JEC **WTW** v5

Well-to-Wheels analysis of future automotive fuels and powertrains in the European context

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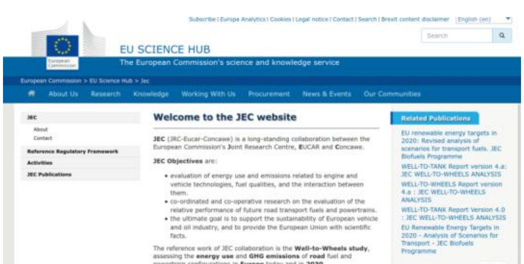
JEC WTW – **Goal and scope**



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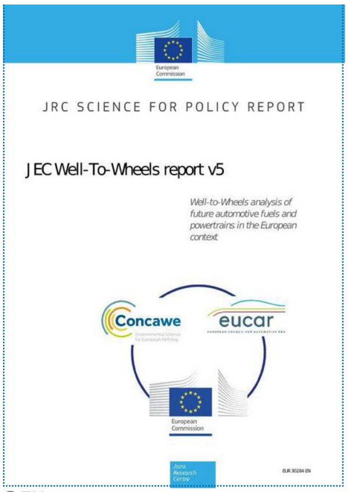
The **JEC** (**J**RC-**E**UCAR-**C**oncawe) is a long-standing **collaboration** between the European Commission's **J**oint **R**esearch **C**entre, **EUCAR** and **CONCAWE**.
Objectives of the **JEC are:**

- the **evaluation** of **energy use** and **GHG emissions related to engine** and vehicle technologies**, fuel production routes** and final quality**,** and the **interaction** between them**;**
- **provide** the **European Union** with **scientific WTW facts, supporting** the **sustainability development of European vehicle and refining industries.**

JEC WTW – **Goal and scope**



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In this brand new update, version 5, you will find:

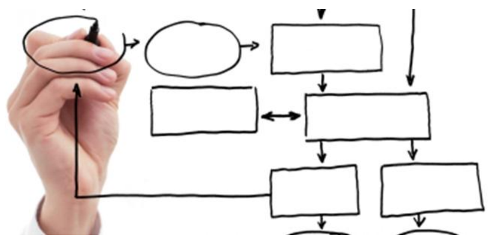
- **New fuel production pathways**, including new conversion technologies, new fuels and new feedstocks. Complemented by the update of version 4 pathways.
- **Heavy-duty vehicles**, included for the first time in the report. Long-haul and regional trucks have been added to the updated passenger car model.
- *Worldwide Harmonized Light Vehicle Test Procedure* (**WLTP**) replacing the *New European Driving Cycle* (NEDC).

JEC **WTW**

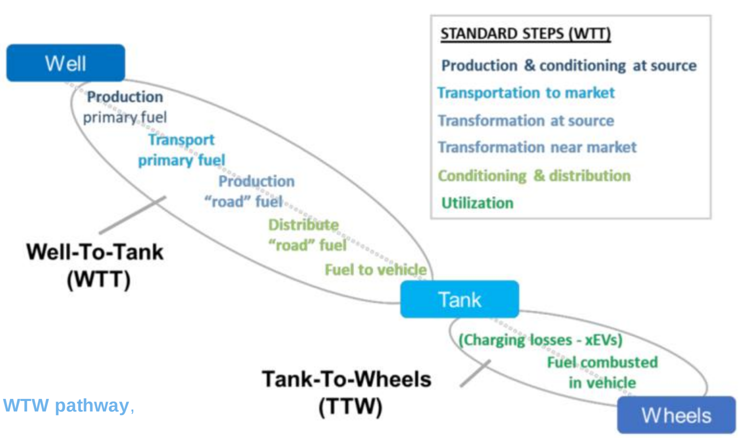
Currently, **JEC WTW has been used as source** for:

- DG-MOVE report "**State of the art on alternative fuels transport systems in the European Union - 2020 update**",
- DG-CLIMA study "**Determining the environmental impacts of conventional and alternatively fuelled vehicles through LC**A", performed by a consortium led by RICARDO.
- Data have been supplied for work of the **IPCC WG3 LCA data** (call for data on climate footprints and costs of mitigation options within the transport sector).

