DECARBONIZING NON-ELECTRIFIED REGIONAL RAILWAYS:

SHIFTING TO ALTERNATIVE PROPULSION SYSTEMS AND ENERGY CARRIERS

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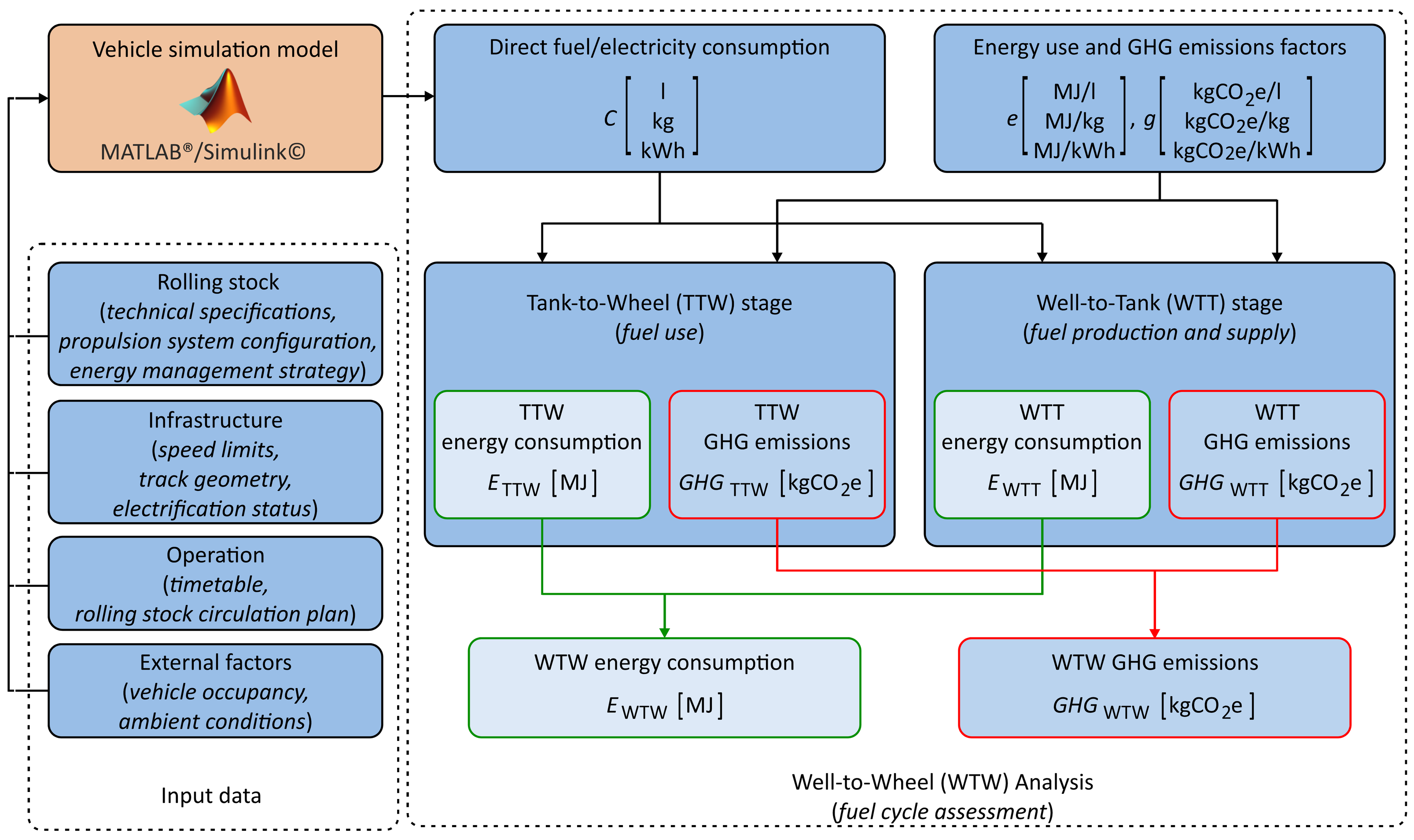
Motivation & Objectives

Non-electrified regional railways require replacement of diesel traction to meet increasingly strict emissions regulations. With complete electrification of regional lines often not economically viable due to the relatively low utilization, solutions are being sought in advanced catenary-free propulsion systems and alternative low-carbon fuels.

