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Technological, Economic and Ecological Assessment of Powertrain Technologies in the Railway Sector

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Bundesministerium Arbeit und Wirtschaft
Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie
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Motivation

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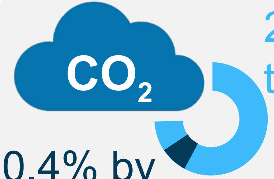
Emissions and Rail Network in the EU

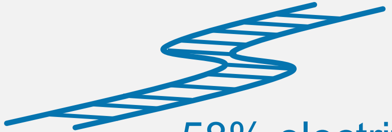
3.2 Gt



29% by transport

0.4% by railways

→ one of the most environmentally friendly forms of mobility



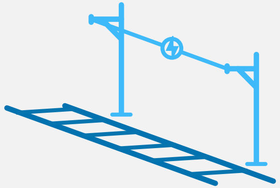
58% electrified (130,000 km)

Benchmark

Decarbonizing the Railway Sector

Alternatives

Electrification of Regional Railways



substantial costs and resources

→ other zero-emission technologies as suitable alternatives

case-by-case decision analysis

References: eea, statista

Methodology

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Scientific, Technology-neutral and Holistic Comparison

Extraction
Processing

Operation
Maintenance

Disposal
Recycling

Pre-Use (Production) → **Use** → **Post-Use** (End-of-Life)

➊ Longitudinal Dynamics Simulation

Calculation of the Energy Demand of the Vehicles

➋ Life Cycle Inventory and Dynamic Investment Calculation

Vehicle (energy use) + Infrastructure (energy supply)

Quantification of Resources, Emissions and Costs based on **valid and profound Data** from the Literature, Manufacturers and Experts

