TGV Lyria

Ecological comparison of transport modes on selected routes

Final report
Zurich, 5 March 2021

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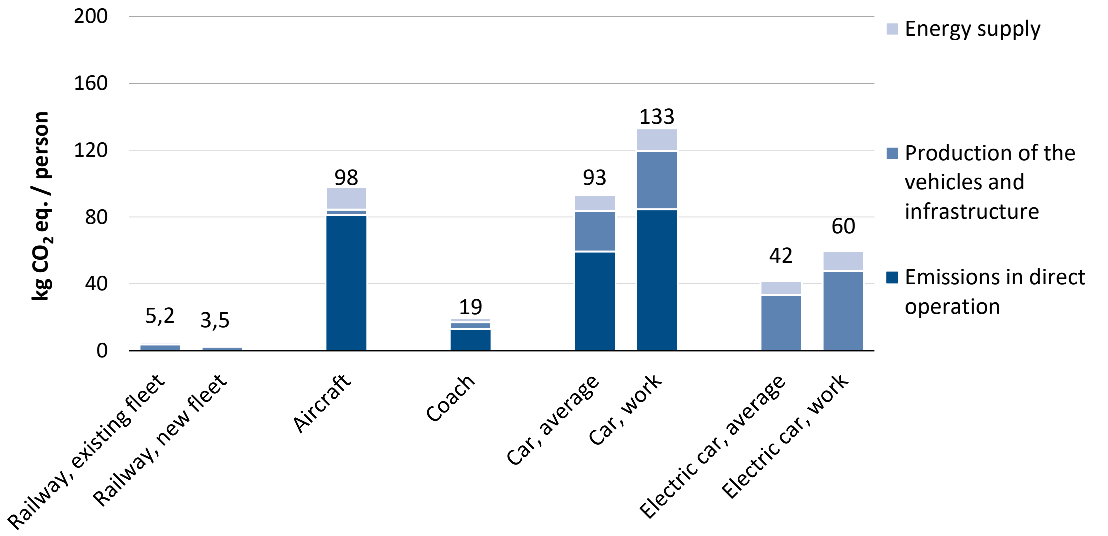
Summary

This study comprises an ecological comparison of transport modes on five transnational routes between Switzerland and France. INFRAS developed this comparison of transport modes based on current scientific findings and knowledge on behalf of TGV Lyria, and in accordance with the European standard SN EN 16258 for calculating the effects of transport services on the climate. All the routes considered are also served by TGV Lyria. The railway and more specifically the TGV is compared with the other modes of transport, i.e., coaches, cars and aircraft. Cars are differentiated by electric and conventional (petrol or diesel) engines. The study compares the various modes of transport with regard to climate footprint, final energy balance, environmental and accident costs as well as travel time, including usable working time. In a second step, the pre and post travel to the mode of transport, i.e., the journey to and from the station or airport, is always taken into account too. However, the results show that the main journey clearly dominates, and the climate and environmental impact of the pre and post travel is of secondary relevance for the overall result. For cars, a calculation is also made for a journey with lower occupancy (1.12 people per vehicle in accordance with the statistics for business travel compared with the average occupancy of 1.6 people per vehicle for general car travel).

Figure 1 shows, for example, the **climate footprint** for different modes of transport for the Geneva–Paris route.

