Matthias Landgraf

Sustainable Railway Infrastructure

In our research, we focus on environmental impacts of production, provision and maintenance of railway infrastructure by using the methodology of life cycle assessment (LCA). The goal is to identify main drivers for environmental impacts in order to enhance mitigation and implementation of circular economy. Moreover, we implement these findings within the planning and public procurement processes in the railway system.

Mitigating environmental impacts is one of the main challenges faced by society. In past decades, the regulatory focus in regards to mobility was largely on tailpipe emissions only, and neglected the environmental impacts of manufacturing, construction, maintenance and disposal of the infrastructure components as well as the vehicles[1]. Hence, we focus on environmental impacts of production, provision and maintenance of railway infrastructure by using the methodology of life cycle assessment (LCA).

Our calculation of network-wide environmental impacts is the first which is specific to local conditions and representative of the entire railway network[2]. Previous studies have referred to railway track with a generic service life while neglecting a variation in maintenance demands and service lives due to different boundary conditions such as alignment, types of components and traffic load. Carrying out a top-down approach for the whole railway infrastructure shows that track is the main contributor of greenhouse gas emissions and energy demand within the Austrian network (Figure 1). There is a high potential of implementing innovations as there is a continuous renewal rate of around 3% of Austria's track network length each year. This means any innovation can be implemented promptly whereas construction of tunnels is carried out less frequently. >

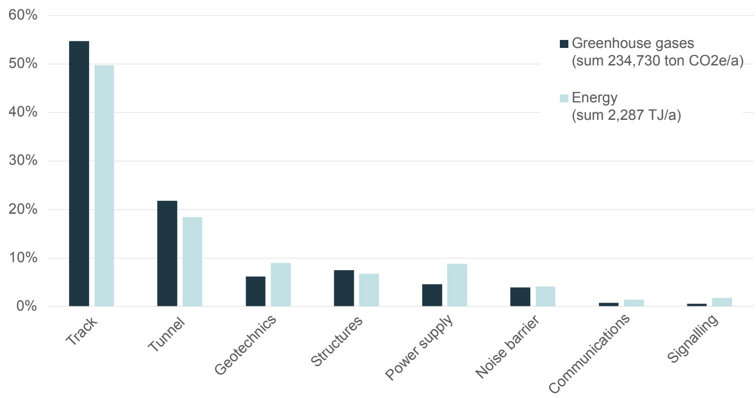

Figure 1: Contribution to energy demand and GHG emissions of relevant railway infrastructure component production and construction in the Austrian network (cradle-to-gate emissions per year from network-wide top-down approach).

Source: Matthias Landgraf

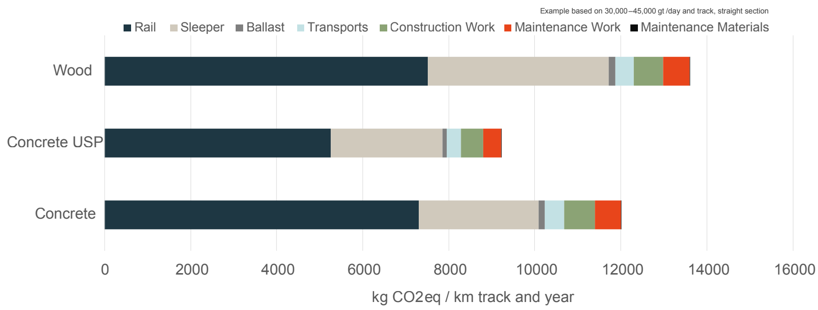

Figure 2: GHG emissions per km of track and year for straight sections, traffic load between 30,000–45,000 gt/day and track.

Source: Matthias Landgraf

1 Chester M V, Horvath A. Environmental assessment of passenger transportation should include infrastructure and supply chains. Environ Res Lett. 2009;4(2):24008.

2 Landgraf M., Horvath A. Embodied greenhouse gas assessment of railway infrastructure: the case of Austria Environmental Research: Infrastructure and Sustainability, IOP Publishing, 2021, https://doi.org/10.1088/2634-4505/ac1242

