JEC WTW Version 4: European perspective on advances in vehicle technology

October 17, 2013

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OUTLINE

Background

- Ford Research Center Aachen
- JEC Consortium
- Scope and methodology of JEC Well-to-Wheels (WTW) study

Results

- Tank-to-Wheels (TTW) work
- Powertrain portfolio, regulatory drive cycle and test procedures
- 2010 status and outlook into 2020+

Outlook

- Updates in WTT work
- Draft WTW results
- Summary and next steps

FORD RESEARCH & ADVANCED ENGINEERING EUROPE

- Founded in 1994
- Only research facility of Ford outside the US
- Managing Directors:
  - Dr. Andreas Schamel
  - Prof. Dr. Pim van der Jagt
- 280 employees from 25 different nations
- Locations:
  - Aachen (Ford Forschungszentrum Aachen), Germany
  - Cologne, Germany
  - Lommel (test track site), Belgium

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THE JEC CONSORTIUM: A SHORT HISTORY

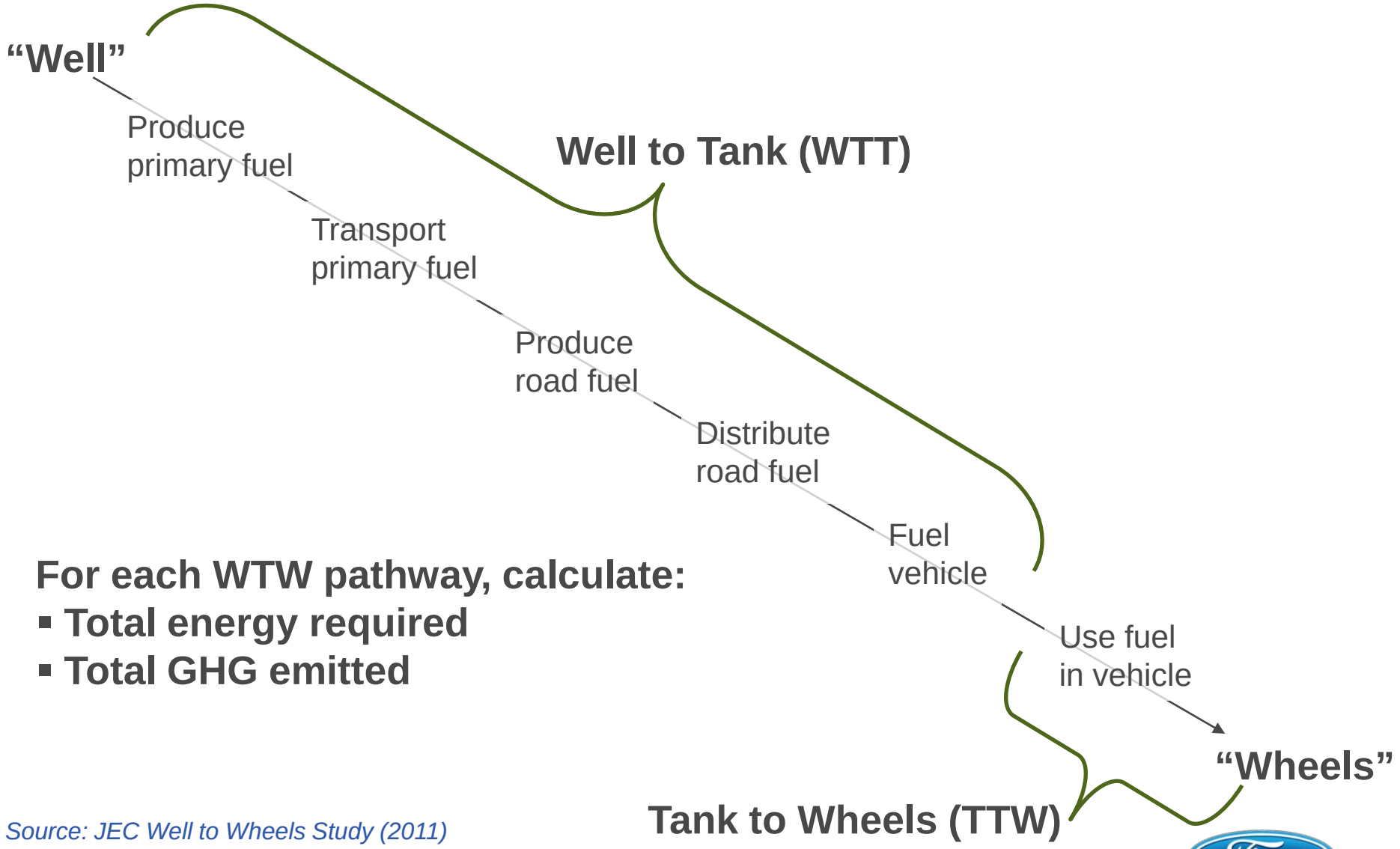
The **JEC** research collaboration was initiated in 2000 by:

