Electrification of Public Transport in Austria

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Contents

1 Introduction

With a share of 28.8% of total greenhouse gas (GHG) emissions in Austria, the mobility sector represents one of the biggest pollution sources, as shown in Figure 1. (Umweltbundesamt, 2019a).

Austria's climate protection law determines yearly maximum quantities of GHG emission which were exceeded in the years 2016 and 2017, especially in the mobility sector (Umweltbundesamt, 2019a).

For that reason a sustainable development in the mobility sector is necessary for reaching the goals of the Paris Agreement 2015 with the central aim of strengthening the global response to the threat of climate change by keeping a global temperature rise well below 2 degrees Celsius above pre-industrial levels in this century (Umweltbundesamt, 2019a).

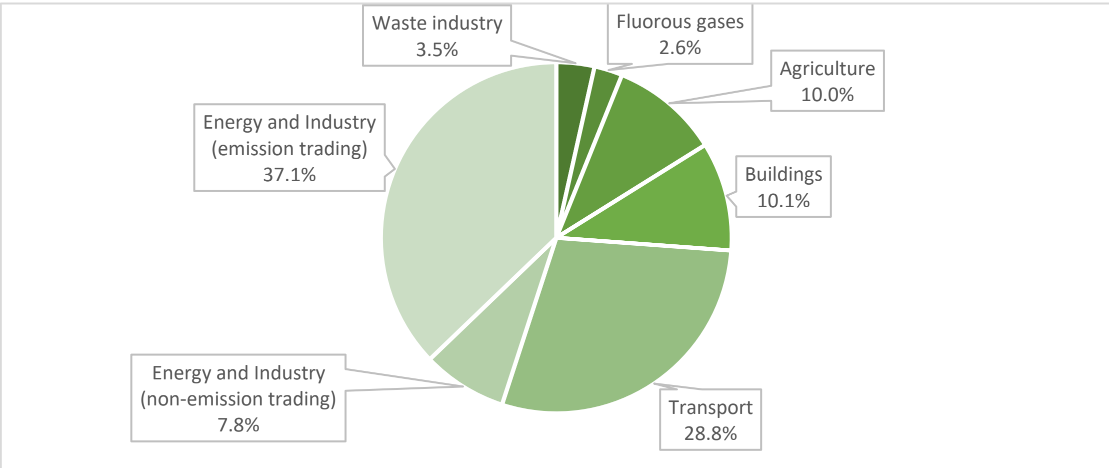

Figure 1: Shares of sectors in total GHG-emissions in 2017 (Umweltbundesamt, 2019a)

Several transformations are sought to achieve a low-carbon mobility sector. Among them a modal shift from individual motorized transportation to public transport is essential for the decarbonization of the mobility sector. To reach this in the most efficient way, the expansion of the electrification of public transport is necessary. So, the funding of electric mobility or respectively the shift to alternative engines and fuels is a relevant topic for public transport. The state-of-the-art literature is mostly focusing on either the support of the launch of e-mobility in private transport or enhancing the usage of public transport possibilities. However, the combination of public transport usage and switching to low-carbon engines for public transport vehicles, such as electric powertrains, has not been intensively approached.

The public transport sector consists of rail traffic with train, tram and metro and road traffic covered by buses. Rail traffic shows a relatively high level of electrification, which could be due to the relatively easy electrification of rail vehicles powered by electric powertrains through overhead-wires (ÖBB-Holding AG, 2019c). Moreover, the metros and trams are usually already electrically operated, whereas for trains further electrification potential still exists.

In comparison, public transport on roads shows a relatively low degree of electrification. Installing overhead-wires for buses is an option, as shown e.g. in Salzburg (Salzburg AG, 2019), but limited to urban traffic with short distances and not useful for longer tracks. For long distances, alternative engines, such as hydrogen propulsion or battery operation, are necessary techniques. For the expansion of electrification of road traffic, higher efforts in supporting these alternative fuels are required.

Figure 2 shows a massive difference between the various transport modes regarding their environmental impact in terms of CO_2 emissions. In 2018, travelling by rail caused 8.1 grams CO_2-equivalents per passenger-kilometre, which is relatively low compared to the other transport modes and indicates a low-carbon railway system. The second lowest value of CO_2-emissions is connected to transportation by bus (55.4 grams CO_2-equivalents per passenger-kilometre), however considerable higher than that of rail. On the third place is the e-car followed by the fossil fuelled car and the airplane. Focusing on public transport, mainly covered by railway and bus, the transportation by bus offers a high CO_2 saving potential, which can be reached by further electrification.