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



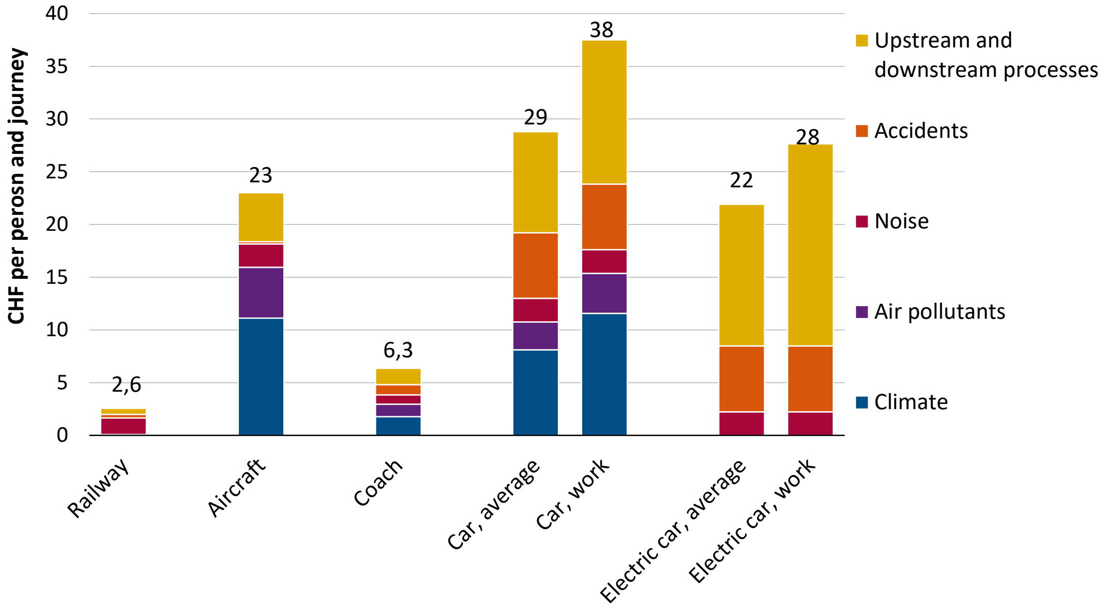
NFRAS graph.

The comparison of the climate footprint for the different modes of transport shows that the railway (TGV) causes by far the lowest CO_2 emissions per person and journey. The greenhouse gases emitted per person are around 4 to 6 times lower for a journey by TGV from Geneva to Paris (depending on whether it is the old or new fleet) than for the coach, around 8-12 times lower than for the average electric car, around 18 to 27 times lower than for the average conventional car, and around 19 to 28 times lower than for the flight. From the perspective of climate protection, a journey by TGV offers the greatest advantage on the routes surveyed. It should also be noted here that the electrically driven modes of transport, the TGV and the electric car, do not give out any direct emissions in operation, and only very low emissions in terms of energy production (electricity). The major part of the emissions from both modes of transport come from the production of the infrastructure and vehicles[1].

The environmental impacts, such as greenhouse gas emissions, create costs that are not borne by the polluter but by the general public. So-called external costs or **environmental costs and accident costs** are also calculated and compared for journeys with the various modes of transport. Figure 2, for example, shows the results for the Geneva–Paris route.

[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 CO_2 than a flight on the same route.

Figure 2: Environmental and accident costs by transport mode per person and journey on the Geneva – Paris route



INFRAS graph.

The result shows that for environmental and accident costs too, the rail journeys with TGV Lyria generate the lowest environmental costs per person and journey. 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-and-a-half times higher than those for the TGV, those for the electric car are almost 8 times as high, those for flights also around 9 times as high and those for the conventional car approximately more than 11 times as high as for the TGV.

In the **overall comparison** of the long-distance traffic routes under consideration, the railway or TGV Lyria comes out best in all areas and for all routes. The TGV clearly leads the way in respect of the climate footprint as well as the environmental and accident costs. With regard to the environment, however, the closest to the railway are coaches, which have greenhouse gas emissions and environmental costs that are still considerably higher. The car and aircraft show a considerably poorer climate and environmental footprint than the railway (TGV Lyria). Indeed, electric cars demonstrate a better climate footprint and lower environmental costs than petrol and diesel cars. However, the climate footprint and environmental costs of the electric car on the routes surveyed come out higher than for the TGV. The railway therefore retains a clear environmental advantage compared to the car in international long-distance traffic, even with the progressive electrification of the car. Just as significant is the environmental advantage of the railway compared to flying.

1. Initial position and objective

In the context of the discussion regarding climate, the ecological comparison of various modes of transport for long-distance travel becomes more significant. What is paramount here is the climate footprint of modes of transport in particular. Besides the climate effects, traffic leads to a whole range of other negative environmental impacts (air pollutant emissions, noise, accidents, etc.). These negative effects engender economic costs, so-called external costs or environmental costs.