- **J**RC: Joint Research Centre of the European Commission
- **E**UCAR: European Council for Automotive R&D
- **C**ONCAWE: Research Association of the European Oil Refining Industry

Collaborative Projects

- 2000-2011: Projects Completed
  - Well-to-Wheels (WTW) Studies:
    - Version 1 (2004)
    - Version 2a and 2b (2007)
    - Version 3c (2011)
  - Impact of ethanol on vehicle evaporative emissions (SAE 2007-01-1928)
  - Impact of ethanol in petrol on fuel consumption and emissions
  - JEC Biofuels Study for a 2020 time horizon (2011)
- 2013: Projects in Progress
  - 2013: Version 4 WTT, TTW, and WTW Studies
  - 2013: Update of the 2011 JEC Biofuels Study

WELL-TO-WHEEL: SCOPE & METHODOLOGY



For each WTW pathway, calculate:

- **Total energy required**
- **Total GHG emitted**

Source: JEC Well to Wheels Study (2011)

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TANK-TO-WHEEL: SCOPE

- Define and characterize **reference vehicle** & **vehicle technologies**
- Establish **performance criteria** based on customer expectations
  - Range, acceleration times, grade ability, top speed, …
- All vehicles are based on **same reference** for comparability
  - All **vehicles share same glider** as reference (body & chassis)
  - Alternative vehicles are defined by virtually removing and adding specific components
  - **Weight** impact of tanks, extra batteries, etc. is covered
- **Future advanced technologies**
  - The potential impacts of future technologies need to be carefully assessed

TANK-TO-WHEEL: METHODOLOGY (NEW IN VERSION 4)

- Generic C-segment vehicles
  - Conventional “ICE-only” vehicles
  - Portfolio of electrified vehicles (xEV)
    - Hybrids, Plug-in Hybrids, Range Extended, Battery and Fuel Cell Electric Vehicles
- Compliance with Euro 5 and Euro 6 emission regulations
- New European Driving Cycle (NEDC) & UNECE R101 applied
- Fuel consumption & electric energy consumption
- GHG emissions: CO_2, CH_4 & N_2O
- Comprehensive vehicle simulations with AVL Cruise
  - Input data (component details, calibrations, controls, …) agreed between EUCAR and AVL experts
- Timeline: 2010 & 2020+

TANK-TO-WHEEL: VEHICLE CHARACTERISTICS

- C-segment **reference vehicle** model year 2010:
- 1.4L DISI ICE, 6 speed Manual Transmission, Front Wheel Drive.