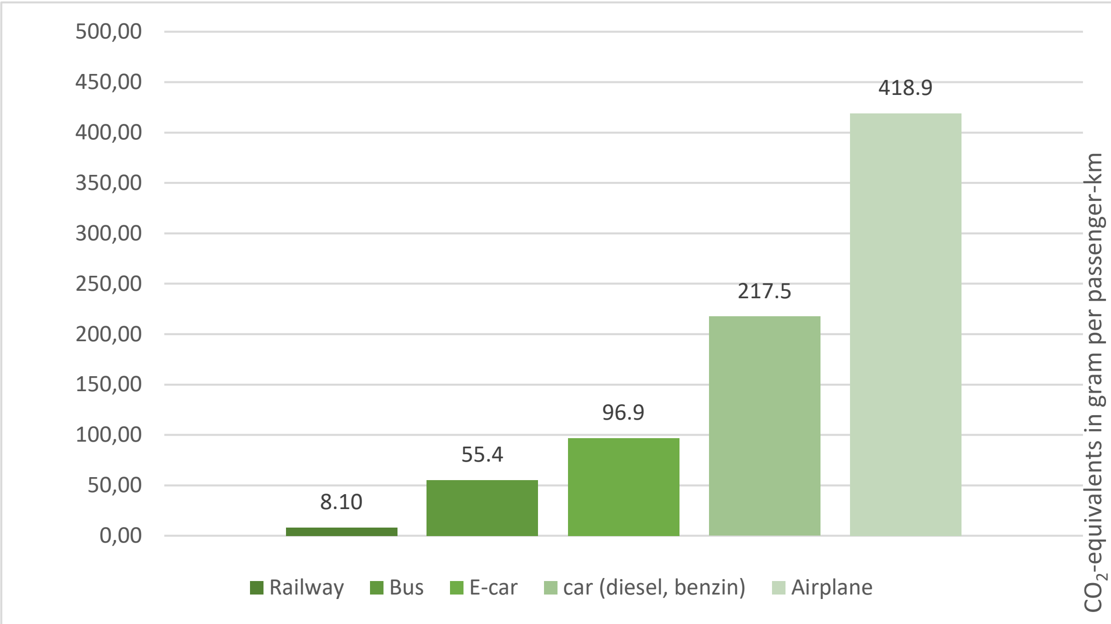

Figure 2: CO_2-equivalents in gram per passenger-kilometre of the main transport modes (Umweltbundesamt, 2020)

2 Status quo of electrification in public transport in Austria

2.1 Overview of status-quo electrification

As described above, the public transport can be split into transportation by bus and railway (metro, tram, train). In Austria 25% of passenger kilometres driven by public transport are covered by bus, the remaining 75% by railway (bmvit, 2016b).

The aggregated railway network in Austria with 400 km tram and metro lines and 5 650 km train lines shows a total length of 6 050 km, as shown in the overview in Table 1. The electrification share of the total railway system amounts to 73% (Schienen Control GmbH, 2020), from which 66% are covered by train lines and 7% by tram and metro lines (GSV, 2017). The bus fleet contains 10 148 vehicles (Statistik Austria, 2020), electrified currently at a scale of 176 buses (Austriatech, 2020), i.e. a share of 1.73%.

Table 1: Overview of the public transport infrastructure and their electrification

Type of transport		**Routes/vehicles**		**electrified**			
Train	Railway	5 650 km	6 050 km	71%	73%	4 008 km	4 408 km
Tram/Metro		400 km		100%		400 km	
Bus		10 148 buses		1.73%		176 buses	

The survey “Österreich unterwegs 2013/2014” collected data including the following mobility parameters: traffic performance (passenger-km/day), traffic duration (passenger-h/day) and traffic density (trips/day). These parameters display the total traffic demand volume in Austria. Within this paper the traffic performance (see Table 2) is of particular interest, since this indicator is relevant for environmental impact assessment of travel.

The traffic performance covered by public transport amounts to 57 800 000 passenger-km/day. This is an average travel distance by public transport of 19.2 km per person and day, considering the aspect of a population of 7 976 000 (bmvit, 2019).

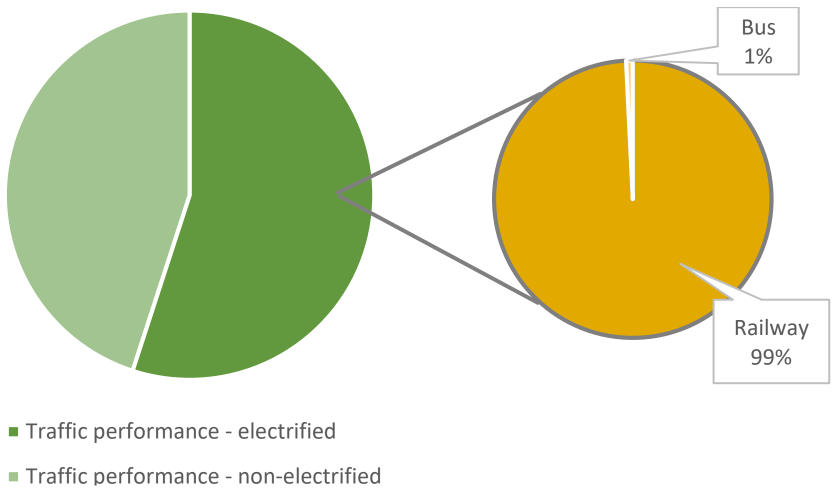

Figure 3: Share of electrification of traffic performance

Considering the distribution of the distance covered by bus and railway and the degrees of electrification of both transport modes, about 31 900 000 km in total or 10.62 km per person of the daily travel distance covered by public transport are electrified. This means about 55% of the traffic performance of public transport is electrified (see Figure 3).

