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Well to Wheel Greenhouse Gas Emissions Analysis of Different Powertrain Technologies

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Introduction

Electrified powertrains such as BEV, HEV, PHEV, and FCEV tend to be promoted as zero or very low GHG emitting vehicles. This might be misleading, as the actual carbon footprint of a vehicle:

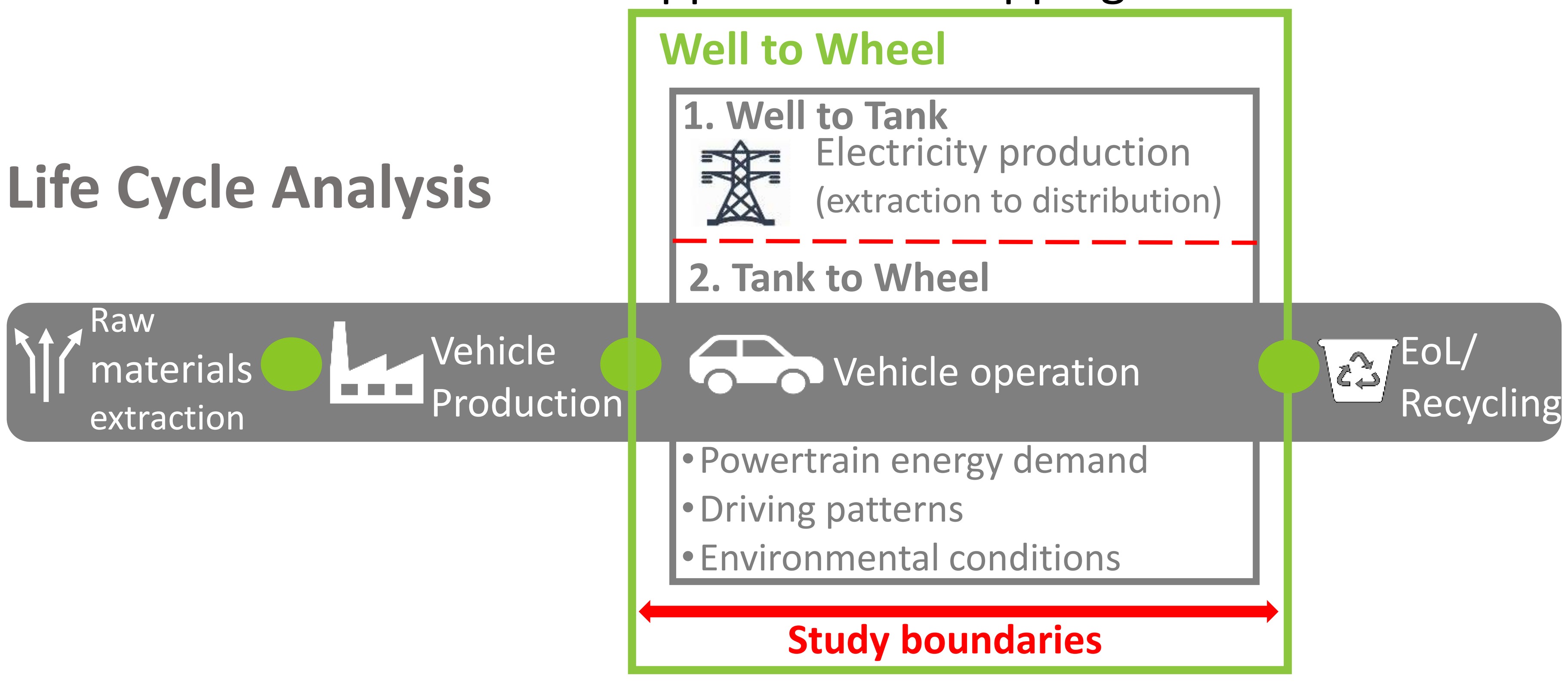
1. Includes upstream emissions (not only tailpipe)
2. Depends also on other GHG such as CH_4 and N_2O
3. Emissions measured under legislative tests are underestimated

Study objective: Quantifying GHG emissions (CO_2, CH_4 and N_2O) based on a WtW approach and considering real world consumption data of different powertrain technologies to make a more reliable comparison across different technologies.

