TGV Lyria

Ecological comparison of transport modes on selected routes between France and Switzerland

Final report
Zurich, 4 June 2024

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Editorial Information

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Content

Summary

This study presents an ecological comparison of modes of transport on five transnational routes between Switzerland and France for the year 2023. On behalf of TGV Lyria, INFRAS prepared a comparison of modes of transport in 2019 on the basis of scientific principles and in accordance with the European standard SN EN 16258 for calculating the climate impact of transport services. The introduction of the new TGV Lyria fleet at the end of 2019 could in the 2019 study only be included as projection based on estimated parameters. The availability of real data on the new fleet and that the Lausanne-Marseille route is now also served by TGV Lyria prompted the calculations to be updated. This includes the consideration of new technological developments as well as developments of the utilisation of means of transport by incorporating most recent data basis. All the routes considered in this study are served by TGV Lyria. Rail, in this study represented by TGV Lyria, is compared with the other modes of transport, i.e. coaches, cars and airplanes. In the case of cars, a distinction is made between electric and conventional (petrol, diesel) drive types. The study compares the different modes of transport in terms of four aspects: **climate balance, final energy balance, environmental and accident costs** as well as **travel time including usable working time**. In a second step, the pre and post journeys for every mode of transport, i.e. the journey to and from the train station or airport, are also taken into account. However, the results show that the main journey clearly dominates and that the climate and environmental impact of the pre and post journeys is of secondary relevance for the overall result. In the case of cars, an additional trip with a lower occupancy rate (1.09 persons per vehicle according to statistics for business trips compared to the average occupancy rate of 1.53 persons per vehicle) is also calculated.

Table 1 gives an overview of the carbon footprint of the modes of transport for all the routes examined.

Table 1: Overview Climate Footprint

	Climate footprint (kg CO_2-eq/person)						
Journey	**Train**	**Airplane**	**Coach**	**Car Ø**	**Car work**	**e-car Ø**	**e-car work**
Geneva-Paris	2.6	114.8	15.1	98.8	138.7	56.5	79.4
Lausanne-Paris	2.4	114.8	15.1	98.4	138.2	51.2	71.9
Basel-Paris	2.7	112.8	16.1	97.0	136.1	50.4	70.8
Zurich-Paris	3.1	131.9	18.3	108.7	152.6	56.5	79.4
Lausanne-Marseille	2.9	93.0	16.0	108.0	151.6	56.2	78.8

Table INFRAS

A comparison of the carbon footprint of the various modes of transport shows that rail (TGV Lyria) clearly produces the lowest CO_2-eq. emissions per person and journey. The greenhouse

gas emissions emitted per person for a journey by TGV Lyria are around 6 times lower than by coaches, around 20 times lower than for the average electric car, around 36 times lower than for the average conventional car and around 41 times lower than for airplanes. From the point of view of climate protection, traveling by TGV Lyria offers the greatest advantage on the routes examined. It should be noted that the electrically powered TGV Lyria and e-car modes of transport do not produce any direct emissions during operation and only very low emissions during energy production (electricity). Most of the emissions from these two modes of transport come from the production of infrastructure and vehicles[1].

The environmental effects, such as greenhouse gas emissions or noise, cause costs that are not borne by the polluter but by the general public. Those so-called external costs or **environmental and accident costs** are calculated and compared for journeys using the various modes of transport. Table 2 gives an overview of the results for all journeys.

Table 2: Overview Environmental and Accident Costs

	Environmental and Accident Costs (CHF/person)						
Journey	**Train**	**Airplane**	**Coach**	**Car Ø**	**Car work**	**e-car Ø**	**e-car work**
Geneva-Paris	2.6	29.0	5.1	31.0	40.3	22.9	28.8
Lausanne-Paris	3.1	30.9	5.7	30.9	40.1	22.8	28.7
Basel-Paris	2.9	29.3	5.6	30.4	39.5	22.4	28.3
Zurich-Paris	3.4	33.5	6.4	34.1	44.3	25.1	31.7
Lausanne-Marseille	4.4	26.2	6.8	33.9	44.0	25.0	31.5

Table INFRAS

The results show clearly that for environmental and accident costs generated travelling by the Train/TGV Lyria are lowest compared to the other modes of transport. The main reasons are the very low direct costs in terms of climate, air pollutants and accidents for operating TGVs, which are among the most significant cost categories for the other modes of transport. The environmental and accident costs for coaches are around two-times higher than those for the TGV Lyria, those for the electric car are almost 9 times as high, those for flights also around 10 times as high and those for the conventional car approximately more than 12 times as high as for the TGV Lyria.

Choosing a mode of travel, the potential **usable travel time to work** is another relevant factor. When travelling by coach, the time available for work is the highest, but this is mainly due to the fact that the total travel time is high. Travelling by TGV Lyria offers a very high share of usable travel time on all routes.

[1] In ecological comparisons of modes of transport, often only the parameters mandatorily required by the standard SN EN 16258 are taken into account (direct operation and energy production), which is why a journey by train emits around 70 to 100 times less equivalent CO2 than a flight on the same route.

Table 3: Overview Usable travel time

	Usable travel time (h)			
Journey	**Train**	**Airplane**	**Coach**	**Car work**
Geneva-Paris	3.0	0.8	7.3	0.0
Lausanne-Paris	3.5	0.8	7.1	0.0
Basel-Paris	2.9	0.9	7.7	0.0
Zurich-Paris	3.8	0.9	8.9	0.0
Lausanne-Marseille	4.2	1.9	6.8	0.0

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In an **overall comparison** of the long-distance routes considered, TGV Lyria performs best in all areas and for all routes. The TGV Lyria is clearly ahead in terms of carbon footprint and environmental and accident costs and offers further advantage with usable travelling time. In environmental terms, coaches come closest to rail, although they still have significantly higher greenhouse gas emissions and environmental costs. Cars and airplanes have a significantly worse climate and environmental balance than trains (TGV Lyria). Electric cars have a better climate balance and lower environmental costs than gasoline and diesel cars. However, the carbon footprint and environmental costs of electric cars are still worse than those of TGVs on the routes examined. This means that rail will retain a clear environmental advantage over cars in international long-distance transportation even as the electrification of cars progresses. The environmental advantage of rail over air travel is just as clear.

1. Initial Position and Objective

In the context of the climate debate, the ecological comparison of different modes of transport for long-distance travel provides highly relevant information. Calculations based on current data are of great importance here, as they are the only way to make a valid comparison for the current days. This study presents the results of the update of the ecological comparison of modes of transport for journeys between Switzerland and France, which was carried out by INFRAS in 2019 on behalf of TGV Lyria. The focus of the comparison is particularly on the climate footprint of the modes of transport. However, in addition to its impact on the climate, transportation also has various other negative environmental effects (air pollutant emissions, noise, accidents, etc.). These negative effects lead to economic costs - so-called external costs or environmental costs. Here we compare different modes of transport for specific routes served by TGV Lyria between Switzerland and France and the comparison includes the following four parameters:

- Climate footprint (greenhouse gas emissions, "CO_2 balance")
- Energy balance
- Environmental and accident costs
- Use of time (productively usable travel time)

The aim of the update was in particular the inclusion of real data for the new TGV Lyria fleet, which was put into operation at the end of 2019 but for which no data was available at the time of the first study. The update also takes into account the new Lausanne-Marseille route, which is now served by TGV Lyria. In addition, all data bases were updated, including emission factors, capacity utilization rates and energy consumption data. Hence, the updated study is based on the latest scientific findings (regarding climate emissions, environmental costs, etc.). The results provide a basis for a profound communication on the comparison of different modes of transport for specific TGV Lyria routes.

2. Methodological Procedure

2.1. Concept

The concept is based on a route comparison for different modes of transport. This means that the ecological footprint of selected modes of transport on the same five routes is compared (on the one hand, the main means of transport on the routes and on the other hand, the door-to-door journeys). This is carried out in the form of a climate footprint (greenhouse gas emissions), an energy balance and in the form of environmental and accident costs too. In addition to the environmental impacts, the varying usage of time (based on the productively usable travel time) of the individual modes of transport is evaluated. All calculations relate to one person and journey (outward journey only).

2.2. Methodological Procedure

System Boundaries

The reference year for the calculations in this ecological transport mode comparison is 2023. This has no significant effect on basic principles such as travel time and distances. However, the emissions factors and cost rates applied are dependent upon the year in question. The emissions factors are subject to a technological pathway (e.g., nitrogen oxide emissions from cars) and the cost rates had to be updated for the year in question (adjusted for inflation). The spatial delimitation is clear based on the prescribed routes. In terms of content, the direct costs and emissions from operation as well as the indirect costs and emissions from production, maintenance and disposal of energy, vehicles and infrastructure are always taken into account, too.

Routes

A total of five routes operated by TGV Lyria between France and Switzerland were selected. In each case, the routes consist of a main journey and a pre and post journey. The main journey is defined by the route taken by the vehicle in question for each mode of transport, i.e., from station to station for the train or from airport to airport for the airplane. In a first step, only these main journeys are compared with one another in terms of their climate and energy footprint. In a second step, a definition of the other vehicles besides the main modes of transport (aircraft, railway, car and coach) is taken into account for the door-to-door comparison. This is required because passengers have a choice of different modes of transport (e.g., tram or taxi) for the so-called first and last mile (to the “door”, i.e., to the location of the meeting for business travellers or to their accommodation for leisure travellers). In this study we refer to these parts of the journey as pre and post journeys. Table 4 shows the five different routes and the pre and post journeys in each case.

Compared to the 2019 study, one route got updated: While in 2019 the journey between Geneva and Marseille was analysed, we now updated this journey to the extended connection between Lausanne and Marseille. This is due to TGV Lyria now offering this connection during summer.

The Geneva–Paris route is an example of a route from city centre to city centre (i.e., with only marginal pre and post journeys). For the railway, the main journey is defined as being from station to station, for flying it is airport to airport, and for the coach from bus station to bus station. The pre and post journeys consist of taxis, cars, local buses, trams and local rail or underground services. Journeys by cars go directly from door to door and do therefore not consist of a pre and post journey.

Table 4: Routes under consideration, including pre and post journey

Journey	From	To	Mode of Transport	Details on the main journey
Geneva-Paris	Geneva city centre	Paris city centre	Train	Geneva Cornavin - Paris Gare de Lyon
Geneva-Paris	Geneva city centre	Paris city centre	Airplane	Geneva Airport (GVA) - Paris Charles de Gaulle (CDG)
Geneva-Paris	Geneva city centre	Paris city centre	Coach	Geneva ZOB - Paris Bercy Seine
Geneva-Paris	Geneva city centre	Paris city centre	Passenger car	From door-to-door by car
Zurich-Paris	Zurich city centre	Boulogne-Billancourt	Train	Zurich main station - Paris Gare de Lyon
Zurich-Paris	Zurich city centre	Boulogne-Billancourt	Airplane	Zurich Airport (ZRH) - Paris Charles de Gaulle (CDG)
Zurich-Paris	Zurich city centre	Boulogne-Billancourt	Coach	Sihlquai car park - Paris Bercy Seine
Zurich-Paris	Zurich city centre	Boulogne-Billancourt	Passenger car	From door-to-door by car
Basel-Paris	Reinach	Paris city centre	Train	Basel SBB - Paris Gare de Lyon
Basel-Paris	Reinach	Paris city centre	Airplane	EuroAirport (BSL) - Paris Charles de Gaulle (CDG)
Basel-Paris	Reinach	Paris city centre	Coach	Basel SBB - Paris Bercy Seine
Basel-Paris	Reinach	Paris city centre	Passenger car	From door-to-door by car
Lausanne-Paris	Montreux	Paris city centre	Train	Lausanne CFF - Paris Gare de Lyon
Lausanne-Paris	Montreux	Paris city centre	Airplane	Geneva Airport (GVA) - Paris Charles de Gaulle (CDG)
Lausanne-Paris	Montreux	Paris city centre	Coach	Lausanne P+R Vélodrome - Paris Bercy Seine
Lausanne-Paris	Montreux	Paris city centre	Passenger car	From door-to-door by car
Lausanne-Marseille	Fribourg	Marseille city centre	Train	Lausanne CFF - Marseille-Saint-Charles
Lausanne-Marseille	Fribourg	Marseille city centre	Airplane	Geneva Airport (GVA) - Marseille Provence (MRS)*
Lausanne-Marseille	Fribourg	Marseille city centre	Coach	Lausanne P+R Vélodrome - Marseille-Saint-Charles
Lausanne-Marseille	Fribourg	Marseille city centre	Passenger car	From door-to-door by car

* There are no direct flights for the Geneva-Marseille route at the moment. In order to maintain comparability between the routes, a hypothetical direct flight was assumed.

Table INFRAS.

Modes of Transport under Consideration

When comparing the journeys, the main means of transport are examined and compared with each other in Table 5.

Table 5: Modes of transport under consideration

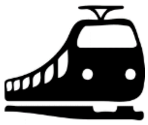
Means of Transport	Description
	All routes are operated directly by TGV Lyria. The train is therefore also represented by a TGV Lyria train on the main route. In December 2019, the new rolling stock was introduced, which offers more seats. The key figures used here refer to the rolling stock in use in 2023.
	The aircrafts are represented by a large number of different aircraft types and their key figures (Atmosfair 2021) that are used on the routes examined. European average values for the year 2023 are used for the capacity utilization of the aircraft (IATA 2023).
	The long-distance coaches are represented by average coaches. One problem with coaches is that many journeys are made overnight and therefore the travel time is much longer than for cars. Assumption on capacity utilization corresponds to the latest available values for long-distance coach travel from Germany (DESTATIS 2023).
	Two different drive types were included for passenger cars. On the one hand, internal combustion engines, based on the Swiss fleet average, and on the other hand, battery electric vehicles. The vehicle utilization rates are taken from the Swiss Transport and Mobility Microcensus 2021 (ARE 2023). The utilization rates in France are similar to those in Switzerland, which is why the comparison can also be applied to France. The same applies to battery electric vehicles (electricity mix). In terms of the carbon footprint, the electricity mix used to charge the battery naturally has an impact on emissions. In terms of greenhouse gases, the consumer electricity mix in Switzerland and France is relatively similar. Switzerland has a high proportion of hydroelectric and nuclear power, while in France it is mainly nuclear power. Both energy sources have a relatively low CO_2 emission factor (compared to fossil energy sources). In addition, a European average instead of a country-specific electricity mix is assumed for the construction of the vehicles and batteries.

Table: INFRAS.