Table 2: Share of electrification in traffic performance of Public Transport (passenger-km/day) *

total	**electrified in total**		
57 800 000	**bus**	**railway**	**Total**
	249 985	31 645 500	31 895 485
per person	**electrified per person**		
19.2	0.0824	10.5412	10.6235

*These figures represent a first approximation to the current degree of electrification in public transport and are based on aggregated data for the public transport sector.

The following sections give a deeper insight in the public transport infrastructure, their electrification level and energy supply as well as in future electrification plans, measures for realization, developments and hampering barriers to reach electrification goals.

2.2 Rail traffic: Train, Tram, Metro

Electrification of railways means installing overhead-wires on the routes or contact rails to supply energy to the electric-powered railways. Another way could be to power the engine of the railways by electric batteries or range extender.

A beneficial fact is that usually the electrification of the railway is made by overhead-wires. As opposed to the automotive industry, no battery is necessary as in electric cars, which constitutes one of the biggest issues in the development of electric mobility: the storage of electricity for longer distances and the refueling as fast as possible. These problems do not exist for the electricity supply through overhead-wires. Therefore, the electrification for railways is in principle easier to implement than for road traffic. (ÖBB-Holding AG, 2019c)

As of December 31, 2018, the inventory of rail infrastructure and rail vehicles was surveyed. The Austrian railway system (excl. tram and metro) comprise 5 650 km rail installation length or respectively 5 526 km operating length. 3 448 km installation length or 3 336 km operating length of the railway system were single-track. 71% of the installation length offered by all infrastructure supplier (ÖBB and regional railway) are electrified, this corresponds to 4 008 km rail length, whereas 1 642 km are not. 3 951 km of the operating length are electrified, and 1 575 km are not. The operating length is defined as the length where the railway services take place, whereas the installation length corresponds to the total tracks system which is dedicated as railway facility. Table 3 gives an overview of the electrification of the rail infrastructure in 2018 (Statistik Austria, 2019).

Table 3: Electrification of the rail infrastructure excl. tram and metro in 2018

	Installation length			Operating length		
	Electrified	Not electrified	total	Electrified	Not electrified	Total
Single- and double-track	4 008	1 642	5 650	3 951	1 575	5 526

On December 31, 2018 the Austrian railway and railway infrastructure companies offered in total 1.206 locomotives, of which 824 were electrically driven, 362 were powered by diesel engines, twelve by steam and eight were hybrid-driven. In rail traffic, a locomotive is a railway traction vehicle, which is exclusively used to move railway vehicles and can be differentiated according to their mode of engine, i.e., as mentioned above, electric, diesel or steam locomotives.

The inventory of rail vehicles in 2018, shown in Table 4, includes also 709 railcars, from which 516 were electrically actuated and 193 were driven by diesel engines. In 2019 the railcars in operation increased to 723, from which 527 were electrically actuated and 196 were driven by diesel engines. A railcar is a railway traction vehicle, which is used for the transport of goods as well as passengers. While a traction vehicle is defined as a motor-driven railway vehicle, which is used to move other vehicles (locomotive) as well as for transportation of passengers and/or goods (railcar, multiple unit). So, traction vehicle can be used as the umbrella term for locomotives, railcars and multiple units. Further 92 multiple units and 18 242 goods wagons were also part of the fleet in 2018. While in the year 2018, 1 806 passenger coaches were part of the vehicle stock, in 2019 the passenger coaches increased to 2 315.

Table 4: Inventory of rail vehicles in 2018

Type of propulsion	Locomotives	Railcars
Diesel	362	193
Steam	12	-
Hybrid	8	-
Electric	824	516
Total	**1 206**	**709**

The next subchapters give an overview of the main public transport companies related to rail, such as the Austrian Federal Railways and regional railways.

Austrian Federal Railways - ÖBB

The Austrian Federal Railways, in German Österreichische Bundesbahnen, formally Österreichische Bundesbahnen-Holding Aktiengesellschaft ("Austrian Federal Railways Stock Corporation"), now commonly known as ÖBB, is the national railway system of Austria. The ÖBB group is owned entirely by the Republic of Austria and is divided into three separate main businesses, ÖBB-Personenverkehr AG, Rail Cargo Austria AG and ÖBB-Infrastruktur AG which are again split into several sub-companies and manage the infrastructure and operate passenger and freight services. An overview can be seen in the organigram in Figure 4.