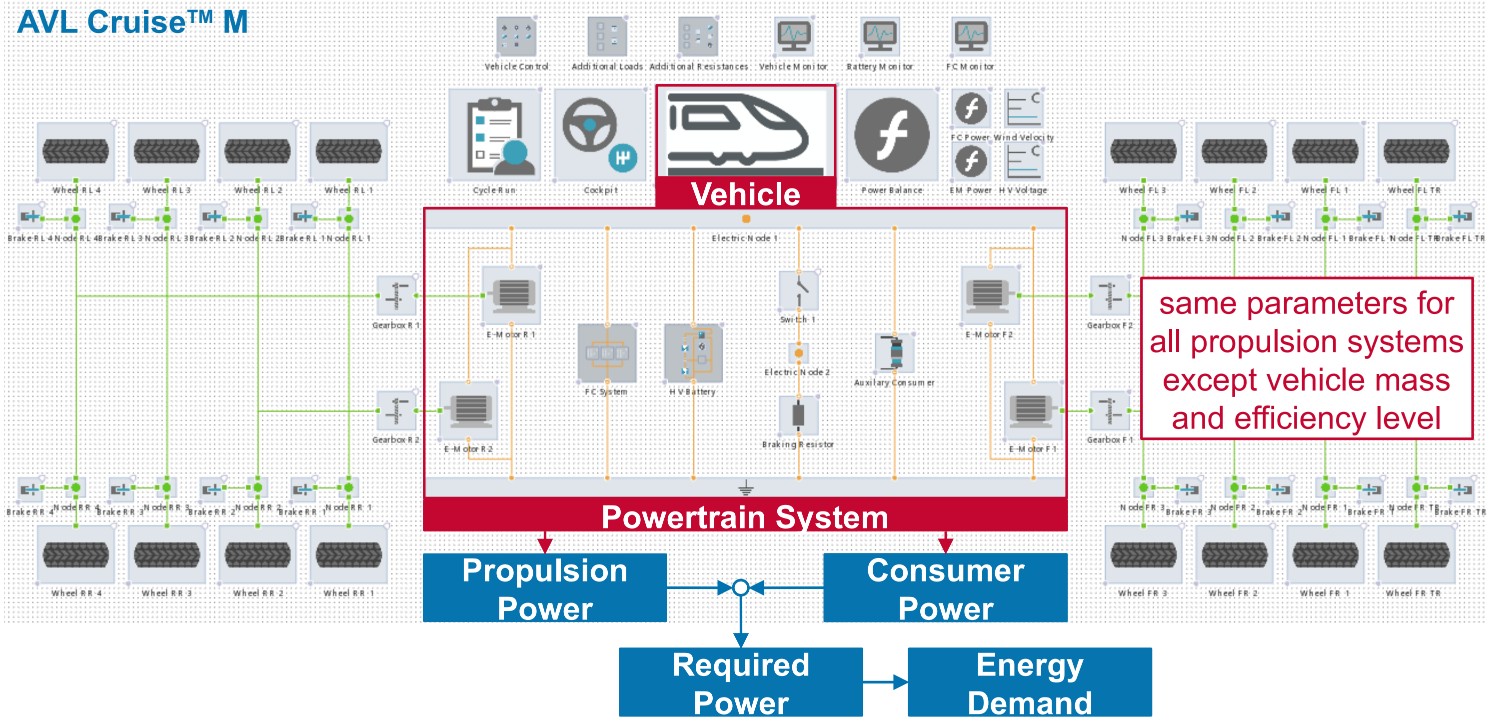
➌ Use-Value Analysis

Determination of the best Alternative Technology

References: ÖNORM EN ISO 14040, ÖNORM EN ISO 14044, ÖNORM M 7140

Methodology

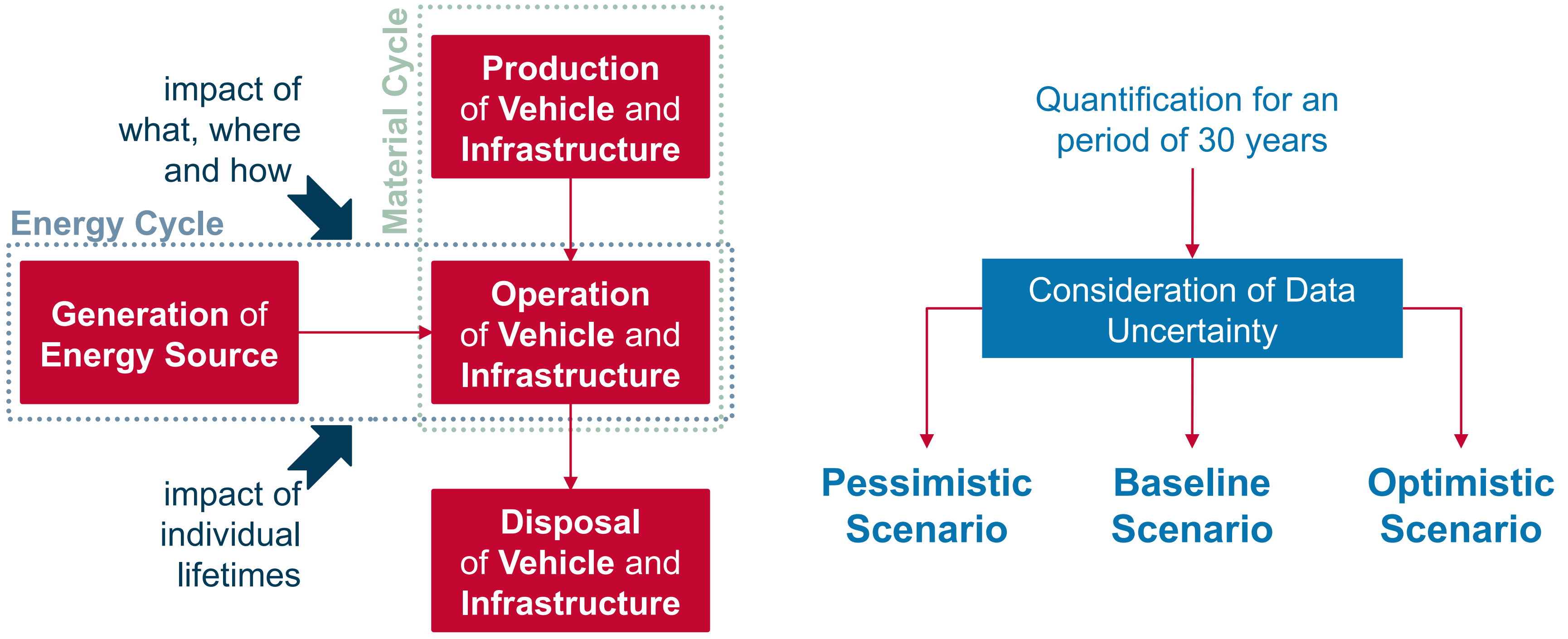
➊ Longitudinal Dynamics Simulation



→ realistic operation according to the boundary conditions and vehicle specifications

