RailTech® RAIL INFRA FORUM '23

Improving Environmental Sustainability of Regional Railway Services in the Netherlands

Marko Kapetanović

Delft University of Technology

TU Delft

Project Setup

Parties

arriva a DB company | TU Delft | Lab Smart Public Transport | Lab Digital Rail Traffic

Project Goals

- Development of integrated models for dynamic monitoring and prediction of GHG emissions.
- Identification and assessment of solutions for improving the energy efficiency and reducing the total emissions on the network.

Principal Researcher

Marko Kapetanović

Supervision Team

Niels van Oort

Rob M.P. Goverde

Alfredo Núñez Vicencio

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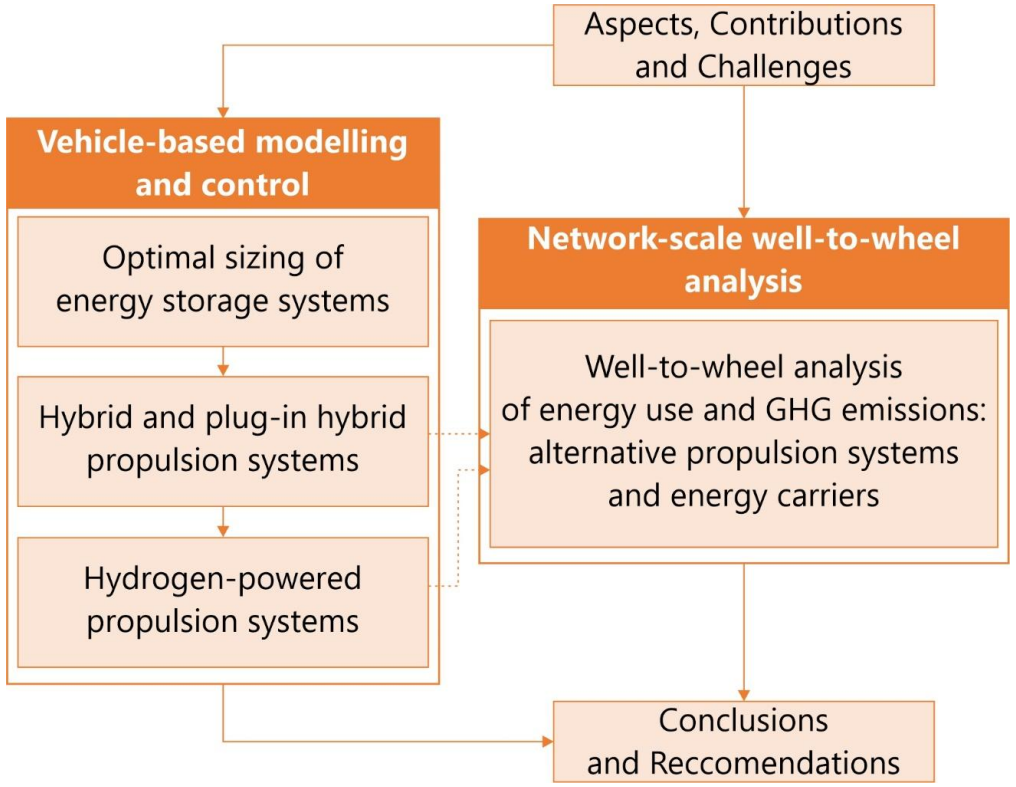

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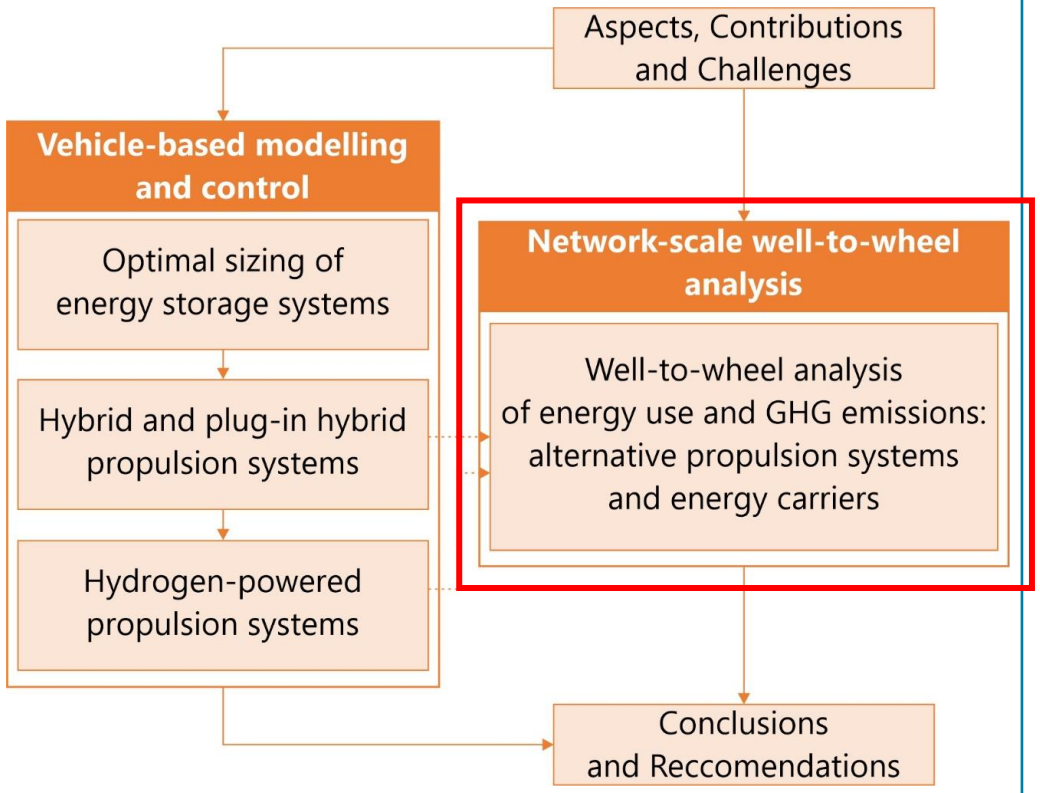
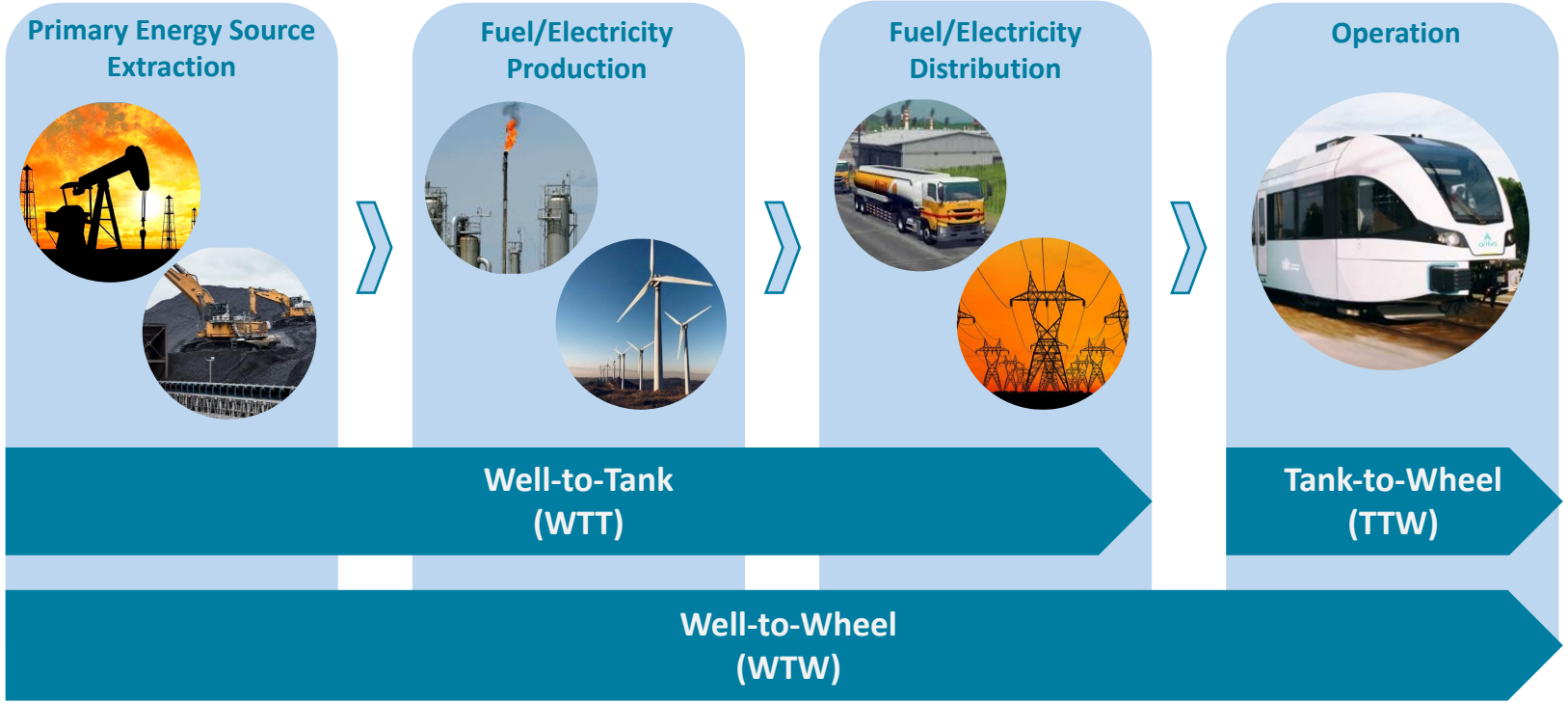
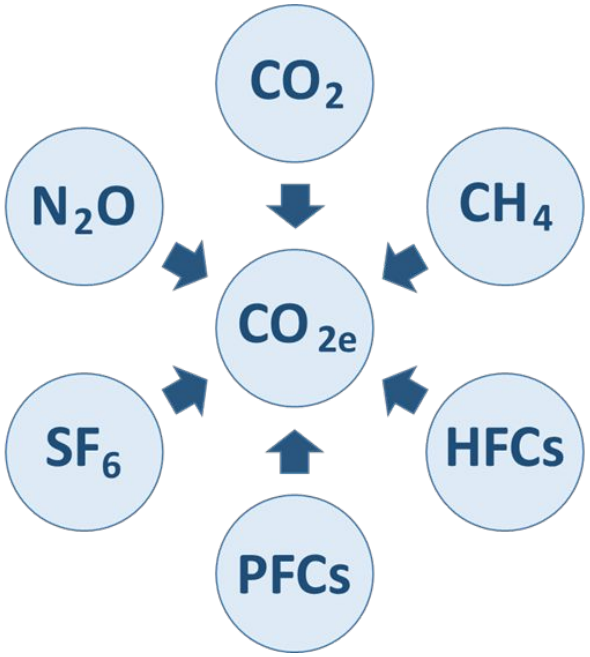