Present study proposes a methodological framework for comparative analysis of Well-to-Wheel energy use and GHG emissions linked to the implementations of various (hybrid) propulsion systems combined with prominent low-emission energy carriers, including commercially mature and novel technologies and energy carrier production pathways.

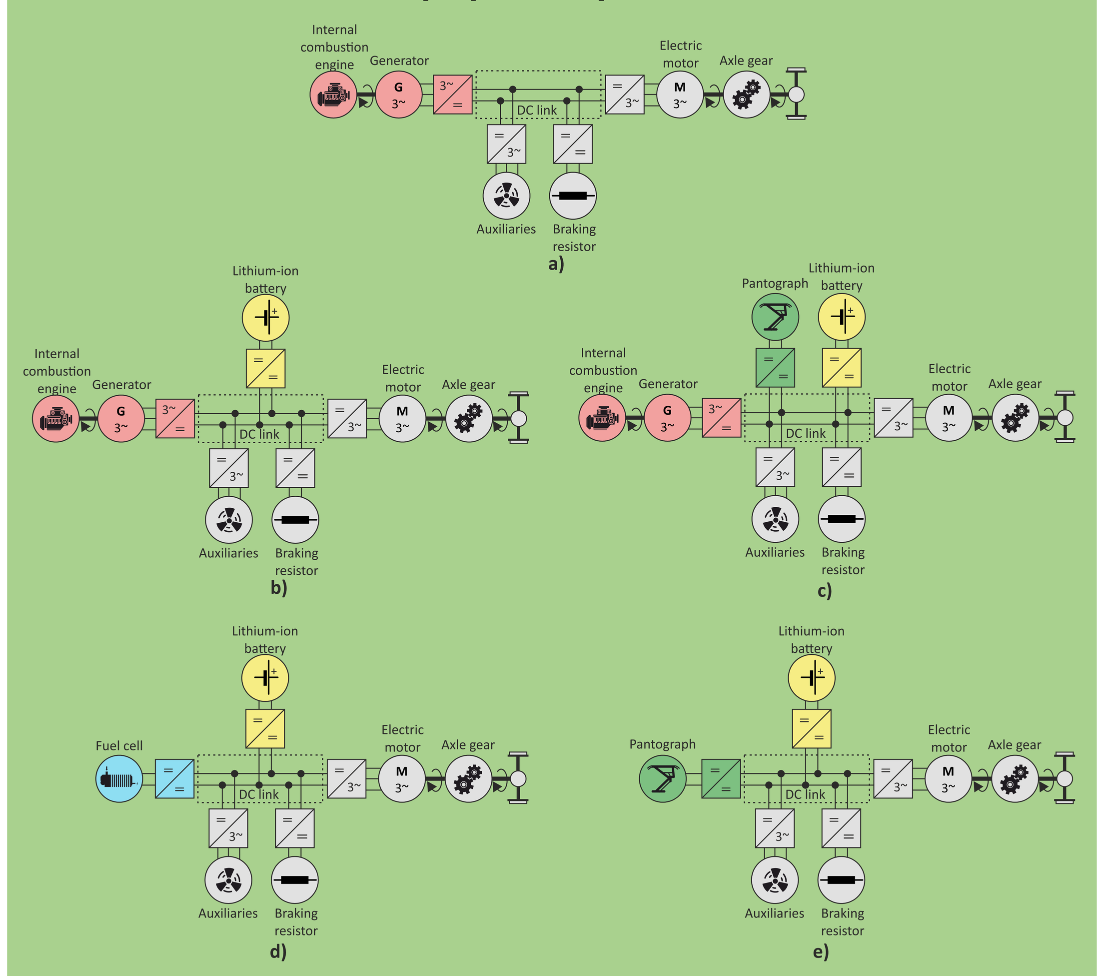
Proposed method is applied in the real-world case of regional rail passenger transport in the Netherlands using production pathways and emission factors relevant to European and Dutch contexts, providing the railway undertaking and policy-makers with new essential information for planning future rolling stock and infrastructure investments.