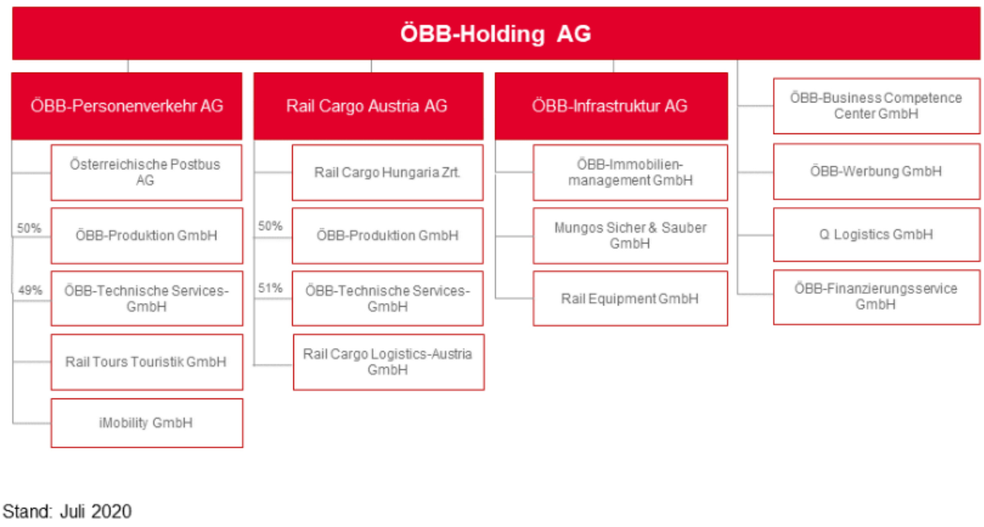

Figure 4: ÖBB company structure (ÖBB-Holding AG, 2019d)

The ÖBB is Austria's largest mobility service provider. It is offering infrastructure as well as different means of railway transport (train, tram) and bus. The vehicle fleet of the ÖBB includes 1 047 locomotives and 2 691 passenger coaches. The company offers railway lines to a total length of 4 877 km. 2 708 km are single-track, from which 1 446 km are electrified and 2 169 km are double tracked, from which again 2 137 km are electrified. Altogether 3 583 km of the ÖBB-railway network are electrified which correspond to a electrification share of 73% from the total railway network offered by the ÖBB (ÖBB-Infrastruktur AG, 2020).

Meanwhile more than 90% of the public passenger transport managed by the ÖBB are electrically actuated (ÖBB-Holding AG, 2019d).

ÖBB - Actual and future electrification plans for railway

According to the ÖBB-Holding AG, their mobility sector shall be CO_2 neutral till 2030. For this purpose, electrification is one instrument to reach this goal. A multilevel electrification strategy should increase the extent of electrified rail lines from the current 73% to 85% by 2030, and to 89% by 2035. To reach these two electrification stages, the company is planning to electrify 50 km of railway lines per year (ÖBB-Holding AG, 2019c).

The remaining share of 11% are secondary railway lines and amount to about 500 km (ÖBB-Holding AG, 2019c). The electrification of the railway in the sense of overhead-wires for secondary lines are currently not aspired for economic reasons. Nevertheless, the diesel fleet should be replaced by vehicles powered by alternative engines, like hydrogen propulsion or battery operation. Also, the ÖBB-road traffic should be electrified. The fleet of Postbus (owned by ÖBB) should be converted to buses driven by hydrogen and electricity (ÖBB-Holding AG, 2019a).

According to the climate protection plan of the ÖBB (ÖBB-Holding AG, 2019c), their electrification strategy is composed of three phases. In phase zero the following specific tracks are planned to be electrified through the implementation of overhead-wires till 2027 (according to the master plan 2018 – 2023):

- Koralmbahn (regional sections in Carinthia), 28 km, till 2023
- Marchegger Ast (Vienna – National border Slovakia), 38 km, till 2022
- Gänserndorf – Marchegg, 18 km, till 2020
- Herzogenburg – Krems, 20 km, till 2025 (costs: € 35 million (bmvit, 2018))
- Arnoldstein – Hermagor, 31 km, till 2020 (costs: € 21 million (bmvit, 2018))
- Steindorf bei Straßwalchen – Friedburg, 4 km, till 2022
- Klagenfurt – Weizelsdorf, 12 km, till 2024
- Steirische Ostbahn (Graz to Szentgotthárd), 75 km, till 2027
- Wiener Neustadt – Loipersbach-Schattendorf, 25 km, till 2026 (costs: € 59.8 million (bmvit, 2018))
- Reutte – Staatsgrenze nach Schönbichl, 16 km, till 2019
- Linz Stadthafen, 10 km, till 2021

Till 2027 the ÖBB are planning to electrify 277 km railway lines through the equipment with traction current supply.

For phase one, the ÖBB are planning to electrify additional 200 to 250 km railway lines till 2028. The company is actually conducting agreements with the federal government and individual federal provinces as well as other stakeholders. The focus lies on highly frequented tracks and connecting tracks sections.

In the last stage, phase two, the electrification of additional 285 km railway lines in the timeframe from 2027 to 2035 is planned. The evaluation of the exact tracks starts in 2020.

For the remaining railway lines different solutions are intended, mainly alternative engine concepts, which should be implemented till 2035.