Project Scope

Life Cycle Stages

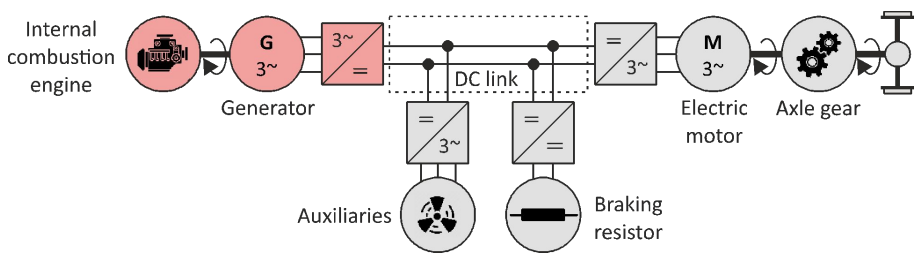


Greenhouse Gases

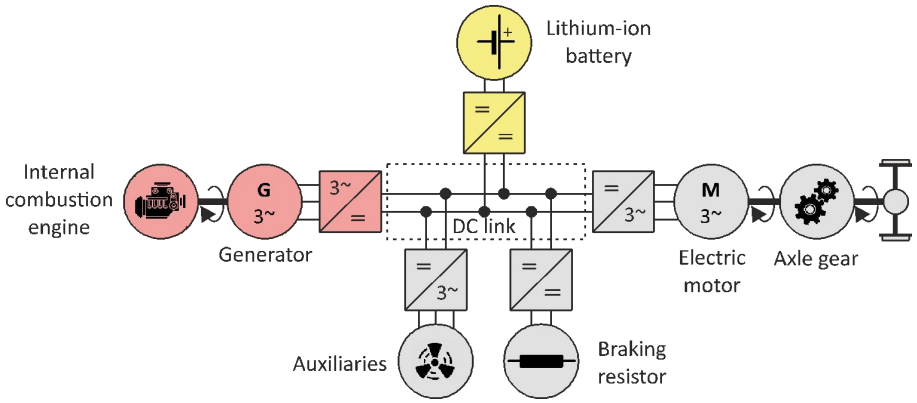


Propulsion systems

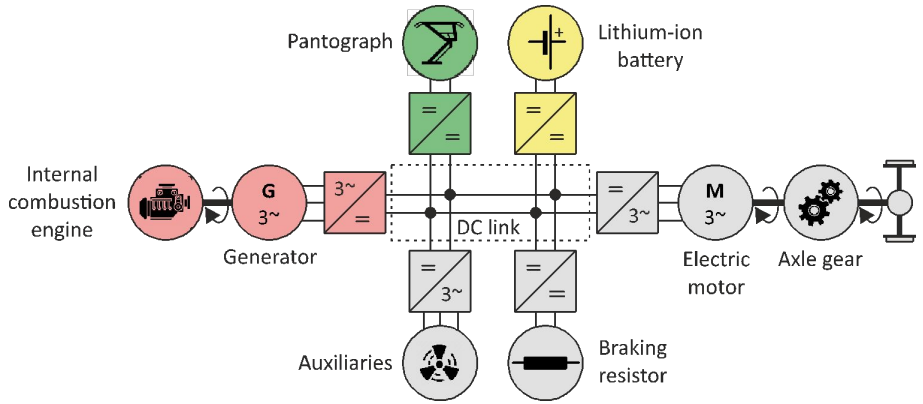
Diesel-electric



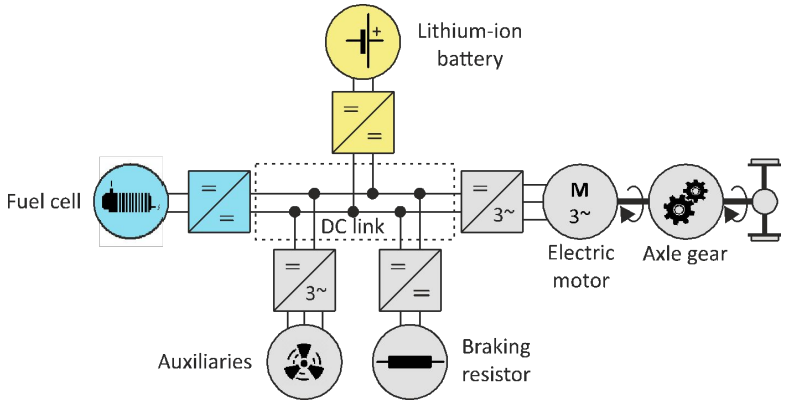
Hybrid-electric



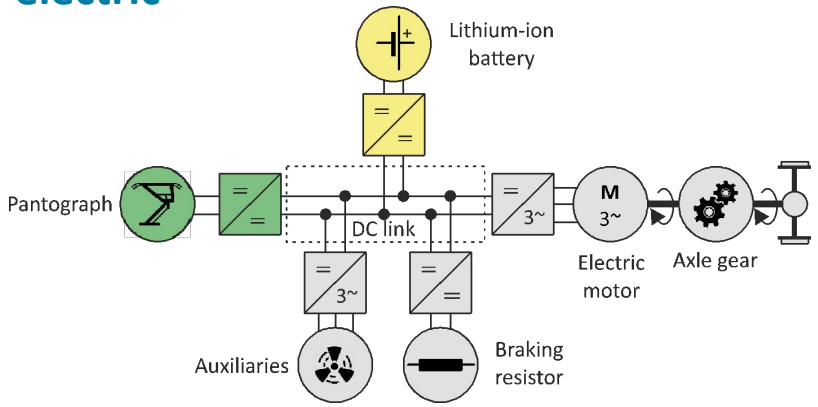
Plug-in hybrid-electric



Fuel cell hybrid-electric



Battery-electric



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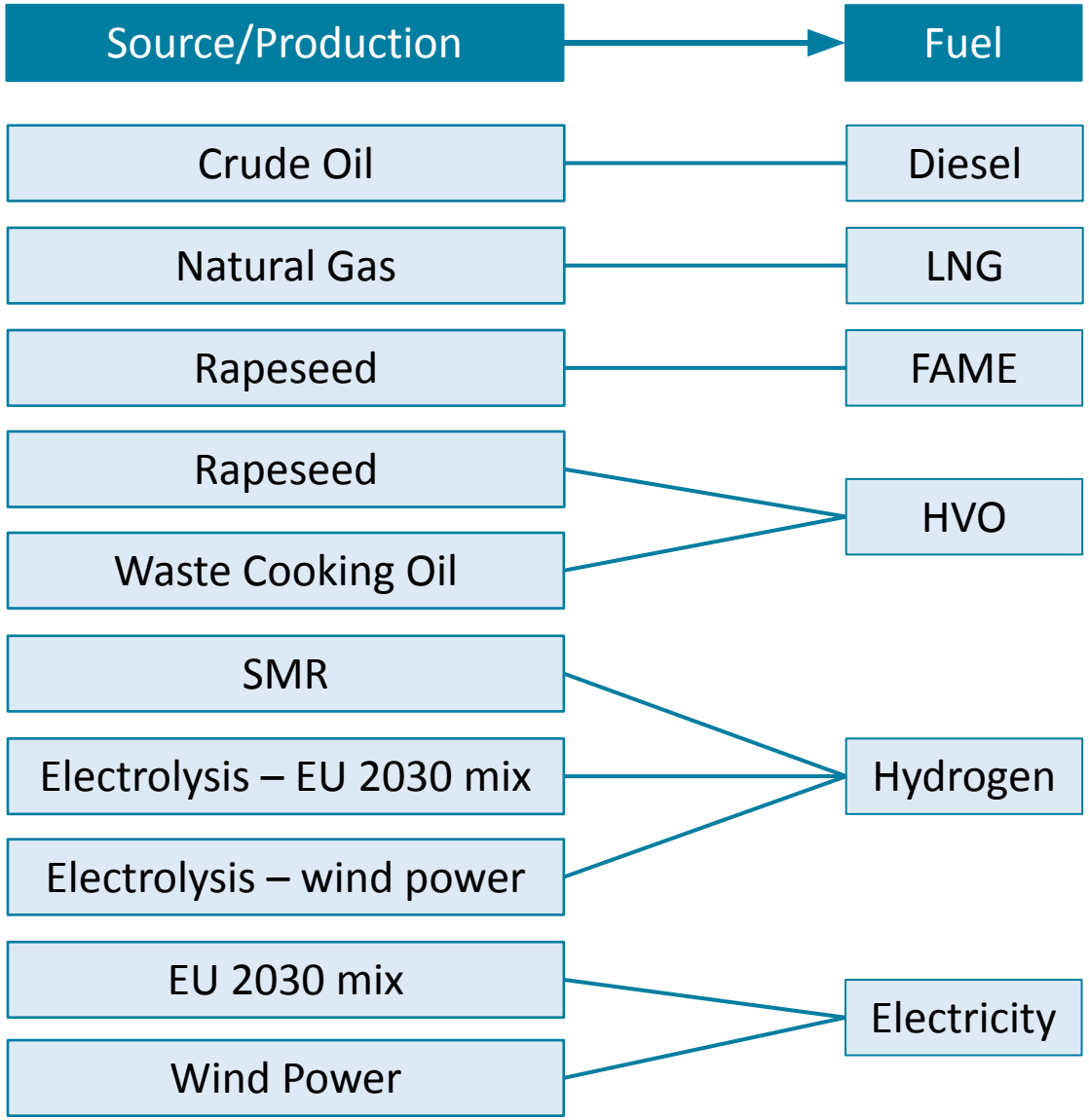
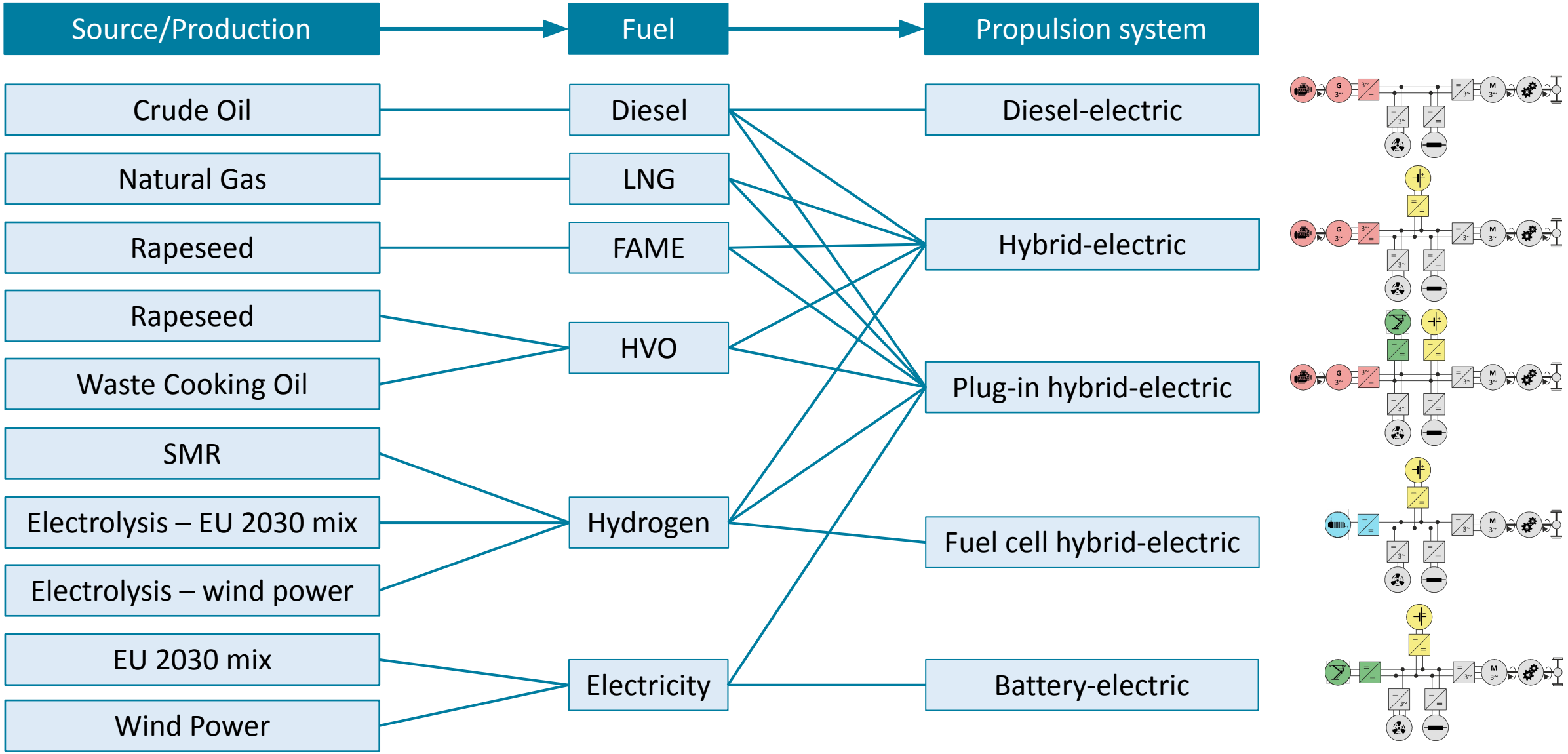
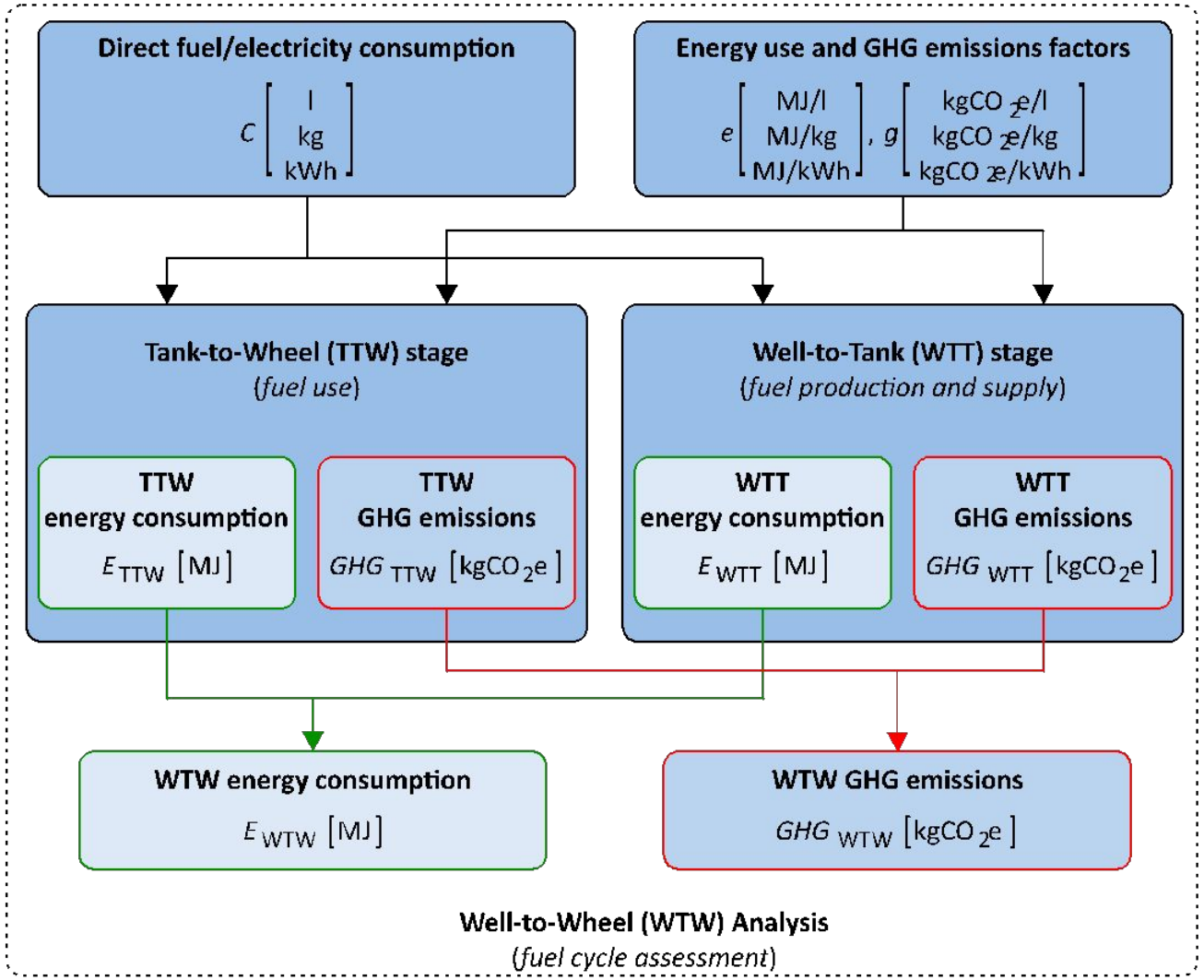
Energy carriers