Generic C-segment reference vehicle with 1.4L DISI ICE (2010)			Improved Reference Vehicle for 2020+
Curb weight (incl. driver and 90% fuel)	kg	1310	1200 (*)
ITW class	kg	1360	1250
Length	mm	4326.5	
Width (without exterior mirror)	mm	1789.4	
Height	mm	1484.8	
Cross-sectional area	m^2	2.2	
Air drag coefficient	---	0.30	0.24
Rolling resistance coefficient	---	0.007	0.005
Wheel base	mm	2638.9	
Height of gravity center	mm	600	
Distance of gravity center from front axle	mm	1200	
Dynamic Rolling Radius	mm	309	
(*) Vehicle mass is reduced by 110 kg			

TANK-TO-WHEEL: VEHICLE PERFORMANCE CRITERIA

- Like TTW V3: **equal vehicle minimum performance** criteria for all powertrains
- **Top-speed** criterion for **BEV / REEV** reduced to reflect the market reality in 2010
- **Battery capacity** restricts **BEV driving range**, but **increases** from **2010 to 2020+**
- However, **acceleration** and **gradeability** criteria are identical.

		2010					2020+				
		PISI DISI DICI Hybrid SI Hybrid CI	PHEV SI PHEV CI	REEV SI	BEV	FCEV	PISI DISI DICI Hybrid SI Hybrid CI	PHEV SI PHEV CI	REEV SI REEV CI REEV FC	BEV	FCEV
Time to accelerate from 0-100 km/h	[s]	11	11	11	11	11	11	11	11	11	11
Elasticity for 80-120 km/h	[s]	11	11	11	11	11	11	11	11	11	11
Gradeability at 1 km/h	[%]	30	30	30	30	30	30	30	30	30	30
Gradeability at 10km/h	[%]	20	20	20	20	20	20	20	20	20	20
Minimum Top speed	[km/h]	180	180	130	130	180	180	180	130	130	180
Minimum Top speed pure electric	[km/h]	#	100	130	130	180	#	100	130	130	180
Total minimum driving range	[km]	500	500	500	120	500	500	500	500	200	500
Battery powered minimum driving range	[km]	#	20	80	120	#	#	20	80	200	#
Fuel consuming minimum driving range	[km]	500	480	420	#	500	500	480	420	#	500

VEHICLE AND FUEL COMBINATIONS

Powertrain / Fuel	PISI	DISI	DICI	Hybird DISI	Hybrid DICI	PHEV20 DISI	REEV80 SI	PHEV20 DICI	REEV80 CI*	BEV	FCEV	REEV80 FC**
Gasoline	■	■		■		■	■					
Gasoline E10 market blend	■	■		■		■	■					
Gasoline E20 high RON	■	■		■		■	■					
Diesel			■		■			■	■			
Diesel B7 market blend			■		■			■	■			
LPG	■	■										
CNG	■	■										
E85	■	■		■		■	■					
FAME			■		■			■	■			
DME			■									
FT-Diesel			■		■			■	■			
HVO			■		■			■	■			
Electricity						■	■	■	■	■		■
Hydrogen (CGH2)											■	■
Hydrogen (cCGH2)											■	■

■ 2010 & 2020+

■ 2020+ only

PISI / DISI: Port Injection / Direct Injection Spark Ignited engine

DICI: Direct Injection Compression Ignited engine

PHEV20: Plug-In Hybrid Vehicle with an electric range of 20km (NEDC)

REEV80: Range Extended Electric Vehicle with an electric driving range of 80km (NEDC)

BEV: Battery Electric Vehicle

FCEV: Fuel Cell Electric Vehicle

REEV80 FC: Range Extended FC. Vehicle with an electric driving range of 80km (NEDC) and Fuel Cell Range Extender

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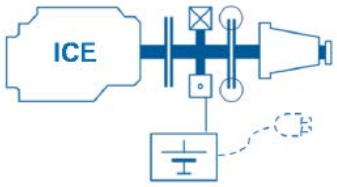
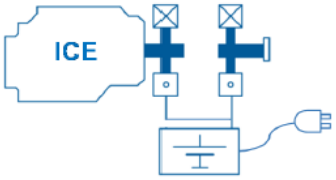
HEV AND XEV TOPOLOGIES

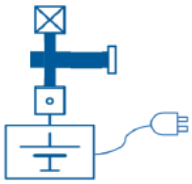
The TTW study determines definitions of **powertrain topologies** and **system architectures**, estimates of **Hybrid functionalities** and **operational strategies**.