Distances and Travel Times of the Routes per Mode of Transport

An important basis for the energy, climate and cost calculations are the passenger-kilometres covered by the various modes of transport. As the results are presented per person and journey, the distances multiplied by the capacity utilization of the various modes of transport already provide the passenger-kilometres. The distances of the routes were collected using sources. The rail kilometers come from TGV Lyria, the flight distances from www.greatcircle-mapper.net and the car distances from www.maps.google.com. Googlemaps was used for the distances of the pre and post journeys. If the departure or arrival point is the city centre, then the pre and post journey was calculated in a simplified manner with 2 km. Train and coaches have the same distances for the pre and past journeys, as for all routes the bus stations are located in the immediate vicinity of the train stations. The pre and post journey distances are slightly longer for airports, as these are always a little further out.

An additional analysis was carried out to compare the part of the travel time that can be used for working. For this purpose, only the modes of transport relevant for business trips were compared. The results of this analysis are presented in Chapter 3.4. The travel times for train and coach rides as well as flights are taken from official timetables, those for cars from Googlemaps. Multiple queries were made at different times of the week and day and an average was calculated. In the case of flight times, the travel times differ depending on the direction in which the flight is made. In the present analyses, the direction from Switzerland to France was selected. Delays, strikes, traffic jams and other disruptions were not taken into account.

For the estimation of the usable travel time, the share of the journey that could be used for work got estimated by independent experts. Therefore, for each mode of transport the experts have set what they consider to be a realistic percentage that applies to all routes. For trains, that equals 95% of the journey time in the main mode of transport, 70% for airplanes, and 90% for coaches. For travelling by car (conventional and electric) it is assumed that the person travelling is driving, hence the usable travel time equals 0%. Pre and post journey travel times were not considered to be used as potential working time, but they are still considered for the overall travel time. For the pre and post journeys, usually a mix of transport modes is used by the travellers. This includes besides others public transport, taxis, cars, cycling or walking. A weighted average of travel times needed by the different modes of transport is calculated for the journey to and from the train station/airport/bus terminal.

Table 6: Distances of the routes surveyed

Route	Mode of Transport	Main Journey	Pre Journey	Post Journey	Total route	Travel Time
			kilometre			minutes
Geneva-Paris	Train	503	2	2	507	245
	Airplane	457	5	28	507	169
	Coach	538	2	2	542	545
	Passenger car	547	0	0	490	315
Zurich-Paris	Train	617	2	12	631	293
	Airplane	525	8	38	571	163
	Coach	650	2	12	664	650
	Passenger car	602	0	0	602	385
Basel-Paris	Train	526	8	2	536	214
	Airplane	449	42	28	519	148
	Coach	573	8	2	583	546
	Passenger car	537	0	0	583	351
Lausanne-Paris	Train	480	30	2	512	252
	Airplane	457	93	28	512	170
	Coach	535	30	2	567	507
	Passenger car	545	0	0	545	357
Lausanne-Marseille	Train	580	67	2	649	322
	Airplane	370	132	24	598	284
	Coach	568	67	2	637	512
	Passenger car	598	0	0	598	354

Table INFRAS.

Emission and Energy Calculations

The carbon footprint considers both, emissions from direct operation and the upstream and downstream processes. Upstream and downstream processes include emissions from vehicle and infrastructure production and disposal as well as the energy supply chain. These are often just as relevant in terms of air pollutants and greenhouse gases as the emissions from operation. The energy balance takes into account the final energy. This means that only the energy efficiency of the vehicle is considered. The underlying energy systems are not taken into account in the energy balance.

For the carbon footprint, all greenhouse gases for direct operation and the up- and downstream processes were taken into account in the form of CO_2 equivalents. This means the following: In direct operation, only the combustion engines that run on fossil fuels cause greenhouse gases. This means that the burning of gasoline and diesel in the case of cars and coaches and kerosene in the case of airplanes was taken into account. The greenhouse gases from upstream and downstream processes originate from the provision of electricity and fuels (electricity, petrol, diesel and kerosene) on the one hand and from the production, maintenance and disposal of vehicles and infrastructure on the other. The French and Swiss electricity mixes were weighted for the TGV Lyria. The Swiss electricity mix was used for the electric cars. This is also transferable to France, as the French and Swiss electricity mixes do not differ greatly in terms of their carbon footprint. In addition, a large proportion of the greenhouse gas emissions in the carbon footprint of electric cars is attributable to the production of the vehicles (and batteries). A European average is used for the electricity mix in production for all countries. As a result, the influence of the consumer electricity mix is relatively small for Switzerland and France. Emission factors weighted by mode of transport were calculated for the pre and post journeys. The basis for the weighting was a survey of TGV Lyria customers, which determined the modes of transport used to travel to the stations. These are made up of public transport (streetcars, buses, suburban trains, etc.), walking, cycling and cars. As there are no separate surveys for bus stations and airports, the weighted emission factor was also used for the pre and post journey of airports and bus stations. As the survey was carried out in France and Switzerland, it was possible to calculate a weighted emission factor for the pre-carriageways in Switzerland and the on-carriageways in France.

One important point concerns air traffic. For the conversion of CO_2 equivalents, an RFI[2] was considered, which describes the increased greenhouse effect of aircraft emissions at high altitudes (Atmosfair 2019).

The energy balance shows the final energy of each mode of transport that must be used for the journeys. Renewable and non-renewable energy sources are not differentiated, and everything is shown in kilograms of petrol equivalents. Table 7 shows the sources of the emission factors used for the calculations of the climate and energy balance.

The emission factors for air pollutants mentioned in Table 7 are required for the calculation of environmental costs and are therefore also listed here, as they mostly come from the same sources as the emission factors for greenhouse gases.

[2] RFI = radiative forcing index, describes the increased greenhouse effect of aircraft emissions (particularly from CO_2, H_2O (gaseous) and nitrogen oxides) at high altitudes. The heating effect of all flight emissions is around three as high as when CO_2 alone is taken into account. This effect comes into play in flights from an altitude of 9,000 metres and is factored into the calculations from this altitude.

Table 7: Information bases for the emission factors applied

Mode of Transport	Scources	
	Emissions direct operation	**Up- and downstream processes**
Train	▪ PM10 non-exhaust: Ecoinvent 3.10 ▪ Energy consumption: Operating data TGV Lyria	▪ CO_2-eq: Operating data TGV Lyria ▪ Air pollutants: EcotransitWorld und Mobi-tool 3.0 ▪ Energy supply: Mobitool 3.0
Airplane	▪ CO_2-eq: Atmosfair 2024a ▪ Air pollutants: Mobitool 3.0 ▪ Energy consumption: Mobitool 3.0	▪ CO2-eq: Atmosfair 2024a und Ecoinvent 3.10 ▪ Air pollutants: Mobitool 3.0 ▪ Energy supply: Mobitool 3.0
Coach	▪ CO_2-eq: HBEFA 4.2 ▪ Air pollutants: HBEFA 4.2 ▪ Energy consumption: HBEFA 4.2	▪ CO2-eq: Mobitool 3.0 ▪ Air pollutants: Mobitool 3.0 ▪ Energy supply: Mobitool 3.0
Passenger car	▪ CO_2-eq: HBEFA 4.2 ▪ Air pollutants: HBEFA 4.2 ▪ Energy consumption: HBEFA 4.2	▪ CO2-eq: Mobitool 3.0 ▪ Air pollutants: Mobitool 3.0 ▪ Energy supply: Mobitool 3.0
Passenger car elec-tric	▪ CO_2-eq: HBEFA 4.2 ▪ Air pollutants: HBEFA 4.2 ▪ Energy consumption: HBEFA 4.2	▪ CO2-eq: Mobitool 3.0 ▪ Air pollutants: Mobitool 3.0 ▪ Energy supply: Mobitool 3.0

Table INFRAS.

Bases for Environmental and Accident Costs

All environmental costs are composed of five different cost categories. Table 8 shows these cost categories and describes what they include.

Table 8: Cost categories for Climate and Accident Costs

Cost Categories	Description
Climate costs	Costs as a result of the emission of greenhouse gases and the climate changes arising (damage costs estimate).
Air pollution costs	The environmental costs resulting from air pollution comprise the following four sub-categories: Health costs, crop failure, damage to buildings and materials as well as biodiversity losses.
Costs of upstream and downstream processes	Consequential costs due to the emission of greenhouse gases and air pollutants from production, maintenance and disposal of: ▪ Energy sources (fuels and electricity) ▪ Vehicles ▪ Traffic infrastructure Monetarisation related to air pollution and climate costs (see above)
Accident costs	Traffic accidents (damage cost rate); this includes costs that are not covered by the person responsible for the accident or the person(s) involved.
Noise costs	Noise-related health costs and costs due to noise pollution (damage costs).

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Based on the calculated carbon footprint and air pollutant emissions, the environmental costs were calculated using specific cost rates. The same procedure was also used for the up- and downstream processes. These processes also take greenhouse gases and air pollutants into account. The climate cost rate is taken from the Federal Office for Spatial Development's annually updated report "Costs and Benefits of Transport in Switzerland 2016" (ARE 2019). The cost rate was extrapolated to 2023 and therefore amounts to CHF 154 per tonne of CO_2. The cost rates for air pollutants are taken from the European Commission's publication "Handbook of the external cost of transport" (DG MOVE 2019). The handbook contains separate cost rates for all major air pollutants for all European countries. These were also updated to the year 2023.

A slightly different approach was taken for accident and noise costs. These were not calculated using a quantity structure, which was then monetized using cost rates. They were calculated directly using typical accident and noise cost rates per passenger kilometre. These were also taken from the European Commission's "Handbook of the external cost of transport" (DG

MOVE 2019). These are country-specific cost rates for France. The EU study derived specific values for high-speed trains for the rail cost rates. Even though there have been no accidents on the rail and air routes under consideration in the last ten years, the corresponding average values are used due to consistency. However, the accident costs for rail and air transport are still negligible. In the case of road transport, no exact accident figures are available for the routes under consideration, which is why average values were also used for freeways.

3. Results

3.1. Climate Footprint

In this section, the climate footprints for the modes of transport under consideration are shown for all five routes. The results are presented as greenhouse gas emissions in CO_2 equivalents per person and journey. Table 9 presents an overview of the total greenhouse gas emissions for the investigated routes and the five modes of transport. This overview clearly shows that travelling by TGV Lyria causes the lowest amount of greenhouse gas emissions.

Table 9: Climate footprint for the investigated routes: CO_2-equivalents per person and journey for different modes of transport.

	Climate footprint (kg CO_2-eq/person)						
Journey	**Train**	**Airplane**	**Coach**	**Car Ø**	**Car work**	**e-car Ø**	**e-car work**
Geneva-Paris	2.6	114.8	15.1	98.8	138.7	56.5	79.4
Lausanne-Paris	2.4	114.8	15.1	98.4	138.2	51.2	71.9
Basel-Paris	2.7	112.8	16.1	97.0	136.1	50.4	70.8
Zurich-Paris	3.1	131.9	18.3	108.7	152.6	56.5	79.4
Lausanne-Marseille	2.9	93.0	16.0	108.0	151.6	56.2	78.8

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In the following section the greenhouse gas emissions for every route investigated are broken down according to energy supply, production of the vehicles and infrastructure and by the emissions in direct operation. According to the standard SN EN 162583[3], only the emissions from direct operation and those from the energy supply must be shown. In this climate footprint, the emissions from the production of the vehicles and the infrastructure are also taken into account. In the first route, Geneva–Paris, an additional analysis and graph is shown for a door-to-door comparison. Therefore, the pre and post journey for travelling on the Geneva–Paris route are also taken into account. For the routes that follow, these graphs are included in the Annex for reasons of clarity.

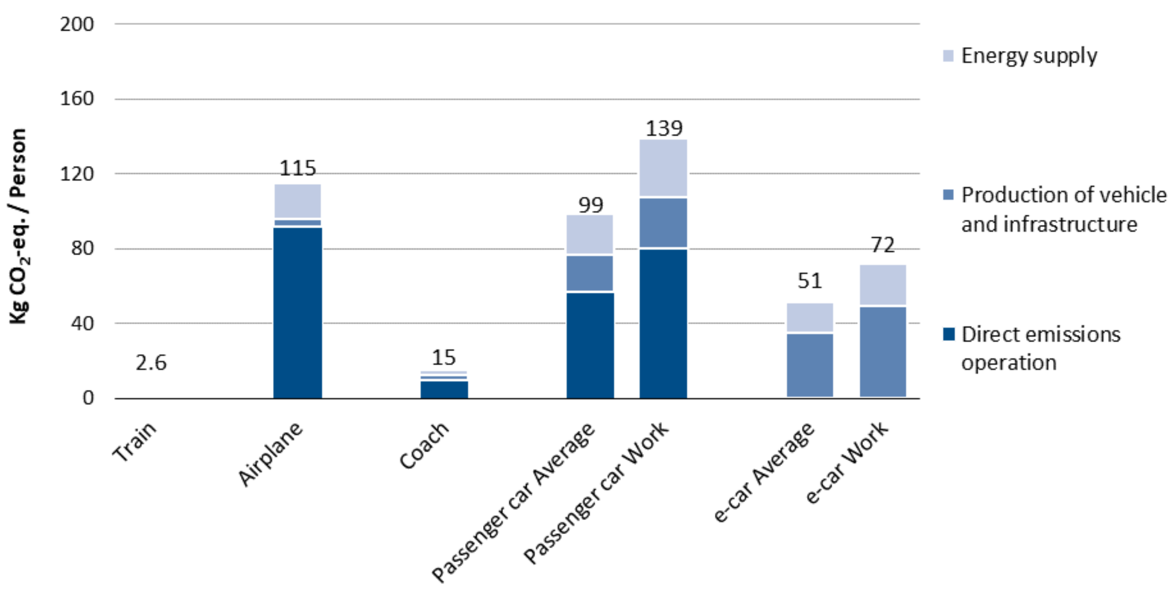
Geneva – Paris

Figure 1 shows the results of the carbon footprint of the Geneva - Paris route for the modes of transport considered. The kilograms of CO_2 equivalents per person and journey are shown, broken down by energy supply, vehicle and infrastructure production and emissions from direct operation. For passenger cars, two different load factors are indicated. "Work" means that a lower utilization of 1.09 persons per vehicle (according to statistics for business trips) was

[3] The standard SN EN 16258 describes a method for calculating and declaring the energy use and greenhouse gas emissions for transport services. The standard comes from the European Committee for Standardization.

calculated instead of the average value of 1.53 persons per vehicle (ARE 2023). For the journey from Geneva to Paris (city centre to city centre), the TGV Lyria causes the lowest GHG (greenhouse gas) emissions with 2.6 kg CO_2-eq. per person and journey. The means of transport with the next highest emissions per person and journey is the coach with around 15 kg CO_2-eq., followed by the electric car with around 51 kg CO_2-eq. The highest greenhouse gas emissions per person and journey are emitted by the airplane (115 kg CO_2-eq.) and the conventional car (99 kg CO_2-eq. and 139 kg CO_2-eq, respectively).