Methodology



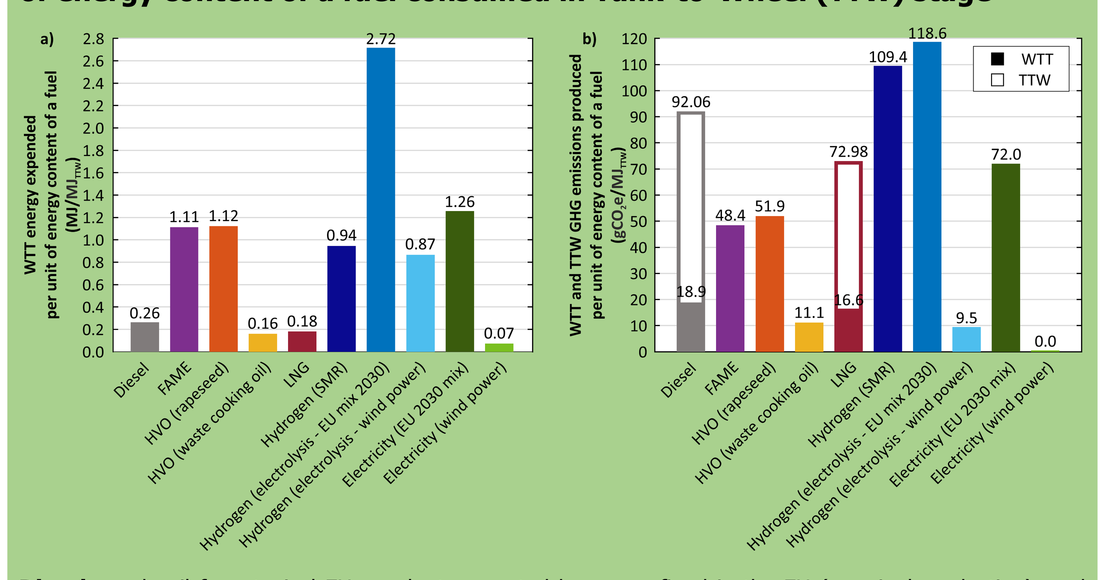
Considered Solutions

Schematics for alternative propulsion systems



(a) Conventional (diesel-electric)
(b) Hybrid-electric
(c) Plug-in hybrid-electric
(d) Fuel cell hybrid-electric
(e) Battery-electric

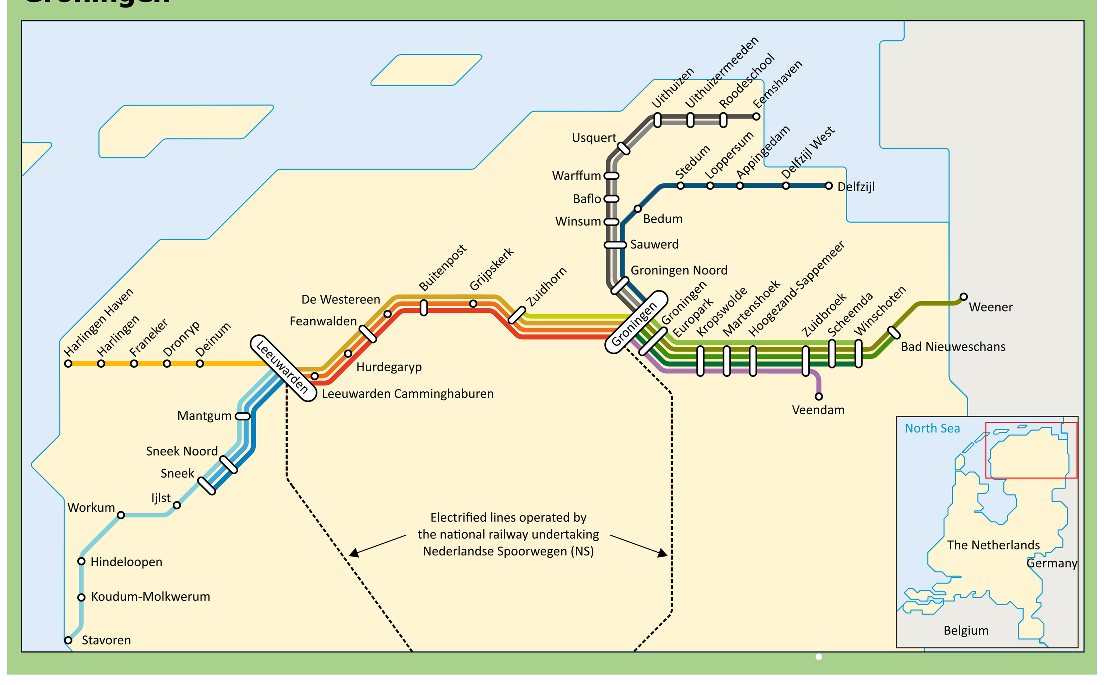
Well-to-Tank (WTT) (a) energy expended and (b) GHG emissions per unit of energy content of a fuel consumed in Tank-to-Wheel (TTW) stage