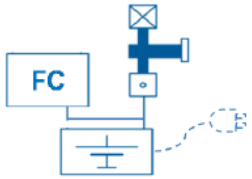
Hybrid Electric Vehicle (HEV) &
Plug-in Hybrid Electric Vehicle (PHEV) aka 'P2 Hybrid'



Range Extended Electric Vehicle (REEV)



Battery Electric Vehicle (BEV)



Fuel Cell Electric Vehicle (FCEV)

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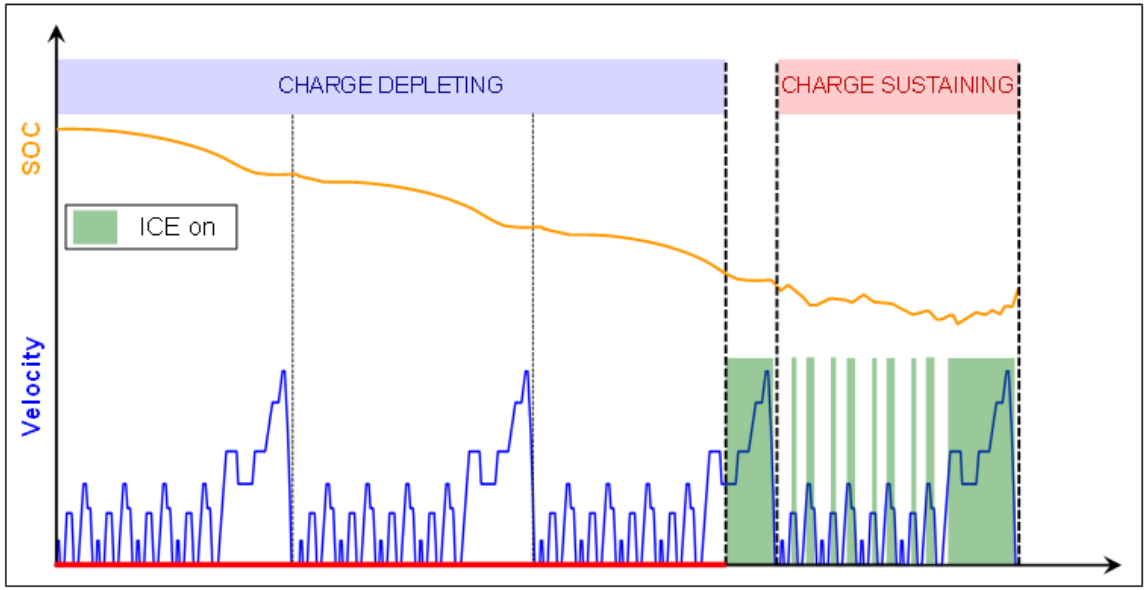
DRIVE CYCLE: NEDC CYCLE AND UNECE R101

- **NEDC** is used to ensure comparability of results for 2010 and 2020+
- It is expected that by 2020+ the Worldwide harmonized Light vehicles Test Procedure (**WLTP**) will be used for vehicle fuel consumption, emission testing.
- However, during the TTW study work, the **WLTP has not been finally defined**.
- **Real world driving** may show different results due to a range of **impacting parameters** and **customer choices** like different **driving habits**, **road conditions** and **cabin comfort needs**.
- Fuel consumption of **PHEV** and **REEV** is determined by **UN ECE R101**



$$FC_{Cert.} = \frac{D_e \cdot FC_{CD} + 25 \cdot FC_{CS}}{D_e + 25}$$

FC_{CD}: *Fuel Consumption during Charge Depleting*

FC_{CS}: *Fuel Consumption during Charge Sustaining*

D_e: *All Electric Range (marked in red)*

Assumed average distance between two battery recharges: ***25km***

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TECHNOLOGY WALK: 2010 TO 2020+

- **2020+ simulation results** include a "**Technology Walk**"
- Reflecting the **expected improvements** in **technology development** compared to the **2010 configurations** – on an average C-segment car