In Switzerland and abroad there are various studies comparing climate impact, other environmental effects and the external environmental costs of different modes of transport with one another. However, in most studies, the focus is placed on overall effect for a country (thus, for example, the total greenhouse gas emissions or the full environmental costs) or the average impact for a whole country (for instance, the effects of an average passenger kilometre in Switzerland). Figures for the comparison of transport modes for specific routes (e.g., Zurich–Paris), on the other hand, have scarcely been available up to now. Some tools enable such comparisons but environmental costs are not taken into consideration, for example, and the bases are not usually adjusted for the specified route (i.e., no data for the TGV, for example).

In the context of this study, a comparison of different modes of transport has therefore been undertaken for specific routes that are served by TGV Lyria. The comparison includes the following parameters:

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

The study is based on the latest scientific findings and knowledge (with regard to climate emissions, environmental costs, etc.). The results represent a basis for further communication of 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), and an energy balance 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 limits

The reference year for the calculations in this ecological transport mode comparison is 2019. 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

In a first stage, 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 or from airport to airport. In a first step, only these main journeys are compared with one another in the climate and energy footprint. A second step gives a definition of the other vehicles besides the main modes of transport (aircraft, railway, car and coach) taken into account for the door-to-door comparison has to be considered. This is required because passengers have a choice of different modes of transport (e.g., tram or taxi) at the end point to reach the target destination (to the “door”, i.e., to the location of the meeting for business travellers or to their accommodation for leisure travellers). Table 1 shows the five different routes and the pre and post journeys in each case. 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. The cars go directly from door to door and there is therefore no pre and post journey.

Table 1: Routes under consideration, including pre and post journey

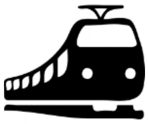
Route	From	to	Main mode of transport	Notes on the main journey
Geneva–Paris	Geneva city centre	Paris city centre	Railway	Geneva Cornavin–Paris Gare de Lyon
Geneva–Paris	Geneva city centre	Paris city centre	Aircraft	Geneva Airport (GVA)–Paris Charles de Gaulle (CDG)
Geneva–Paris	Geneva city centre	Paris city centre	Coach	Geneva ZOB–Paris Bercy Seine
Geneva–Paris	Geneva city centre	Paris city centre	Car	From door to door by car
Zurich–Paris	Zurich city centre	Boulogne-Billancourt	Railway	Zurich main station–Paris Gare de Lyon
Zurich–Paris	Zurich city centre	Boulogne-Billancourt	Aircraft	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	Car	From door to door by car
Basel–Paris	Reinach	Paris city centre	Railway	Basel SBB–Paris Gare de Lyon
Basel–Paris	Reinach	Paris city centre	Aircraft	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	Car	From door to door by car
Lausanne–Paris	Montreux	Paris city centre	Railway	Lausanne SBB–Paris Gare de Lyon
Lausanne–Paris	Montreux	Paris city centre	Aircraft	Geneva Airport (GVA)–Paris Charles de Gaulle (CDG)
Lausanne–Paris	Montreux	Paris city centre	Coach	Lausanne P+R Velodrome–Paris Bercy Seine
Lausanne–Paris	Montreux	Paris city centre	Car	From door to door by car
Geneva–Marseille	Nyon	Marseille city centre	Railway	Geneva Cornavin–Marseille-Saint-Charles
Geneva–Marseille	Nyon	Marseille city centre	Aircraft	Geneva Airport (GVA)–Marseille Provence (MRS)
Geneva–Marseille	Nyon	Marseille city centre	Coach	Geneva ZOB–Marseille-Saint-Charles
Geneva–Marseille	Nyon	Marseille city centre	Car	From door to door by car

INFRAS table.

Modes of transport under consideration

When making the comparison for the journeys, the main vehicles shown in Table 2 were surveyed and compared with one another.