Figure 1: Climate footprint for Geneva–Paris: CO_2 equivalents per person and journey for different modes of transport



INFRAS graph

Table 10 shows the emissions broken down according to their origin. It is shown that the electrically powered rail and e-car modes of transport do not generate any direct emissions. According to the SN EN 16258 standard, only the emissions from direct operation and those from energy supply would have to be reported. In case of the TGV Lyria, this would only take into account traction with 1.1 kg CO_2 eq. per person which accounts for around 40% of total emissions. This ratio is reversed for airplanes, for example. Here, direct emissions and the provision of energy together account for around 95% of total emissions, at around 110 kg CO_2 eq. per person. Thus, if only the parameters required by the standard are taken into account in ecological transport mode comparisons, rail travel emits around 70 to 100 times less CO_2 eq. than a flight on the same route. The situation is similar, but not quite as pronounced, for passenger cars, where the provision of energy and direct emissions together account for a significantly higher proportion of total emissions for combustion engines than for electric cars.

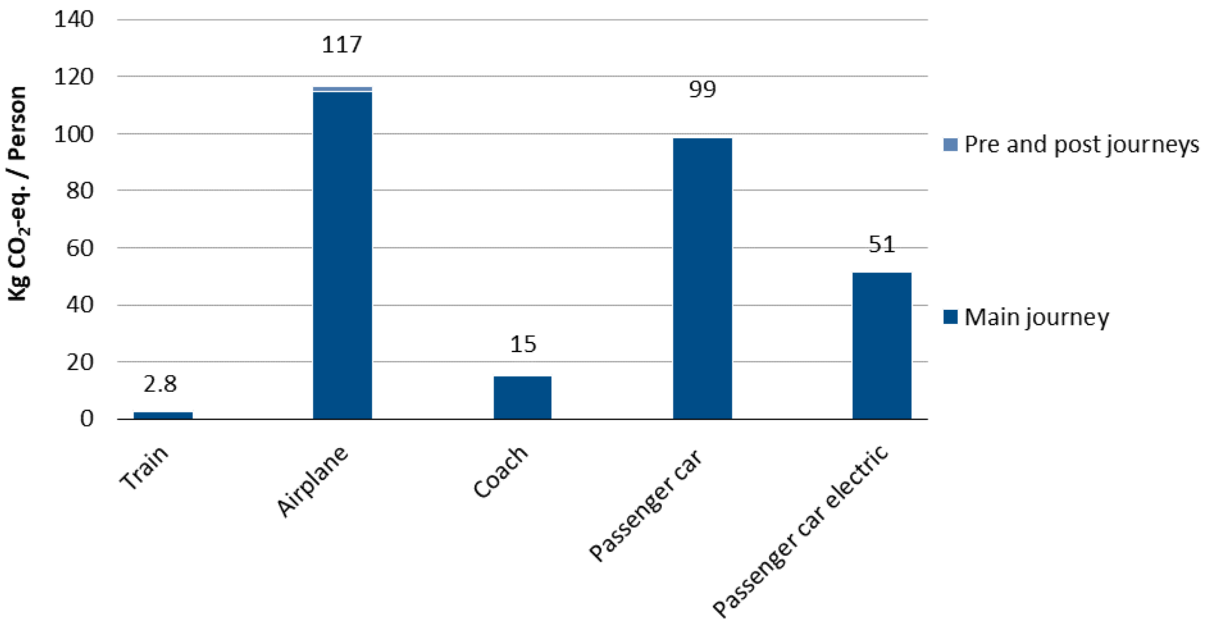
Table 10: Greenhouse gases, Geneva–Paris, according to source of emissions

Kg CO_2-eq / Person	Train	Airplane	Coach	Passenger car Average	Passenger car Work	e-car Average	e-car Work
Direct emissions operation	0	91	10	57	80	0	0
Energy supply	1.1	19	2.6	22.4	31	16	23
Production of vehicle and infrastructure	1.4	4.0	2.7	20	27	35	49
Total	**2.6**	**115**	**15**	**99**	**139**	**51**	**72**
Total according to Norm SN EN 16258	*1.1*	*111*	*12*	*79*	*111*	*16*	*23*

Table INFRAS.

Figure 2 shows the same comparison as above, but with the distinction of the pre and post journey. In other words, a so-called door-to-door comparison was made here and the journeys to and from the train station, airport or bus station were also taken into account (see Table 4 for details). It is striking that the share of pre and post journeys in total emissions is very small. In terms of share, the GHG emissions from pre and post journeys are highest for rail, about 8% (almost invisible in the graph due to the low absolute values for train). The figure for air travel is just under 2% and for long-distance buses around 1%.

Figure 2: Climate footprint for Geneva–Paris, according to type of journey: CO_2 equivalent per person and journey for different modes of transport

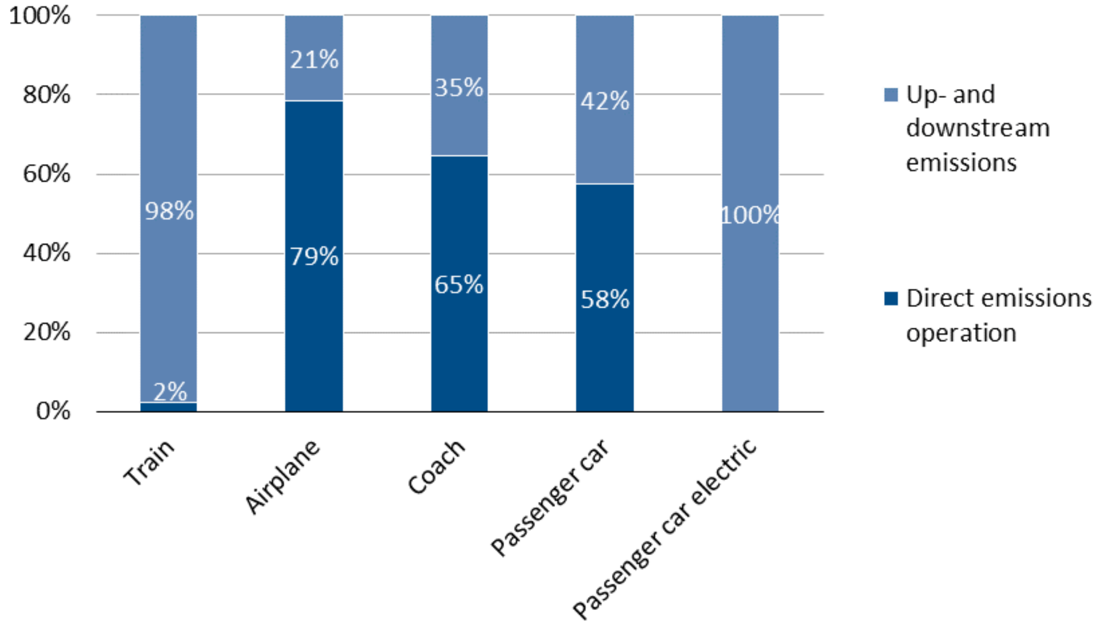


INFRAS graph.

In Figure 3 the shares of up- and downstream GHG emissions in the total GHG emissions of a trip from Geneva to Paris are shown (including pre and post journeys). The upstream and downstream processes include the production, maintenance and disposal of vehicles, infrastructure and energy.

No GHG emissions are caused by electric cars during the journey. This means that 100% of GHG emissions come from upstream and downstream processes. In the case of trains, around 98% of GHG emissions come from upstream and downstream processes and around 2% from direct operation. The emissions from direct rail operations all come from upstream and downstream processes (e.g. bus journey to the station). The main train journey also causes no GHG emissions. In the case of conventional cars, around 42% of GHG emissions come from upstream and downstream processes. This figure is around 35% for long-distance buses and around 21% for air travel.

Figure 3: Proportion of upstream and downstream greenhouse gas emissions in terms of all greenhouse gas emissions

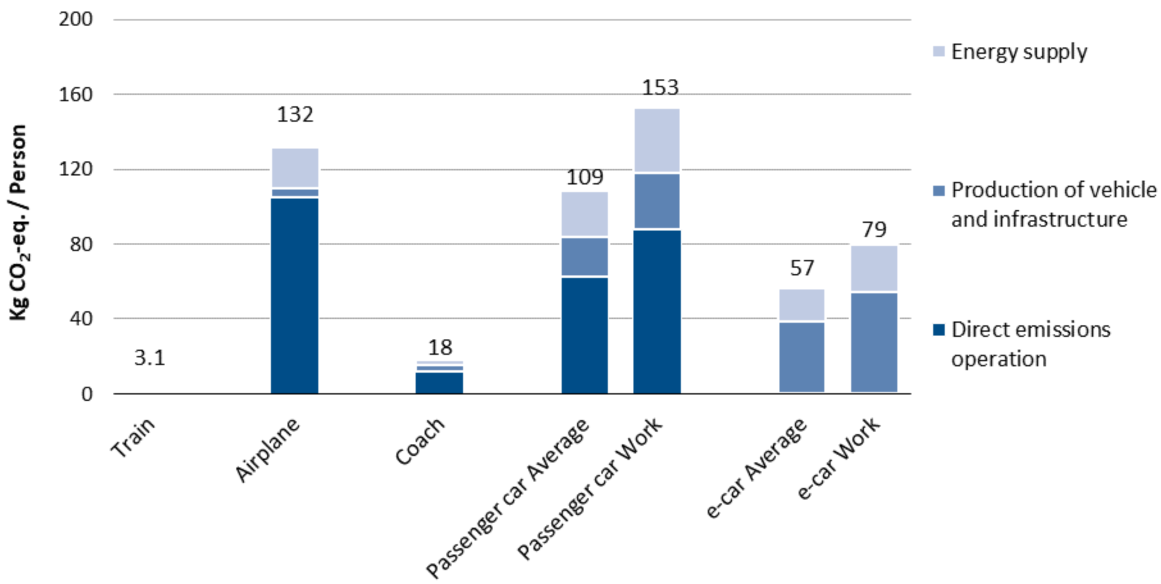


INFRAS graph.

Zurich – Paris

Traveling by TGV Lyria from Zurich to Paris causes around 3.1 kg of CO_2 eq. per person and journey. At around 18 kg of CO_2 eq. per person, a long-distance bus journey from Zurich to Paris causes slightly higher emissions. The situation for passenger cars is as follows: Driving an electric car causes around 57 kg CO_2 eq., while driving a conventional combustion engine car causes around 109 kg CO_2 eq. With lower capacity utilization (e.g. business trips), emissions per capita increase on average to 79 kg CO_2 eq. for electric cars and 153 kg CO_2 eq. for conventional cars. Air travel causes 132 kg CO_2-eq. per person and journey.

Figure 4: Climate footprint for Zurich–Paris: CO_2 equivalents per person and journey for different modes of transport

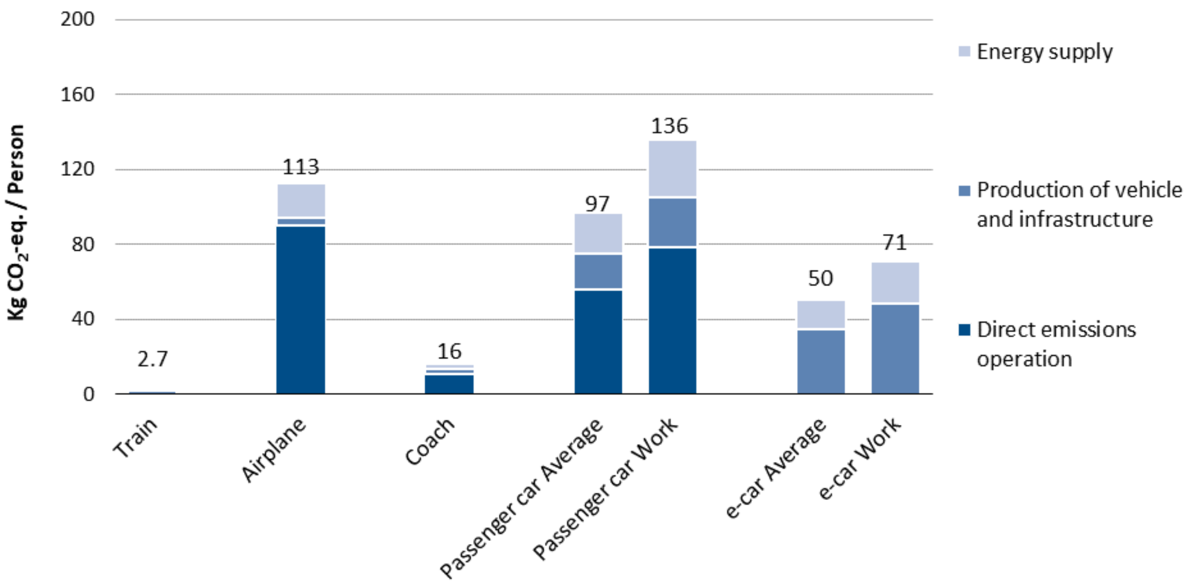


INFRAS graph.

Basel – Paris

A comparison of the GHG emissions of different modes of transport for the journey from Basel to Paris shows that the TGV Lyria produces the lowest GHG emissions per person and journey at 2.7 kg CO_2 eq. A journey by long-distance bus causes 16 kg of CO_2 eq. per person. In the case of cars, a journey in a conventional car generates around 97 kg CO_2 eq. per person and a journey in an electric car generates around 50 kg CO_2 eq. The GHG emissions increase to 136 kg CO_2-eq. (fossil-fuelled cars) and 71 kg CO_2-eq. (electric cars) when business travellers use their cars. Air travel causes 113 kg CO_2-eq per person and journey.

Figure 5: Climate footprint, Basel–Paris: CO_2 equivalents per person and journey for different modes of transport

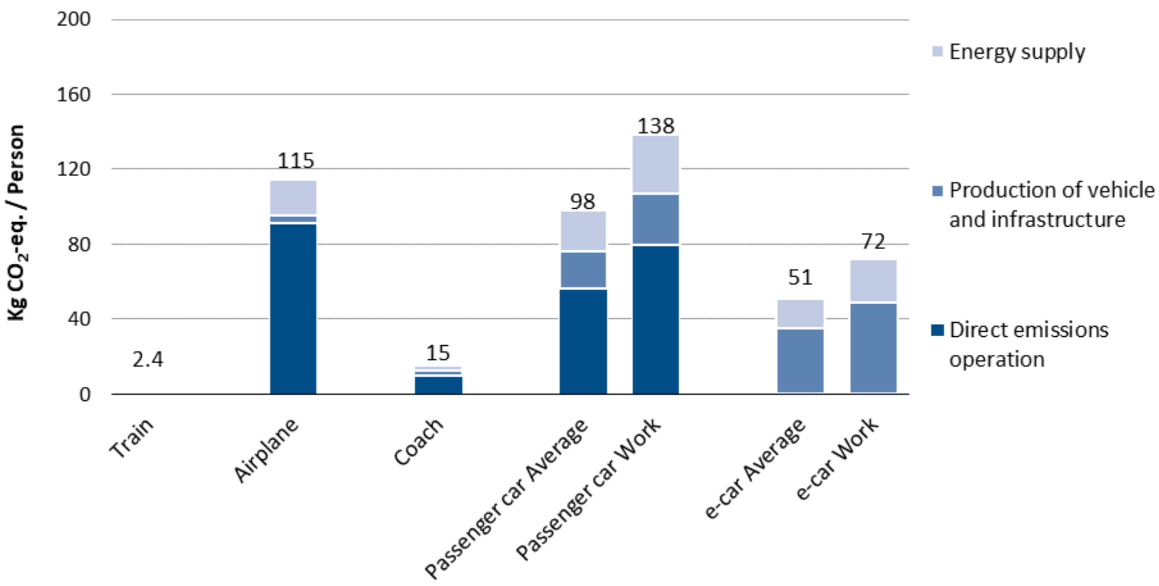


INFRAS graph.