Overview of scenarios



Methodology



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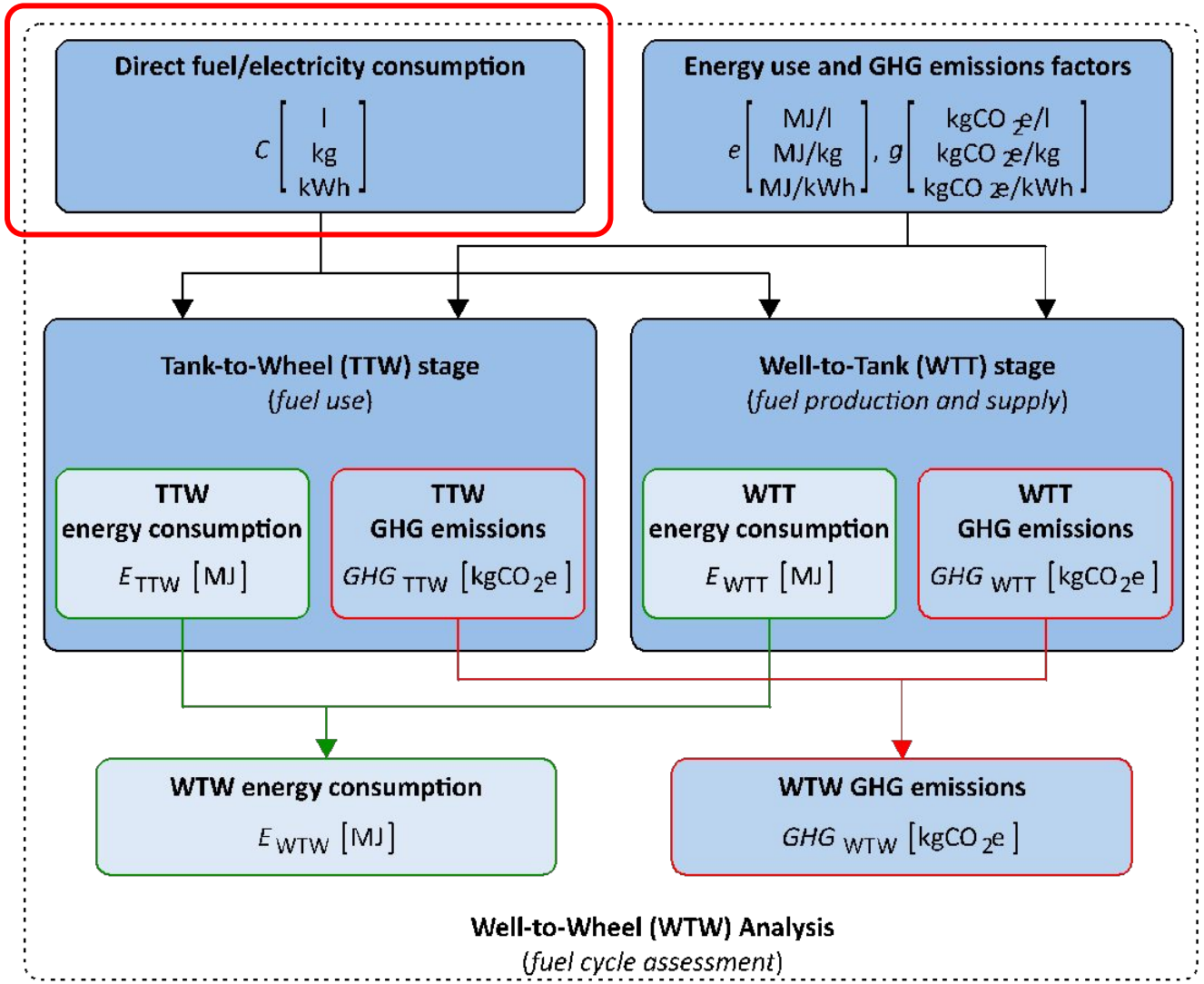

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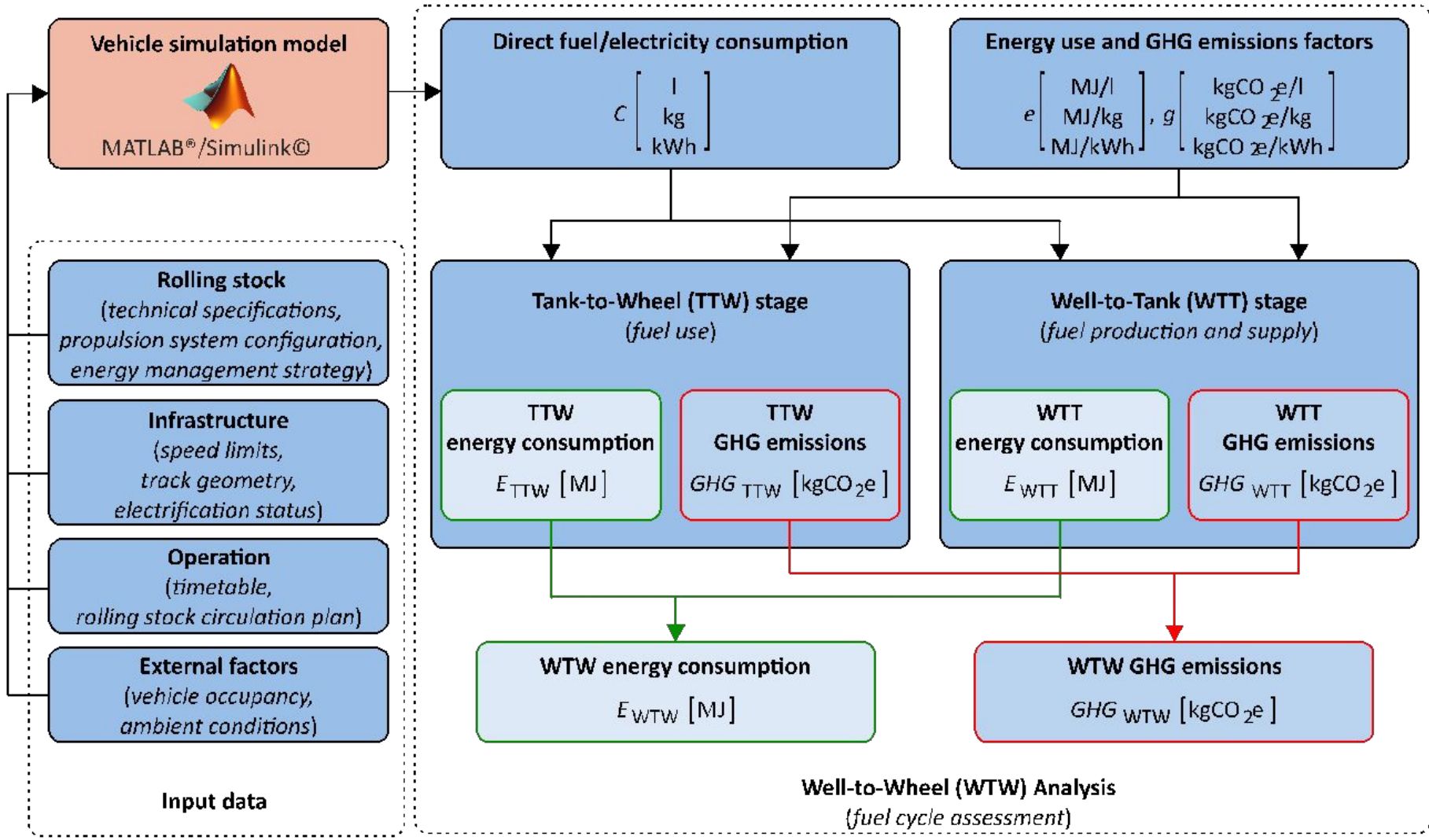


Simulation Tool

INPUTS

STADLER

Vehicles

Topology | Powertrain Components
Powertrain Control | Efficiency Maps
Vehicle Geometry