According to the ÖBB Zielnetz 2025+ (ÖBB-Infrastruktur AG, 2011), on the following routes electrifications shall take place:

- Wr. Neustadt – Sopron: gap closure for the possibility of electric-powered through trains in Wr. Neustadt and Sopron
- Graz Ost – Szentgotthard: gap closure because of the electrification of the route Szombathely – Szentgotthard by Raaberbahn.
- Krems – Herzogenburg: gap closure for the possibility of electric-powered through trains in Krems

- Wien ZVBF – Knoten Achau: Future usage of the route for traffic from ZVBF southwards, for the relief of the Ostbahn in the section ZVBF – Gramatneusiedl.
- Stadlau – Marchegg : electrification as part of the double-track expansion
- Gänserndorf – Marchegg – Devinska Nova Ves: securing of a second electrified connection to the Slovakia, primarily for the goods traffic.

It should be mentioned that the priority of railway lines which will be electrified is dependent on several criteria. Trans-European as well as high-speed railway lines are more likely to undergo the electrification process. A further criterion is whether the railway schedule and punctuality can be optimized through electrification, as are the current and future market requirements of passenger and goods traffic for the individual tracks (ÖBB-Holding AG, 2019c).

ÖBB – Projects for alternative engines

As already mentioned, the ÖBB is aiming to be CO_2-neutral in its transport sector till 2030. To reach this goal apart from the electrification through overhead-wires about 400 rail vehicles powered by diesel should be replaced by vehicles operated by alternative engines. Alternative engines are useful especially for secondary railways, since the electrification of these tracks is difficult for both technical and economic reasons (ÖBB-Holding AG, 2019c).

The minimum distance or range requirement for alternative engines to be considered is 80 km, as most secondary tracks operate within this range so that a normal transport service is possible without loss of velocity or energy scarcity. Battery-operation and hydro propulsion show future potential for these purposes (ÖBB-Holding AG, 2019b).

The idea of battery-operation is that electric rail vehicles should be additionally equipped with a battery for tracks where overhead-wires do not exist.

A project in cooperation with Siemens concerning the alternative-operated passenger transportation on railway is the train “Cityjet eco” which is driven by electro-hybrid battery-operation. If the “Cityjet eco” is not driving on electrified tracks with overhead-wires, the train switches to battery-operation. The charging process of the battery happens on tracks with overhead-wires. Since autumn 2019, the train is in a test-phase with passenger service for one year all over Austria (ÖBB-Holding AG, 2019b).

Another project of ÖBB regarding alternative engines is the E-Hybridlok. The aim is the conversion of the shunting locomotives with the class 2068 to a fuel cell-hybrid vehicle (ÖBB-Holding AG, 2019a).

The hydrogen-based propulsion is another auspicious option. Here the energy is offered by fuel cells in the vehicle which are powered by hydrogen – this is why they are called fuel cell electric vehicles (FCEVs). Further it could be used for higher distances, for which the battery-operation is currently not applicable for technical reasons. However, this alternative engine is relatively unexplored. Further, and in contrast to battery-operated trains, an appropriate infrastructure is necessary for charging on tracks during transport (ÖBB-Holding AG, 2019c).

- Private Regional Public Transport - Railway
- Graz Köflacher Bahn und Busbetrieb GmbH (GKB)
- Montafonerbahn Aktiongesellschaft
- NÖVOG Niederösterreichische Verkehrsorganisationsgesellschaft m.b.H.
- Raaberbahn AG
- Salzburger Lokalbahnen (Salzburger und Pinzgauer Lokalbahn)
- Steiermärkische Landesbahnen
- Stern & Hafferl Verkehrs GmbH
- Stubaitalbahn GmbH

- Wiener Lokalbahnen AG
- Zillertaler Verkehrsbetriebe AG

  - Urban traffic enterprises -railway

The five urban traffic enterprises Graz Linien GmbH, Innsbrucker Verkehrsbetriebe GmbH, Linz Linien GmbH, Wiener Linien GmbH & Co KG and Stern & Hafferl Verkehr in Gmunden are focusing on e-mobility since 1897 and are offering electrified public transport on tracks, only.

Table 5: Tram and metro lines of urban traffic transport enterprises *(WKO, 2018)*

Graz Linien	67.2 km	6 tramlines
Innsbrucker Verkehrsbetriebe	44.8 km	6 tramlines
Linz Linien	30.9 km	4 tramlines
Wiener Linien	255.3 km	5 metro lines + 28 tramlines
Gmunden	2.315 km	1 tramline
Total	**400.52 km**	

2.3 Road traffic: Bus

Austria's bus fleet contains 10 148 vehicles (Statistik Austria, 2020), from which 176 buses (Austriatech, 2020) are currently electrified, i.e. a share of 1.73%. This relatively low electrification level and the high CO_2 emissions lead to unexploited potential for further decarbonization through the usage of alternative engines for bus traffic.

The actual status quo of alternative powered road transport is reported in the following subchapters.

  - Postbus ÖBB

Postbus is the largest bus company in Austria and one of the sub-companies of ÖBB Holding AG. The company also operates in areas where no other public transport connections are available and provide public transport connections to Austria's rural areas.

The Österreichische Postbus Aktiengesellschaft (ÖBB-Postbus GmbH) is offering 751 bus lines which are frequented by 2 314 buses. The buses serve 1 795 municipalities throughout Austria which refers to 85% of all municipalities. For one third of the supplied municipalities it is the only means of public transport (ÖBB-Holding AG, 2019d).