Methodology

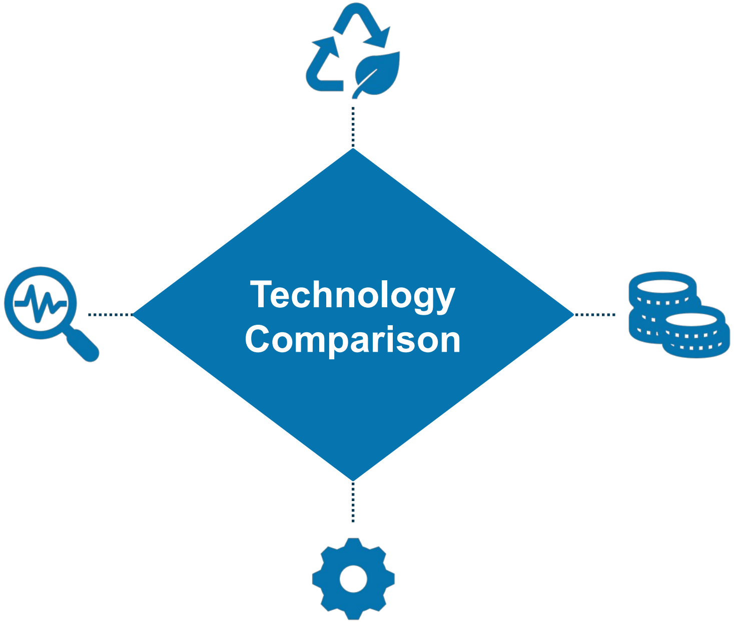
❷ Life Cycle Inventory and Dynamic Investment Calculation



→ focus only on pre-use and use-phase as data for post-use phase misses consistency

Methodology

❸ Use-Value Analysis



Ecological: carbon / particle emissions, area demand

Economical: capital / operational costs

Technical: powertrain mass / volume, constructional effort, technological maturity, durability / reliability

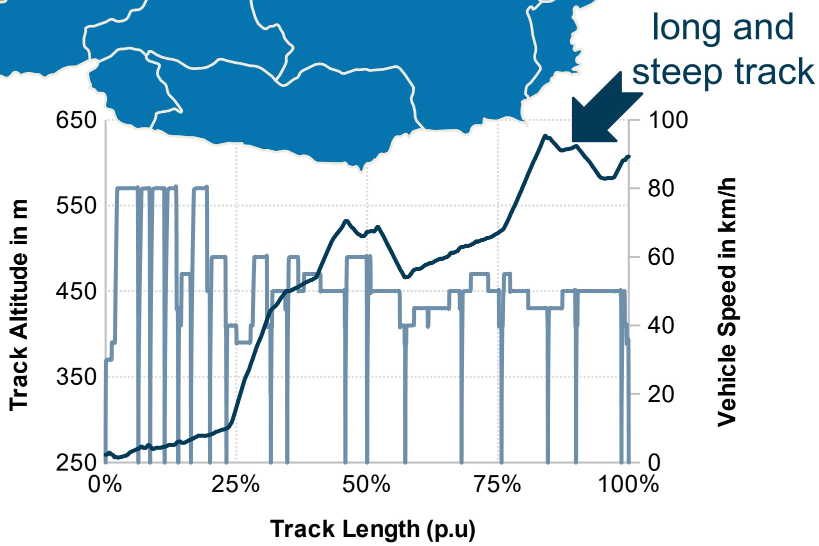
Operational: driving range, recharging / refueling time, grid stress, timetable stability, synergy potential

→ no consolidation as each stakeholder would weigh these four aspects individually

Boundary Conditions

Mühlkreisbahn in Austria

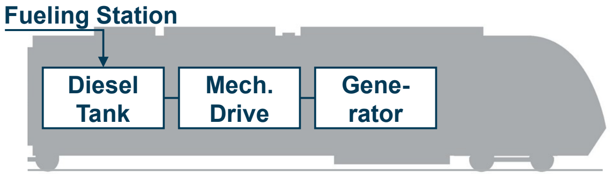
- **Avg. Temperature:** 10 °C
- **Track Distance:** 58 km
- **Height Difference:** 358 m
- **Max. Inclination:** 5.0 %
- **Driving Time:** 75 min
- **Cycle Interval:** 45 min
- **Cycles per Day:** 18
- **Mileage per Year:** 378,000 km
- **Emissions per Year:** 2.200 t