Lausanne – Paris

For the journey from Lausanne to Paris, the TGV Lyria also produces the lowest GHG emissions per person and journey at 2.4 kg CO_2 eq. A journey by coach generates 15 kg CO_2 eq. per person. In the case of passenger cars, a journey by conventional car causes around 98 kg CO_2 eq. per person, a journey by electric car causes just over half of this (51 kg CO_2 eq.). The GHG emissions increase to 138 Kg CO2-eq. (fossil-fuelled cars) and 72 Kg CO2-eq. (electric cars) when business travellers use their cars. A trip by plane causes GHG emissions per person of around 115 kg CO2-eq. per journey.

Figure 6: Climate footprint, Lausanne–Paris: CO_2 equivalents per person and journey for different modes of transport

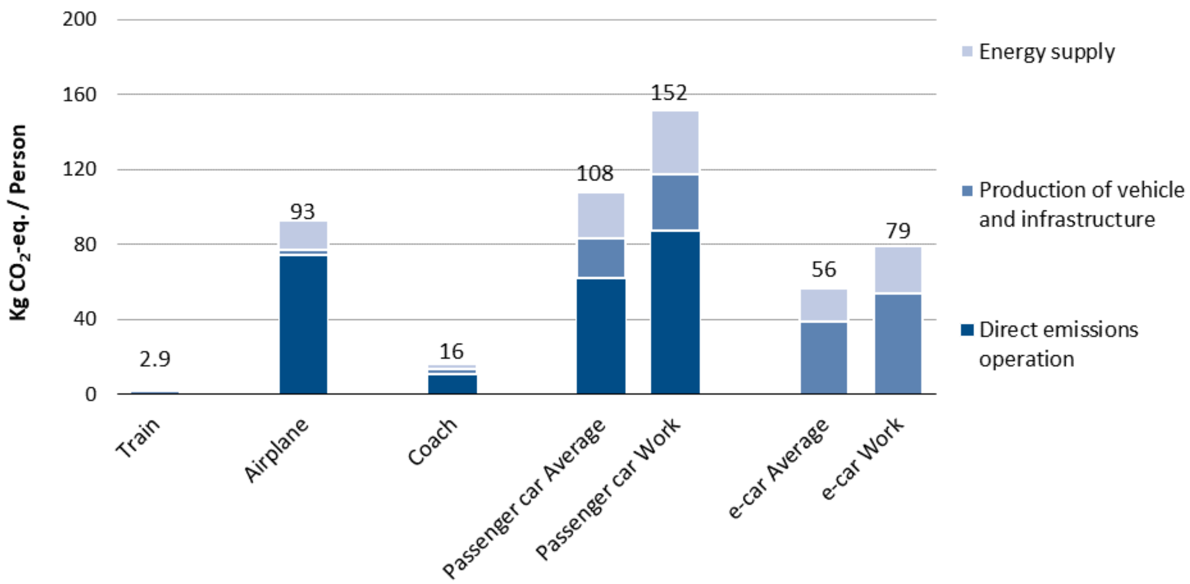


INFRAS graph.

Lausanne – Marseille

For the journey from Lausanne to Marseille, the TGV Lyria produces the lowest GHG emissions per person and journey at 2.9 kg CO_2-eq. A journey by long-distance bus generates 16 kg CO_2-eq. per person. In the case of cars, a journey by conventional car causes around 108 kg of CO_2-eq. per person, a journey by electric car slightly less than half of this (56 kg of CO_2-eq.). The GHG emissions increase to 152 Kg CO_2-eq. (fossil-fuelled cars) and 79 Kg CO_2-eq. (electric cars) when business travellers use their cars. A trip by airplane causes GHG emissions per person of around 93 kg CO_2-eq.

Figure 7: Climate footprint, Lausanne–Marseille: CO_2 equivalents per person and journey for different modes of transport



INFRAS graph.

Changes since 2019

The update of the formerly estimated data for the TGV Lyria fleet included a reduction of the energy consumption per train kilometre, a reduction of the CO_2-eq. emissions per kilowatt hour, but also a slightly reduced number of the utilisation rate. In combination this results in an overall reduction of the carbon footprint for travelling by TGV Lyria. Additionally, the update led to a slight reduction in greenhouse gas emissions for air travel, while emissions from cars increased. This is due to an update of the utilisation rate, which fell from an average of 1.6 to 1.53 for cars with the new publication of the micro-census (ARE 2023) but increased for air travel by 2.1% between 2019 and 2023 according to IATA (IATA 2023). Updating the emission factors for the upstream and downstream processes led to higher emissions, particularly for e-cars. This is because the emission factors from Mobitool 3.0 used here are higher than the emission factors originally used.

3.2. Final Energy Balance

The energy used per person and journey is assessed in the final energy balance. The final energy is typically converted into kilogram petrol equivalents. The energy efficiency of the different modes of transport in operation is therefore compared. The energy that is used for the upstream and downstream processes is not taken into account. It is done this way intentionally because otherwise it would not be the energy efficiency of the modes of transport but of the energy systems behind them that would be under comparison. This means that the efficiency of an electric engine is being compared with that of a combustion engine, for example, and not the energy expenditure of producing nuclear or hydroelectric power as against diesel. Table 11 gives an overview of the results for all journeys, details are discussed in the following sections.

Table 11: Final Energy Balance: Kilogram petrol equivalents per person and journey

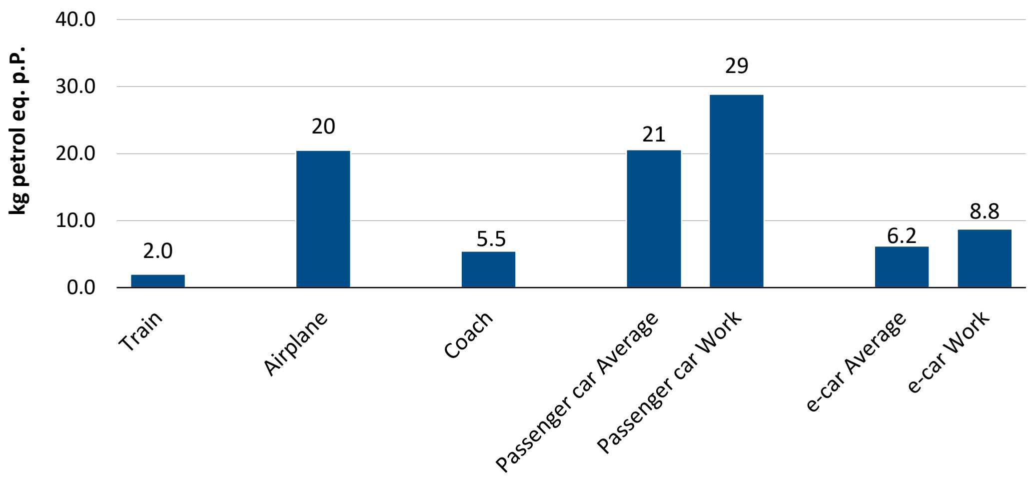
	Final Energy Balance (kg petrol eq/person)						
Journey	**Train**	**Airplane**	**Coach**	**Car Ø**	**Car work**	**e-car Ø**	**e-car work**
Geneva-Paris	2.0	20.5	5.5	20.6	28.9	6.2	8.8
Lausanne-Paris	2.4	21.8	5.9	20.5	28.8	6.2	8.7
Basel-Paris	2.2	20.7	5.9	20.2	28.4	6.1	8.6
Zurich-Paris	2.6	23.7	6.7	22.6	31.8	6.9	9.6
Lausanne-Marseille	3.3	18.6	6.8	22.5	31.6	6.8	9.6

Table INFRAS

Geneva–Paris

In comparison with the modes of transport surveyed, the TGV Lyria fleet shows the lowest final energy consumption on the Geneva–Paris route, with around 2.0 kg petrol equivalent per person and journey. The coach consumes about 5.5 kg petrol equivalent per person and journey, and the electric car around 6.2 kg petrol equivalent. With cars, the energy consumed increases in the case of a lower occupancy for business travel to 8.8 (electric car). The airplane consumes 20 kg petrol equivalent. The fossil fuel driven car, when used for work with a lower occupancy, consumes the highest amount of energy with 29 kg petrol equivalent.

Figure 8: Final energy consumption per person and journey for different modes of transport on the Geneva–Paris route

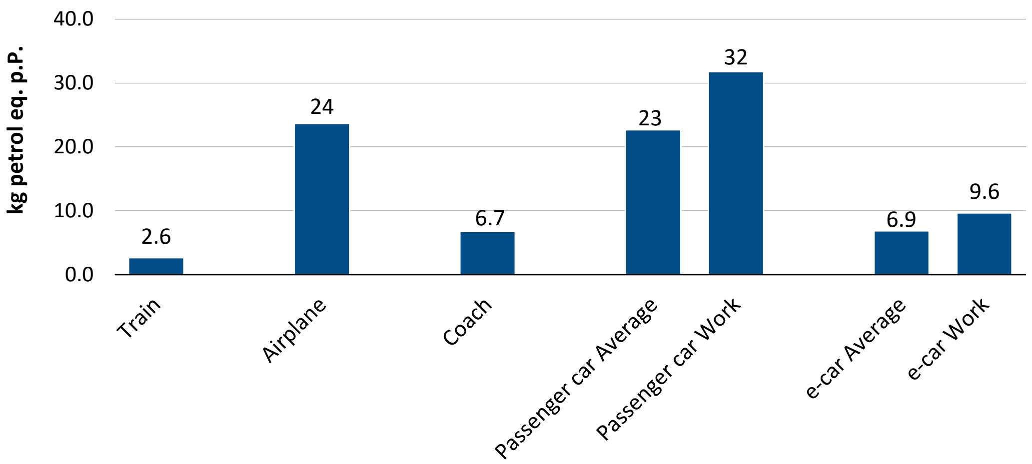


INFRAS graph.

Zurich–Paris

Figure 9 shows the final energy consumption per person and journey from Zurich to Paris. The railway journey by TGV Lyria has the lowest energy consumption per person at around 2.6 kg petrol equivalent. The energy consumption of the coach is around three times higher at 6.7 kg petrol equivalent, and the same applies to an averagely occupied electric car at almost 6.9 kg petrol equivalent. The conventional car consumes around 23 kg petrol equivalent and for the aircraft this is about 24 kg petrol equivalent. With the cars, the energy consumption increases in case of a lower occupancy for business travel to 9.6 kg (electric car) and 32 kg petrol equivalent (fossil fuel powered car).

Figure 9: Final energy consumption per person and journey of different modes of transport on the Zurich–Paris route

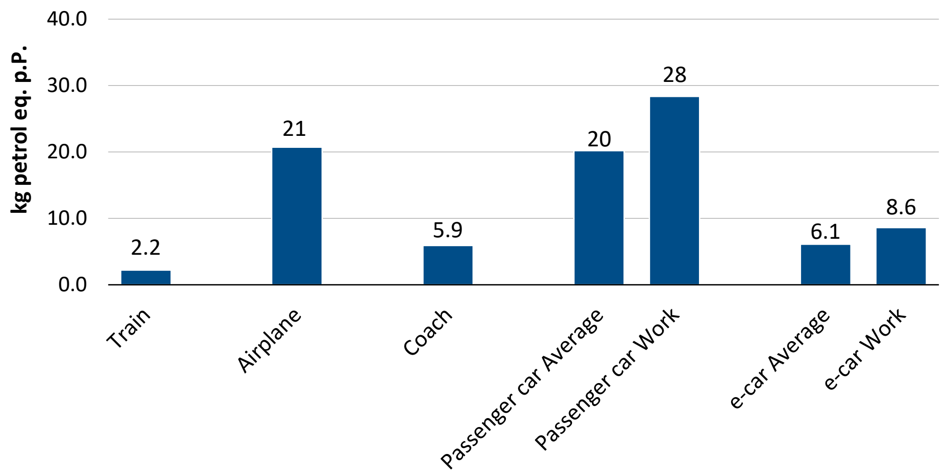


INFRAS graph.

Basel–Paris

Figure 10 shows the final energy consumption per person and journey from Basel to Paris. The railway journey by TGV Lyria has the lowest energy consumption per person at around 2.2 kg petrol equivalent. The energy consumption of the coach and the electric car are around three times higher at 5.9 and 6.1 kg petrol equivalent. The conventional car consumes around 20 kg petrol equivalent and for the aircraft this is about 21 kg petrol equivalent. For cars, the energy consumption increases in case of a lower occupancy for business travel to 8.6 kg (electric car) and 28 kg petrol equivalent (fossil fuel powered car).

Figure 10: Final energy consumption per person and journey of different modes of transport on the Basel–Paris route

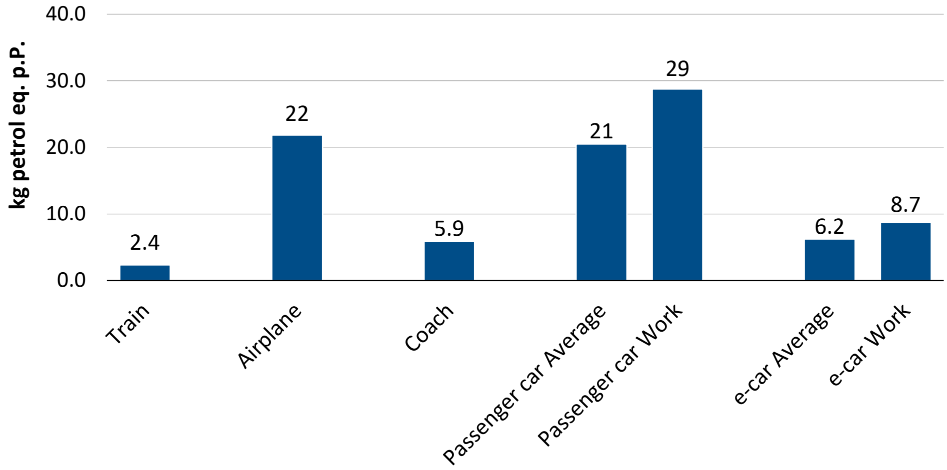


INFRAS graph.