The first battery-operated electric bus went into operation in 2019 and will be tested till 2022. The E-Solar-Citybus on basis of Nissan e-NV 200 (K-Bus) in Judenburg has a capacity of 27 passengers. A test operation of a hydrogen bus in Graz (Styria) and Klagenfurt (Carinthia) was conducted till 2019 and also in Vienna at the Vienna Airport Lines (VAL) till 2018 (ÖBB-Holding AG, 2019c).

ÖBB - Actual and future projects for road traffic

Also the ÖBB-road traffic is intended to be electrified or respectively powered by alternative engines, as the company mentioned in their climate protection strategy (ÖBB-Holding AG, 2019c). The fleet of the ÖBB-Postbus GmbH should be converted into buses driven by hydrogen and electricity. While electric buses are useful for shorter distances as in the urban traffic, hydrogen buses can be applied for longer distances up to 450km.

The applications of electric and hydrogen buses in the following areas are planned:

- E-Solar-Citybus in the urban traffic Wolfsberg (Carinthia) starting in January 2020 till 2026
- About 4 12-meter-E-busses in Oberes Rheintal (Vorarlberg) with a range of 240 km starting in 2020, with the option of extension to 20 busses till 2026
- Conversion of the bus fleet of VAL from diesel to 15 hydrogen busses, as soon as possible starting in 2021/22, whereas the funding is announced
- Conversion of the bus fleet for the region Neusiedl (Burgenland) from diesel to 15 hydrogen busses, as soon as possible starting in 2021/22, whereas the funding is announced

In 2020, six additional electric buses shall be applied in the road traffic covered by the ÖBB-Postbus GmbH.

In the long-term, the ÖBB is planning to convert the total bus fleet into vehicles powered by alternative engines. This could lead to a CO_2 reduction by an amount of 140 000 tons per year.

Similar to the hydrogen powered railway, there is special infrastructure necessary to provide the hydrogen for charging the road vehicles. Investments in electrolysis plants are required for hydrogen production.

Urban traffic enterprises -bus

The five urban traffic enterprises Graz Linien GmbH, Linz Linien GmbH, Salzburg AG, Stadtwerke Klagenfurt AG, Wiener Linien GmbH & Co KG are offering electrified busses for public transport.

Table 6: Electrified bus lines of urban traffic enterprises *(WKO, 2018)*

Traffic enterprises	**Bus lines - electrified**	**Bus lines - total**
(Holding) Graz Linien	2	32
Linz Linien	4	18
Salzburger Verkehrsbetriebe	12	12
Stadtwerke Klagenfurt	1	19
Wiener Linien	3	118

2.4 Energy supply for electrified public transport

Energy supply – ÖBB

The traction current demand of the ÖBB from overhead-wires in the year 2019 amounted to 1 830 GWh, while the company produced 722 GWh traction current by their own generation, as shown in Table 7 (ÖBB-Holding AG, 2019a).

Table 7: Overview of the traction current demand and supply in 2019

Traction current demand	Own generation in ÖBB power plants	External supply
1 830 GWh	722 GWh	1 108 GWh

The ÖBB is also engaging in the energy production sector and generates about one third of their electricity demand by their own power plants. They produce 29% of the required traction current mainly in their own hydropower plants but also by other renewable energy sources. The remaining traction current requirement of 1 108 GWh and 71% of the total are from external sources. 22% are generated by the 3 partner power plants. 49% of the needed traction current are received from the public 3-phase 50 Hertz (Hz) current grid and subsequently transformed into traction current (ÖBB-Holding AG, 2019b).

Since the mid of 2018 the total electricity demand for the ÖBB-railway is covered by 100% renewable energy sources, with a focus on hydropower. 95% of the traction current production originates in hydropower and the remaining 5% stem from other renewable energy sources, such as solar and wind power.

ÖBB operates eight hydropower plants (Braz, Spullersee, Fulpmes, Obervellach as well as the group Stubachtal with Enzingerboden, Schneiderau, Uttendorf I and Uttendorf II) for traction current production (16.7 Hz) and two hydropower plants for 3-phase current production (50 Hz). The railway cannot be powered by standard powerline frequency with 50 Hz, the current needs to be transferred into traction current with 16.7 Hz. Seven frequency converting stations (five Umformerwerke, two Umrichterwerke) and 62 traction substations convert electric power from the 3-phase 50 Hz current provided by the electrical power industry for public utility service to the appropriate traction current with 16.7 Hz. (ÖBB-Holding AG, 2019d).

Another renewable energy source used is solar power. The photovoltaic system with 7 000 sqm solar panels is situated in between Bruck an der Leitha and Wilfleinsdorf next to the railway lines, and was activated in 2015. The produced energy (1 100 MWh per year) can be directly fed in the overhead wires as the energy is generated as 16.7 Hz traction current, so the current must not be transformed first. Additionally, the usage takes place where the energy is produced to ensure no transfer losses. But solar does not suffice to produce the total energy demand at least at present, that's why the ÖBB cover the main part of their energy demand by hydro power (ÖBB-Holding AG, 2019b).

