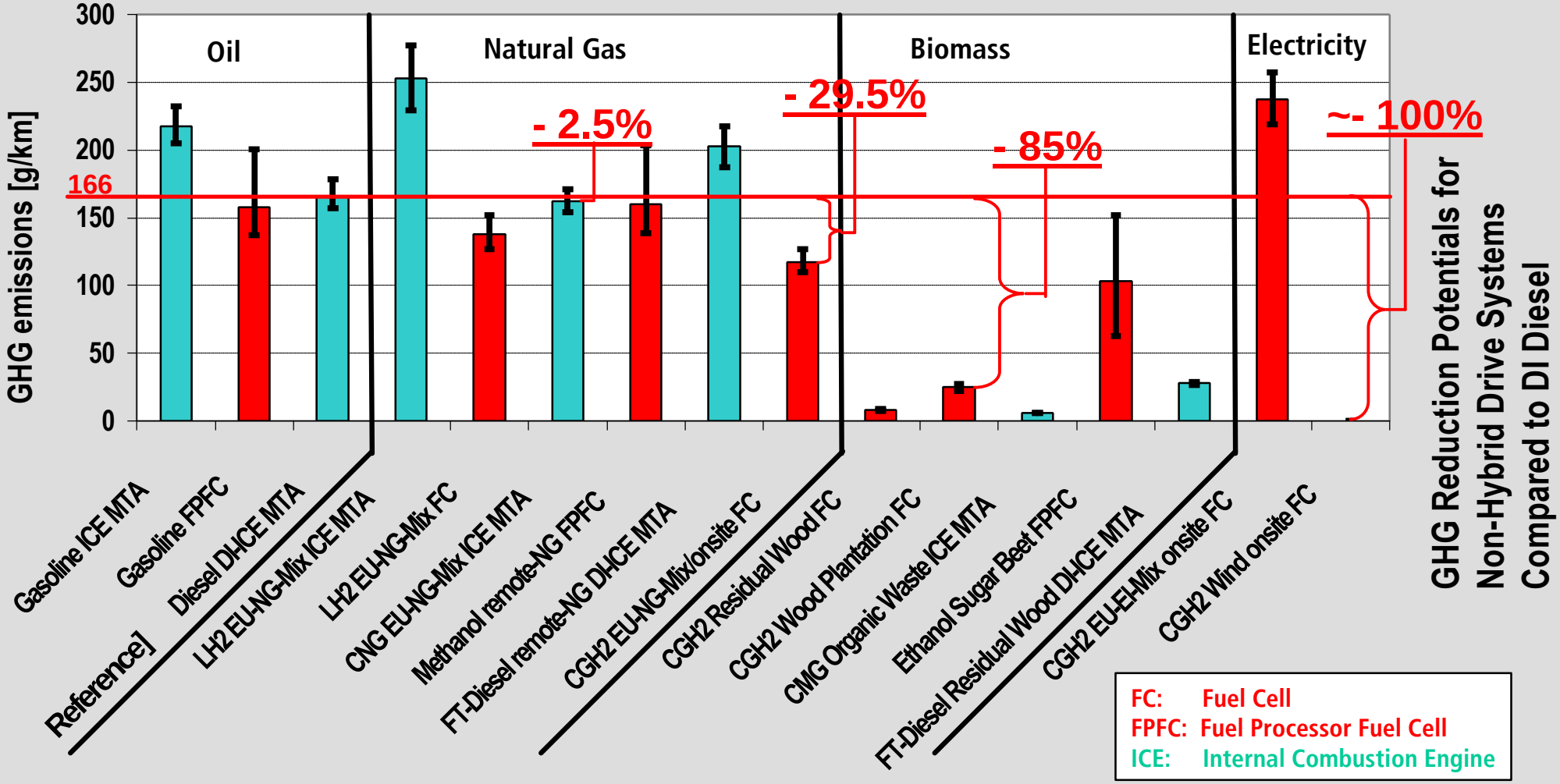
Energy Requirements: Well-to-Wheel

Vehicle: Opel Zafira