Technology Walk for "ICE only" Powertrain Variant (without consideration of GHG)		PISI with Gasoline Fuel		DISI with Gasoline Fuel		DICI with Diesel Fuel	
		NEDC[1] CO_2-Emissions	Technology dependent CO_2-Reduction	NEDC[1] CO_2-Emissions	Technology dependent CO_2-Reduction	NEDC[1] CO_2-Emissions	Technology dependent CO_2-Reduction
		g/km	%	g/km	%	g/km	%
"ICE only" Variant 2010		**155.1**	Reference	**149.6**	Reference	**119.0**	Reference
Transmission	Transmission Measures[2]	**148.2**	**4.4%**	**145.4**	**2.8%**	**114.2**	**4.0%**
ICE	New ICE for 2020+	**133.4**	**9.5%**	**125.6**	**13.2%**	**105.4**	**7.4%**
	Improved Auxiliaries	**129.8**	**2.3%**	**122.1**	**2.3%**	**102.2**	**2.7%**
Start & Stop		**122.4**	**4.8%**	**116.0**	**4.1%**	**98.0**	**3.5%**
Vehicle Measures	Weight Reduction	**118.7**	**2.3%**	**112.6**	**2.3%**	**94.6**	**2.8%**
	Improved aerodynamics	**113.9**	**3.1%**	**108.0**	**3.0%**	**90.4**	**3.5%**
	Improved rolling resistance	**110.2**	**2.4%**	**104.5**	**2.3%**	**86.8**	**3.0%**
"ICE only" Variant 2020+		**110.2**	**28.9%**	**104.5**	**30.1%**	**86.8**	**27.1%**

1) NEDC Cycle results for cold start condition; Vehicle Test Mass = Curb weight incl. Driver, 90% fuel
2) For PISI: New 6-Speed Manual Transmission (MT5 is replaced); For DISI & DICI: Downspeeding & Improved Efficiency of 6-Speed Manual Transmission

<u>Please note</u>: All investigated powertrain configurations are theoretical vehicle configurations and do not represent any existing vehicle or brand