Lausanne–Paris

Figure 11 shows the final energy consumption per person and journey from Lausanne to Paris. The railway journey by TGV Lyria has the lowest energy consumption per person at around 2.4 kg petrol equivalent. More than twice as high is the energy consumption of a coach at 5.9 kg petrol equivalent and of the electric car at 6.2 kg. The conventional car consumes around 21 kg petrol equivalent and for the aircraft this is about 22 kg petrol equivalent. For cars, the energy consumption increases in case of a lower occupancy for business travel to 8.7 kg (electric car) and 29 kg petrol equivalent (fossil fuel powered car).

Figure 11: Final energy consumption per person and journey of different modes of transport on the Lausanne–Paris route

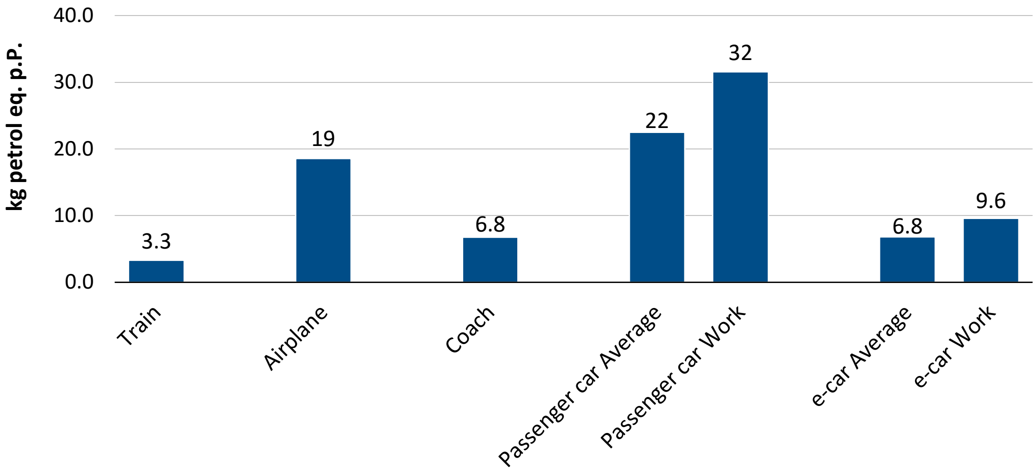


INFRAS graph.

Lausanne–Marseille

Figure 12 shows the final energy consumption per person and journey from Lausanne to Marseille. The railway journey by TGV Lyria has the lowest energy consumption per person at around 3.3 kg petrol equivalent. More than twice as high is the energy consumption of a coach and of the electric car at 6.8 kg petrol equivalent each. The aircraft consumes around 19 kg petrol equivalent and for the conventional car this is about 22 kg petrol equivalent. For cars, the energy consumption increases in the case of a lower occupancy for business travel to 9.6 kg (electric car) and 32 kg petrol equivalent (fossil fuel powered car).

Figure 12: Final energy consumption per person and journey of different modes of transport on the Lausanne–Marseille route



INFRAS graph.

Changes since 2019

Since 2019, there have been various developments in energy efficiency in the modes of transport, which has led to changes in the energy balance. Energy consumption per person and journey by train has remained constant since 2019, as the TGV Lyria fleet has remained the same since introducing the new fleet in 2019. Lower energy consumption can be observed for journeys by airplane, which can be attributed to increased efficiency or an adaptation of the most commonly used aircraft models. On the other hand, the energy consumption of cars (especially electric cars) and coaches has increased (slightly). This could be due to the fact that cars in particular are becoming increasingly larger and heavier and are therefore less energy efficient.

3.3. Environmental and Accident Costs

In this section, the environmental and accident costs of the modes of transport under consideration are shown for all five routes. For details on the aspects considered in this calculation please see Table 8. The results are presented in CHF per person and journey. An overview of the results is given in Table 12, details are discussed in the following sections.

Table 12: Environmental and Accident Costs: CHF per person and journey

	Environmental and Accident Costs (CHF/person)						
Journey	**Train**	**Airplane**	**Coach**	**Car Ø**	**Car work**	**e-car Ø**	**e-car work**
Geneva-Paris	2.6	29.0	5.1	31.0	40.3	22.9	28.8
Lausanne-Paris	3.1	30.9	5.7	30.9	40.1	22.8	28.7
Basel-Paris	2.9	29.3	5.6	30.4	39.5	22.4	28.3
Zurich-Paris	3.4	33.5	6.4	34.1	44.3	25.1	31.7
Lausanne-Marseille	4.4	26.2	6.8	33.9	44.0	25.0	31.5

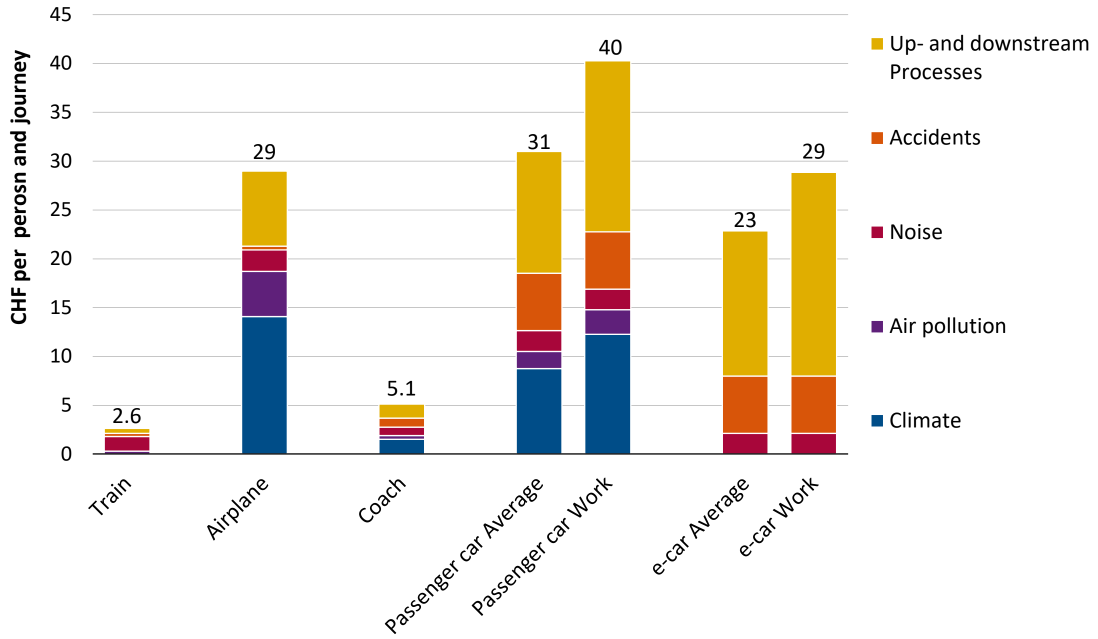
Table INFRAS

For the first route, Geneva–Paris, an additional graph and analysis is shown, which gives insight into the proportions of the individual cost categories in terms of the overall environmental and accident costs. For the other routes, the additional graphs can be found in the Annex.

Geneva–Paris

Figure 13 shows the average environmental and accident costs (external effects) for a journey from Geneva to Paris. The lowest environmental and accident costs are generated by the railway at around CHF 2.6 CHF per person and journey, followed by the coach at CHF 5.1 per person and journey. If an electric car is selected for the journey, average costs come out at CHF 23 per person for environmental and accident costs (occupancy of 1.53 people per car). With lower occupancy for business travellers, the costs increase to CHF 29. A journey by aircraft from Geneva to Paris generates environmental and accident costs of around CHF 29 per person. For conventional cars with a combustion engine with average occupancy, the costs are around CHF 31 per person. With lower occupancy for business travellers, the costs increase to CHF 40 CHF per person.

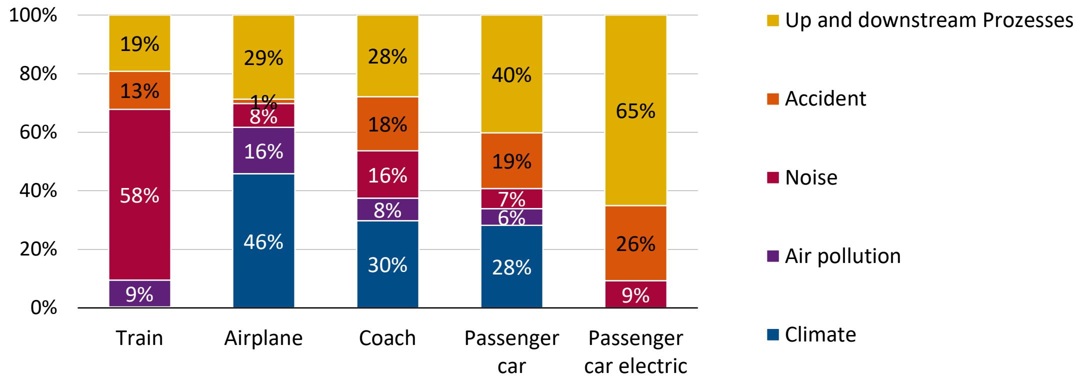
Figure 13: Average environmental and accident costs per person and journey on the Geneva–Paris route



INFRAS graph.

Figure 14 shows the proportions of the individual cost categories in terms of the total environmental and accident costs for each mode of transport. With the train, the noise costs constitute around 58%, followed by the up- and downstream processes at around 19% (for power production, rolling material and infrastructure) and the accident costs at 13%. The direct air pollution costs and the climate costs make up the rest (9%). For airplanes, the climate costs account for the largest percentage of environmental and accident costs of a flight at approximately 46%. The costs of up- and downstream processes generate 29%, the air pollutant costs 16%, noise accounts for 8% and the accident costs another 1%. For the coach, the proportions look as follows: climate costs represent the largest proportion of the overall costs at 30%, the upstream and downstream processes 28%, accident costs 18%, noise costs about 16% and air pollution 8%. For the conventional car, upstream and downstream processes account for 40%, climate costs for 28%, accident costs for about 19%, noise costs for 7% and the costs of air pollution for 6%. The electric car does not create any climate and air pollution costs in direct operation. 65% of the costs arise from up- and downstream processes, and another 26% from accidents, while 9% comes from noise costs.

Figure 14: Proportion of individual cost categories in terms of total environmental and accident costs (Geneva–Paris)

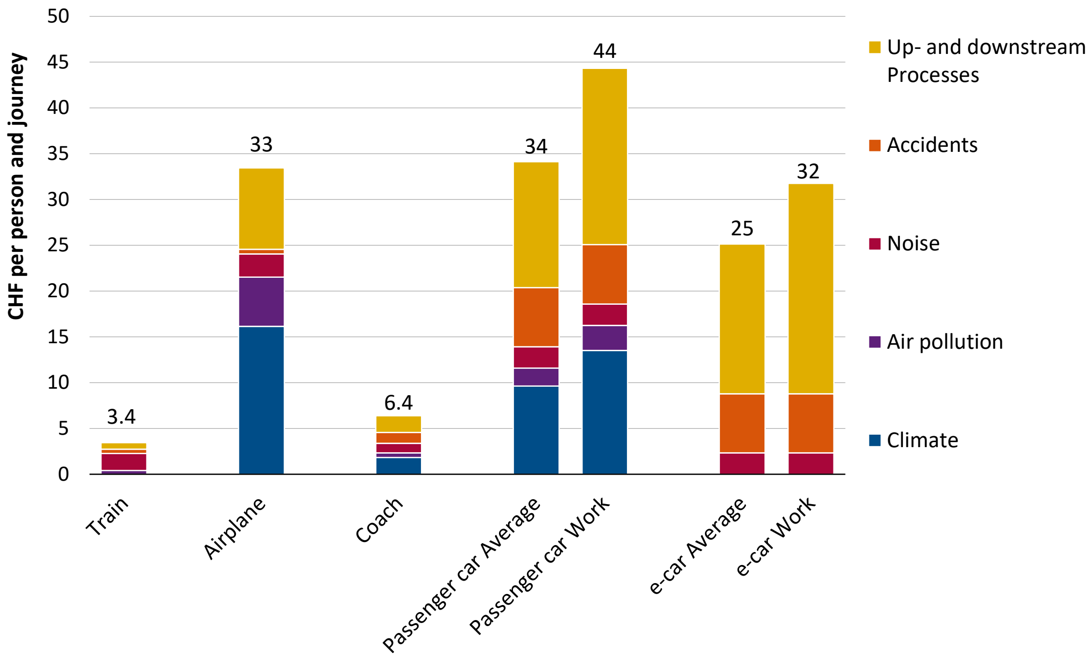


INFRAS graph.

Zurich – Paris

Figure 15 shows the total environmental and accident costs of the individual modes of transport, differentiated according to the cost categories considered. Travelling by TGV Lyria from Zurich to Paris creates environmental and accident costs of around CHF 3.4 per person. A journey by coach generates around CHF 6.4 per person. If an electric car is chosen for the journey, the average environmental and accident costs per person (occupancy of 1.53 persons per car) are CHF 25. With the lower occupancy by business travellers, the costs increase to CHF 32. Travelling by airplane from Zurich to Paris generates environmental and accident costs of around CHF 33 per person. For a conventional car with a combustion engine, for average occupancy, the cost is around CHF 34 per person. With the lower occupancy of business travellers, the environmental and accident costs increase to CHF 44 per person. For all passenger cars, it should be noted that the costs would be considerably reduced if occupancy rates were increased (2 to 5 persons per vehicle).