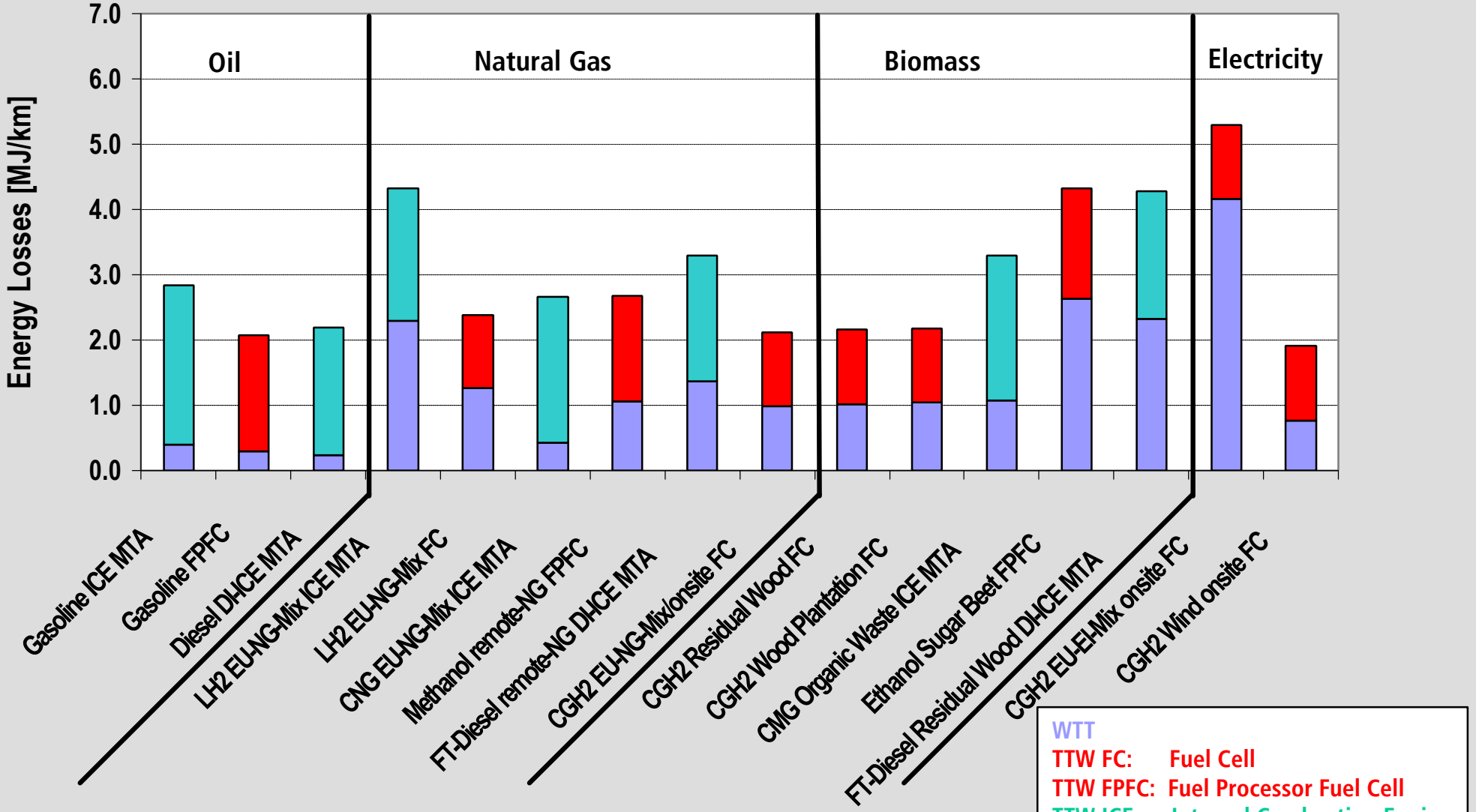
GHG Emissions (CO_2 Equivalent): Well-to-Wheel