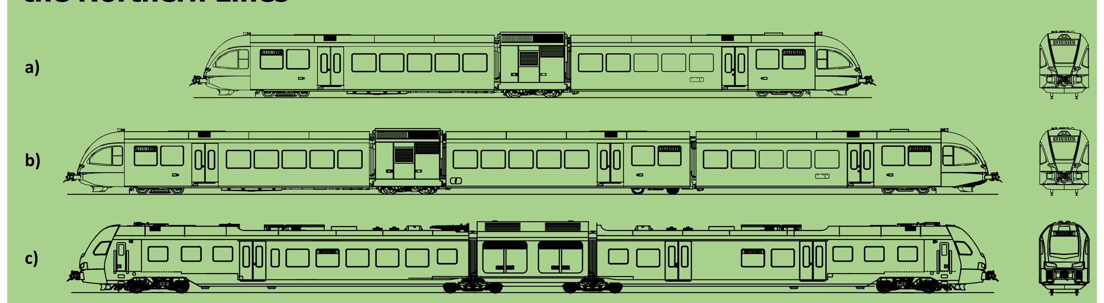
Diesel: crude oil from typical EU supply, transported by sea, refined in the EU (marginal production), and with typical EU distribution and retail.
FAME: rapeseed (Rapeseed Methylester) as the main feedstock for biofuels in the EU, with meal export as animal feed.
HVO: either rapeseed with meal export as animal feed, or from waste cooking oil.
LNG: remote natural gas liquefied at the source, LNG is transported by sea and distributed by road, used as LNG in the vehicle.
Hydrogen: either SMR or electrolysis of water. For the SMR scenario, assumed EU-mix piped natural gas supply, transport to EU by pipeline (1900 km), transport inside EU (500 km), distribution through high-pressure trunk lines and low-pressure grid, small scale reformer at retail site. For the electrolysis scenarios, production using either medium voltage electricity based on EU2030-mix with retail site electrolysis, or electricity from wind energy with central electrolysis and pipeline transport. Compression to 88 MPa in all scenarios.
Electricity: Medium voltage electricity based on EU2030-mix, or produced from wind energy.

Dutch Case Study

Regional railway network and passenger transport services in the Northern Lines (*Noordelijke Lijnen*) in the provinces Friesland and Groningen