Methodological approach



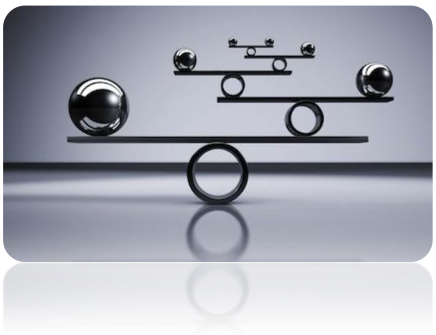
JEC WTW v5. Scheme



For each WTW pathway, calculate:

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

WTW vs LCA



- **JEC** is **not a full LCA** and it **focuses** on CO2eq **emissions**.
- In JEC study are **not considered**:
  - emissions related to plants and vehicles building and manufacturing;
  - plants and vehicles end of life.
- Important **implication** of this **approach**:
  - for **electricity** and derived fuels (e.g. H2 and e-fuel) emission are **free of CO2eq emissions** produced from **wind** and **PV**.

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Time Horizon

- **JEC** investigates this upcoming decade, in particular:
  - **current situation** (values labeled as 2016 but updated at **2018**)
  - **2030** time horizon (labeled as 2025+)

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Co-product emissions: JEC vs REDII

A given (fuel) production process may produce multiple products*

* Co-products

Different routes can have very different implications in terms of energy, GHG, or cost

…and it must be realised that economics – rather than energy use or GHG balance – are likely to dictate which routes are the most popular in real life.

Co-products in RED and RED Recast

- **RED and RED Recast allocate GHG emissions to biofuels and co-products by energy content** (LHV), i.e.:
  - Emissions are allocated to the main product and on co-products on the basis of their respective energy contents

☑ **Allocation methods have the attraction of being simpler to implement**

▯ Any benefit from a co-product depends on what the by-product substitutes: allocation methods take no account of this

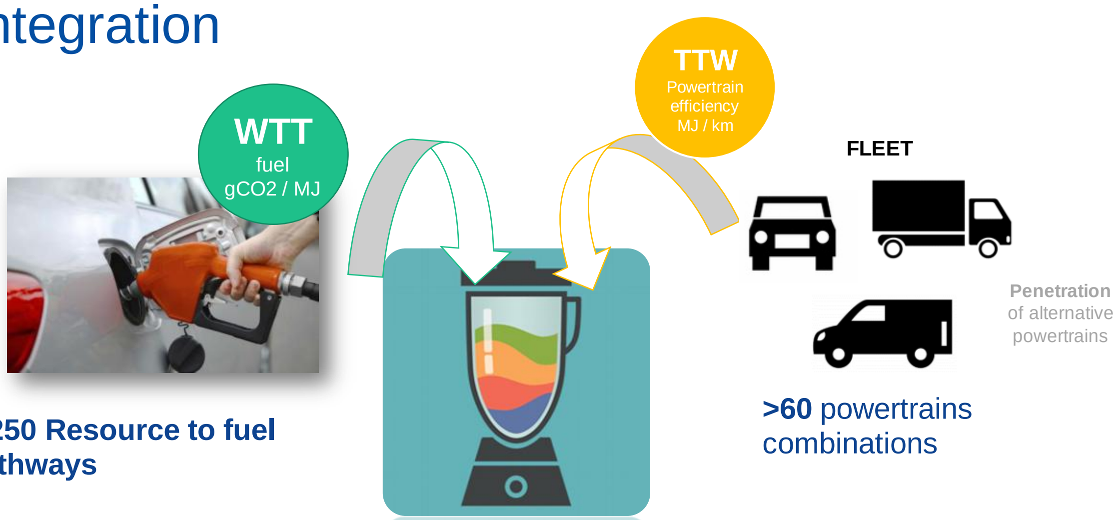
Co-products in JEC WTW Methodology

- **JEC methodology uses a substitution method**, i.e.:
  - All energy and emissions generated by the process are allocated to the main or desired product;
  - The co-product generates an energy and emission credit equal to the energy and emissions saved by not producing what the co-product is most likely to displace.

☑ **Closer representation of "real-life": economic choices of stakeholders**

▯ Uncertainty: outcomes dependent on fate of co-products

Integration



> 1500 possible combinations!