ProRail

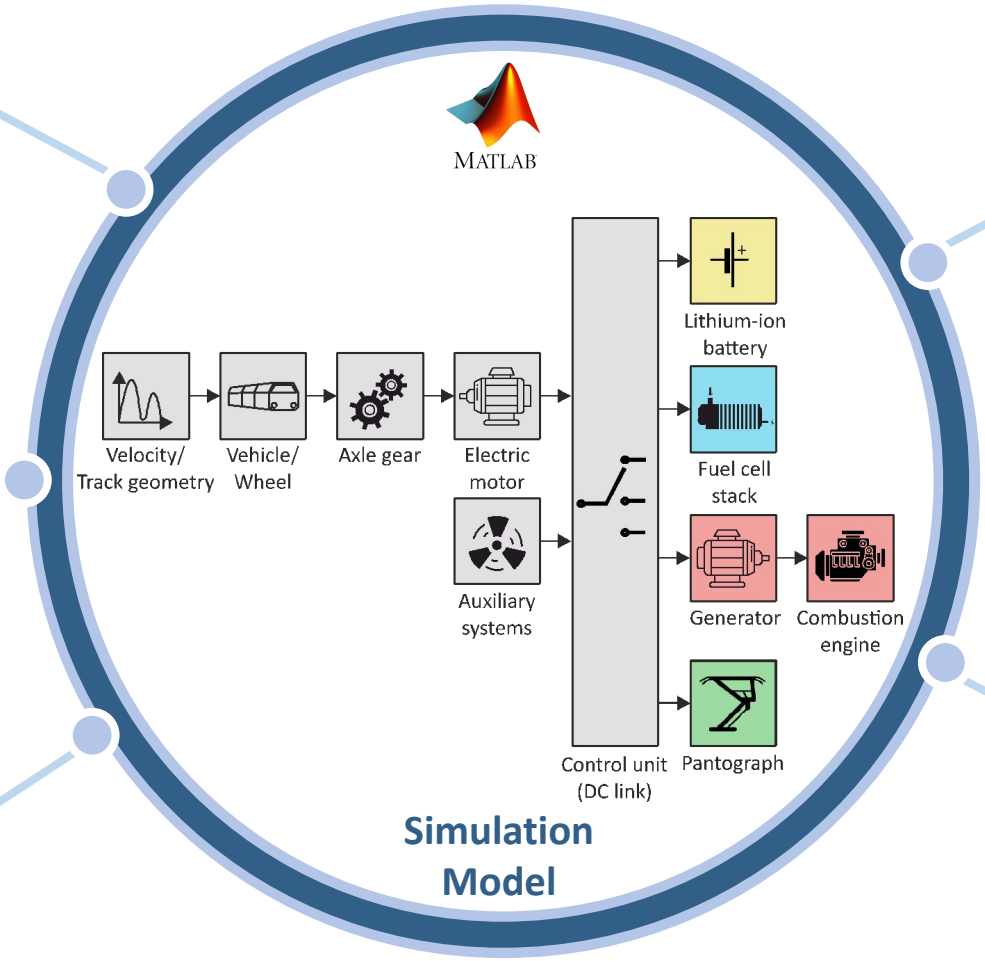
Infrastructure

Track Lengths | Position of Stations
Track Geometry
Speed Limitations

arriva

Operation

Timetable | Number of Passengers
Rolling Stock Circulation Plan



OUTPUTS

Power

kW

Traction Power Profile
Auxiliaries Power Profile

Energy

liters
kg
kWh

Fuel Consumption
Electrical Energy Consumption

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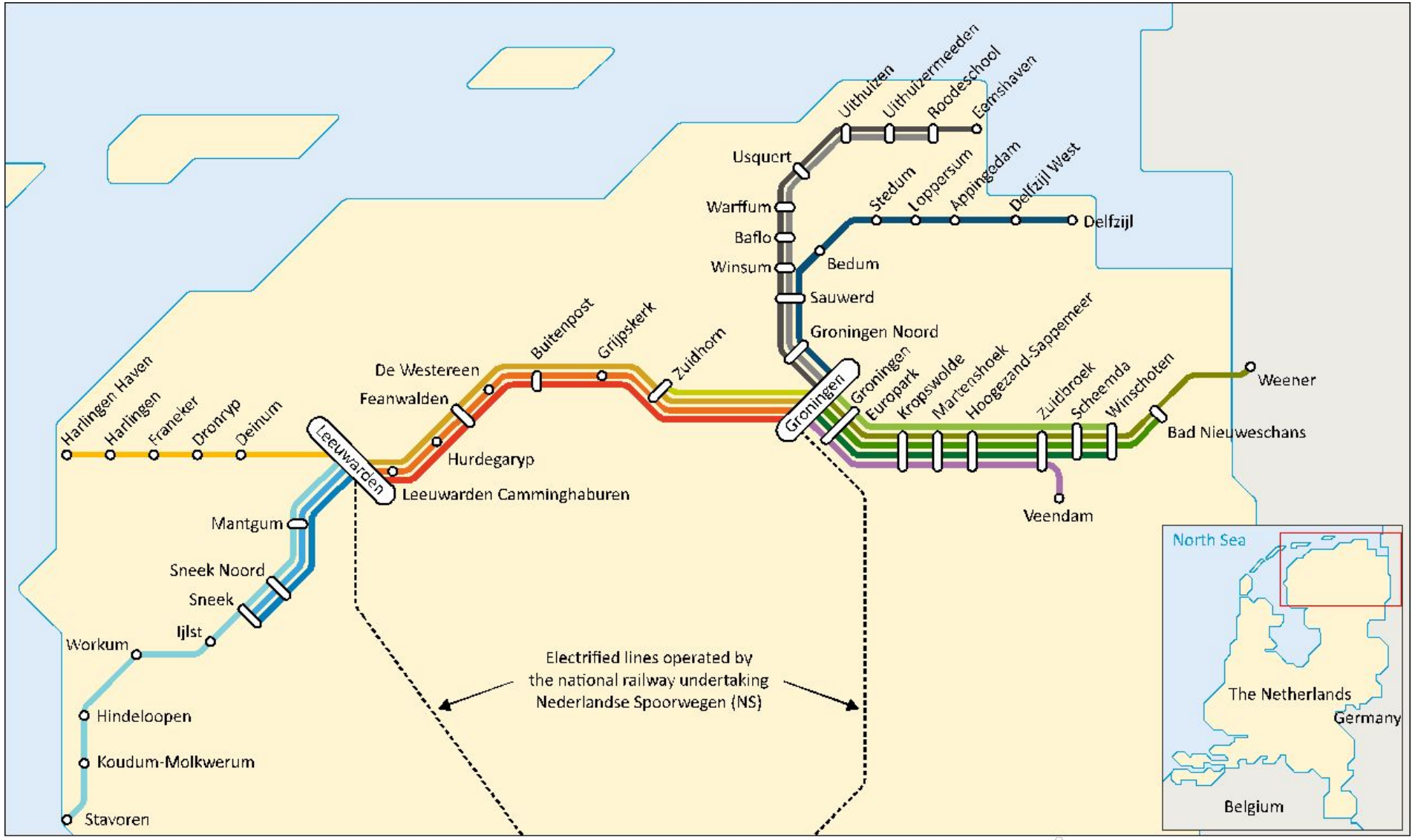
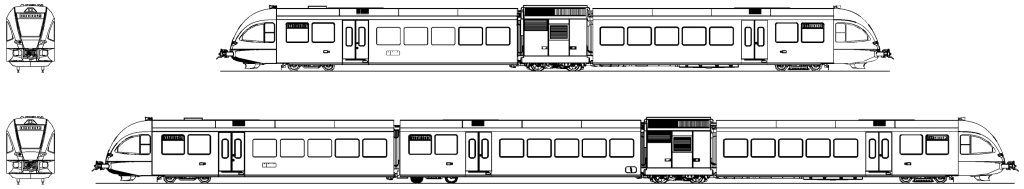
Dutch Northern lines



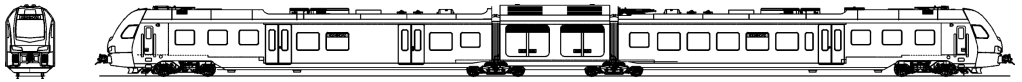
Rolling stock in the Northern lines

GTW 2/6

GTW 2/8



WINK



Rolling stock in the Northern lines

GTW 2/6

GTW 2/8

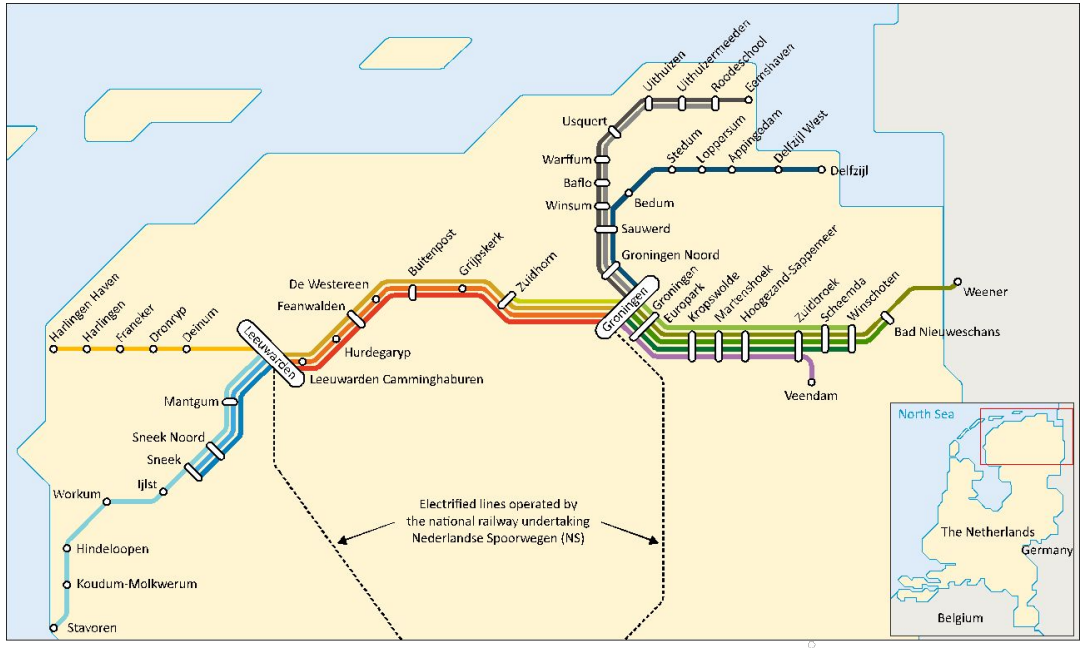
WINK

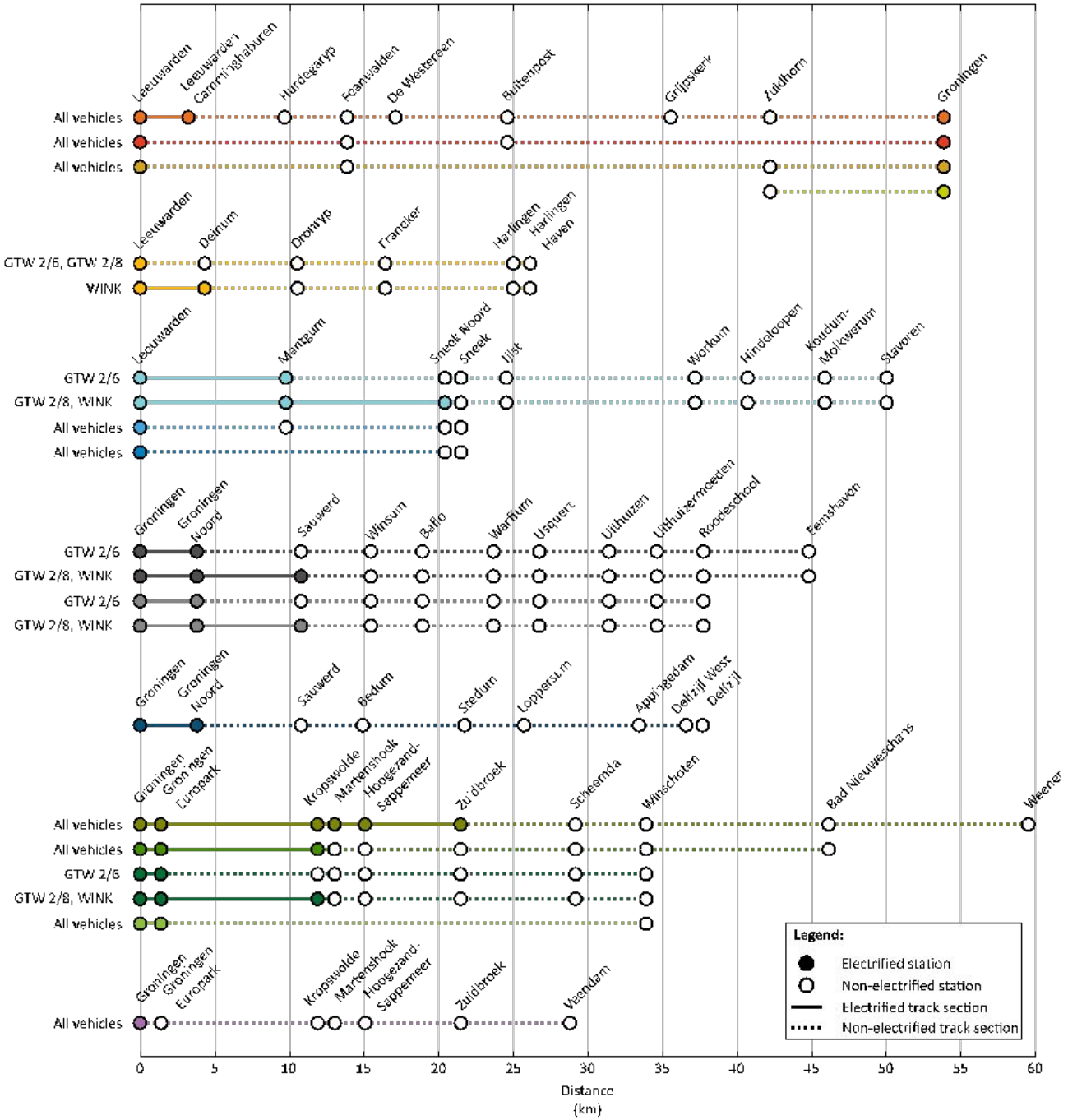
Ballard FCmove™-HD
Based on
FCgen®-LCS stack