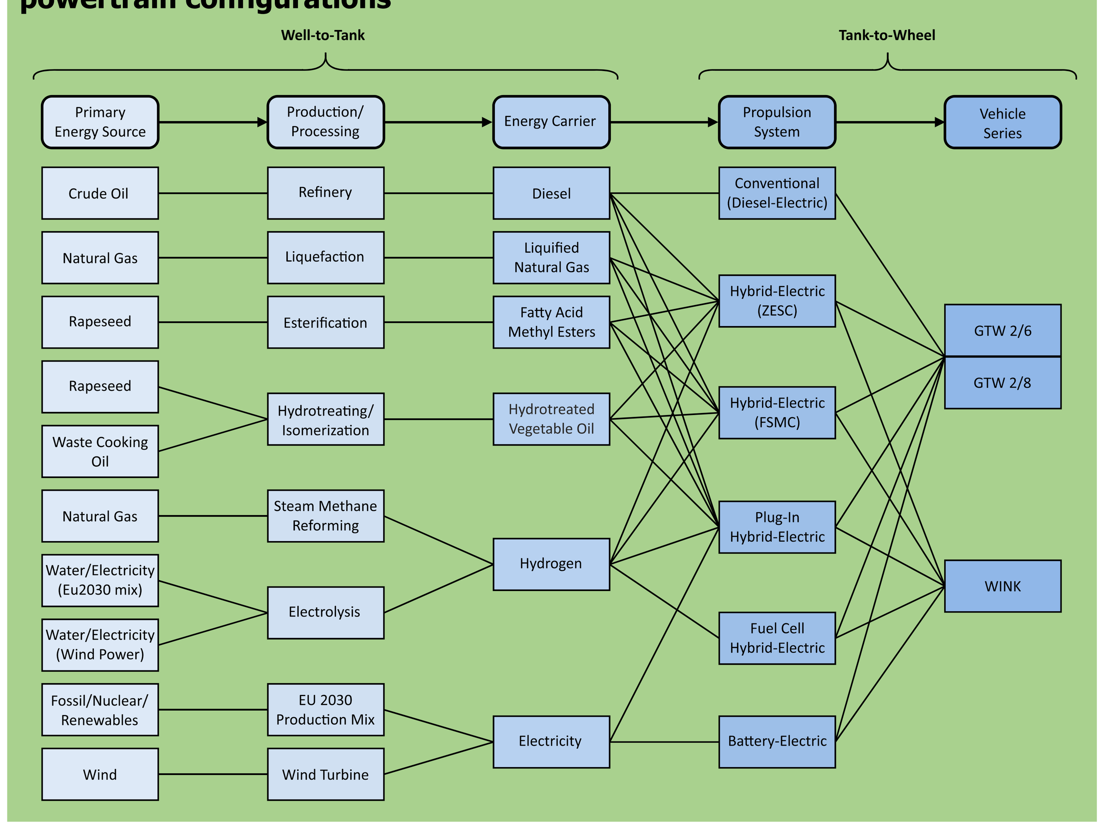


Graphical representation of Stadler's multiple unit vehicles employed on the Northern Lines



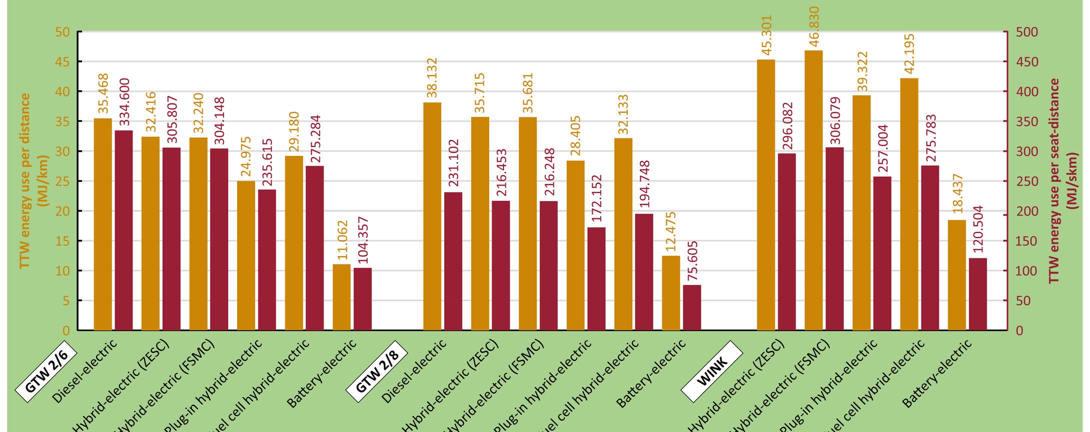
(a) GTW 2/6
(b) GTW 2/8
(c) WINK

Overview of the analyzed scenarios: primary energy sources, production processes and relevant energy carriers used in the propulsion of different powertrain configurations