Vehicle: Opel Zafira



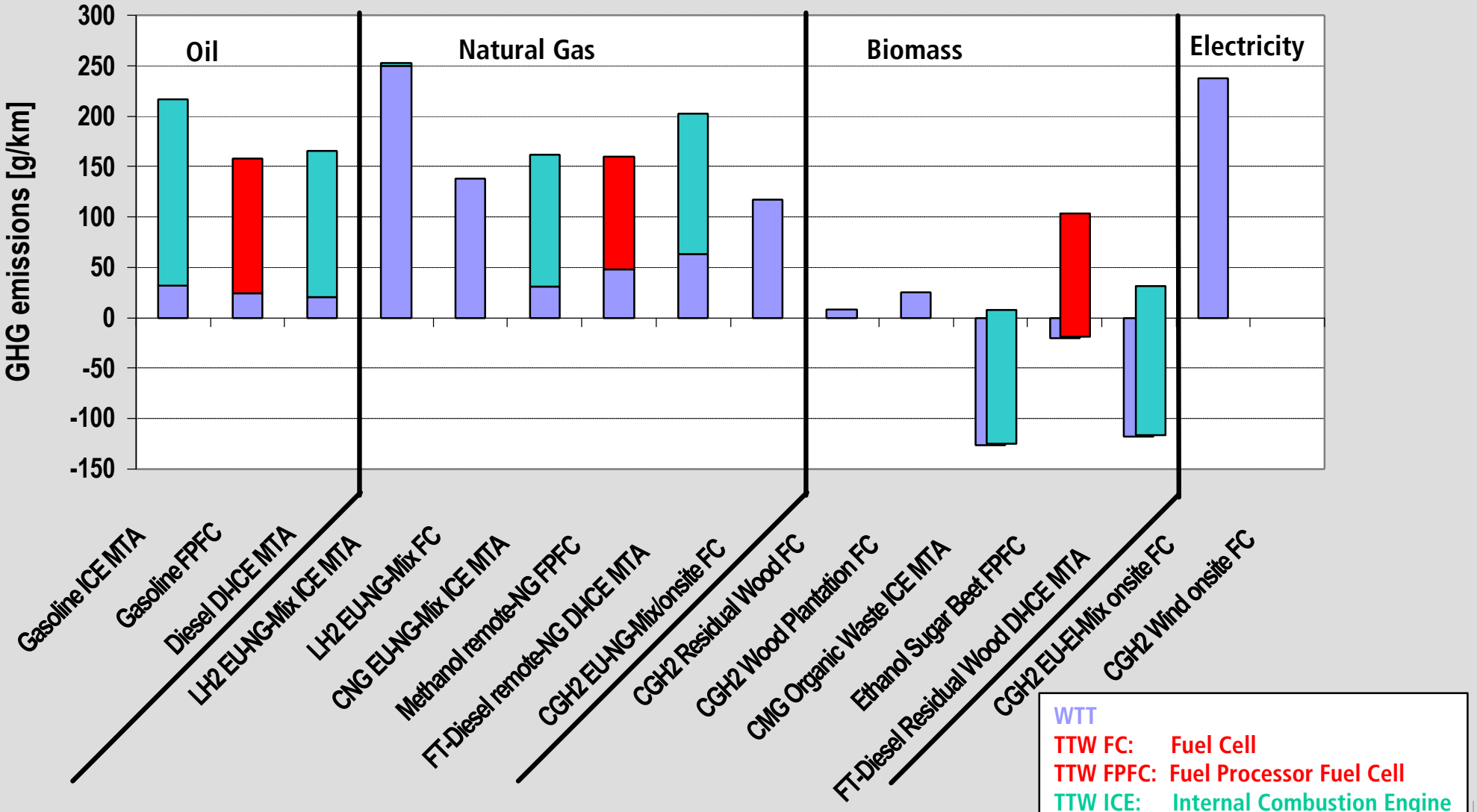
Energy Losses: Split into WTT and WTW

Vehicle: Opel Zafira



GHG Emissions (CO_2 Equivalent): Split into WTT and WTW

Vehicle: Opel Zafira



L-B-Systemtechnik

Some Conclusions from the GM Study

GM Well-to-Wheel Study - Key Findings of WTW Analyses

- WTT analyses may result in different conclusions than WTW analyses
- The advantage of FCVs versus ICEVs depends to a great extent on the fuel supply chain and becomes obvious only in the WTW context
- Clear advantage for hybrid ICE vehicles
- Clear advantage for FCVs in GHG emissions and fuel economy
- Hydrogen has the highest feedstock flexibility of all fuels

GM Well-to-Wheel Study - Key Findings of WTW Analyses (2)

- Renewable energy derived hydrogen is the superior fuel pathway, regarding GHG emissions
- Best biomass derived fuel is hydrogen
- Hydrogen from electricity mix shows no advantages at all
- NG-derived hybridized CGH_2 FCV is 25% better in GHG emissions than the hybridized CNG vehicle
- Advantage of switching to GTL (FT diesel) is non-existent
- Methanol FCVs have no real advantage over advanced diesel vehicles, advantages over gasoline ICE vehicles, no advantages over gasoline onboard reforming vehicles

GM Well-to-Wheel Study - Key Findings for Biomass Pathways

- Biomass pathways depending on given situation differ widely in GHG emissions
- The differences are mainly attributable to N_2O emissions which depend on type of soil, nitrogen fertilizer input and climatic conditions which vary widely in different regions of Europe
- Carbon release (CO_2 emissions) caused by land use change was not considered (but may have a significant influence)

Websites of L-B-Systemtechnik

L-B-Systemtechnik Website:
www.lbst.de

Information on hydrogen and fuel cells:
www.HyWeb.de

Information on fossile energy resources:
www.energiekrise.de

Hydrogen and fuel-cell vehicle overview:
www.h2cars.de

Information on fuel cells:
www.innovation-brennstoffzelle.de

Information on hydrogen projects:
www.h2guide.de

European Integrated Hydrogen Project:
www.eihp.org

EIHP

HyNet - The European Thematic Network on Hydrogen:
www.HyNet.info

HyNet