Figure 15: Environmental and accident costs per person and journey by mode of transport on the Zurich–Paris route

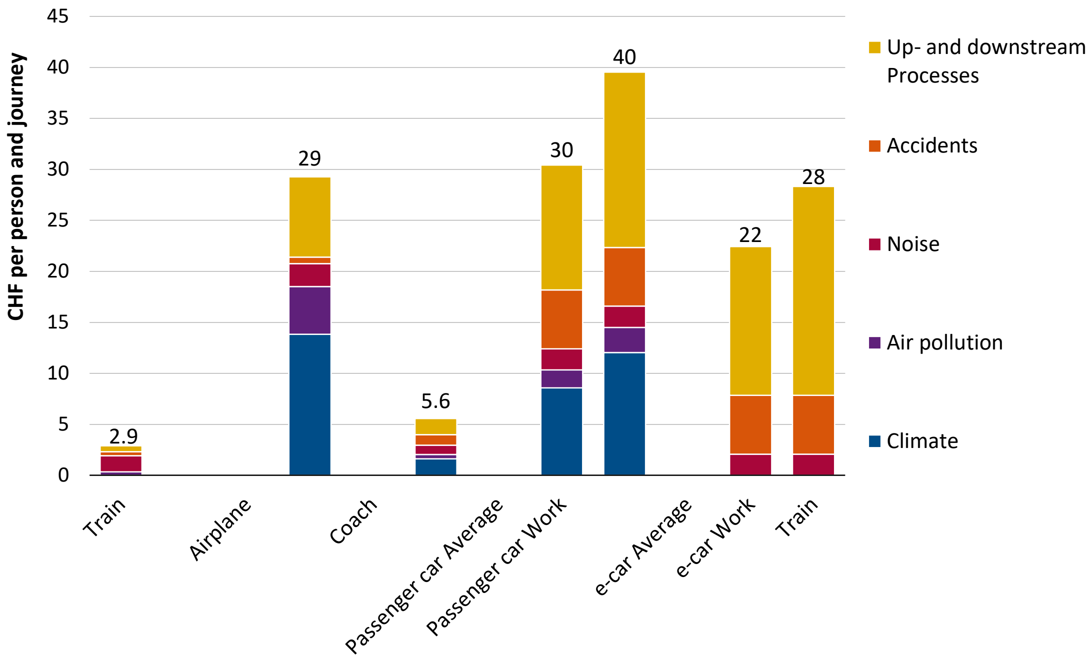


INFRAS graph.

Basel – Paris

A railway journey by TGV Lyria from Basel to Paris generates environmental and accident costs of around CHF 2.9 per person. A journey by coach generates about CHF 5.6 per person. Choosing to travel by electric car (occupancy of 1.53 persons per car) leads to an average of CHF 22 per person in environmental and accident costs. With lower occupancy by business travellers, the costs increase to CHF 28. A journey by aircraft from Zurich to Paris creates environmental and accident costs of around CHF 29 per person. For a conventional car with a combustion engine with average occupancy, it is about CHF 30 per person. With lower occupancy for business travellers, the costs rise to CHF 40 per person.

Figure 16: Environmental and accident costs per person and journey by mode of transport on the Basel–Paris route

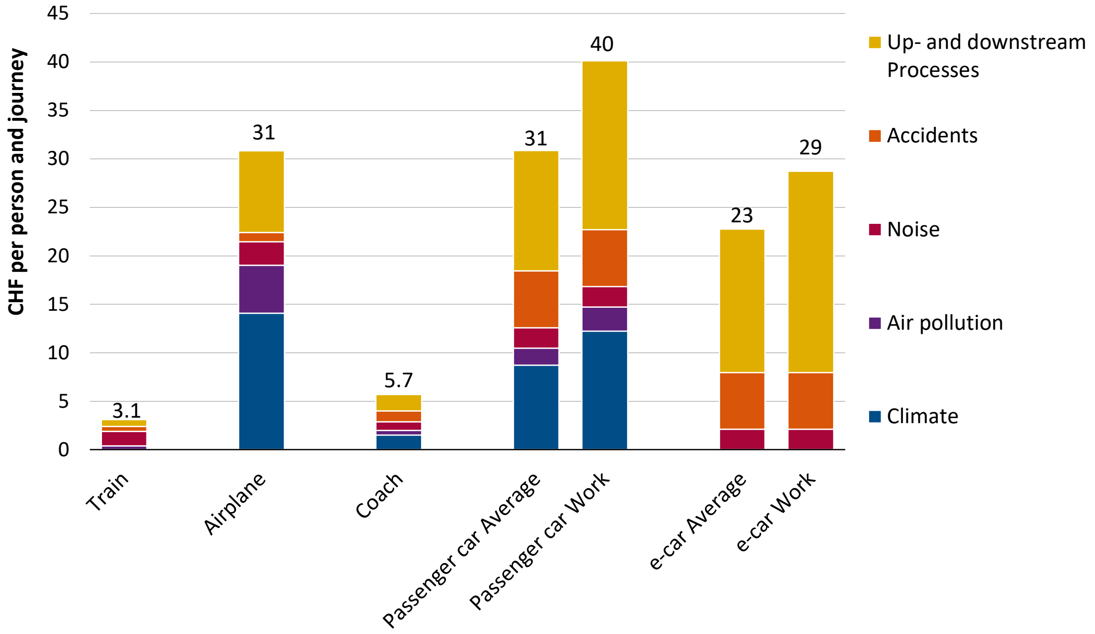


INFRAS graph.

Lausanne – Paris

A railway journey by TGV Lyria from Lausanne to Paris generates environmental and accident costs of around CHF 3.1 per person. A journey by coach generates about CHF 5.7 per person. Choosing to travel by electric car (occupancy of 1.53 persons per car) leads to an average of CHF 23 per person in environmental and accident costs. With lower occupancy by business travellers, the costs increase to CHF 29. A journey by aircraft from Geneva to Paris creates environmental and accident costs of around CHF 31 per person. For a conventional car with a combustion engine with average occupancy, it is at the same level with about CHF 31 per person. With lower occupancy for business travellers, the costs rise to CHF 40 per person.

Figure 17: Environmental and accident costs per person and journey by mode of transport on the Lausanne–Paris route



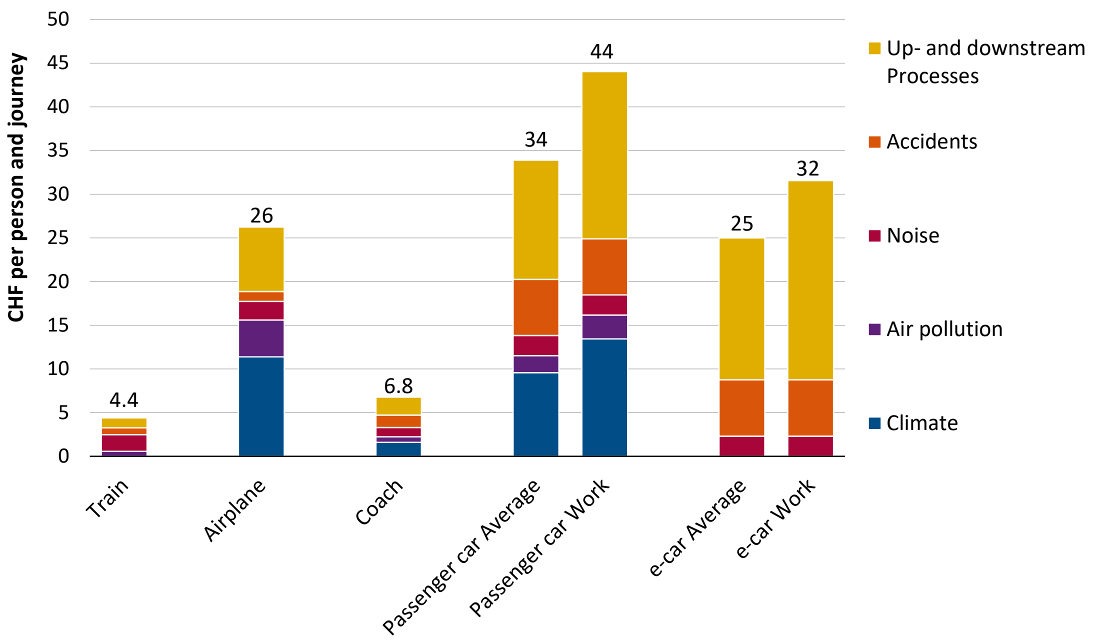
INFRAS graph.

Lausanne – Marseille

A railway journey by TGV Lyria from Lausanne to Marseille generates environmental and accident costs of around CHF 4.4 per person. A journey by coach generates about CHF 6.8 per person. Choosing to travel by electric car (occupancy of 1.53 persons per car) leads to an average of CHF 25 per person in environmental and accident costs. With lower occupancy by business travellers, the costs increase to CHF 32. A journey by aircraft from Geneva to Marseille[4] creates environmental and accident costs of around CHF 26 per person. For a conventional car with a combustion engine with average occupancy, it is about CHF 34 per person. With lower occupancy for business travellers, the costs rise to CHF 44 per person.

[4] As there are no direct flights offered at the moment on this journey, this is a hypothetical connection.

Figure 18: Environmental and accident costs per person and journey by mode of transport on the Lausanne–Marseille route



INFRAS graph.

Changes since 2019

Environmental and accident costs have risen for all modes of transport compared to 2019. The total costs are (slightly) higher for airplanes, and the same applies to conventional cars (both average and work). The update also led to slight shifts in the percentage shares (see Figure 14 and Annex): The share of costs caused by upstream and downstream processes has increased considerably for coaches and cars. In contrast, the proportion of costs caused by air pollutants is lower, especially for coaches.

3.4. Travel Time and working Time

For business travellers, the usable travel time to work can be an important criterion for choosing a mode of transport. It should also be noted that usable travel time additionally has an economic benefit. For this reason, this chapter presents the usable travel time to work for the various modes of transport. The calculations also take into account the pre-carriage and onward carriage. Realistically, however, no usable working time was allocated to these. In these cases, working while traveling is defined as working on a technical device (e.g. notebook) that goes beyond making phone calls. The long-distance bus is a special case: Many coaches run overnight. In principle, it is also possible to work, but realistically this travel time is not used for work. Some connections are also available during the day. In some cases, however, you have to change buses. It is therefore not easy to calculate an average value for long-distance buses. The following examples are based on the ideal case that the bus runs during the day and you only have to change buses once. Table 13 gives an overview of the usable travel time of each mode of transport. When travelling by coach, the possible working time is the highest, which is also due to the fact that the total travel time is comparatively high. Traveling by TGV Lyria offers a very high share of usable travel time on all routes.

Table 13: Usable travel time: in hour per person and route

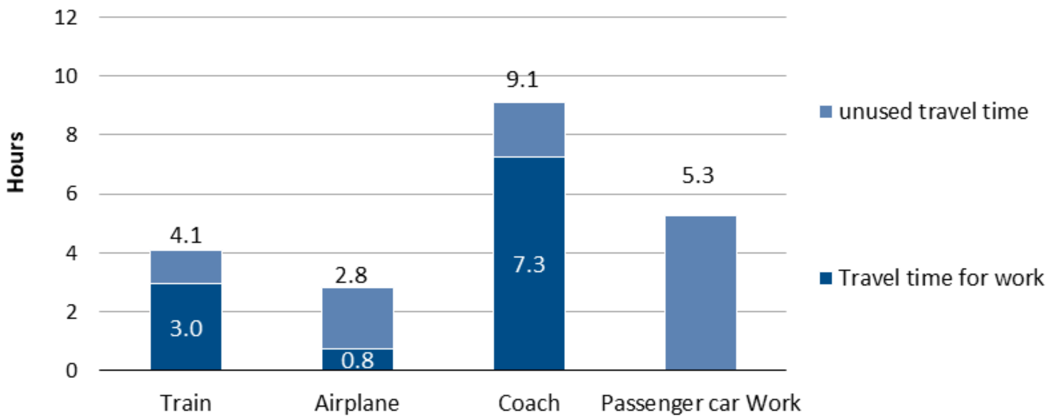
	Usable travel time (h)			
Journey	**Train**	**Airplane**	**Coach**	**Car work**
Geneva-Paris	3.0	0.8	7.3	0.0
Lausanne-Paris	3.5	0.8	7.1	0.0
Basel-Paris	2.9	0.9	7.7	0.0
Zurich-Paris	3.8	0.9	8.9	0.0
Lausanne-Marseille	4.2	1.9	6.8	0.0

Table INFRAS

Geneva – Paris

TGV Lyria travellers have three hours of the approximately 4-hour journey time from Geneva to Paris (Annemasse to Versailles) available for work. On the plane, only just under one hour of the approximately 3 hours of travel time can be used productively. Theoretically, around 7 hours of the total 9 hours could be worked on the long-distance coach. In reality, it is likely to be less due to coaches often offer overnight trips. Car journeys on this route take around 5 hours. None of this time can be used for work.

Figure 19: Geneva–Paris: Proportion of travel time that can be used to work

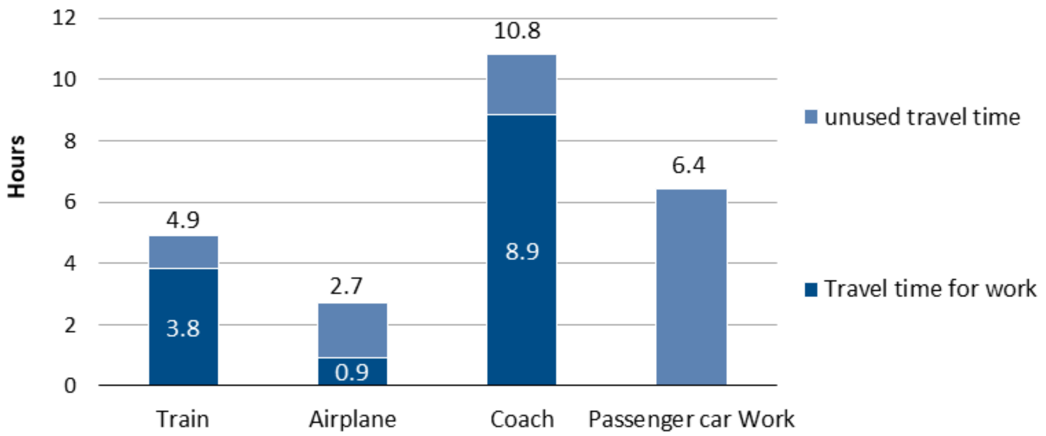


INFRAS graph.

Zurich – Paris

A traveller has the most productive working time on the train. Almost 4 hours of the total 5-hour journey time from Zurich city centre to Boulogne-Billancourt are available to travellers for work. Overall, the journey time by plane is the shortest on this route. However, only just under an hour can be used for work. In theory, almost 9 hours of the total 11 hours could be spent working on the long-distance bus. In reality, however, it is likely to be less (overnight trips). Car journeys on this route take around 6.4 hours. None of this time can be used for work.

Figure 20: Zurich–Paris: Proportion of travel time that can be used to work

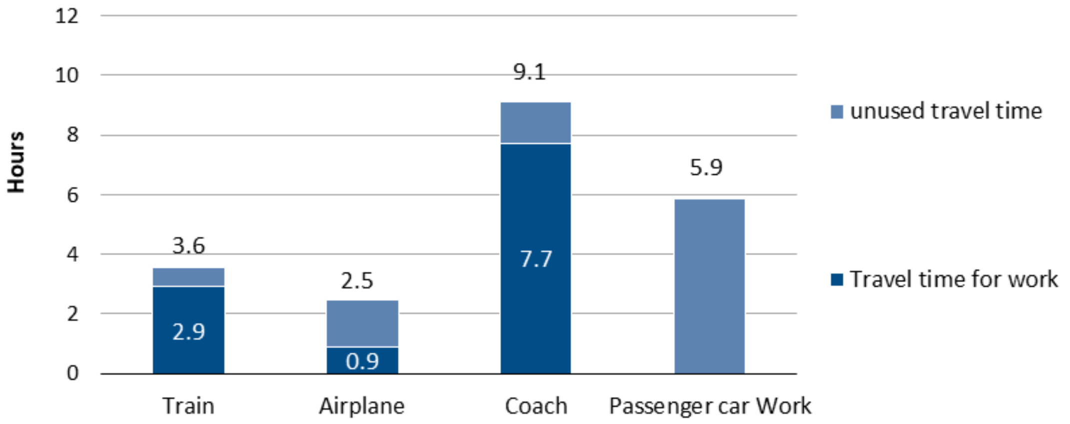


INFRAS graph.