Methodology

Vehicle selection: Representative medium vehicle models (segment C-models year: 2015) selected covering various powertrain technologies.

Emissions calculation: WtW approach is a stepping stone towards LCA



General equation for calculating GHG emissions of any powertrain:

$$GHG_{WtW} = GHG_{TtW} + GHG_{WtT(ICE)} + GHG_{WtT(Electric)}$$

- WtT part: activities from resource extraction through fuel production to delivery of the fuel to vehicle.
- TtW part: energy expended from the vehicle operation.

WtW Total GHG emissions = **WtT** Upstream emissions + **TtW** Tailpipe emissions

Electricity generation GHG intensity

GHG intensity values vary significantly across the EU Member States due to different fuel mix used for electricity generation.

MS	CO_2	CH_4 [g CO_2eq/kWh]	N_2O
FR	34.8	0.05	0.44
GR	829.9	0.29	2.24
EU28	275.9	1.49	2.16

WtT emission factors

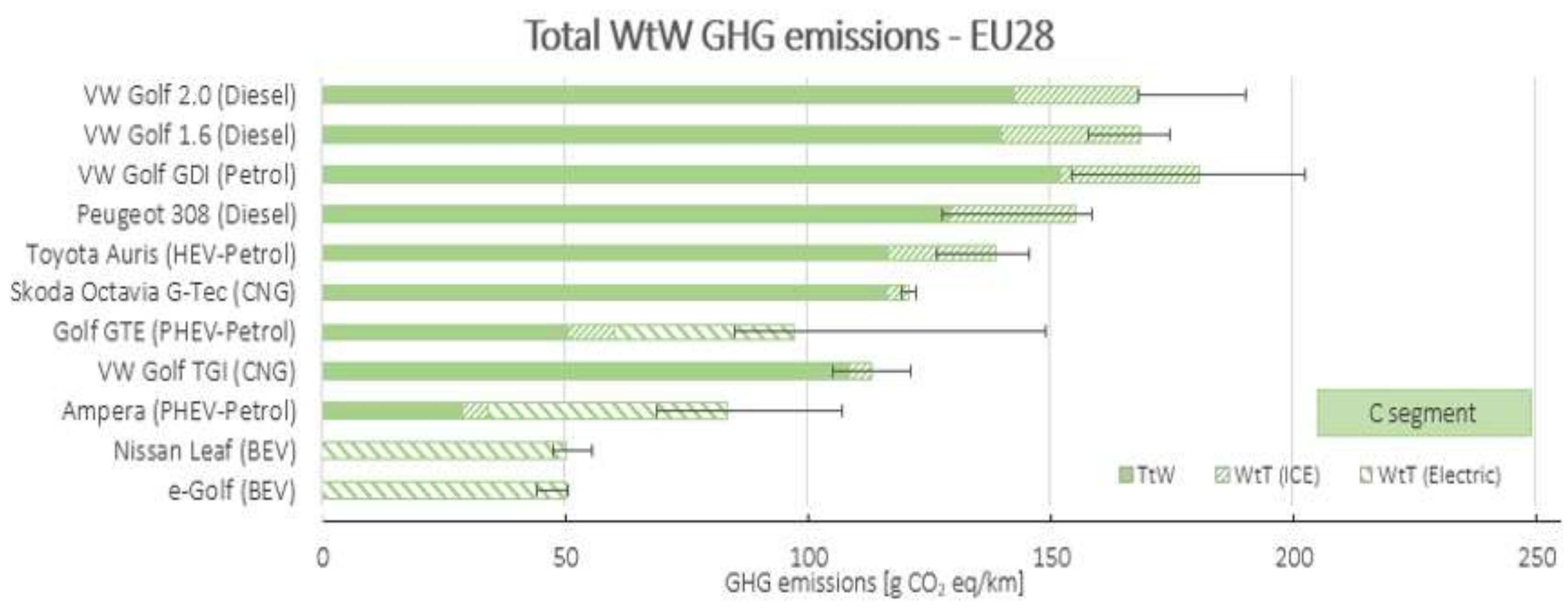
GHG emissions that produced in the steps required to turn a natural resource into fuel and bring that fuel to a vehicle.