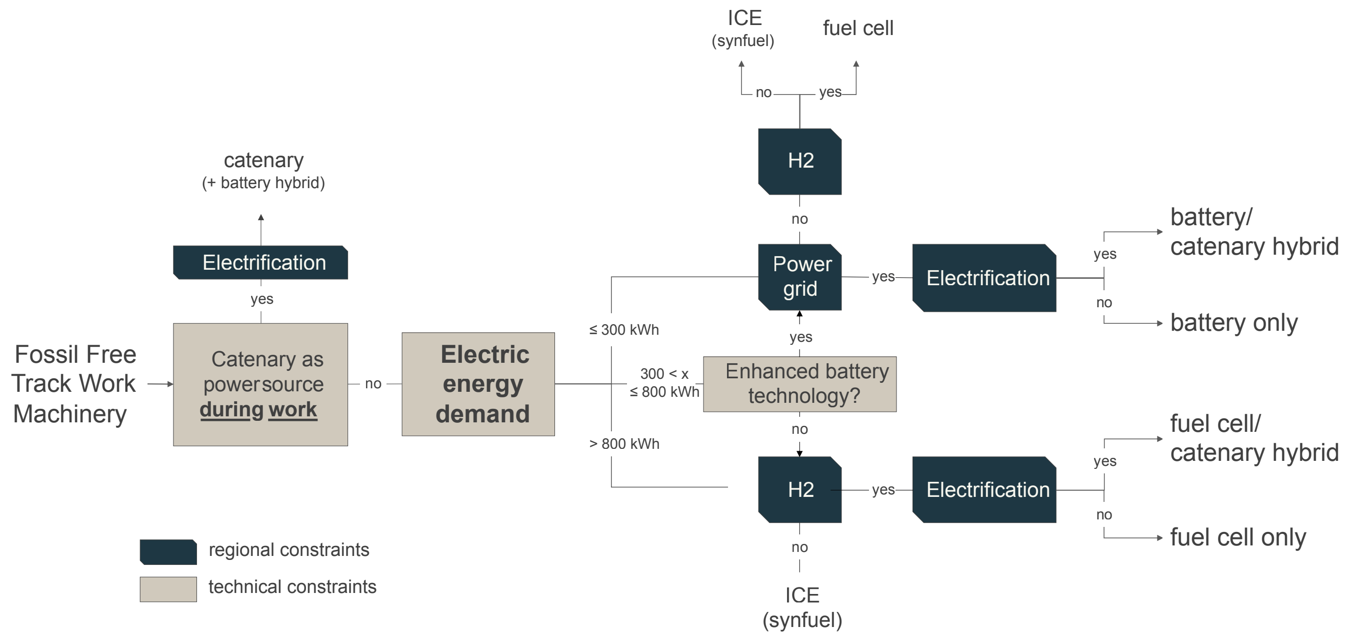

Figure 3: Decision tree for future fossil-free track work machinery.

Source: Matthias Landgraf

The sum of annual cradle-to-gate emissions (based on infrastructure network, asset distribution, and renewal rates of 2015-2019) of railway infrastructure amounts to 234,730 tonnes CO2eq. In 2018, greenhouse gas emissions for passenger operations amounted to 165,600 tonnes CO2eq[3,4]. Thus, for Austrian boundary conditions, railway infrastructure contributes an additional 141% of GHG emissions over emissions associated with passenger operations. This underlines the necessity to include embodied carbon emissions of infrastructure for long-term decision making in regards to sustainability goals.

An in-depth bottom-up approach is carried out for the main contributor of GHG emissions within the Austrian railway network – railway track. For a straight track with a medium traffic density, wooden sleepers show the highest GHG emissions per km track and year (Figure 2). This is mainly caused by the sleeper preservation process in manufacturing, lower service life and a lower potential for reuse compared to concrete sleepers. The lowest GHG emissions per km track and year derive from concrete sleepers with under-sleeper pads. The material of under-sleeper pads causes higher emissions in the production process, but can be easily balanced out due to a significantly higher service life of railway track compared to conventional concrete sleepers.

A relevant potential for mitigation is the track (re-)construction and maintenance process itself. Studies carried out with

3 Austrian Environmental Agency. Austrian Emission factors for transport [Internet]. Vienna; 2019. Available from: https://www.umweltbundesamt.at/umweltsituation/verkehr/verkehrsdaten/emissionsfaktoren_verkehrsmittel/

4 Austrian Federal Railways. OeBB Facts & Figures 2019 [Internet]. Vienna; 2019. Available from: https://presse.oebb.at/en/publications

5 Zeiner M, Landgraf M, Knabl D, Antony B, Barrena Cardenas V, Koczwara C. Assessment and Recommendations for a Fossil Free Future for Track Work Machinery. Sustainability, mdpi Publishing, 2021, https://doi.org/10.3390/su132011444

6 Landgraf M, Zeiner M, Knabl D, Corman F. Environmental impacts and associated costs of railway turnouts based on Austrian data. Transp Res Part D Transp Environ. 2022, Feb 103:103168., Elsevier https://doi.org/10.1016/j.trd.2021.103168

the Austrian Federal Railway, the German Federal Railway Authority and manufacturer Plasser & Theurer focus on track work vehicles and their potential for fossil-free operation in the mid- and long-term future[5]. At the moment, single machine groups burn up to 1000 litres of fossil fuel per 1 km of track renewal. This is the reason why we analysed machines based on their electrical energy demand per working shift. Then, we formulated migration strategies on the path to fossil-free track work following the basic concepts of the established decision tree in Figure 3.

In general, main potentials for mitigation of environmental impacts within railway infrastructure can be identified in steel production, circular economy, use of alternative propulsion systems for heavy maintenance machinery and transport as well as prolongation of service life components and materials by innovative technology. A major point for future research is also the harmonization of environmental pricing schemes[6]. Quantification, monetization and inclusion of environmental impacts within the procurement process may help suppliers to justify investments in environmentally efficient production processes and services.

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is a private lecturer at TU Graz as well as CEO and founder of evias. From 2011 to 2023, he was responsible for project lead, research and teaching at TU Graz's Institute of Railway Engineering and Transport Economics. In 2016, he received his doctorate in the field of condition monitoring of railway infrastructure. He established the research area of Environmental Aspects in the Railway System and after research stays at UC Berkeley (California, US) and ETH Zurich (Switzerland, CH), he completed his habilitation (venia docendi) at TU Graz in 2022.

Source: Sabine Hoffmann