Basel – Paris

TGV Lyria travellers have almost 3 hours of the total 3.6-hour journey time from Reinach BL to the centre of Paris available for work. On an airplane, only just under an hour of the total 2.5 hours of travel time can be used productively. In theory, almost 8 hours of the total 9 hours could be worked on the long-distance bus; in practice, it is likely to be less (overnight trips). Car journeys on this route take around 6 hours. None of this time can be used for work.

Figure 21: Basel–Paris: Proportion of travel time that can be used to work

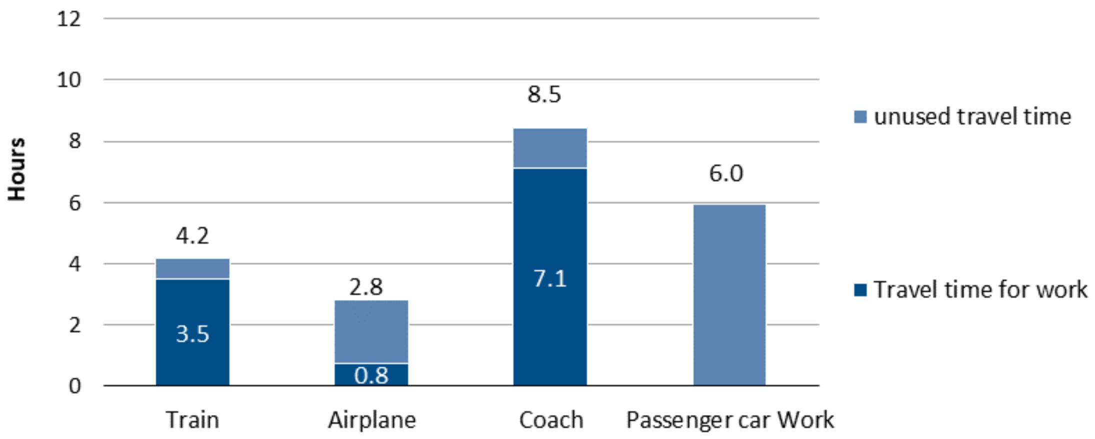


INFRAS graph.

Lausanne – Paris

TGV Lyria travellers have around 3.5 hours of the over 4-hour journey time from Lausanne to Paris (Montreux to Paris city centre) available for work. On the plane, only just under an hour of the approximately 3 hours of travel time can be used productively. Theoretically, around 7 hours of the total 8.5 hours could be spent working on the long-distance coach. In reality, it is likely to be less (overnight trips). Car journeys on this route take around 6 hours. None of this time can be used for work.

Figure 22: Lausanne–Paris: Proportion of travel time that can be used to work

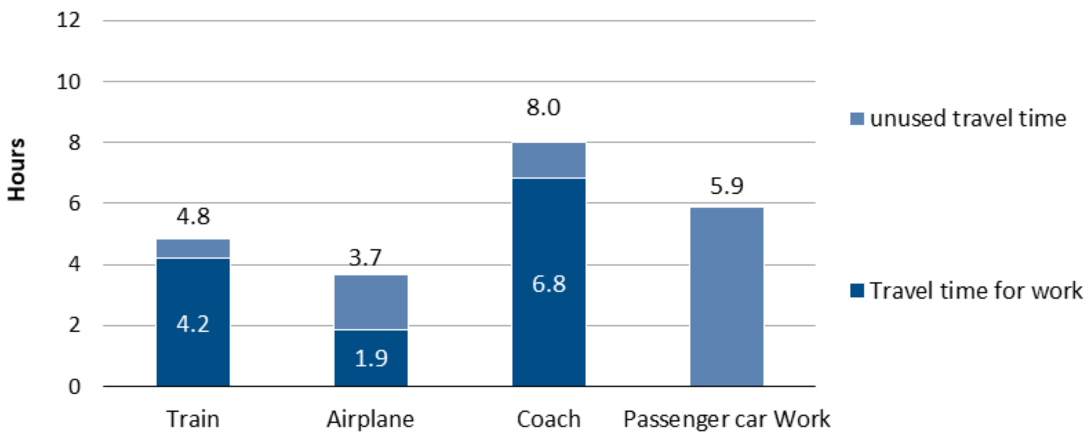


INFRAS graph.

Lausanne – Marseille

Around 4 hours of the almost 5-hour journey time from Lausanne to Marseille (Lausanne to Marseille city centre) are available to TGV Lyria travellers for work. On the plane, around 2 hours of the almost 4 hours of travel time can be used productively. Theoretically, around 7 hours of the total 8 hours could be worked on the long-distance coach. In reality, it is likely to be less (overnight trips). Car journeys on this route take 6 hours. None of this time can be used for work.

Figure 23: Lausanne – Marseille: Proportion of travel time that can be used to work



INFRAS graph.

4. Conclusions

From the analyses of the ecological comparison of the modes of transport, i.e., train (TGV Lyria), car, coach and airplane on the five different routes between Switzerland and France, the following statements apply:

- In a comparison per person and journey, the **occupancy of the vehicles is a central variable**. The modes of transport of TGV Lyria, coach and airplane are well occupied on average and rates for coaches and airplanes even increased during the last four years, while the car has a lower occupancy (1.53 persons per vehicle) on average.
- With the current average occupancies of the modes of transport surveyed, the environmental advantage in terms of the **climate footprint** is clearly with the railway, that is the TGV Lyria. With small differences on each route, the greenhouse gas emissions per person (including preliminary processes) for a journey by TGV Lyria on the main route are around 6 times lower than for the coach, about 20 times lower than for the electric car, approximately 37 times lower than for the conventional, fossil fuel powered car, and around 41 times lower than for the aircraft. From the perspective of climate protection, a railway journey by TGV Lyria offers the greatest advantage on the routes surveyed. The pre and post journeys are almost negligibly small on all the routes in question in comparison with the main part of the journey.
- In the **energy balance**, the final energy of the different modes of transport was deliberately balanced because the study was intended to compare the energy efficiency of the modes of transport and not the efficiency of different energy systems behind them. In other words, the efficiency of an electric motor is compared with that of a combustion engine and not the electricity production with diesel production. On this basis, the comparison of final energy consumption shows that the TGV Lyria has the highest energy efficiency. The next highest are the coach and the electric car. The conventional car with an internal combustion engine is around 7 to 14 times less energy efficient per person and journey and the airplane is around 6 to 10 times less energy efficient. Since 2019, energy consumption of the then introduced new fleet has remained the same. However, other modes of transport experience a shift in energy efficiency due to technological developments or consumer trends: While the airplane became more efficient, journeys by car developed in the opposite direction which is caused by cars becoming larger and heavier.
- To identify **the environmental and accident costs** per person and journey, the five cost categories of climate, air pollutants, noise, accidents and upstream and downstream processes were taken into account. The railway journeys by TGV Lyria generate the lowest environmental and accident costs per person and journey on all routes surveyed. This is largely

because the TGV Lyria generates almost no direct cost in the fields of climate, air pollution and accidents in operation, whereas these are in the highest cost categories for other modes of transport. The environmental and accident costs for coaches are double as high as those of the TGV Lyria, those of the electric car are around 6 to 11 times as high, and those of the aircraft around 6 to 11 times as high. The costs for the conventional car (petrol / diesel) are around 8 to 15 times higher than those of the TGV Lyria. Comparing the results to previous data from 2019 one notices an increase in environmental and accident costs in total terms for airplanes and conventional cars. Also, the shares shifted for some modes, so that the share of costs caused by up- and downstream processes has increased significantly for coaches and cars. Conversely, the share of costs attributed to air pollutants is lower, especially for coaches.

- For companies in particular, the **productive use of travel time** as working time should be a criterion when choosing the mode of transport for business travel. In the study, the entire travel time, including pre and post journeys, was surveyed. A journey by train enables around 80% of the travel time to be used for working. For coaches, this is essentially similar. However, it is worth noting regarding coaches that they often travel at night on the routes surveyed, and as much time can only theoretically be used for working; this is in fact likely to be considerably lower. On a flight, only around 35% of the total travel time can be used for productive working. The definition of working productively, is working with a technical device (laptop, etc.) which goes beyond telephoning. Therefore, there is no usable working time when travelling by car.
- In the **overall comparison** of the long-distance traffic routes surveyed, the train, i.e., TGV Lyria, comes out best in all areas and for all routes and even improved over the last four years. In terms of the climate footprint as well as the environmental and accident costs, the TGV Lyria is clearly in the lead. With respect to the environment, the coach comes after the railway, however, still generates greenhouse gas emissions and environmental costs that are around 6 times higher. Cars and aircraft show a considerably poorer climate and environmental balance than the railway (TGV Lyria). The electric car presents a better climate footprint and lower environmental costs than the petrol and diesel car. Nevertheless, the climate footprint and environmental costs of the electric car are consistently poorer than those of the TGV Lyria on the routes surveyed. The railway therefore currently has a clear environmental advantage in comparison to the car, even with the progressive electrification of cars, for international long-distance traffic. Equally significant is the environmental advantage of the railway in comparison with aircraft.

Annex

Climate footprints for each route based on source of emissions

Zurich - Paris

Table 14: Greenhouse gases, Zurich–Paris, based on source of emissions

Kg CO_2-eq / Person	Train	Airplane	Coach	Passenger car Average	Passenger car Work	e-car Average	e-car Work
Direct emissions operation	0	105.0	11.9	62.5	87.8	0	0
Energy supply	1.4	22	3.2	24.7	35	18	25
Production of vehicle and infrastructure	1.8	4.7	3.2	21	30	39	54
Total	**3.1**	**132**	**18**	**109**	**153**	**57**	**79**
Total according to Norm SN EN 16258	*1.4*	*127*	*15*	*87*	*122*	*18*	*25*

Basel - Paris

Table 15: Greenhouse gases, Basel–Paris, based on source of emissions

Kg CO_2-eq / Person	Train	Airplane	Coach	Passenger car Average	Passenger car Work	e-car Average	e-car Work
Direct emissions operation	0	90	10	56	78	0	0
Energy supply	1.2	19	2.8	22.0	31	16	22
Production of vehicle and infrastructure	1.5	4.0	2.9	19	27	35	48
Total	**2.7**	**113**	**16**	**97**	**136**	**50**	**71**
Total according to Norm SN EN 16258	*1.2*	*109*	*13*	*78*	*109*	*16*	*22*

Lausanne - Paris

Table 16: Greenhouse gases, Lausanne–Paris, based on source of emissions

Kg CO_2-eq / Person	Train	Airplane	Coach	Passenger car Average	Passenger car Work	e-car Average	e-car Work
Direct emissions operation	0	91	10	57	79	0	0
Energy supply	1.1	19	2.6	22.4	31	16	23
Production of vehicle and infrastructure	1.4	4.0	2.7	19	27	35	49
Total	**2.4**	**115**	**15**	**98**	**138**	**51**	**72**
Total according to Norm SN EN 16258	*1.1*	*111*	*12*	*79*	*111*	*16*	*23*

Lausanne - Marseille

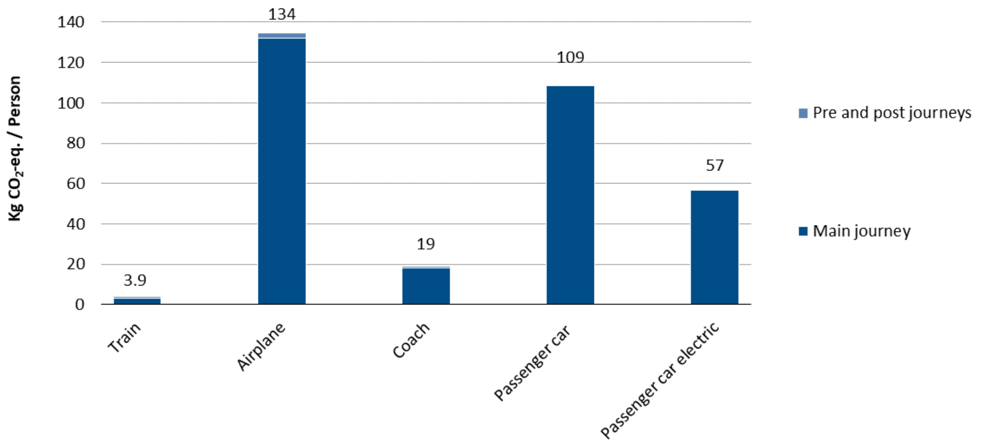
Table 17: Greenhouse gases, Geneva–Marseille, based on source of emissions

Kg CO_2-eq / Person	Train	Airplane	Coach	Passenger car Average	Passenger car Work	e-car Average	e-car Work
Direct emissions operation	0	74	10	62	87	0	0
Energy supply	1.3	16	2.8	24.5	34	18	25
Production of vehicle and infrastructure	1.7	3.3	2.8	21	30	38	54
Total	**2.9**	**93**	**16**	**108**	**152**	**56**	**79**
Total according to Norm SN EN 16258	*1.3*	*90*	*13*	*87*	*122*	*18*	*25*

Climate footprints per route with pre and post journeys

Zurich - Paris

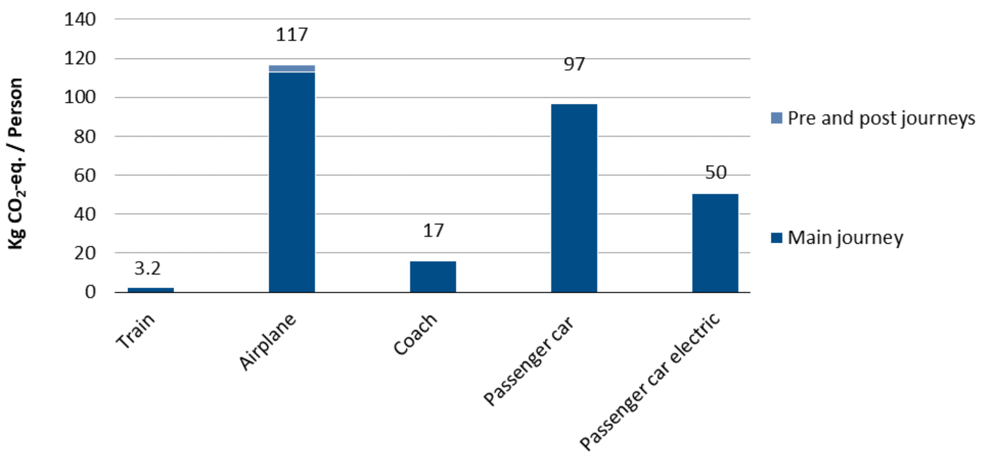
Figure 24: Average values per mode of transport (climate balance in CO_2 eq. per person and journey)



INFRAS graph.