Table 2: Modes of transport under consideration

Modes of transport	Notes
	All routes are operated directly by TGV Lyria. The railway is therefore represented by a TGV train for the main journey. In December 2019, new rolling stock was introduced, offering more seats. The number of passengers per train for the new trains was set according to the economic expectations and presented as a comparison with the future situation for certain analyses and graphs (in the main body of the report for the Geneva - Paris route, for the other routes see annex). The basis for the calculations is derived from the previous trains, however, for which occupancies are known.
	The aircraft which were deployed on the routes surveyed were represented by a variety of different types of model and their key figures. The same applies to the occupancy of the aircraft, which also corresponds to an average of the flights made on the routes (Atmosfair 2019). The highest proportion were Airbus 318, 319 and 320 aircraft types.
	The coaches were represented by average touring coaches. One problem with the coaches is that many journeys are made overnight and the travel time is therefore much longer than by car. The capacities correspond with a European average (DG MOVE 2019).
	With cars, two different engine types were compared. On the one hand, combustion engines, represented by the Swiss fleet average, and on the other hand battery-electric vehicles. The occupancy figures for the vehicles come from the Swiss Microcensus Traffic and Mobility, 2015 (ARE 2018). The capacity utilisations in France are similar to those in Switzerland, so that the comparison can also be applied to France. The same applies for battery-electric vehicles (power mix). In the climate footprint, the power mix used to charge the battery naturally has an effect on the emissions. With regard to greenhouse gases, the power mix consumed in Switzerland is similar to that in France. Switzerland has a high proportion of hydroelectric power and nuclear power, and in France mainly nuclear power is used. Both have relatively low CO_2 emissions (compared to fossil fuel sources). In addition, for the design of vehicles and batteries, a European average and not a country-specific power mix is assumed.

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Distances and travel times for routes for each mode of transport

An important basis for energy, climate and cost calculations is the passenger kilometres travelled by the different modes of transport. As the results are presented per person and journey, the distances multiplied by the occupancies of the different modes of transport give the passenger kilometres. The distances of the routes originate from various sources. The railway kilometres come from the online platform TGV Lyria, the flight distances from www.greatcircle-mapper.net and the car distances from www.googlemaps.com. Google Maps was used for the distances of the pre and post journeys. The railway and coaches involve the same distances for the pre and post journeys, as the bus stations are in the immediate vicinity of the train stations. For the airports, the pre and post journeys are somewhat longer, as these are always located further away. If the city centre counts as the place of arrival or departure, the calculation of the pre or post journey is simplified as 2 km.

An additional analysis was carried out which compares the amount of travel time which can be used as working time for the different modes of transport. Only the relevant modes of transport that are relevant for business travel were compared with one another. The results of this analysis are presented in Chapter 3.4. The travel times come from the official timetables, and those for cars from Google Maps. Multiple searches were made on different days of the week and different times of day to do this, and an average was calculated. For flight times, the travel times differ depending on the direction of the flight. Travel from Switzerland to France was always selected for these analyses. Delays, strikes, congestion times and other negative impacts were not taken into account.

Table 3: Distances of the routes surveyed

Route	Main mode of transport	Main journey	Pre journey	Post journey	Entire route	Travel time
			Kilometres			Minutes
Geneva–Paris	Railway	503	2	2	507	245
	Aircraft	457	5	28	507	169
	Coach	538	2	2	542	545
	Car	547	0	0	490	315
Zurich–Paris	Railway	617	2	12	631	293
	Aircraft	525	8	38	571	163
	Coach	650	2	12	664	650
	Car	602	0	0	602	385
Basel–Paris	Railway	526	8	2	536	214
	Aircraft	449	42	28	519	148
	Coach	573	8	2	583	546
	Car	537	0	0	583	351
Lausanne–Paris	Railway	480	30	2	512	252
	Aircraft	457	93	28	512	170
	Coach	535	30	2	567	507
	Car	545	0	0	545	357
Geneva–Marseille	Railway	476	23	2	501	242
	Aircraft	370	26	24	459	221
	Coach	461	23	2	486	480
	Car	459	0	0	459	269

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Emission and energy calculations

In the climate footprint, the direct operation as well as the upstream and downstream processes are taken into account. For the energy balance, the final energy is summed up. This means that only the energy efficiency of the vehicle is considered. The energy systems behind it are not considered in the energy balance.

