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PROPULSION AND ENERGY ARCHITECTURE FOR SUSTAINABLE LIGHTWEIGHT REGIONAL RAILWAY VEHICLES: A SIMULATION-BASED ASSESSMENT WITHIN THE EUROPE'S RAIL FUTURE PROJECT

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Summary: Motivation: Regional railway lines play a crucial role in connecting rural regions and supporting the core rail network. However, many of these lines have been abandoned due to high operational and maintenance costs. In response to evolving societal mobility needs, several countries, particularly Germany and France, are reconsidering the revitalization of these lines. [1–3] Problem: Due to the often low utilization of lines in rural areas, there is high cost pressure, which makes it particularly important that a sustainable and cost-optimized approach is chosen for railway vehicles and infrastructure. To ensure the economic, social, and environmental sustainability of regional railways while meeting modern mobility demands, it is essential to determine the most suitable railway railway vehicle concept and propulsion system. This study is conducted within the framework of the European-funded project Europe's Rail – Flagship Project 6 – FutuRe, which targets to make rail an attractive and preferred mode of transport. [4] Objective: This work focuses on the development of an alternative propulsion system and energy architecture for novel small and lightweight regional rail vehicle concepts. The primary objective is to establish an initial assessment of power and energy demands in correlation with the development of a vehicle concept. Particular attention is given to determining the most suitable powertrain concept to ensure efficiency, reliability and sustainability in future regional rail operations. Approach: In the first step, the performance indicators, such as specific power, of existing small railway vehicles are analyzed. These insights, combined with the heuristic parameters for the estimation of the driving resistances of the new vehicle focused here, are used to derive initial railway vehicle parameters and longitudinal simulation. Based on this, a digital twin of the novel railway vehicle concept is developed. Subsequently, initial simulations in MATLAB are performed to evaluate power and energy demands for a relevant use case. Finally, various battery technologies and fuel cell powertrain solutions are dimensioned based on a fundamental energy management strategy and assessed for feasibility. Results/ expected results and outlook: The results compare the performance of different battery chemistries—NMC, LFP, and LTO—against hydrogen fuel cell systems for the mountainous Erfurt-Rennsteig route in Germany, with average energy consumption reaching up to 3.4 kWh/km. Furthermore, the study assesses the differences between Battery-Electric Multiple Units (BEMU) and Hydrogen-Electric Multiple Units (HEMU), along with the necessary abstraction for lightweight railway vehicles, particularly in terms of powertrain architecture and energy demand for different driving styles. This provides an initial indication of operational constraints related to recharging and refueling, as well as the feasibility of alternative propulsion technologies for a demanding railway route. Overall, these findings support the broader investigation into the potential replacement of conventional diesel-powered vehicles.

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