Luxfer G-Stor™ H2
Model W322H35
(350bar)

CIMC ENRIC
LNG tank
(383 kg)

Required electrification for BEMUs





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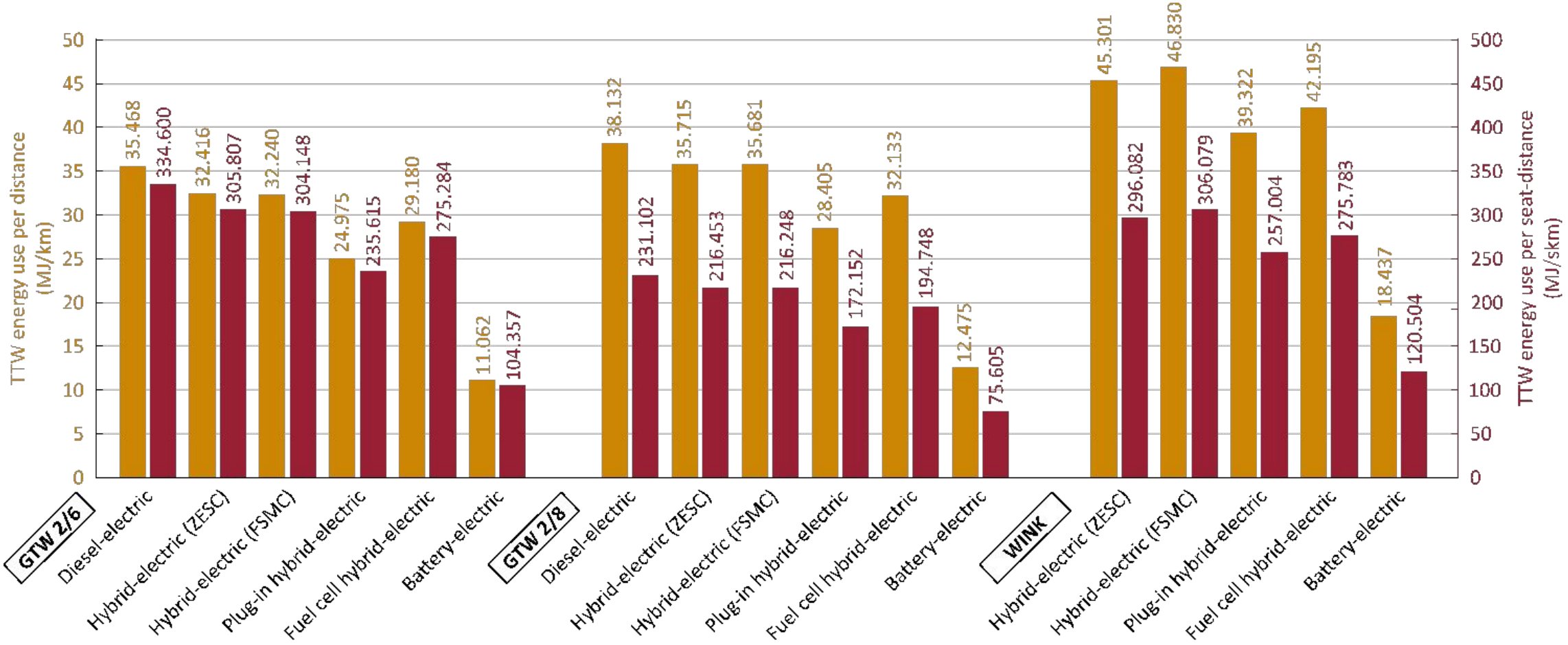
Tank-to-Wheel (TTW) stage

Direct energy use



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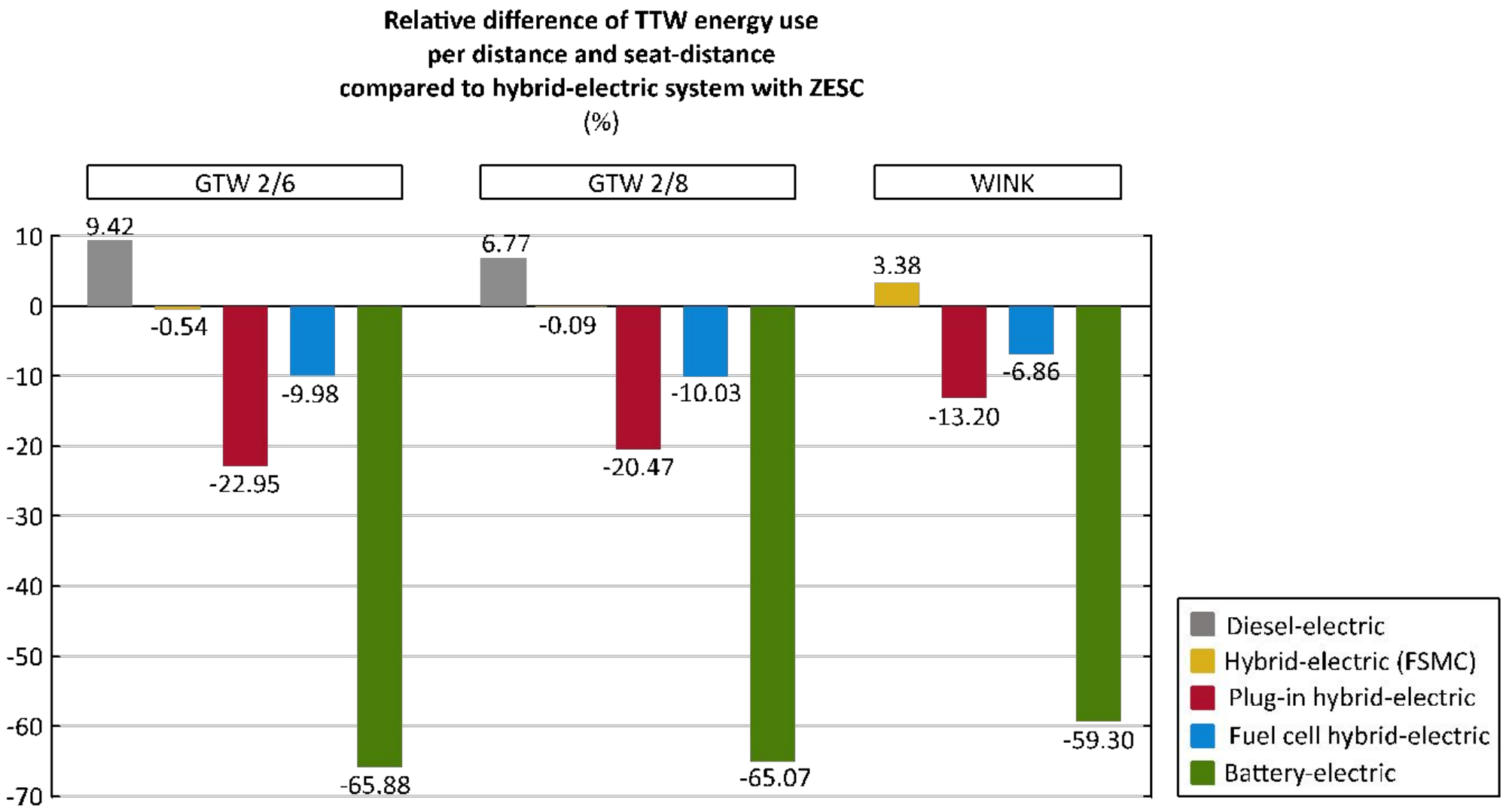