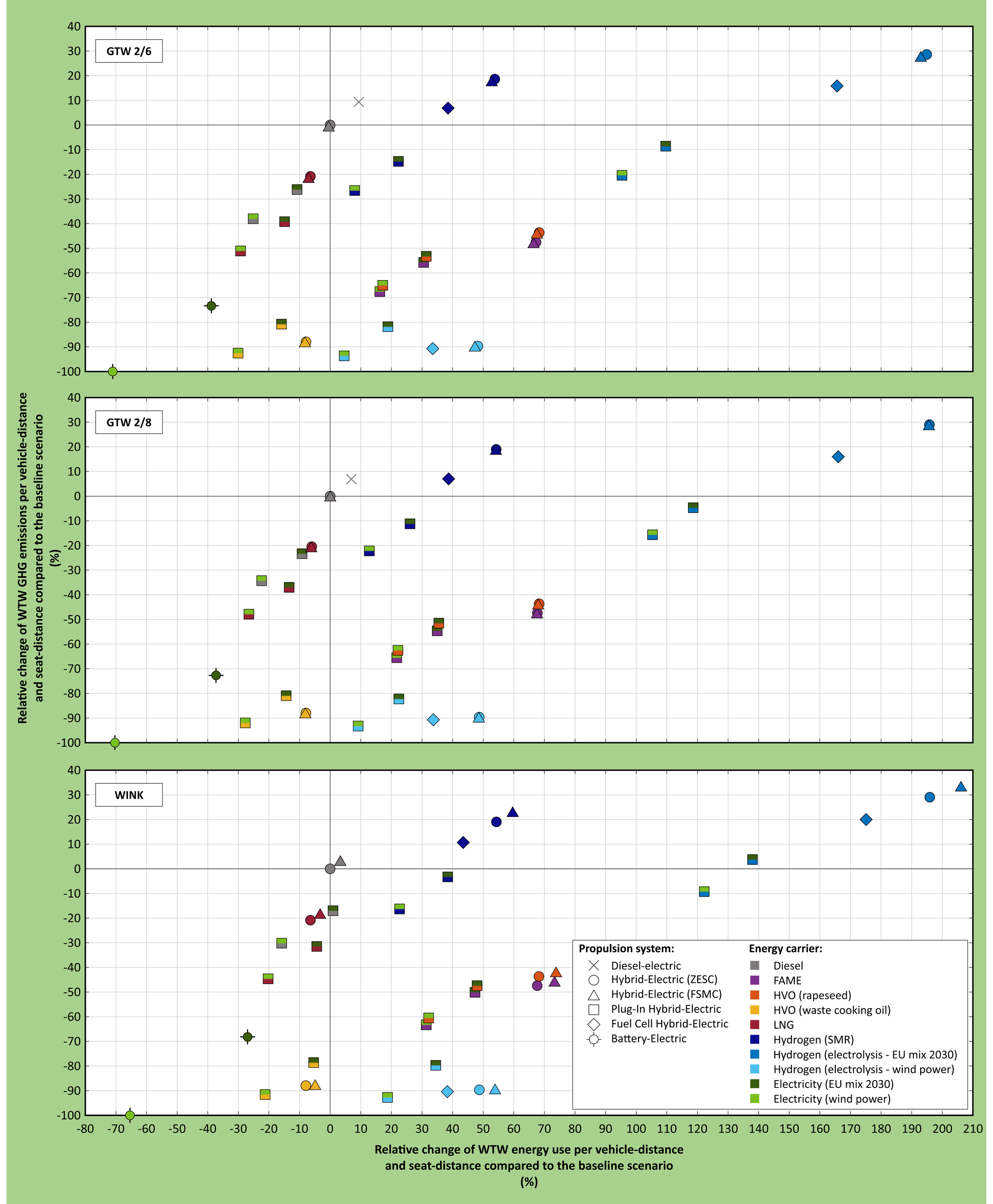


Comparative Assessment

Tank-to-Wheel (TTW) energy use per distance and seat-distance for the multiple unit vehicles and corresponding propulsion systems, based on the overall mean values aggregated over alternative energy carriers



Estimated relative change in Well-to-Wheel (WTW) energy use and greenhouse gas (GHG) emissions per vehicle-distance and seat-distance compared to the baseline scenario (hybrid-electric vehicle with Zero-Emission Station Control (ZESC) and diesel as a fuel) for different multiple unit vehicles in the Northern Lines



Key Results

- The battery-electric system running on wind-power based electricity provides the lowest energy use and zero-emission trains operation from the WTW perspective.
- Hydrogen offers a significant reduction of GHG emissions only if produced from electrolysis using green electricity, with negative effects in both energy use and emissions if produced from non-renewable sources.
- Focusing on fuels such as HVO and systems with infrastructure already in place could be an instantly implementable and cost-effective short-term solution for significant energy and GHG emissions savings.

Research Outlook

- Evaluation of environmental impacts from technology production and end-of-life processes using Life Cycle Assessment (LCA) approach
- Assessment of the fixed costs for both onboard technologies and stationary infrastructure required for alternative systems using Life Cycle Costs analysis
- Investigation of policy mechanisms such as carbon taxes in facilitating the transition towards carbon-neutral railways operation

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