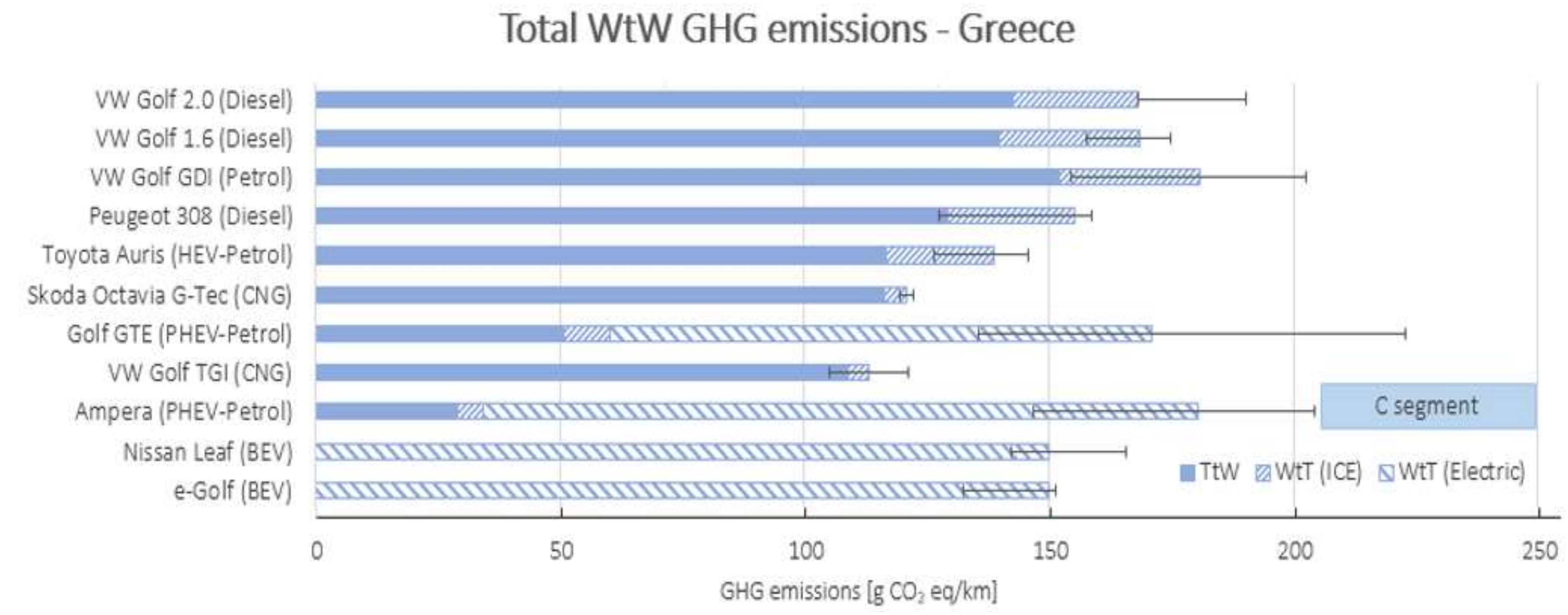
Fuel	CO_2	CH_4 [g CO_2-eq/MJ]	N_2O
Petrol	13	0.7	0.01
LPG	7.6	0.4	0.02
CNG	8.5	4.5	0.09
Diesel	14.6	0.7	0.01
Hydrogen thermal process (NG to H_2)	107.1	7.8	0.29
Hydrogen electrolysis	211	12.5	2.86