For the climate footprint, all greenhouse gases for direct operation and advance processes in the form of CO_2 equivalents were taken into consideration. This means the following: in direct operation only combustion engines which use fossil fuels cause greenhouse gases. Therefore, the combustion of petrol or diesel by cars and coaches or kerosene by aircraft was factored in. The greenhouse gases of the upstream and downstream processes come from the production of electricity or fuels (electricity, petrol, diesel or kerosene) on the one hand, and from the production, maintenance and disposal of vehicles and infrastructure on the other hand. For the TGV, the French and Swiss power mix was used on a weighted basis. For the electric car, the Swiss power mix was applied. This can also be applied to France because, in terms of the climate footprint, the power mix in France does not differ greatly from that in Switzerland. In addition, a large part of the greenhouse gas emissions in the climate footprint of electric cars can be attributed to the production of vehicles (and batteries). A European average is applied for all countries for the power mix used in production. Consequently, the influence of the power mix consumed in Switzerland and France is relatively small. For the pre and post journeys, weighted emission factors were calculated according to the mode of transport. The basis for the weighting was a survey of customers of TGV Lyria, who identified the mode of transport they used for travelling to stations. These consisted of public transport (trams, local buses, local rail or underground services, etc.), travel on foot or by bike or car. As no surveys were available for the bus stations and airports, the weighted emissions factor was also used for the pre and post journeys to the airports and bus stations. As the survey was conducted in France and Switzerland, a weighted emissions factor could be calculated for the pre journeys in Switzerland and the post journeys in France.

One important point relates to air traffic. For the conversion of CO_2 equivalents, an RFI[2] was taken into account, 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 which has to be used for the journeys. Renewable and non-renewable energy sources are not differentiated here and are all presented as kilogramme petrol equivalents. Table 4 shows the sources of emission factors which were used for the calculations of the climate footprint and energy balance.
The emission factors for air pollutants given in Table 4 are required for the calculation of the environmental costs and are therefore also listed here, as these usually come from the same sources as the emissions factors of the 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 twice 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 4: Information bases for the emissions factors applied

Main mode of transport	Sources of the emissions factors Direct operation	 Upstream and downstream processes
Railway	▪ PM10 non-exhaust: Ecoinvent 3.5 ▪ Energy consumption: operating data for TGV Lyria	▪ CO_2 eq.: operating data for TGV Lyria ▪ Air pollutants: EcotransitWorld and Mobitool 2.2 ▪ Energy consumption: Mobitool v2.2
Aircraft	▪ CO_2 eq.: Atmosfair GmbH 2019 ▪ Air pollutants: Ecoinvent 3.5 ▪ Energy consumption: Atmosfair GmbH 2019	▪ CO_2 eq.: Atmosfair GmbH 2019 ▪ Air pollutants: Ecoinvent 3.5 ▪ Energy consumption: Mobitool v2.2
Coach	▪ CO_2 eq.: HBEFA 4.1 ▪ Air pollutants: HBEFA 4.1 ▪ Energy consumption: HBEFA 4.1	▪ CO_2 eq.: Ecoinvent 3.5 ▪ Air pollutants: Ecoinvent 3.5 ▪ Energy consumption: Mobitool v2.2
Conventional car	▪ CO_2 eq.: HBEFA 4.1 ▪ Air pollutants: HBEFA 4.1 ▪ Energy consumption: HBEFA 4.1	▪ CO_2 eq.: Ecoinvent 3.5 ▪ Air pollutants: Ecoinvent 3.5 ▪ Energy consumption: Mobitool v2.2
Battery-electric car	▪ CO_2 eq.: INFRAS, Quantis 2020 ▪ Air pollutants: INFRAS, Quantis 2020 ▪ Energy consumption: INFRAS, Quantis 2020	▪ CO_2 eq.: INFRAS, Quantis 2020 ▪ Air pollutants: INFRAS, Quantis 2020 ▪ Energy consumption: INFRAS, Quantis 2020

INFRAS table.

Bases for environmental and accident costs

All environmental costs are composed of five different cost categories. Table 5 shows these cost categories and describes what they include.

Table 5: Cost categories taken into account

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)
Noise costs	Noise-related health costs and costs due to noise pollution (damage costs)

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Based on the climate footprint and air pollutant emissions calculated, the environmental costs were worked out using specific cost rates. The same procedure was also applied for the upstream and downstream processes. These processes also take account of greenhouse gases and air pollutants. The climate cost rate comes from the annually updated report from the Federal Office for Spatial Development, “Costs and benefits of traffic in Switzerland, 2016” (ARE 2019). The cost rate has been updated to 2019 and totals CHF 137 per tonne of CO_2. The cost rates for air pollutants come from the publication, “Handbook of the external cost of transport” from the European Commission (DG MOVE 2019). The handbook includes cost rates for all important air pollutants for all European countries. These have also been updated to 2019.