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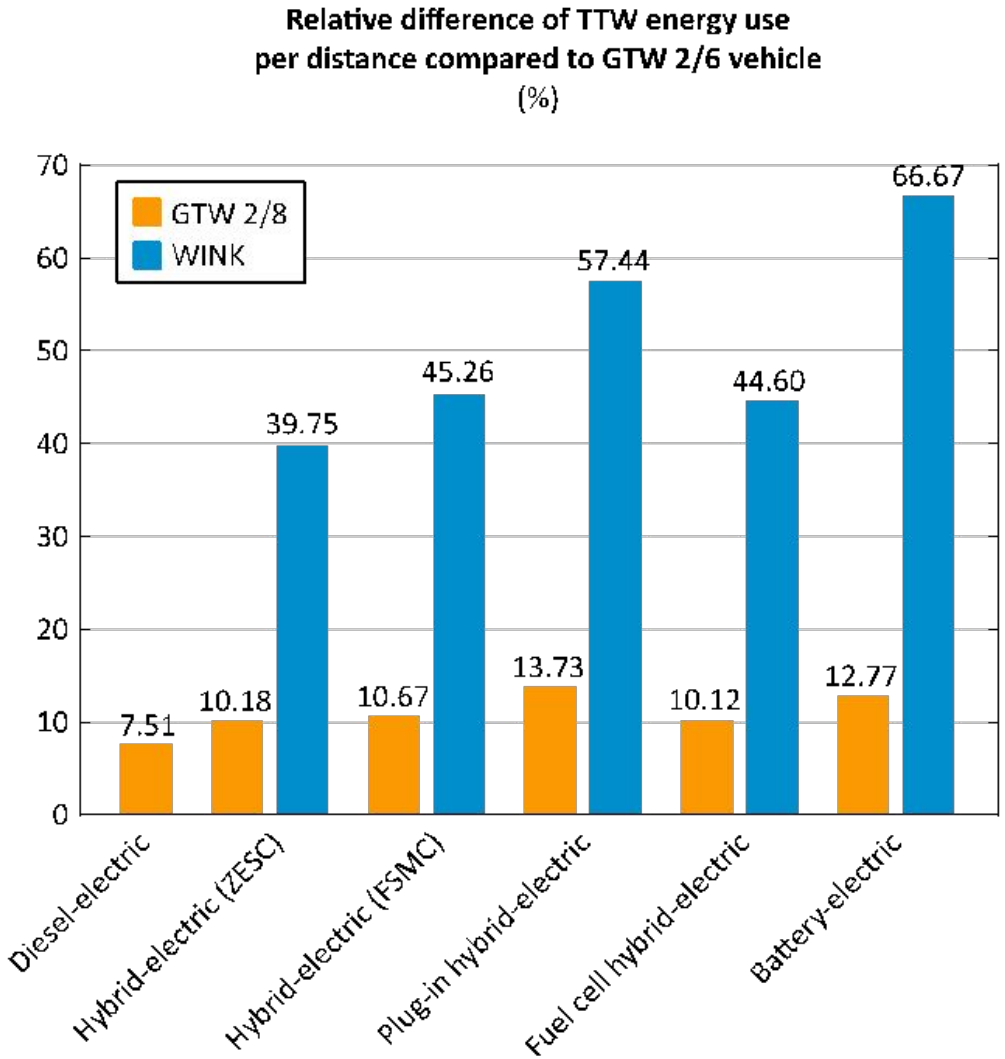
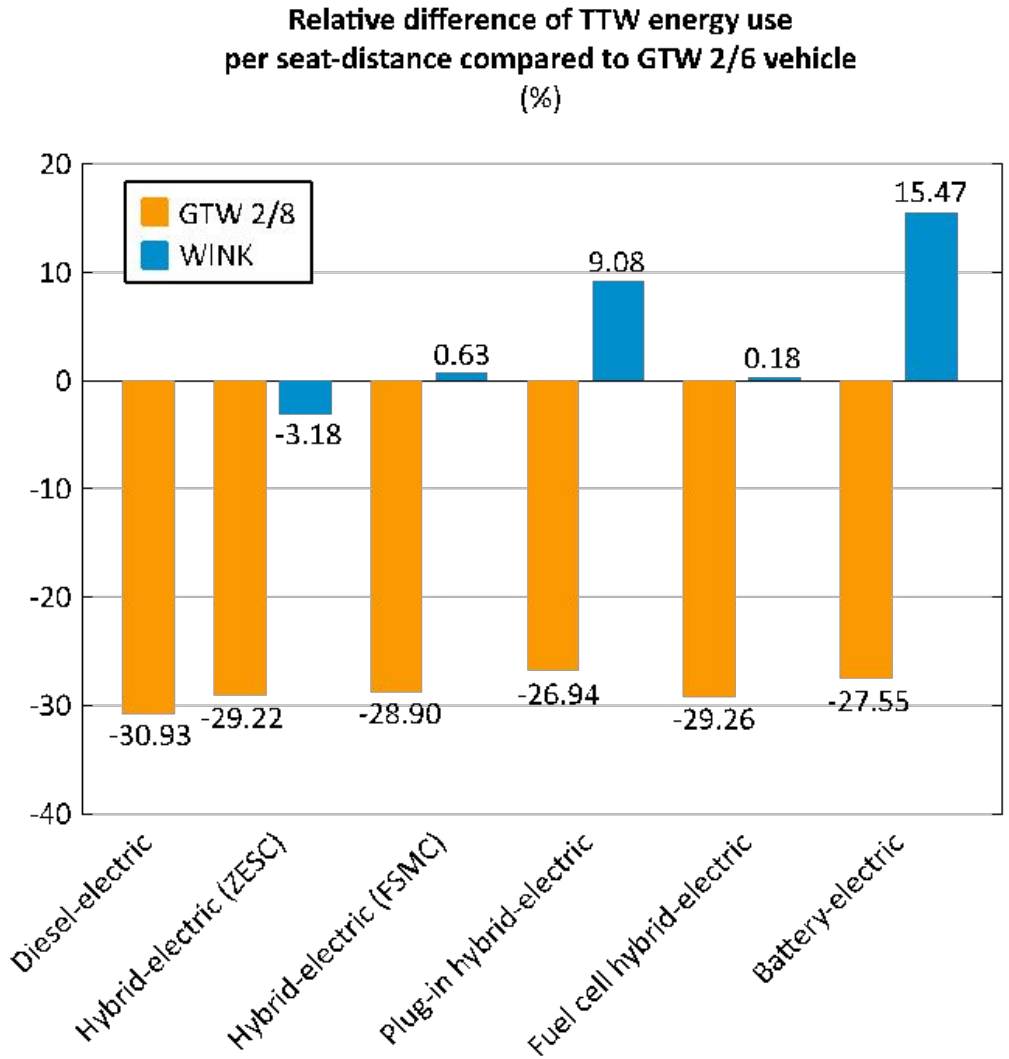
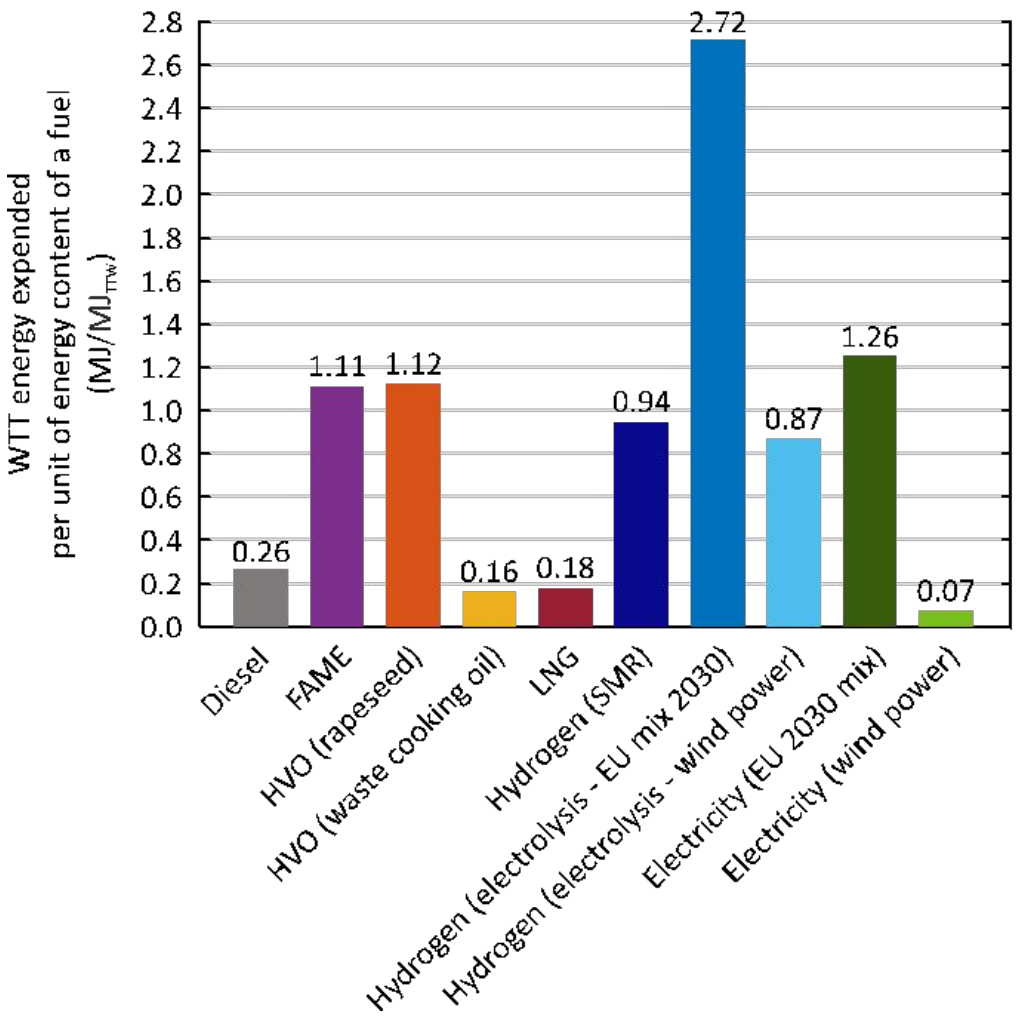
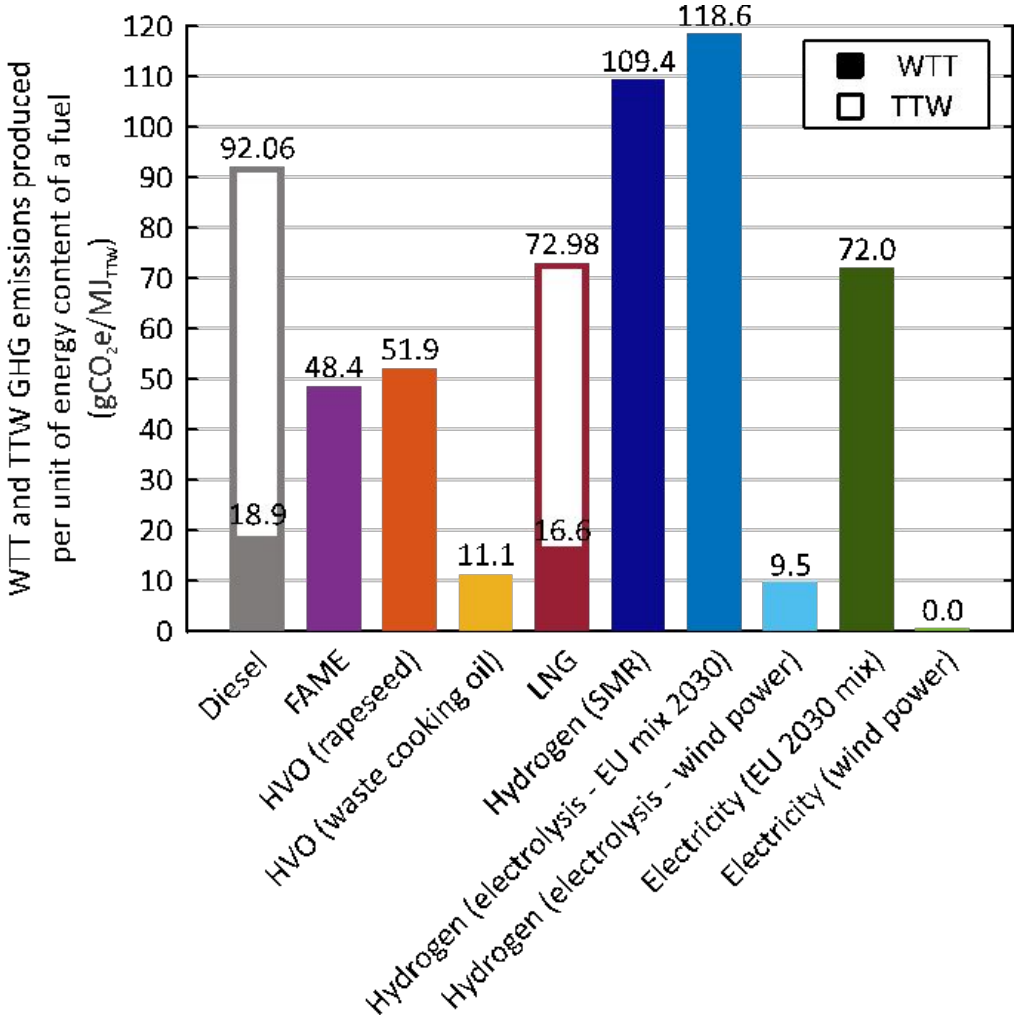