References: meinbezirk

Specifications

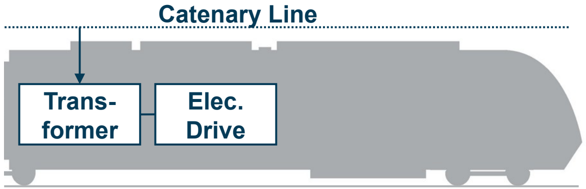
DMU



Vehicle
- **Fleet Size:** 4
- **Diesel Engine:** 1400 kW
- **Efficiency:** 30 – 40%

Infrastructure
- **Fueling Station:** 100 L/min
- **Efficiency:** 85 – 90%

EMU



Vehicle
- **Fleet Size:** 4
- **Electric Machine:** 1400 kW
- **Efficiency:** 80 – 90%

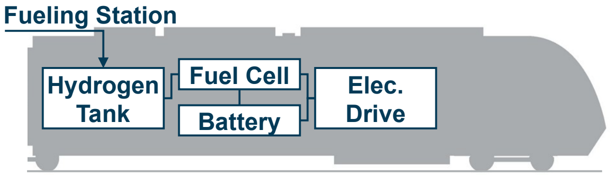
Infrastructure
- **Catenary Line:** 86 km
- **Transformer Station:** 8 MVA
- **Efficiency:** 94 – 96%

BEMU

Vehicle
- **Fleet Size:** 5
- **Battery:** 1800 kWh
- **Electric Machine:** 1400 kW
- **Efficiency:** 72 – 81%

Infrastructure
- **Charging Station:** 2.4 MW
- **Transformer Station:** 4 MVA
- **Efficiency:** 88 – 93%

HEMU

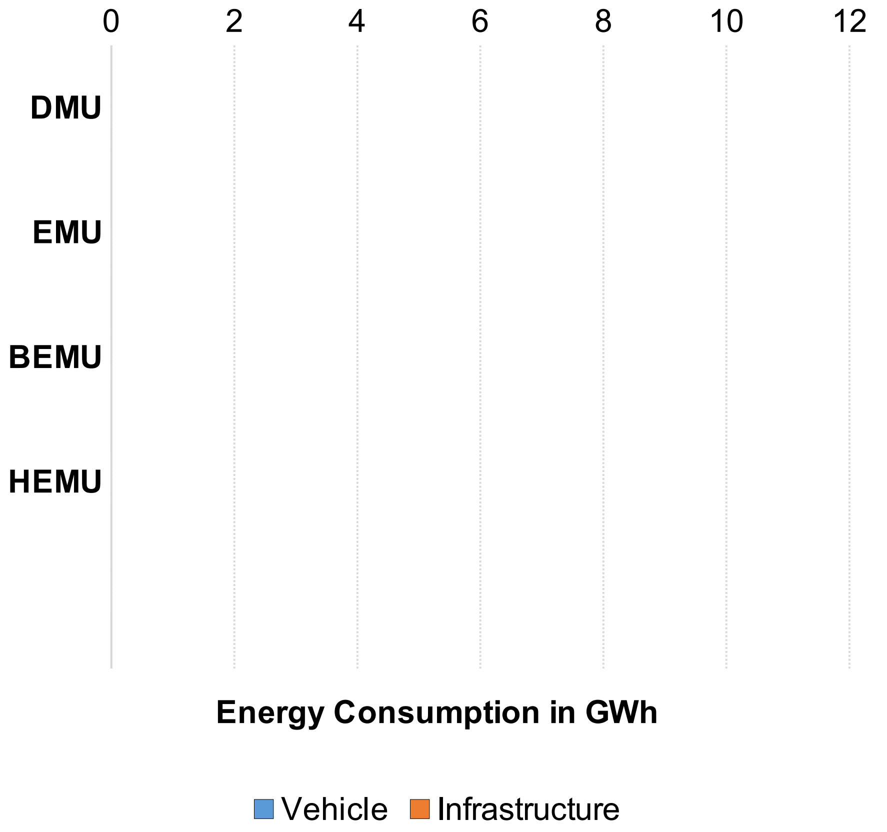


Vehicle
- **Fleet Size:** 4
- **Fuel Cell:** 500 kW
- **Battery:** 420 kWh
- **Efficiency:** 40 – 50%

Infrastructure
- **Fueling Station:** 100 kg/h
- **Electrolysis:** 2 MW
- **Efficiency:** 72 – 81%