The traction current are generated by a single-phase synchronous machine which is actuated with a 3-phase induction motor, different from a hydro power station where the generator is powered by a turbine (ÖBB-Holding AG, 2019b).

Further, the ÖBB electricity grid provides 2 064 km route length of 110 kV/132 kV traction current line and 69 km route length of 55 kV traction current line.

All in all, 1.830 GWh traction current from catenary and 310 GWh 3-phase current are needed per year (ÖBB-Holding AG, 2019d).

- ÖBB – Actual and future plans for energy supply

As stated above, since 2018 the ÖBB receive their required traction current to 100% from renewable resources and produce 29% by their own. Till 2030 they are planning to extend the latter share to 40% own energy generation.

A further power plant in Stubachtal, and a first pumping-storage power plant in Tauernmoos is in the planning and implementation process. It will produce 460 GWh per year and start the energy supply in 2026. The existing hydro power plants shall be optimized. A further focus lies on the extension of the usage of solar power, for that the usage of photovoltaics needs to be reinforced. Noise-insulating walls, rooftops and open spaces, like railway embankments are particularly applicable for the attachment of solar panels. The first projects are implemented in Auhof (on the rooftop of the frequency converting station), Tullnerfeld, Gattendorf, Kottingneusiedl and Ladendorf. Wind power is another source which shall be field-tested for the energy supply in a wind power plant Bruck an der Leitha/Höflein (ÖBB-Holding AG, 2019c).

3 Measures for further electrification of Public Transport

There are several challenges hampering the path to an electrified public transport network.
The application of legal, political and scientific measures, as shown in Table 8, is important to counteract barriers and encourage further electrification of public transport. Current incentives and measures are based on the Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure (bmvit, 2016a).

Table 8: Overview of measures for the further electrification of public transport *(bmvit, 2016a)*

Legal measures	- **Legislation and administrative regulations**: support of the implementation of electric powertrains and related infrastructure, e.g. simplification of building regulations, permissions and authorization processes.
Political measures	- **Direct incentives**: for purchasing of alternative actuated vehicles and for the construction of the necessary infrastructure, e.g. the implementation of technological standards. - **Fiscal incentives:** adaptation of taxes and fees in favor of electric vehicles and infrastructure construction to establish fair competitive structures between rail, road and air traffic. - **Monetary incentives:** through funding and subsidies for investments in alternative actuated vehicles, the extension of adequate infrastructure and the expansion of renewable energy sources. - **Public exemplary effect:** definition of goals for public procurement for public vehicle fleets, such as minimum numbers of emission-free vehicles for new acquisition.
Research and Development	- **Resources for research and technological development:** funding initiatives, especially for road traffic, such as the support of research and development to overcome current technical insufficiencies (e.g. low battery-ranges) of alternative engines.

3.4 Legal measures

Legislation and administrative regulations shall support the implementation of electric powertrains and related infrastructure. Already implemented measures in the legal domain are mainly concerning the building law, e.g. simplification of building regulations, permissions and authorization processes. Especially authorization processes are for the electricity supply and the necessary infrastructure relevant.

3.5 Political measures

- Direct incentives

For the purchase of alternative actuated vehicles and for the construction of the necessary infrastructure direct incentives, such as the implementation of technological standards and guidelines, are supportive.

The “Clean Vehicles Directive” of the EU is an example for such a guideline and targets the procurement of 45% “green” vehicles till 2025 and 60% till 2030.

This Directive requires Member States to ensure that contracting authorities take into account lifecycle energy and environmental impacts, including energy consumption and emissions of CO_2 and of certain pollutants, when procuring certain road transport vehicles.

For Austria, the minimum procurement targets for the share of clean buses with the vehicle classification M3 amount to 45% and from 2 August 2021 to 31 December 2025 and 65% from 1 January 2026 to 31 December 2030 (European Union, 2019).

- Fiscal incentives

The adaptation of taxes and fees in favour of electric vehicles and infrastructure construction are supportive for the electrical transition. The elimination of the "motorbezogene Versicherungssteuer" and motor vehicle tax for electrically actuated vehicles are examples for already implemented fiscal measures.

- Monetary incentives

Funding and subsidies shall be offered for investments in alternative actuated vehicles, the extension of adequate infrastructure and the expansion of renewable energy sources.

The "Sachstandsbericht Mobilität" of Umweltbundesamt promoted financial support in the following way. For example, raising investments for railway tracks and the appropriate rail infrastructure for electrification according to „#mission2030" is defined in the offensive for electrification of the railway tracks. Also, the increase of funding for private regional railways between 2020 and 2030 for investments in infrastructure for electrification shall be accelerated. For sustainable energy supply, the generation of electric energy for the railways from 100% renewable sources is another focus.

For the electrification of the road traffic "klimaaktiv mobil" provides financial support. "Klimaaktiv mobil" is a funding program on a federal level which offers resources for the acquisition of alternative powered vehicles (cars, bikes, buses) as well as for the charging infrastructure for privates, enterprises and public communities.

The actual funding for buses of the vehicle classification M2, M3 in 2020 is as the following:

- Electric-Minibuses of the car classification M2: €24.000 per vehicle
- Buses of the car classification M3: €52.000 - €130.000 per vehicle depending on the passenger capacity

There are also several funding offers for electric vehicles on the level of the federal states.