Pathways selection criteria

For **each fuel group** (i.e. ethanol, biodiesel, etc.) we selected a maximum of **5 WTT pathways** for WTW integration

Criteria to select pathways		Icon
Reference fuel for comparison	Conventional fuel: the alternative can be compared against (e.g. regular diesel).	● (blue circle)
GHG emissions - Max **(Maximum value - gCO_{2eq}/MJ)**	Value close to the maximum allowed GHG Emissions, according to RED recast. As a general rule, WTT pathways with significantly higher GHG Emissions are not included in the comparison[5].	★ (red star)
GHG emissions - Min **(Minimum value - gCO2eq/MJ)**	The route offering the minimum WTT GHG emissions. This value, along with the maximum route mentioned above, determine the WTT range of the production routes explored towards a final fuel.	★ (orange star)
Representative pathway	Selected pathway for the final fuel. Chosen by consensus within the JEC as example of one of the commercially available routes depending on the case (e.g. most frequent in Europe, higher share in the current mix, etc.).	△ (blue triangle)
Special interest	Selected examples of interesting new pathways/ feedstock.	◆ (yellow diamond)
Technology Readiness Level	TRL > 6 (*)	(no icon)

Note. (*) In this WTW report we have focused on WTT feedstock/conversion routes at or close to be ready for commercialization. Therefore, WTT pathways with Technology Readiness Level (TRL) <6 have been excluded for the present WTW comparison (For additional comparisons, we would suggest the reader to refer back to the individual WTT and TTW reports where all the results for individual pathways/powertrain modelled are detailed).

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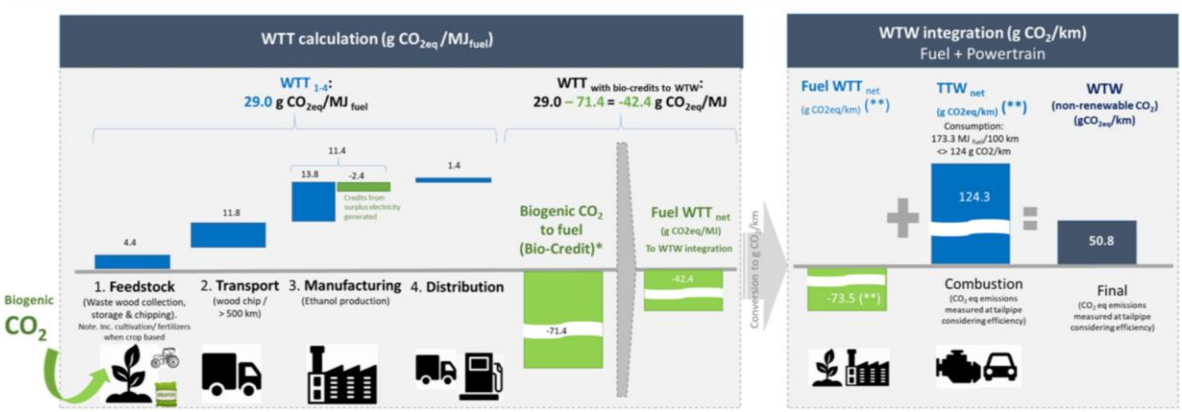
WTW integration



(*) CO_2 released back to the atmosphere when 1 MJ of the fuel is totally combusted. Equivalent to the amount of CO_2 initially captured by the tree during the photosynthesis process (zero net effect)

(**) WTT fraction related to the amount of fuel consumed in a specific powertrain: $WTT_{net\ to\ WTW}$ = -42.4 (g CO_{2eq}/MJ) x 173.3 MJ fuel/100 km <> - 73.5 g CO_{2eq}/km

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HEAVY DUTY VEHICLES (HDV)

MAIN RESULTS

HDV in JEC v5

- Baseline year for vehicle simulations 2016 and the outlook 2025+
- **Powertrain**: Diesel (CI Compression Injection), Dual fuel (PI Port Injection + gas), Hybrid, **Battery** electric, **Fuel cell** electric, Electric road (**Catenary** Electric Vehicle)
- **Fuels**: Conventional (Diesel), alternatives diesel fuels (Biodiesel (B100), Paraffinic diesel (HVO hydrotreated vegetable oil, paraffinic diesel, eFuel) and ED95, Gaseous fuels (DME Di-Methyl-Ether), OME (Oxy-methylene-ethers), LNG (liquefied natural gas)/LBG (liquefied biogas), CNG (compressed natural gas)/CBG (compressed biogas), **Electricity**, **Hydrogen**
- Two applications using **VECTO** test cycle:
  - **Long haul 325kW** (VECTO **group 5**)
  - **Regional haul 220kW** (VECTO **group 4**)

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Specifications reference models 2016 & 2025+