Well-to-Tank (WTT) stage
Upstream processes

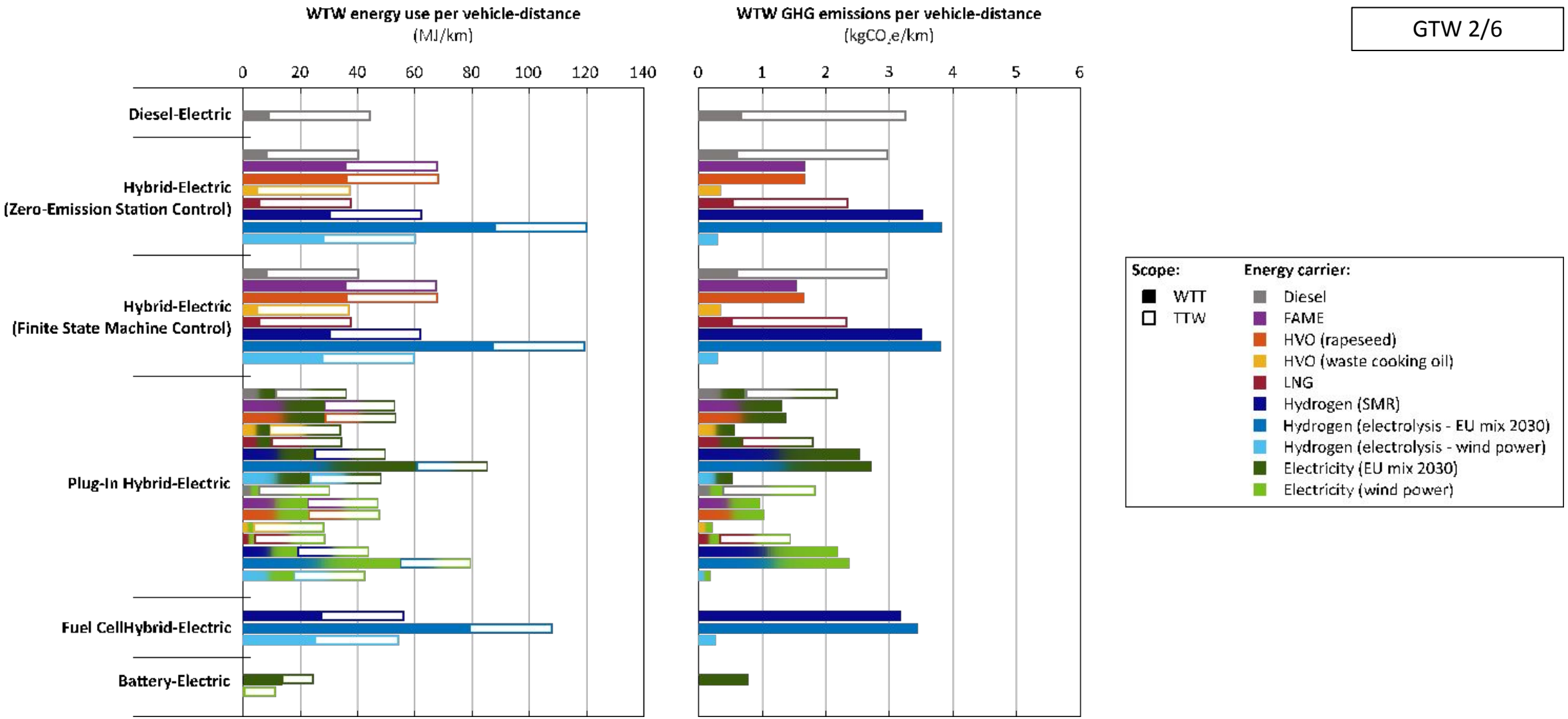




Source: JEC Well-to-Wheel report (2020)

Overall Well-to-Wheel (WTW) estimates

GTW 2/6



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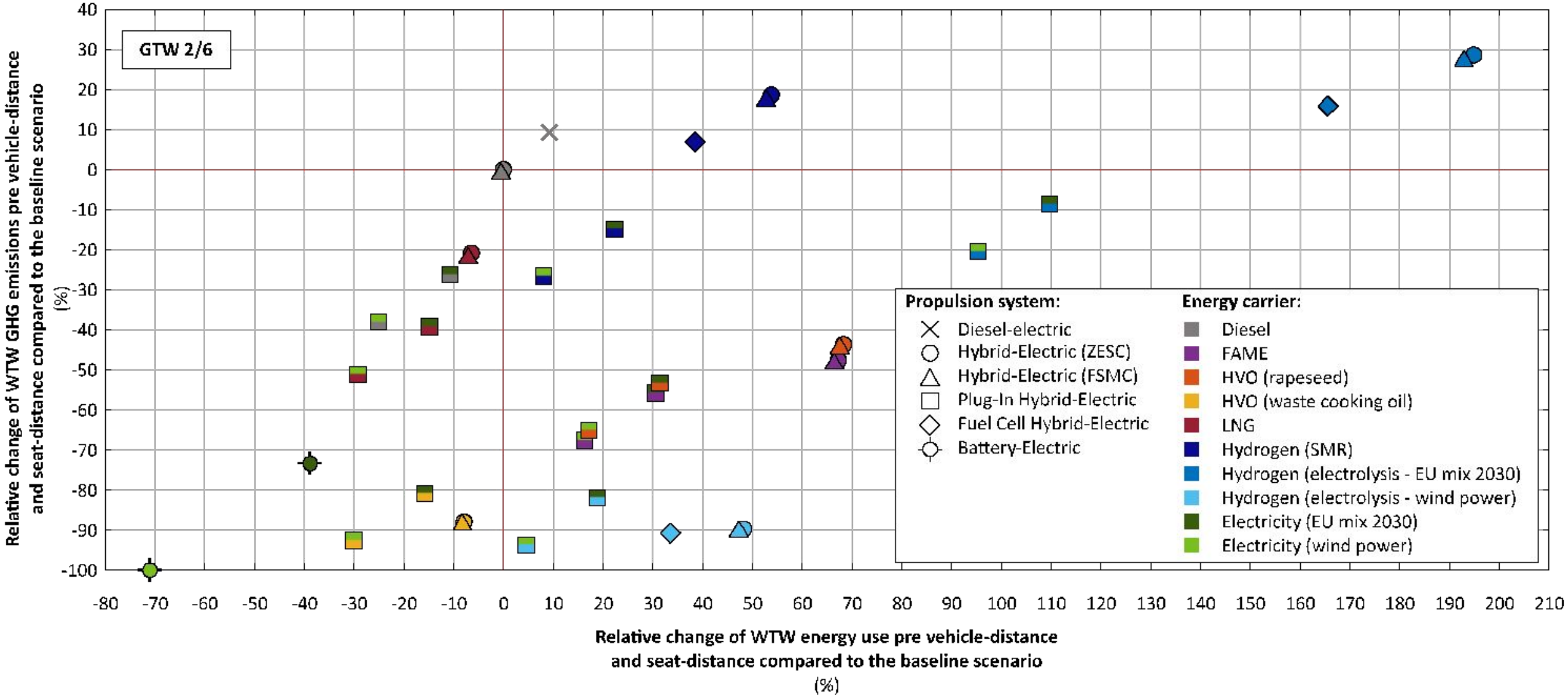

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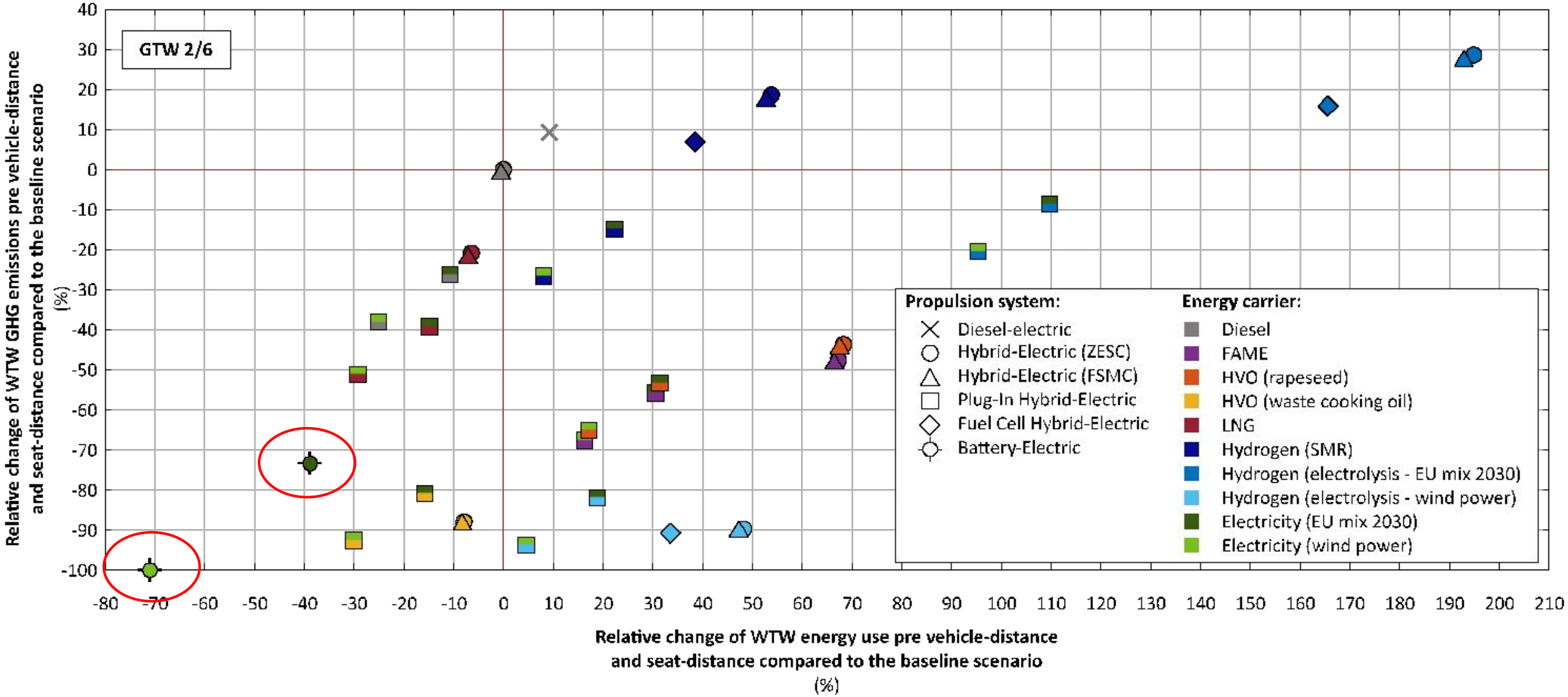

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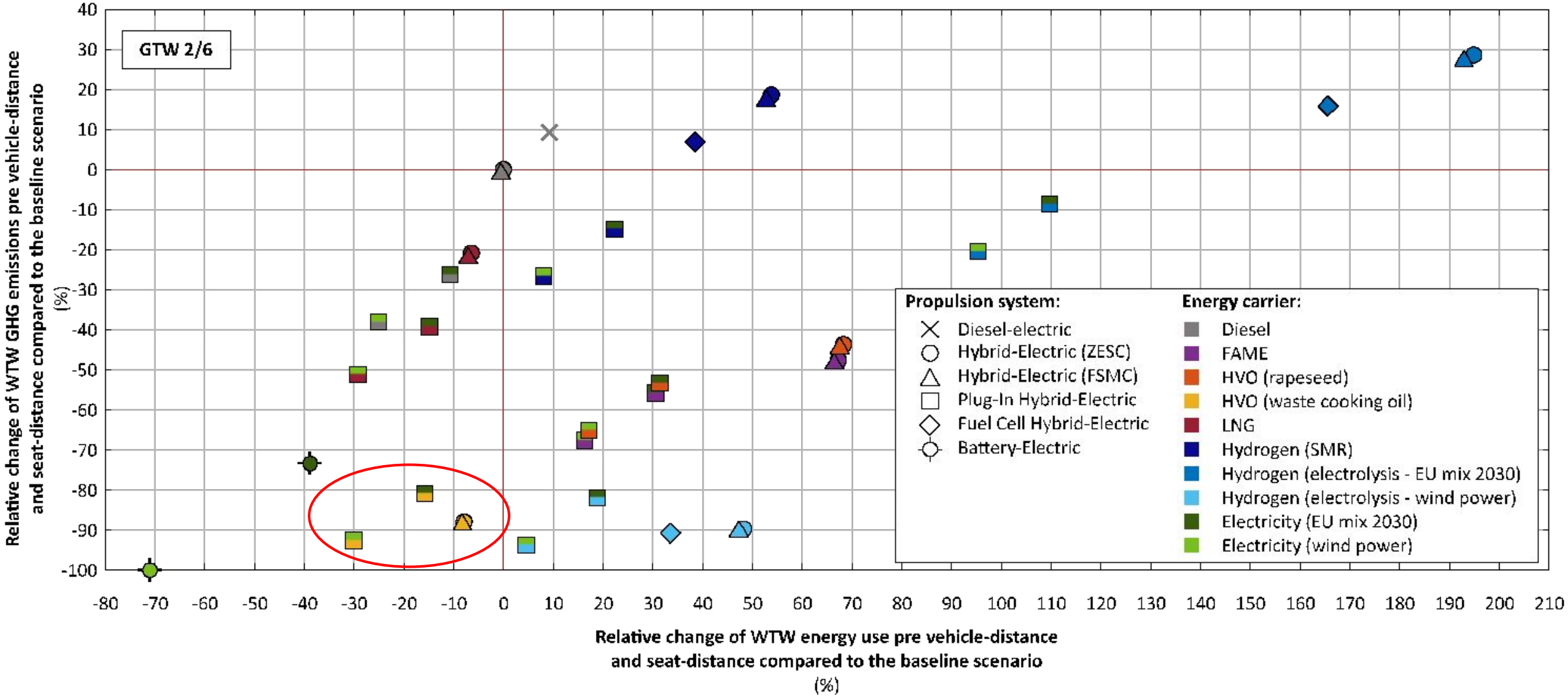