- Public exemplary effect

The definition of goals for public procurement for public vehicle fleets and infrastructure, such as minimum numbers of emission-free vehicles for new acquisition is also an effective instrument, as is the extension of the public electrified system. So can the public sector set a good example.

In the report "Sachstandsbericht Mobilität", the establishment of an electrified system is recommended, i.e. overhead-wires including a comprehensive energy supply network for the high-level road network till 2040. This instrument is planned for freight traffic and heavy commercial vehicles, but it is also conceivable for passenger service.

The public sector is considered as especially applicable to act as early adopter of e-mobility, and thus for making use of their lead role. The increase of electrification of the public transport will improve the image of e-mobility in general. The useful and rapid transition of public transport fleet to electric vehicles has an exemplary effect and can provide incentives for the development of the electric vehicles market. Public acquisition is a tool to stimulate early markets for electric vehicles. This can be done through the utilization of existing structures, as the Bundesbeschaffungsgesellschaft (BBG), for the procurement of innovative products by the public sector. As a pioneer in e-mobility, public transport can strengthen the role of e-mobility (bmvit et al., 2012).

3.6 Research and Development

Funding initiatives for scientific research are necessary for technological development. Especially the road traffic needs support in R&D to overcome current technical insufficiencies of alternative engines (e.g. low battery-ranges). The Austrian federal government as well as the federal states support research activities for alternative engines and fuels as well as clean energy in the transport sector through different funding initiatives such as "Leuchttürme der Elektromobilität", "Mobilität der Zukunft" and "Smart Cities" (bmvit). "Leuchttürme der Elektromobilität" supports the development of technologies and business plans during the whole value chain of electric mobility and has invested more than 40 million euros, since 2009. EMPORA is the biggest research project in Austria and a result of this initiative. 22 companies of the automotive industry, energy industry and the infrastructure sector as well as research institutions worked together. They have developed a technical and organisational feasible framework for the integration of electromobility in Austria. The improvement of electrical engines and charging technologies are examples for generated developments (Klima- und Energiefonds, 2018).

4 Developments till 2040

The implementation of the offensive for electrification of the railway tracks according to „#mission2030" shall lead to an increase in the electrification of the ÖBB tracks up to 85% and an expansion in electrical traction in shunting to 50% until 2030. 100% electrification of tracks and shunting should be reached in the years after 2030 (Umweltbundesamt, 2019b).

Following the electrification path of the ÖBB, the company is planning to register CO_2 emission savings to an amount of 2.4 million tons per year due to passenger transport via railway.

Table 9: Yearly GHG saving potentials through expansion in four areas starting in 2030 (ÖBB-Holding AG, 2019c)

Electrification	Alternative engines – railway	Alternative engines – road	Renewable energy
0.044 million tons	0.082 million tons	0.162 million tons	0.164 million tons

According to the climate protection strategy of the ÖBB, the company plans to save 44 200 tons of greenhouse gases per year starting in 2030. This should be reached through the multilevel electrification strategy of the ÖBB, mentioned in chapter 2.2. Other potential savings can be achieved through the implementation of alternative engines, as battery-operation or hydrogen-based propulsion. Starting in year 2030, 81 600 tons of greenhouse gases can be reduced yearly by alternative engines in the railway sector, further 162 500 tons can be saved on the road by converting the bus fleet to electricity and hydrogen vehicles (ÖBB-Holding AG, 2019c).

5 Challenges

According to the “Zielnetz 2025+” the rest of the railway infrastructure will be modified depending on so called system-adequate demand. Some subsections, rail stations or the shunting which need to be frequented by diesel vehicles do not fit in this schedule. The transmission to full electrification of the railway infrastructure is considered to be unprofitable (ÖBB-Infrastruktur AG, 2011).

There are several challenges hampering the path to a climate-neutral mobility concept. That is why appropriate framework conditions are crucial in order to pursue the expansion of sustainable mobility supply and the necessary infrastructure as well as electrification.

The establishment of fair competitive structures between rail, road and air traffic is one of those issues. Another point is the funding of the extension of the capacity and quality of the railway network including the electrification infrastructure as well. Funding and subsidies should be adjusted relating to their impact on the CO_2 balance. Thus, investments for the expansion of traffic infrastructure can be prioritized referring to their climate impact, which entails the extension of rail infrastructure ahead of the expansion of motorways and airports or EU-notified subsidies for rail cargo to compensate for current lack of cost transparency (ÖBB-Holding AG, 2019a).

Another important aspect is the coherent pricing or respectively taxing of CO_2 emissions for all goods and services. Further adequate incentives for the expansion of renewable energy sources and the use of public transport. For the creation of these conducive framework conditions the government and EU need to intervene (ÖBB-Holding AG, 2019a).

To run electrified public transport environmental beneficially, electricity from renewable energy sources is necessary. However, depending on the balance between cost degression of renewable production and costs of integrating variable renewables into the system, it may be the case that the costs for sustainable energy will increase, which would pose another challenge for the conversion to electric operation.

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