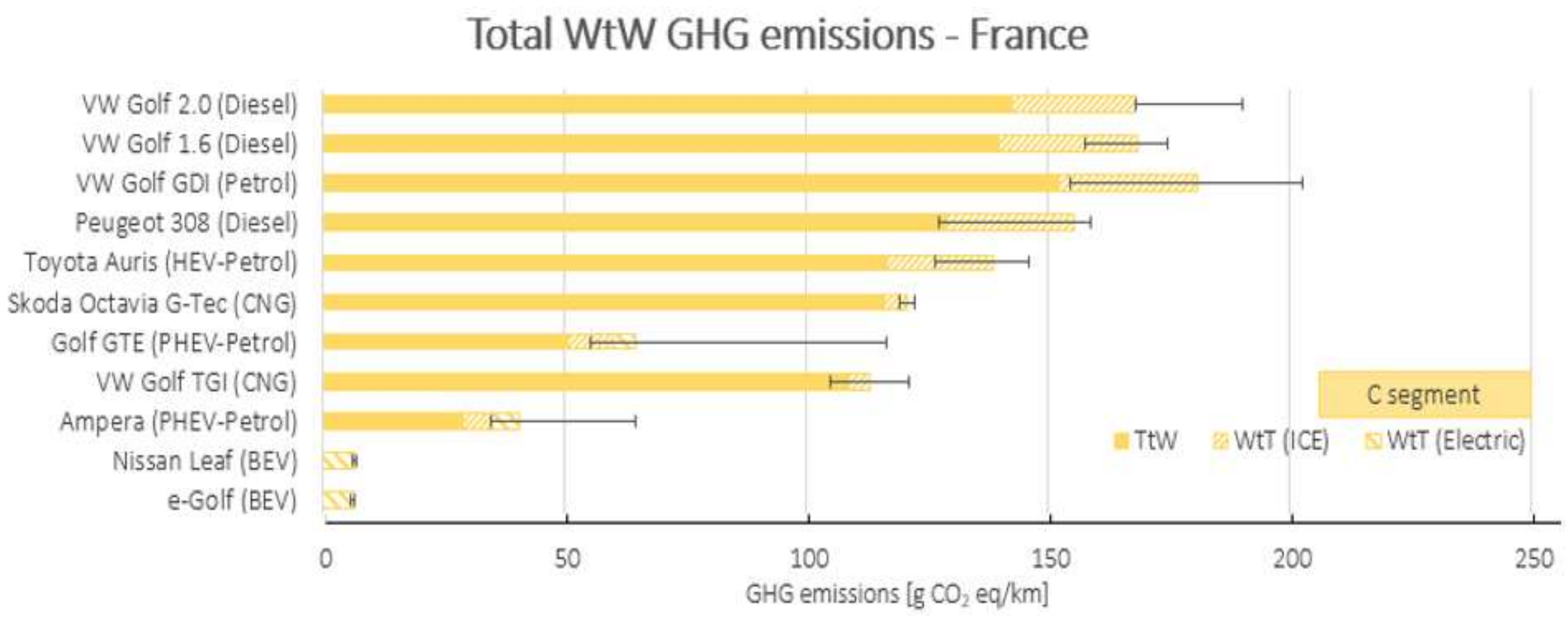
TtW emission factors

Instead of using officially reported values, **real-world** fuel and electric energy consumption data was collected by a large variety of sources.

Results and discussion







- Total GHG emissions of a vehicle can not be expressed as a single value. Several factors such as fuel mix for electricity generation, carbon footprint for fossil fuels production, driving patterns and environmental conditions greatly affect GHG emissions.
- BEVs are not zero emission vehicles since they are responsible for the "upstream" GHG emissions from electricity generation.
- The WtW GHG emissions of BEVs and PHEVs vary significantly across EU Member States. In some countries, their GHG emissions levels are similar to those of conventional vehicles.
- CNG vehicles perform very well in terms of emissions. Excluding France, their GHG emissions are in the same range with PHEVs.
- The energy-intensive process needed to produce hydrogen, results in similar GHG emissions from conventional and FCEVs.
- There is high uncertainty in the CH_4 and N_2O data. Typically, TtW emission factors for these GHG are not publicly available.

Conclusions

- WtW analysis enables fair comparisons across different vehicle powertrain technologies. Still, this approach can only be seen as a stepping stone towards LCA as it ignores the production and end-of-life treatment of the vehicle.
- GHG emissions differences between conventional and electrified vehicle technologies are much lower than the tailpipe type-approval values suggest.
- Until the GHG intensity of electricity generation drops drastically, the ICE-based powertrains will remain competitive to electrified vehicle technologies in terms of GHG emissions. Even then, ICE could be competitive if a sustainable fuel is used.

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