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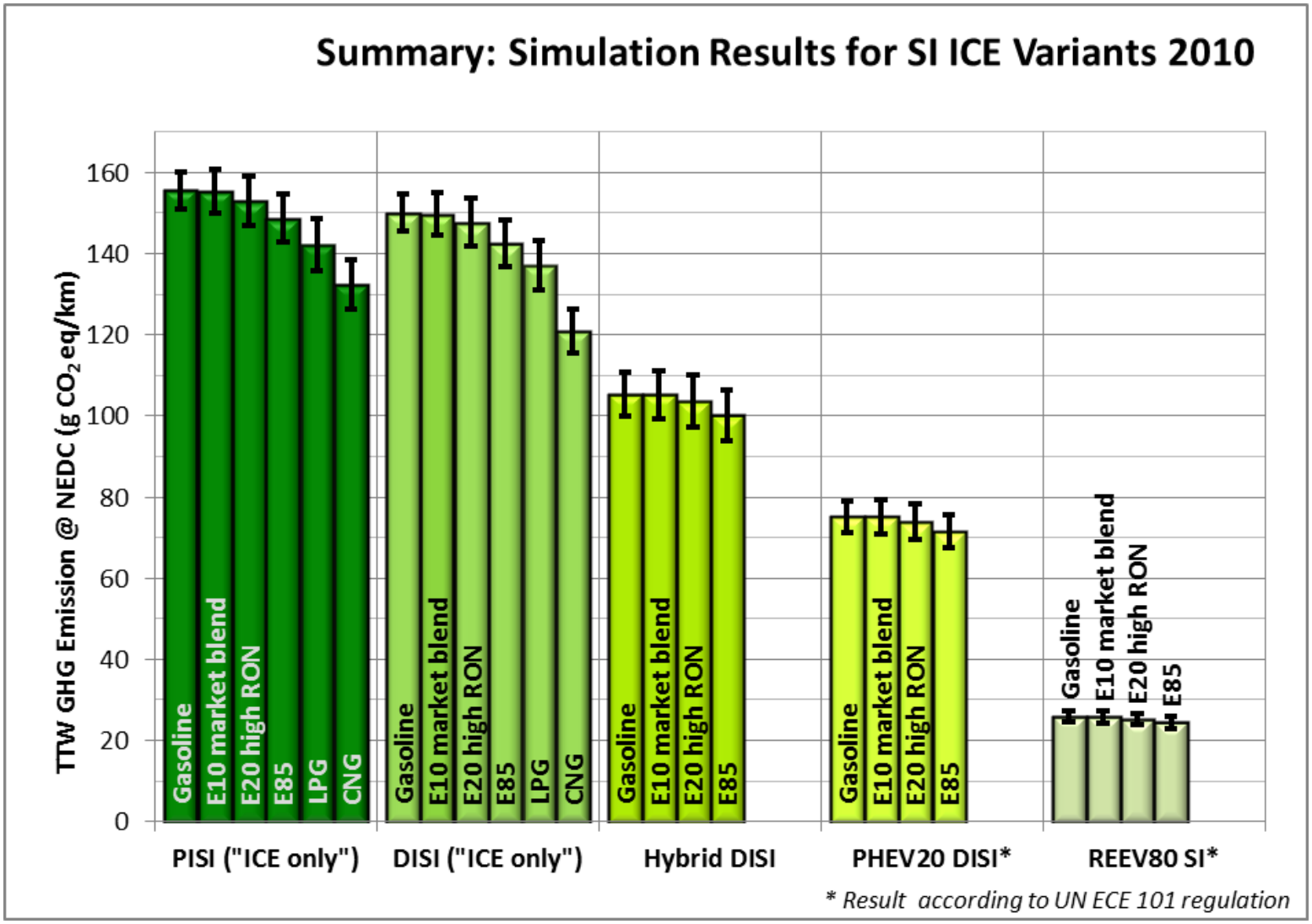
TTW: RESULTS FOR SPARK-IGNITED VARIANTS