DMU = Diesel Multiple Unit // **EMU** = Electric Multiple Unit // **BEMU** = Battery Electric Multiple Unit // **HEMU** = Hydrogen Electric Multiple Unit

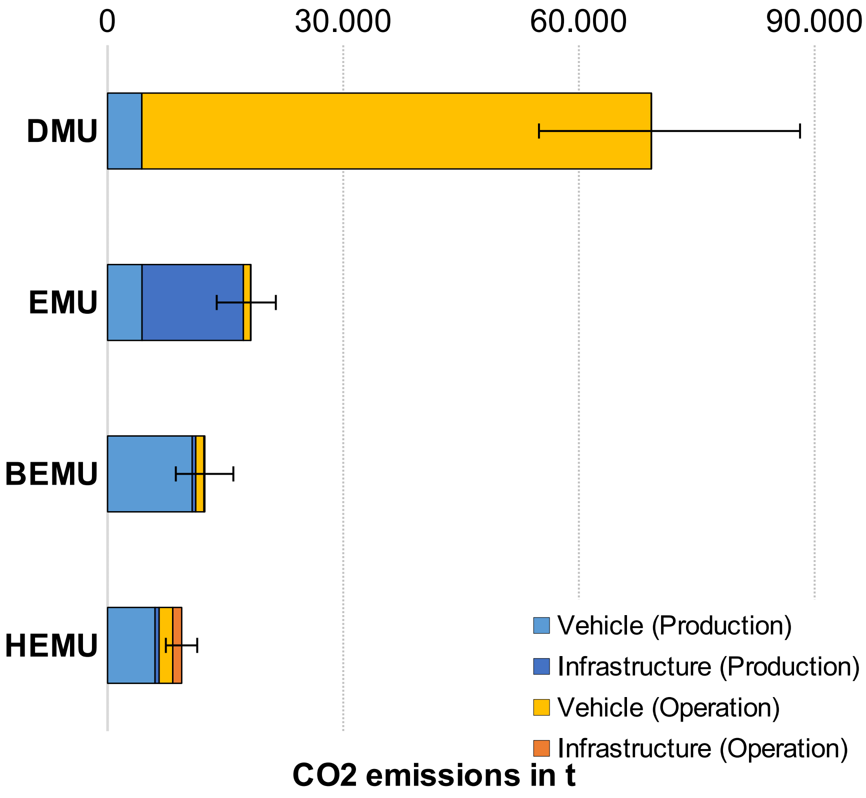
Energy Consumption

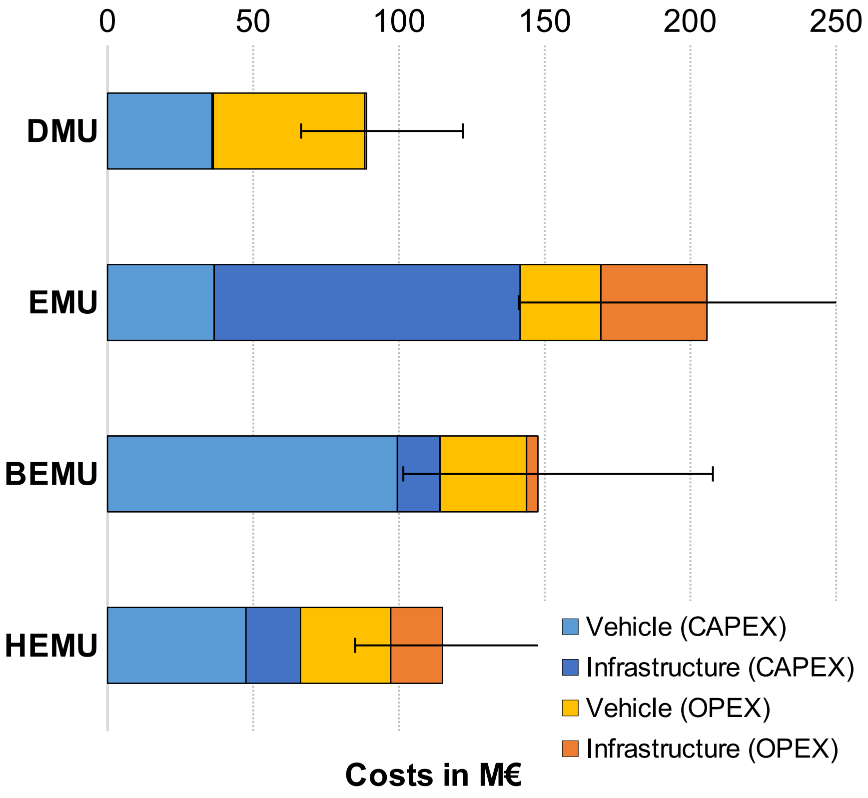


- **Scenario:** Results of pessimistic, baseline and optimistic scenarios
- **Energy:** Focus only on renewable energies in terms of operation
- **DMU:** Fossil diesel produced centralized via refining of petroleum
- **EMU + BEMU:** Renewable electricity supplied from renewable power plant
- **HEMU:** Renewable hydrogen produced decentralized via electrolysis using renewable electricity

DMU = Diesel Multiple Unit // **EMU** = Electric Multiple Unit // **BEMU** = Battery Electric Multiple Unit // **HEMU** = Hydrogen Electric Multiple Unit

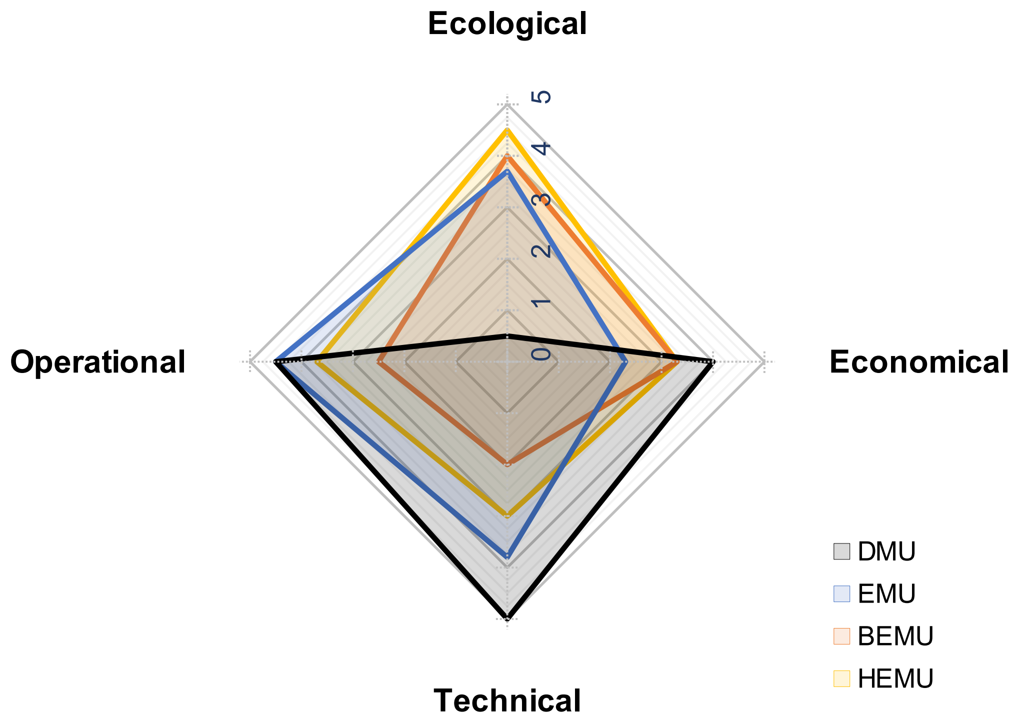
Emissions and Costs





DMU = Diesel Multiple Unit // **EMU** = Electric Multiple Unit // **BEMU** = Battery Electric Multiple Unit // **HEMU** = Hydrogen Electric Multiple Unit

Technology Comparison



Summary: In this scenario the HEMU has an advantage over the BEMU and EMU

Rating
0 … failed
1 … inadequate
2 … sufficient
3 … satisfactory
4 … good
5 … excellent

DMU = Diesel Multiple Unit // **EMU** = Electric Multiple Unit // **BEMU** = Battery Electric Multiple Unit // **HEMU** = Hydrogen Electric Multiple Unit

Conclusion

Transition to Renewable Technologies

Future powertrains are based on electric machines

Classic electric railcars remain the best option for most areas of application

Battery / Hydrogen electric railcars are suitable alternatives for regional railway

Benchmark

Alternatives

Commitment to Sustainable Technologies

Suitability depends on the respective boundary conditions

Technology-neutral comparison is a basis for profound decision-making

Renewable electricity or hydrogen is a prerequisite for all the alternatives

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