Basel - Paris

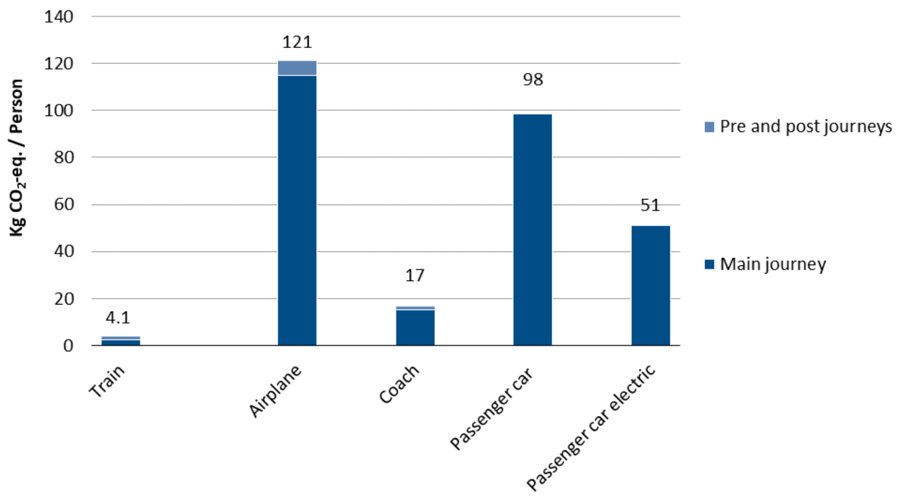
Figure 25: Average values per mode of transport (climate balance in CO_2 eq. per person and journey)



INFRAS graph.

Lausanne - Paris

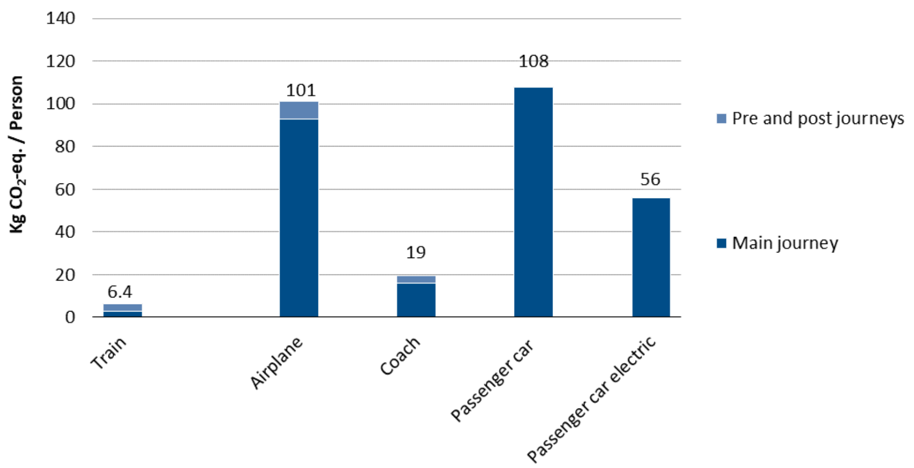
Figure 26: Average values per mode of transport (climate balance in CO_2 eq. per person and journey)



INFRAS graph.

Lausanne - Marseille

Figure 27: Average values per mode of transport (climate balance in CO_2 eq. per person and journey)

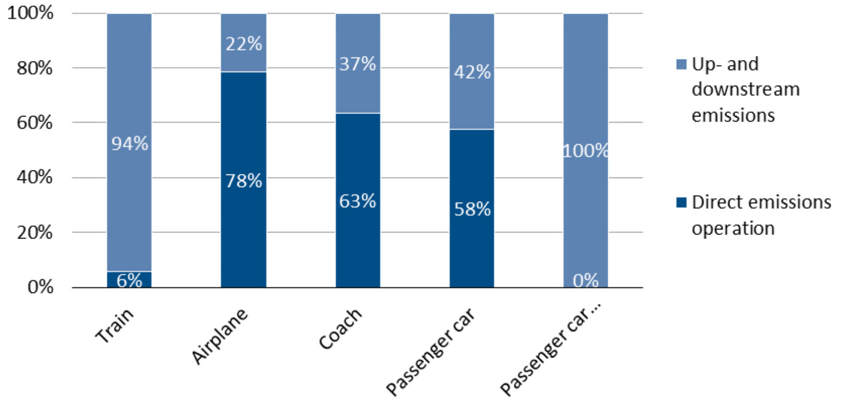


INFRAS graph.

Shares of upstream and downstream GHG emissions

Zurich - Paris

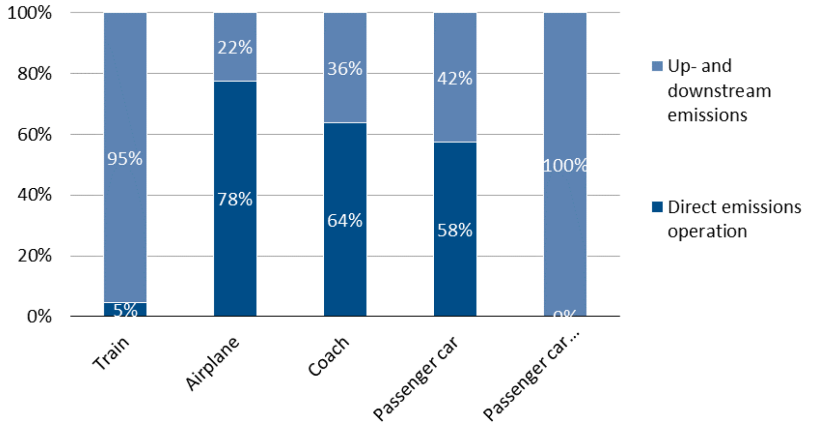
Figure 28: Zurich–Paris: Proportion of upstream and downstream greenhouse gas emissions in terms of overall greenhouse gas emissions



INFRAS graph.

Basel - Paris

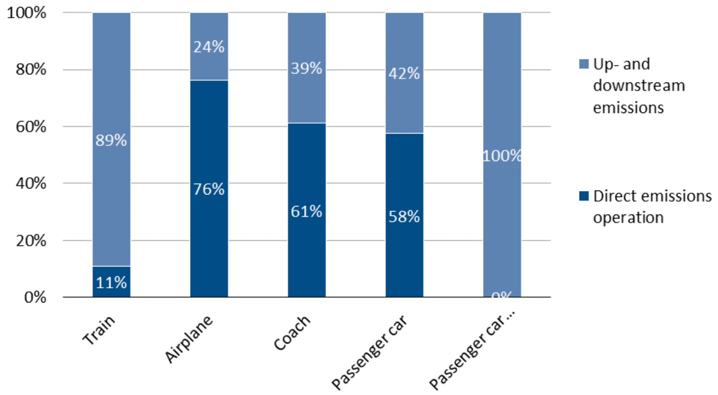
Figure 29: Basel–Paris: Proportion of upstream and downstream greenhouse gas emissions in terms of over-all greenhouse gas emissions



INFRAS graph.

Lausanne - Paris

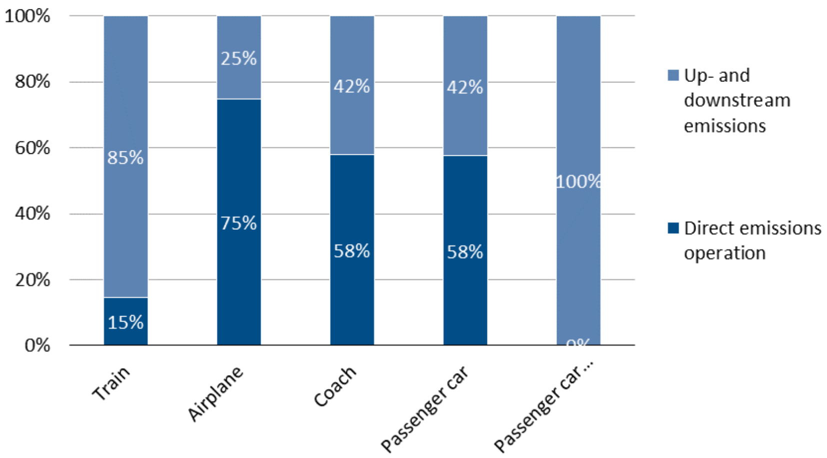
Figure 30: Lausanne–Paris: Proportion of upstream and downstream greenhouse gas emissions in terms of overall greenhouse gas emissions



INFRAS graph.

Lausanne - Marseille

Figure 31: Geneva–Marseille: Proportion of upstream and downstream greenhouse gas emissions in terms of overall greenhouse gas emissions

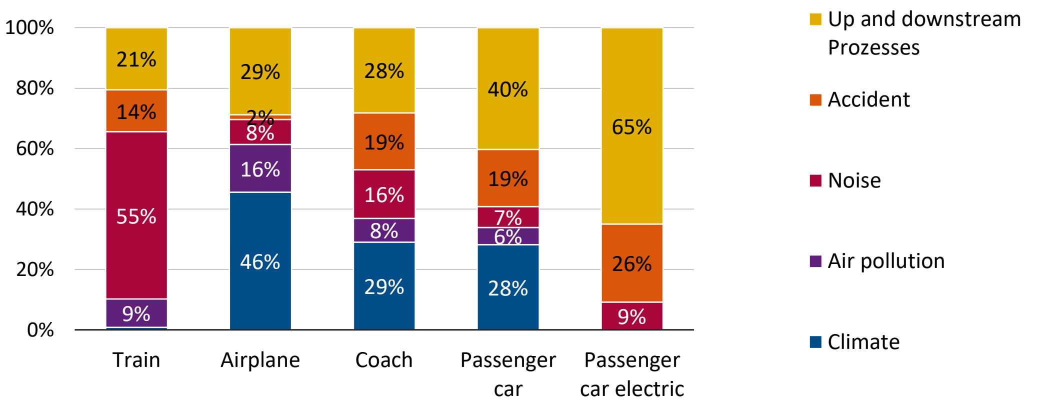


INFRAS graph.

Proportions for individual cost categories

Zurich - Paris

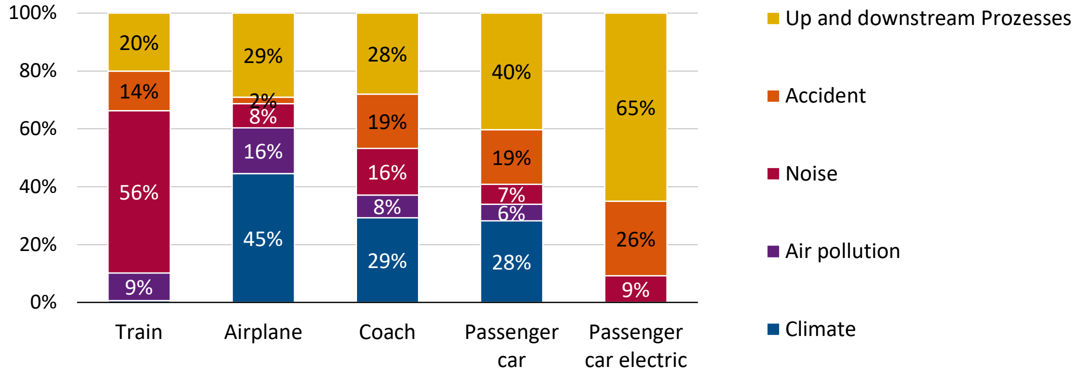
Figure 32: Zurich–Paris: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

Basel - Paris

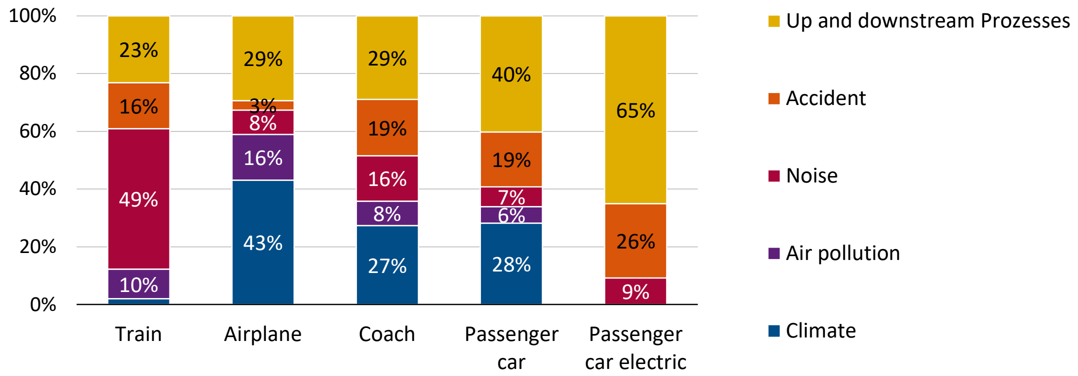
Figure 33: Basel–Paris: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

Lausanne - Paris

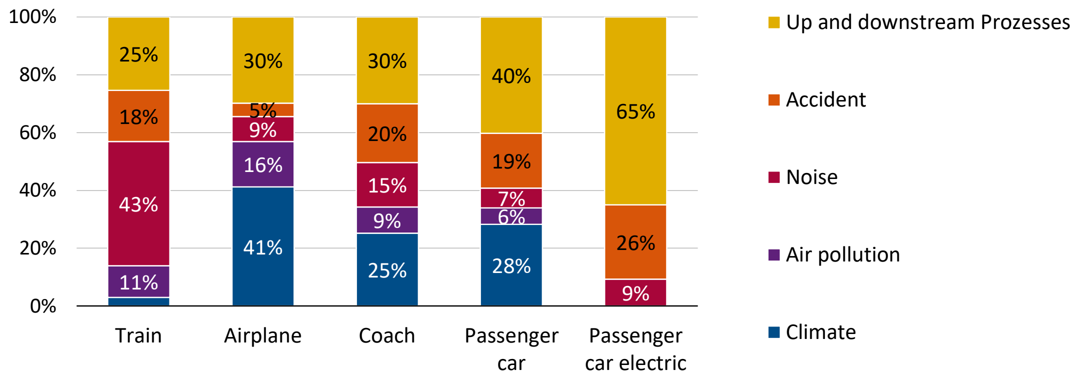
Figure 34: Lausanne–Paris: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

Lausanne - Marseille

Figure 35: Lausanne–Marseille: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

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