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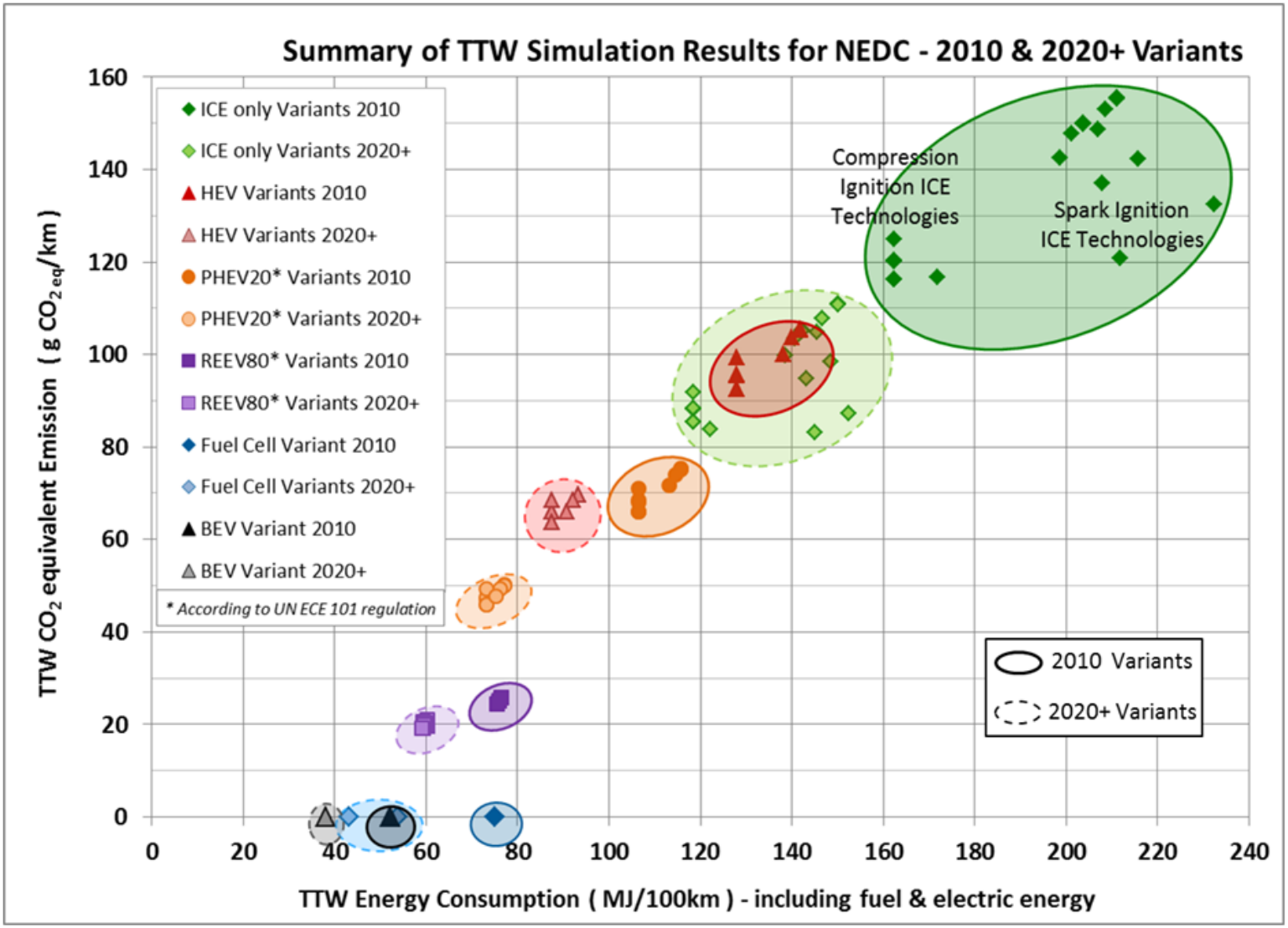
TTW: SUMMARY OF RESULTS