A rather different approach was taken for accident and noise costs. This was not calculated via a quantity structure which was then monetarised using cost rates. They were worked out directly from typical accident and noise cost rates per passenger kilometre. These are also taken from the “Handbook of the external cost of transport” from the European Commission (DG MOVE 2019). This involves country-specific costs rates for France. For the cost rates for the railway, specific values were derived for high-speed trains in the EU study. Even though there have not been any railway or air accidents on the routes under consideration in the last ten years, the relevant average values were used for reasons of consistency. However, the accident costs for railway and air are negligible. For road modes of transport, no precise accident figures are available for the routes under consideration either, which means that average values have been calculated for this too.

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. The greenhouse gas emissions 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 16258[3], only the emissions from direct operation and those from the energy supply have to 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. That is, 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.

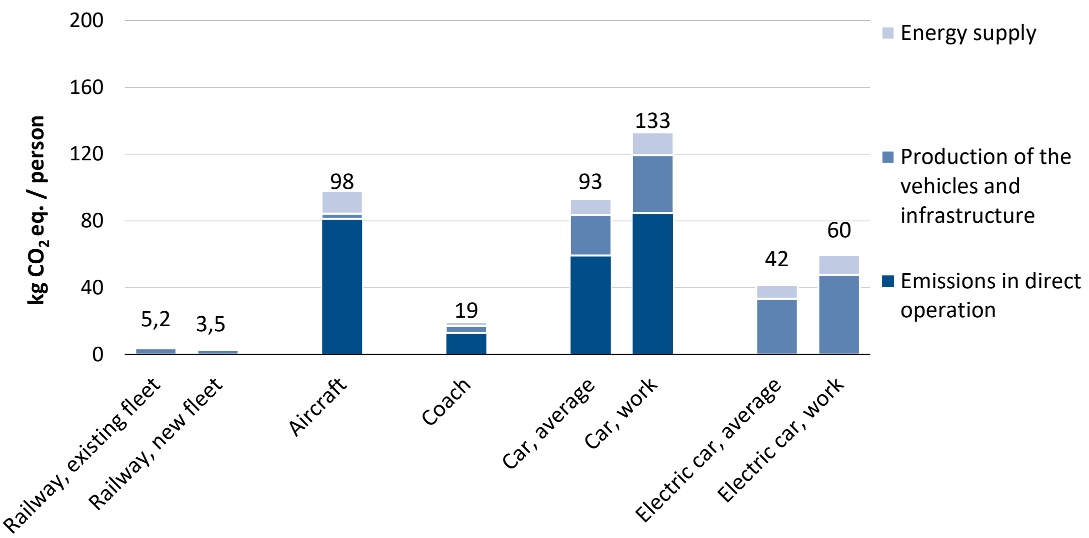
Geneva–Paris

Figure 3 shows the results of the climate footprint for the Geneva–Paris route for the modes of transport under consideration. The kilogramme CO_2 equivalents per person and journey are presented, broken down by energy supply, production of the vehicles and infrastructure and according to the emissions from direct operation. For the car, two different occupancies are also given. “Business” means that a lower occupancy of 1.12 persons per vehicle (according to statistics for business trips) was calculated, in place of the average value of 1.6 persons per vehicle for general car travel (ARE 2018).

For the journey from Geneva to Paris (city centre to city centre), the TGV with its previous fleet caused the lowest emissions per person and journey (5.2 kg CO_2 equivalent). If the expectations for the occupancy of the new fleet are fulfilled, this value will decrease even further to around 3.5 kg CO_2 equivalent per person and journey. The mode of transport with the next highest emissions per person and journey is the coach at approximately 19 kg CO_2 equivalent, followed by the electric car at about 42 kg CO_2 equivalent. The highest greenhouse gas emissions per person and journey were emitted by the conventional car (93 kg CO_2 equivalent) and the aircraft (98 kg CO_2 equivalent).

[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.

Figure 3: Climate footprint for Geneva–Paris: CO_2 equivalents per person and journey for different modes of transport



INFRAS graph.

Table 6 shows the emissions broken down according to their origin. It becomes apparent here that the electrically driven modes of transport, railway and electric car, do not generate any direct emissions.