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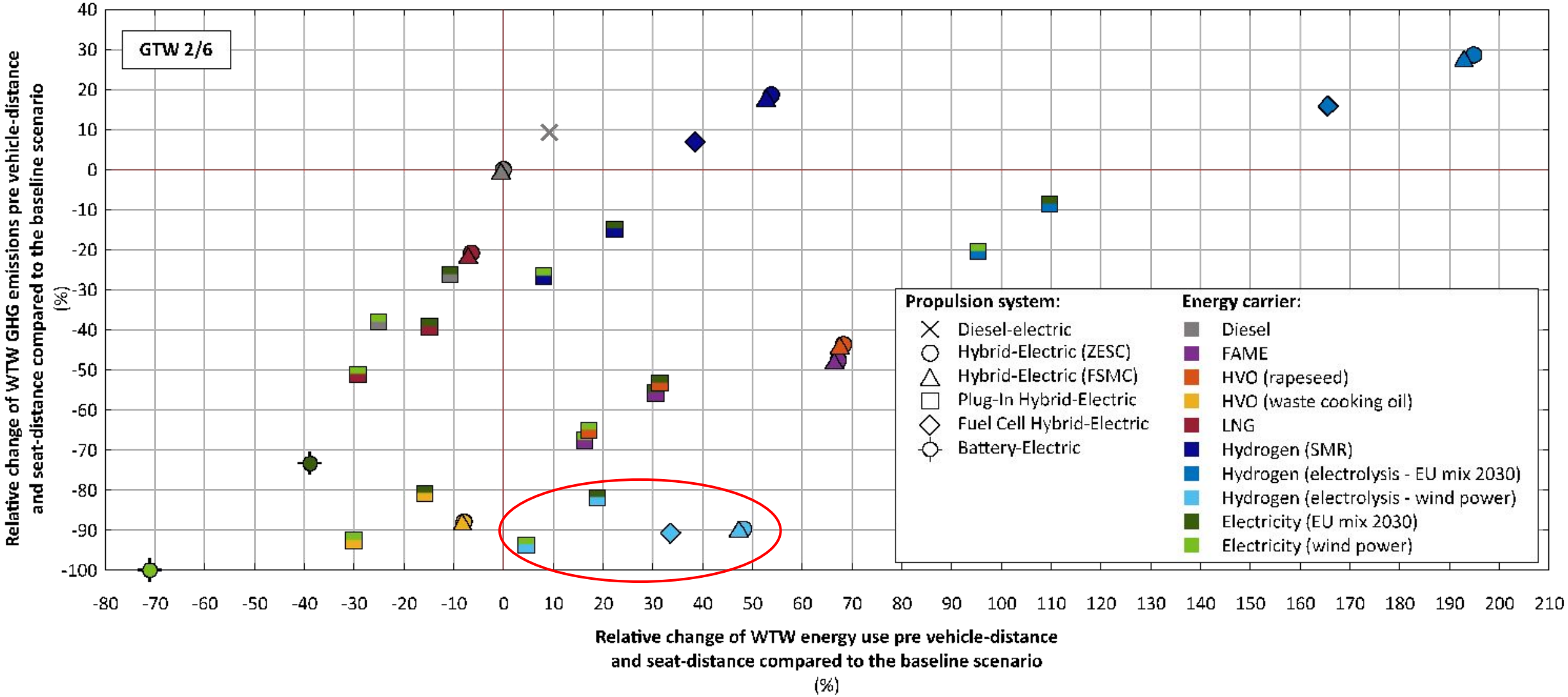

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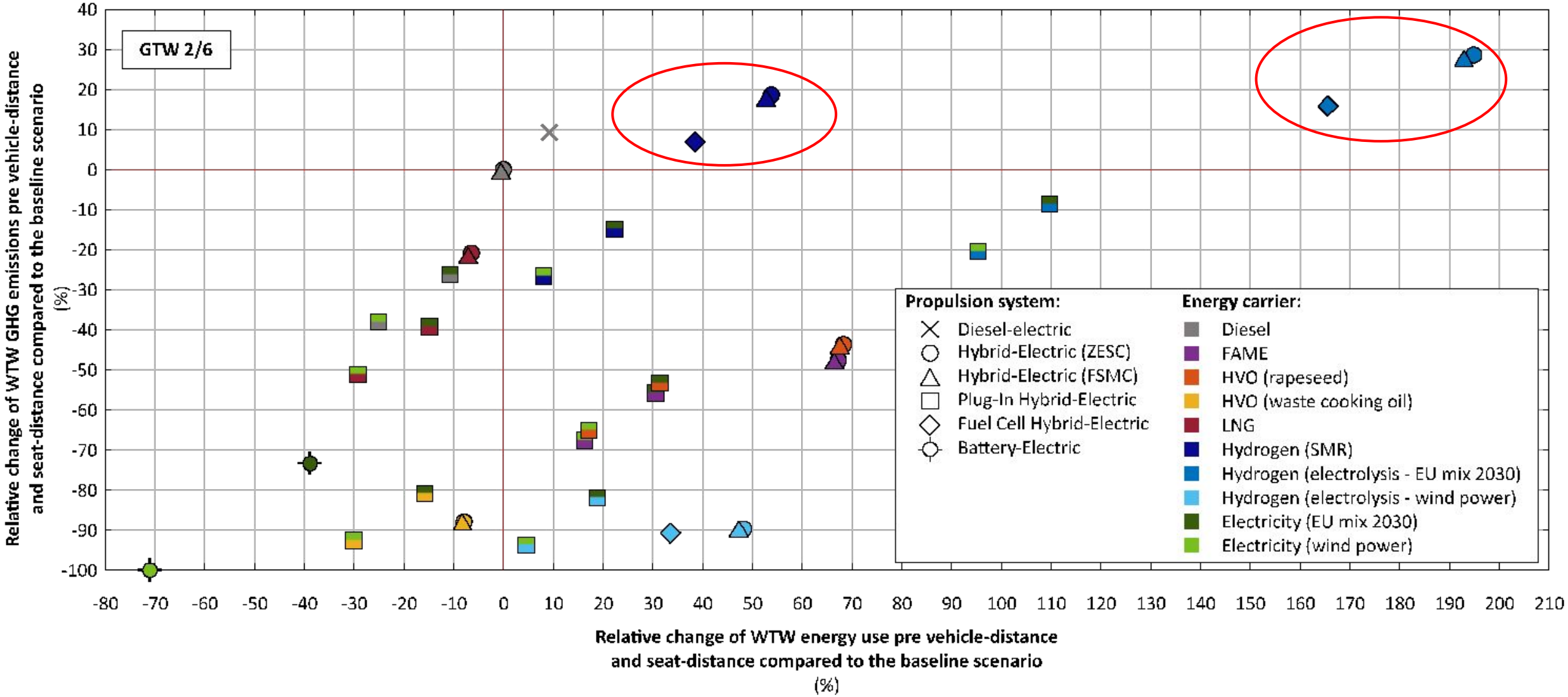

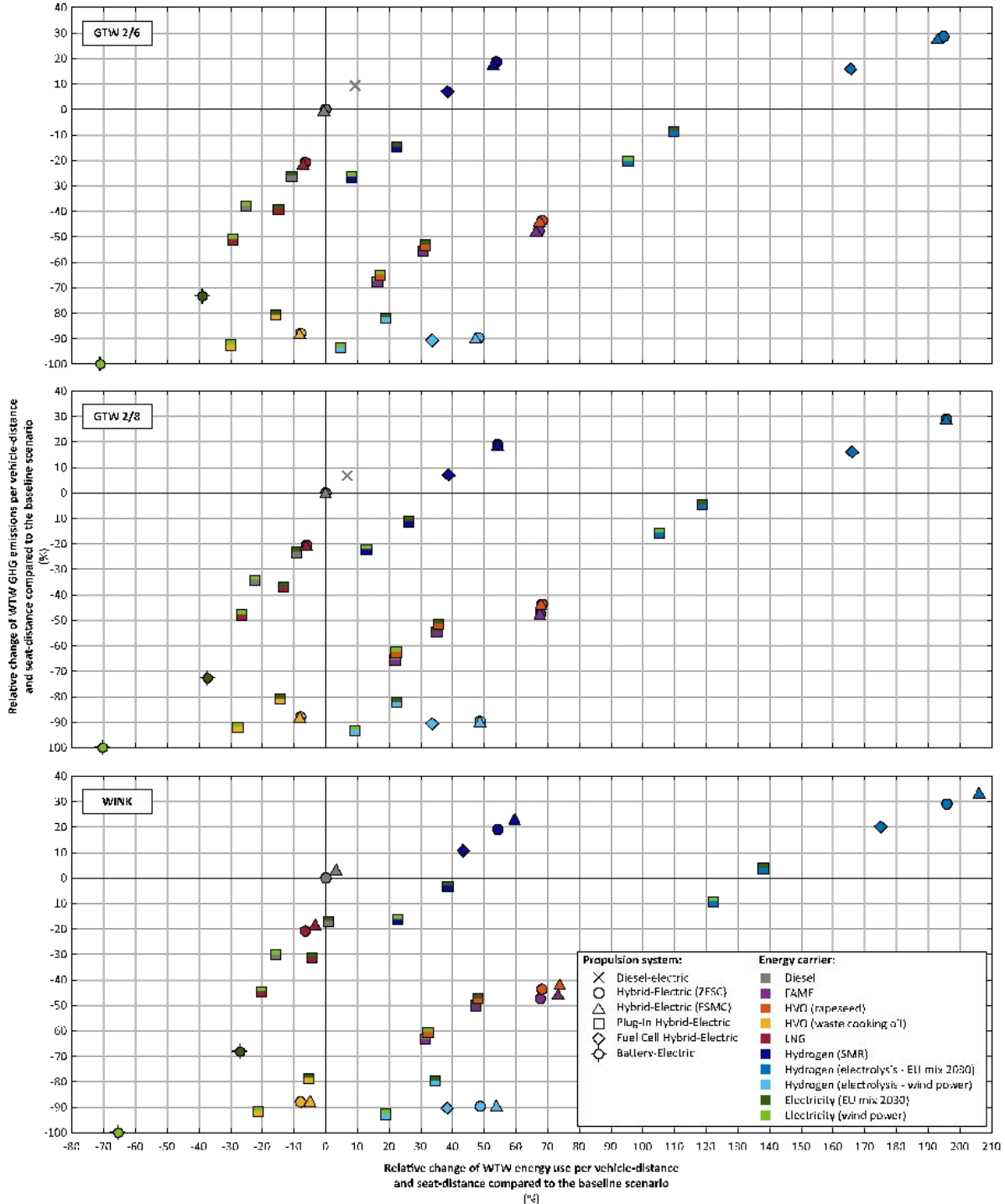
GTW 2/6
GTW 2/8
WINK
Relative change of WTW GHG emissions per vehicle-distance and seat-distance compared to the baseline scenario (%)
Relative change of WTW energy use per vehicle-distance and seat-distance compared to the baseline scenario (%)
Propulsion system:
Diesel-electric
Hybrid-Electric (ZFSC)
Hybrid-Electric (FSMC)
Plug-In Hybrid-Electric
Fuel Cell Hybrid-Electric
Battery-Electric
Energy carrier:
Diesel
FAME
HVO (rapeseed)
HVO (waste cooking oil)
LNG
Hydrogen (SMR)
Hydrogen (electrolysis - EU mix 2030)
Hydrogen (electrolysis - wind power)
Electricity (EU mix 2030)
Electricity (wind power)

TUDelft

Key Takeaway

	Pros	Cons
ICE + HVO	• High reduction of energy use and GHG emissions (~90%). • Instantly implementable.	• Emission of local pollutants (NOx and PM). • High price of HVO compared to diesel.
Battery-electric system	• The highest reduction of WTW energy use. • Emissions-free trains operation if green electricity is used.	• Requires partial track electrification, in addition to the vehicles retrofit.
Fuel cell hybrid-electric system	• Improved powertrain efficiency compared to ICE-based systems. • Noise-free and zero-emissions trains operation at the point of use.	• Can be justified only if green hydrogen obtained from renewable sources is used.

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