	Group 4	Group 5
Curb mass (90% Fuel + driver) [kg]*	5800	7550
Curb mass body/trailer [kg]	2100	7500
Engine power [kW]	220	325
Displacement [ccm]	7700	12700
Max. Torque [Nm]	1295 (1100 -1600 rpm)	2134 (1000-1400 rpm)
Rated speed [rpm]	2200	1800
Idling speed [rpm]	600	600
Engine peak BTE (%)	44.3	45.8
RRC [N/kN] (Steer/Drive/Trailer)	5.5/6.1/---	5.0/5.5/5.0
CdxA [m2]/vehicle height [m]	5.6/4	5.57/4
Transmission type	AMT	AMT
Efficiency indirect gear	96%	96%
Efficiency direct gear	98%	98%
Axle Ratio	4.11	2.64
Axle Efficiency	96%	96%
Advanced Driver Assistance Systems (ADAS)	---	Predictive Cruise Control (PCC)** + Eco-roll***

* This definition refers to the mass as specified under the 'actual mass of the vehicle' in accordance with Commission Regulation (EC) No 1230/2012 (1) but without any superstructure
** Predictive cruise control manages and optimises the usage of the potential energy during a driving cycle
*** Eco-roll reduce the engine drag losses by disengaging the engine from the wheels during certain downhill conditions

	Group 4	Group 5
Curb mass (90% Fuel + driver) [kg]*	5665	7485
Curb mass body/trailer [kg]	2035	7365
Engine power [kW]	220	325
Displacement [ccm]	7700	12700
Max. Torque [Nm]	1295 (1100 -1600 rpm)	2134 (1000-1400 rpm)
Rated speed [rpm]	2200	1800
Idling speed [rpm]	600	600
Engine peak BTE (%)	45.6	47.2
RRC [N/kN] (Steer/Drive/Trailer)	5.02/5.57/---	4.57/5.02/4.57
CdxA [m2]/vehicle height [m]	5.39/4	4.96/4
Transmission type	AMT	AMT
Efficiency indirect gear	96%	96%
Efficiency direct gear	98%	98%
Axle Ratio	4.11	2.64
Axle Efficiency	96%	96%
ADAS	PCC** + Eco-roll***	PCC + Eco-roll

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Fuel and powertrain configurations considered

Powertrain / Fuel	ICE CI (Diesel)	ICE PI (Gasoline)	ICE CI + HEV	ICE PI + HEV	BEV	FCEV	CEV (electric road)
Diesel B0	Both						
Diesel B7 market blend	Both		Both				
DME	Both						
ED95	Both						
Electricity					Both		Both
Biodiesel (B100)	Both						
Paraffinic Diesel	Both						
CNG		Both		Group 4			
Hydrogen						Both	
LNG (EU mix.)	Both	Both		Group 5			
OME	Both						

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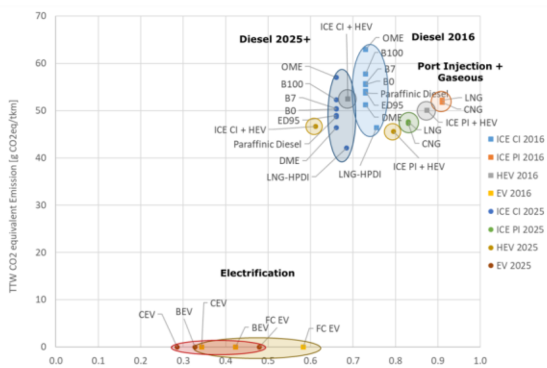
TTW - Results



Group 5; VECTO Long-Haul cycle; Weighted payload (13064 kg for BEV 2016; 14290 g for all others)
Analysed propulsion systems do vary in performance criteria like operating range, payload capacity or fuelling time

When **upstream emissions** are **not considered** (TTW):

- **Fully electric** and **fuel cell alternatives** offer **zero TTW GHG emissions** and **significantly higher energy efficiency, up to 2.5 times** for **catenary electric vehicle** (CEV, electric road).