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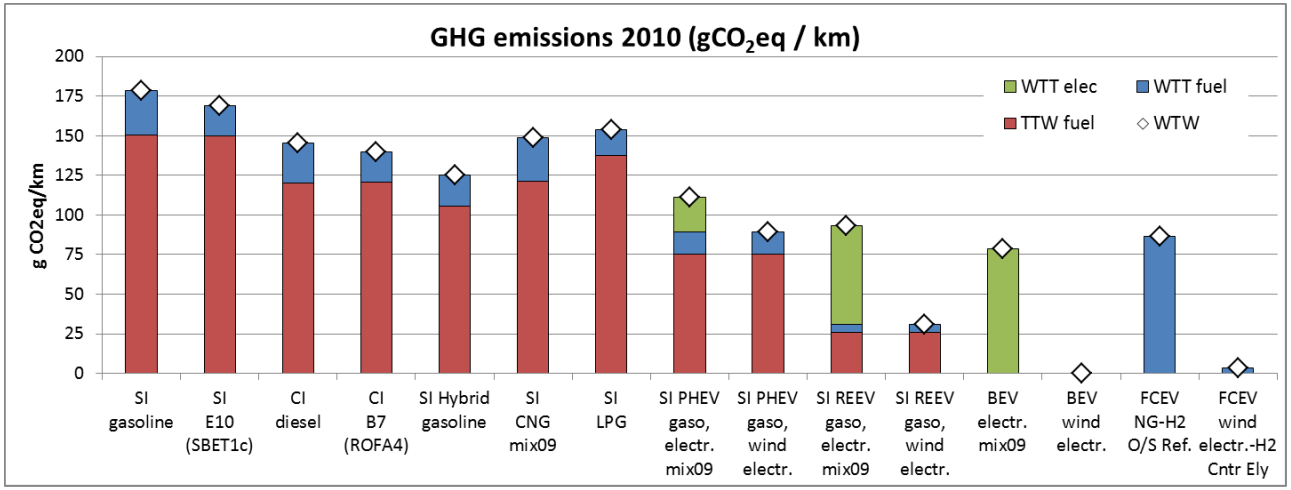
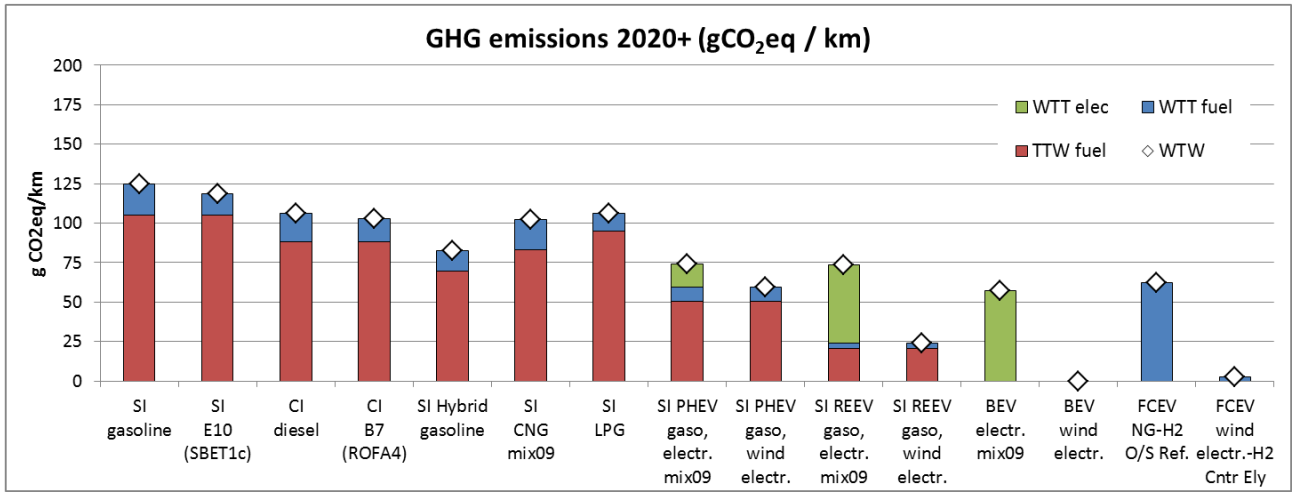
UPDATES OF WELL-TO-TANK WORK

- Considering WTT there are several updates:
  - Some pathways have been deleted
    - GTL plant in EU
  - New pathways have been added
    - FAME from Used Cooking Oil
    - Shale Gas in Europe
  - Some pathways are still being reviewed, e.g. Hydrogen
  - New work by JRC considering updated N_2O emission data from farming
  - Update on EU27+2 electricity mix, now based on 2009 market statistics
  - Update on EU27+2 natural gas mix, now based on 2009 market statistics

- Well-to-Wheels results will be updated and broaden with fuel and powertrain line-up.

SELECTED WELL-TO-WHEELS DRAFT RESULTS: GHG EMISSIONS





Draft results

Efficiency improvements in all powertrain options expected

Alternative vehicles and low carbon fuels show significant GHG savings

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SUMMARY OF THIS PRESENTATION AND NEXT STEPS

- A portfolio of vehicles and assigned fuels have been simulated for a generic European C-segment vehicle
  - Fuel consumption, Electric energy consumption & GHG emissions have been calculated for the NEDC and according to UN ECE R101
  - Two time horizons covered: 2010 and 2020+
- The results for the various vehicle technologies and fuels span a wide range in the Energy Consumption – GHG emissions manifold

- Next Steps:
  - Finalize work on WTW integration

All JEC reports are published on the JRC website:

http://iet.jrc.ec.europa.eu/about-jec

Any questions, enquiries, or requests about JEC activities and results can be addressed to the centralized email address:

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