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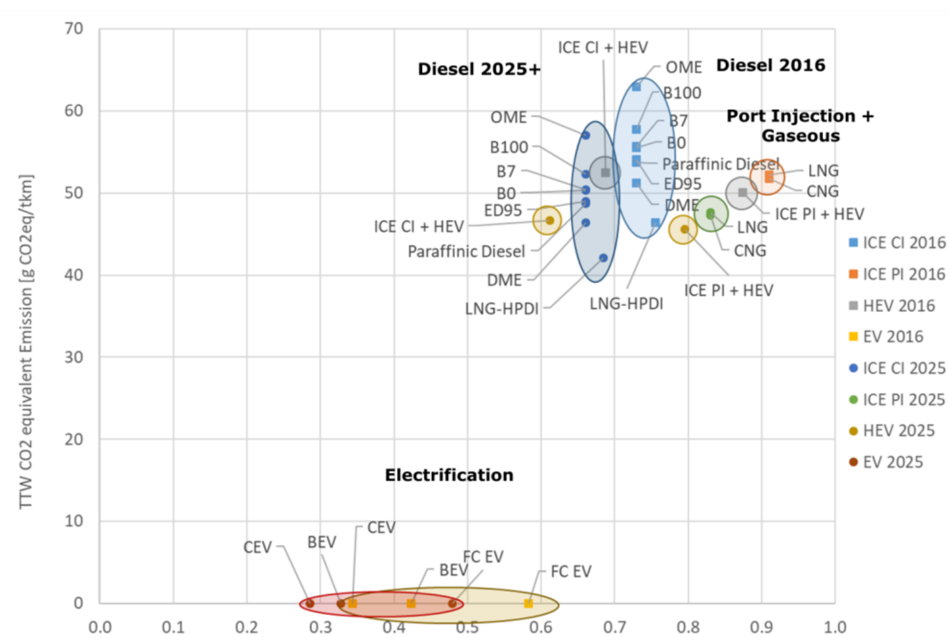
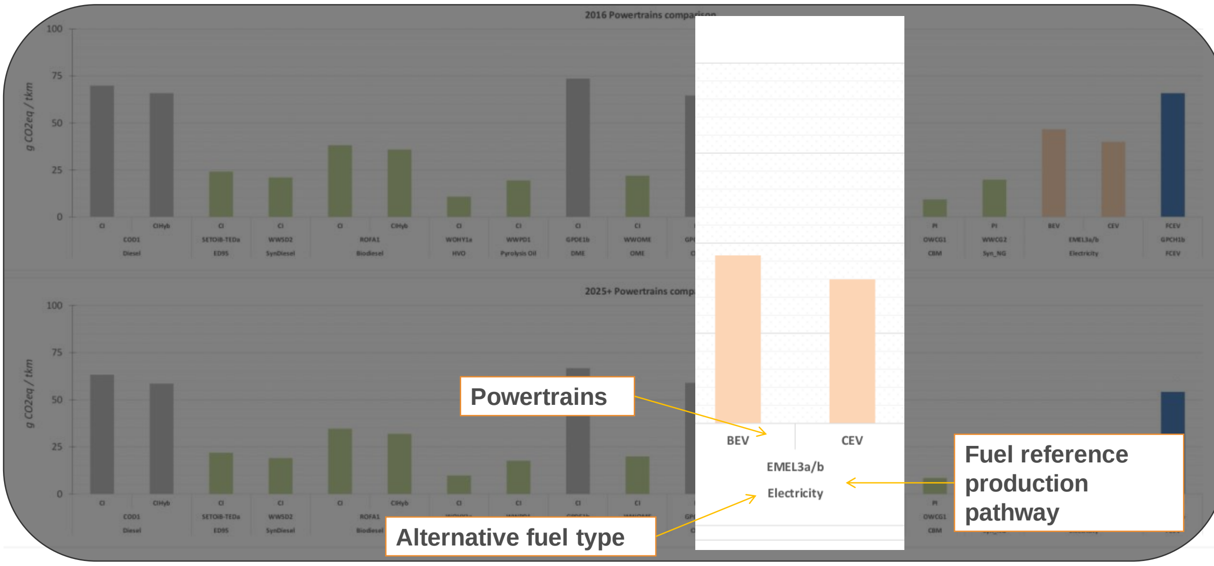
TTW results

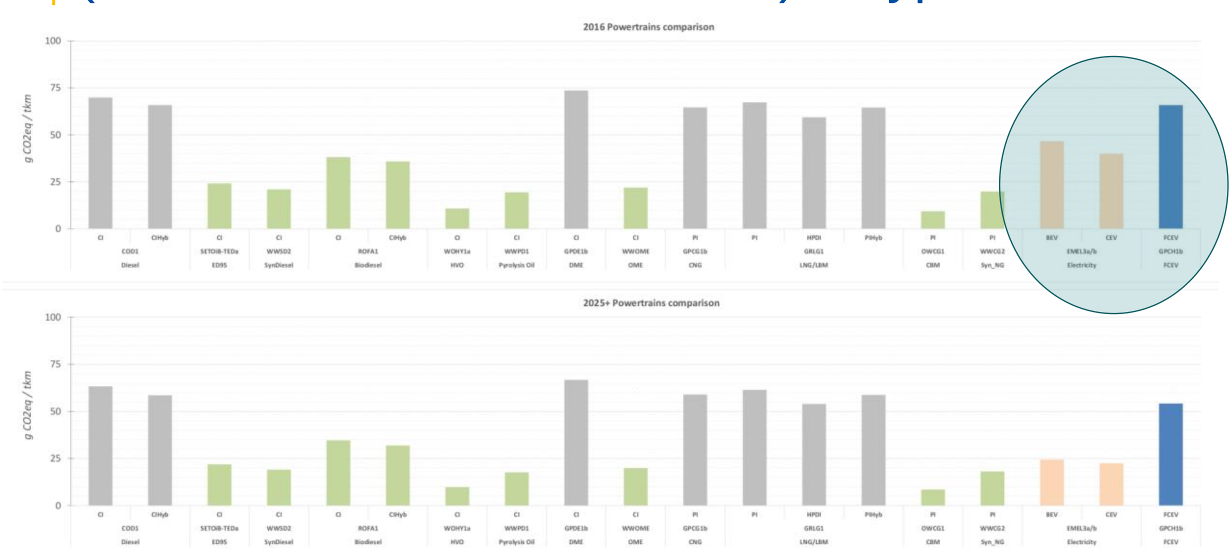


Group 5; VECTO Long-Haul cycle; Weighted payload (13064 kg for BEV 2016; 14290 g for all others)
Analysed propulsion systems do vary in performance criteria like operating range, payload capacity or fuelling time

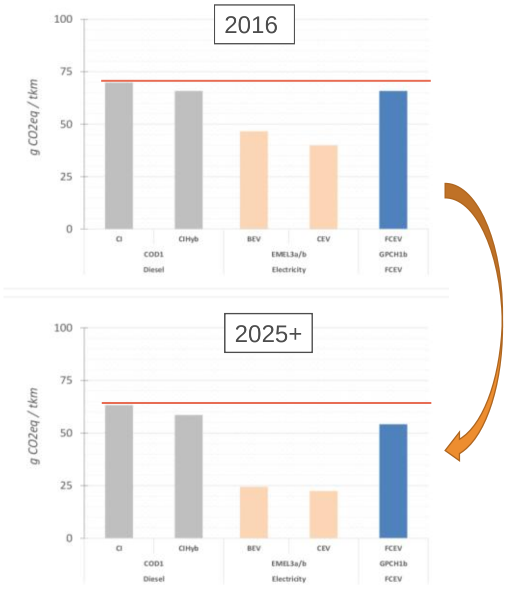
HDVs **WTW** – Powertrains (2016 – NEDC / 2025+ WLTP) - Type 5



HDVs **WTW** – Powertrains (2016 – NEDC / 2025+ WLTP) - Type 5



PC WTW – Powertrains - Type 5



EU electricity **mix** is used as a **proxy**.

EU-ETS and **European Green Deal** are expected to push for **reducing GHG intensity** of EU **energy mix**, **far beyond** what modeled on the base of the current status of knowledge.

In the **transition**, the **reaction** of the **whole electricity production system** will **define** GHG **emissions**, **related to** a **marginal increase** in electricity demand for **road sector**.

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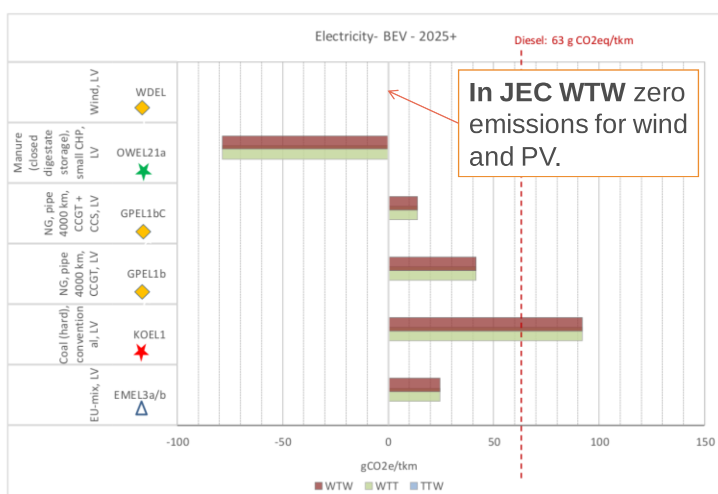
Electricity in Battery Vechicles

Additional demand from transport, in the **transition** towards a fully green electricity production system**, may lead to displace 1 green kWh from a sector to another (**economic value/4X multip.**). If** the **production generation is limited, system may react consuming fossil resources.**

BEV using **EU mix** are already **able to provide a significant saving against** standard **ICE/diesel.**



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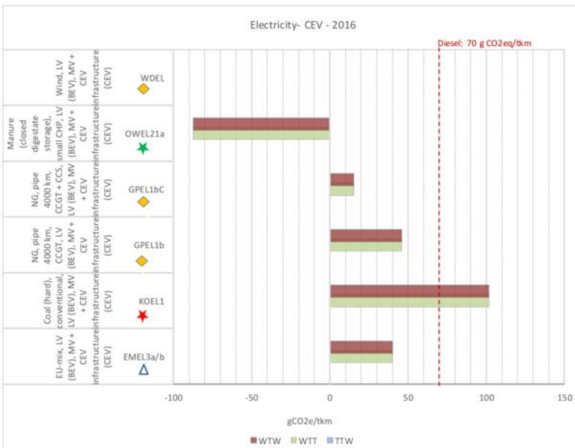
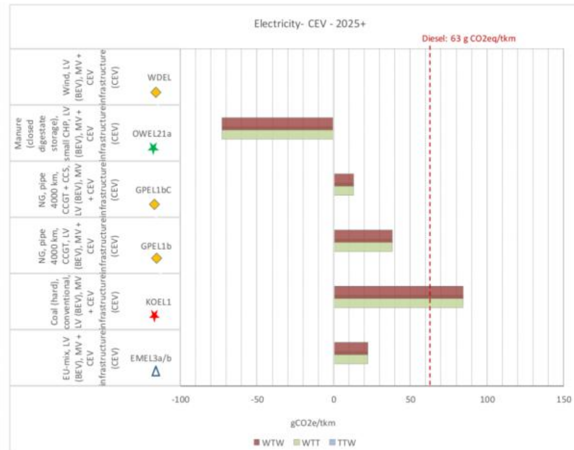
Electricity driven powertrains - Catenary





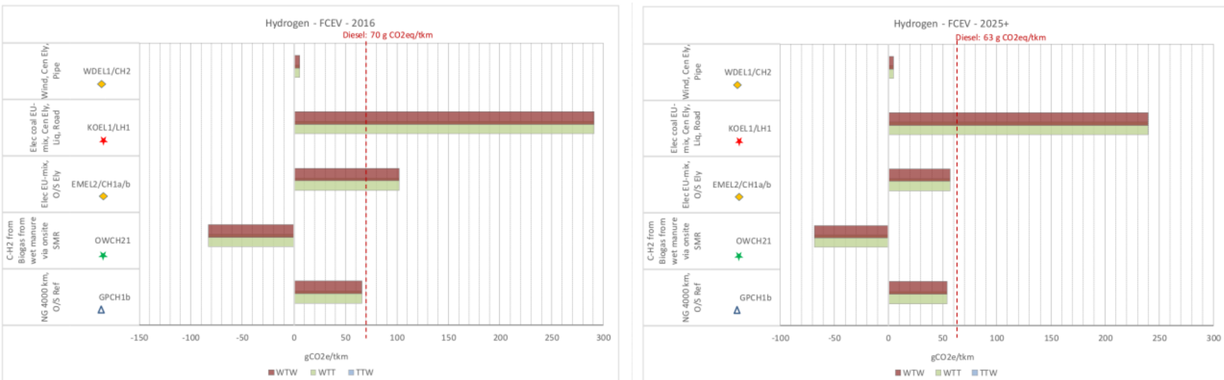
CEV are **mainly operated** at **catenary** mode and **partly at battery (BEV) mode**

Main outcomes – fuel comparison

1. **Electricity** and **Hydrogen** are energy vectors, so their WTW potential to lower **CO_2 emissions depend on the primary source of energy used** for the production.

2. The use of **renewable electricity** for **xEVs** and **H2** production for **FCEV** offer **one of the lowest WTW intensive combinations**.

Hydrogen - FCEV **Emissions**



Hydrogen is assumed to be produced from electricity, via electrolysis**. Emissions are then determined by the electricity production pathway.**

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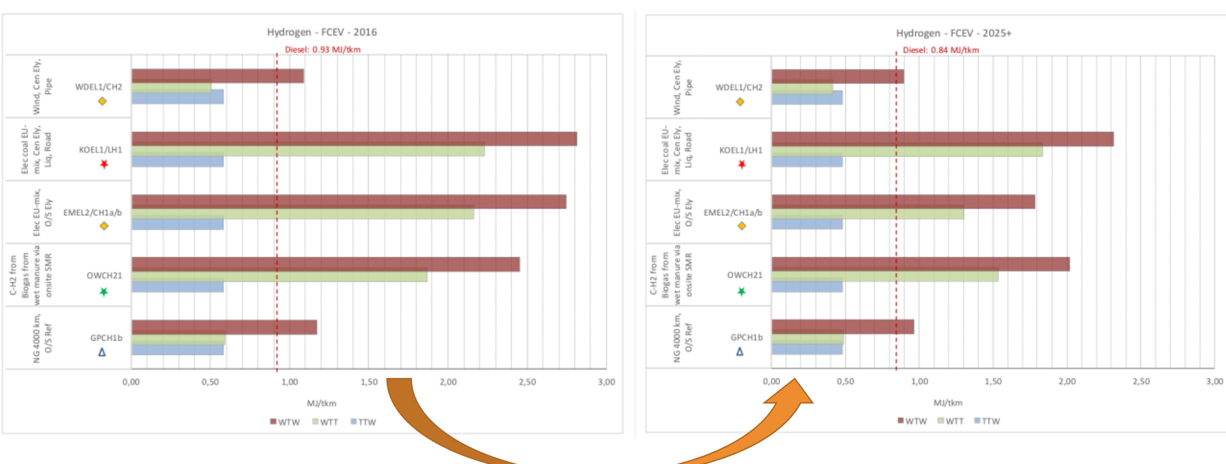
Hydrogen - FCEV **Energy expanded**



Strong **reduction in energy demand** expected for all the analysed pathways.

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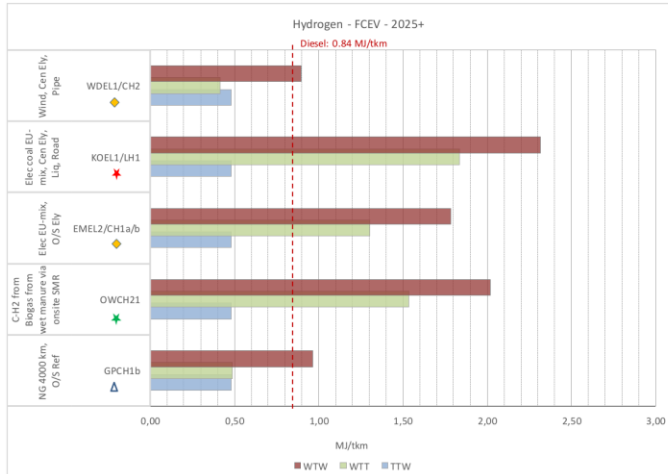
Hydrogen - FCEV **Energy expanded**

The **WTW energy use** for **FCEV** combined with the selected pathways **is higher than that for conventional diesel** used **in CI engines**.

Significant amount of **primary energy required** for **H2 production** using electrolysis => overall **system efficiency issue.**



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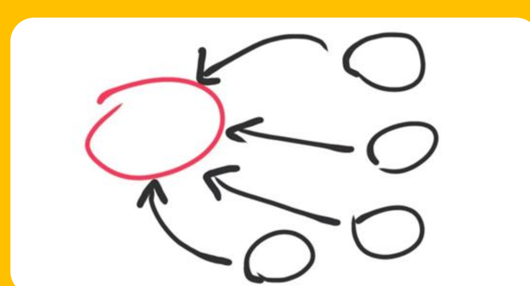
Conclusions



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Conclusions

- When the **WTT** and **TTW results** are **combined**, **factors** such as the **conversion pathways**, the **feedstock/resource** used, together with the **specific powertrain** technology in the 2015/2025+ **timeframe** have a **strong impact** on the final **results**.

- **Electricity** in BEV and PHEV, **e-fuels** in ICE as well as **Hydrogen** in FCEV are **promising options but** their potential for **GHG saving** is **mainly determined** by the pathway of the **electricity production** and/or by the **system reaction** from **displacement** of the **kWh from a sector** (i.e industry) to **another** (i.e. transport).

FEEDBACK, COMMENTS...

Suggestions and enquiries are welcome, simply **contact us** through the JEC WTW website or, for specific questions to:

- JEC **WTW**: info@concawe.eu
  and JRC-infoJEC@ec.europa.eu
- JEC **WTT**: info@concawe.eu
- JEC **TTW**: eucar@eucar.be

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Thank you

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