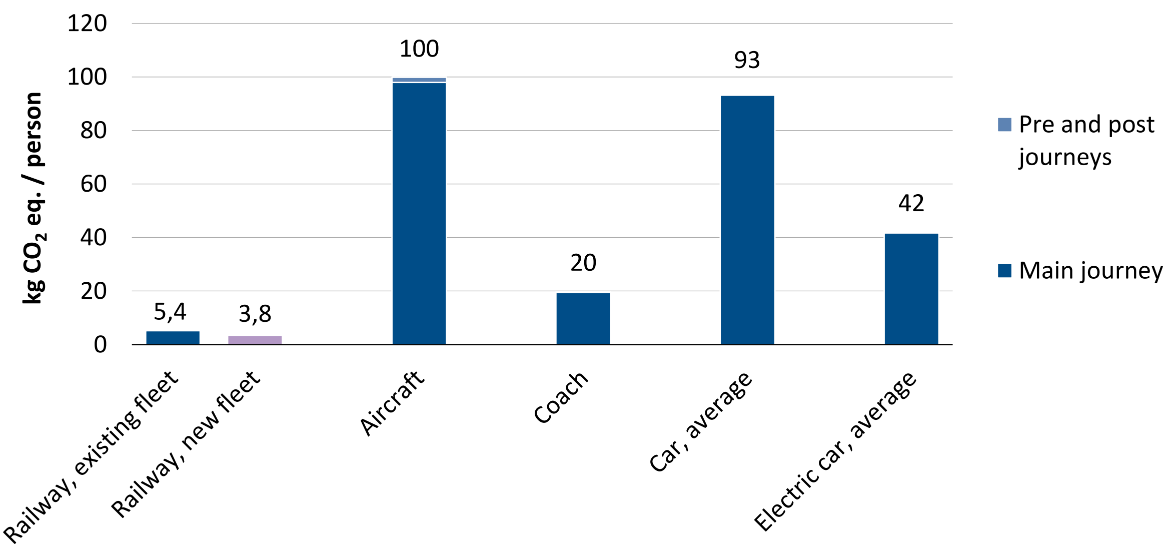
According to the standard SN EN 16258 only the emissions from direct operation and those from the energy supply have to be shown. With the train, at 1.4 kg CO_2 equivalent per person (old fleet) or 0.9 kg CO_2 equivalent (new fleet), the traction accounts for around a quarter of the total emissions. The rest comes from the production of the vehicles and the infrastructure. This proportion is reversed for the example with flights. Here, direct emissions and energy supply together make up around 97% of the direct emissions with approximately 95 kg CO_2 equivalent per person. In ecological comparisons of modes of transport, often only the parameters required by the standard are taken into account, which is why a journey by train emits around 70 to 100 times less in terms of CO_2 equivalent than a flight on the same route. It looks similar for the car, but not quite so pronounced, in that with combustion the energy supply and the direct emissions together account for a considerably higher proportion of the total emissions than with the electric car.

Table 6: Greenhouse gases, Geneva–Paris, according to source of emissions

kg CO_2 eq. / person	Railway, existing fleet	Railway, new fleet	Aircraft	Coach	Car, average	Car, work	Electric car, average	Electric car, work
Emissions in direct operation	0	0	81	13	59	85	0	0
Energy supply	1,4	0,9	14	2,5	9,6	14	8	12
Production of the vehicles and infrastructure	3,8	2,6	3,1	4,0	24	35	33	48
Total	**5,2**	**3,5**	**98**	**19**	**93**	**133**	**42**	**60**
Total according to the standard SN EN 16258	*1,4*	*0,9*	*95*	*15*	*69*	*98*	*8*	*12*

Figure 4 shows the same comparison as above but with a pre and post journey. That is, a so-called door-to-door comparison was made here, and in each case the journeys from and to the station, airport or coach station were taken into account (see Table 3 for details). What is striking is that the proportion of the pre and post journeys is very small in terms of overall emissions. As a proportion, the highest are the greenhouse gas emissions from the pre and post journeys for the railways, at approximately 15% (in the graph, this is barely discernible due to the very low absolute values for the railway). For aircraft this is around 2%, and for the coach about 3.5%.

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

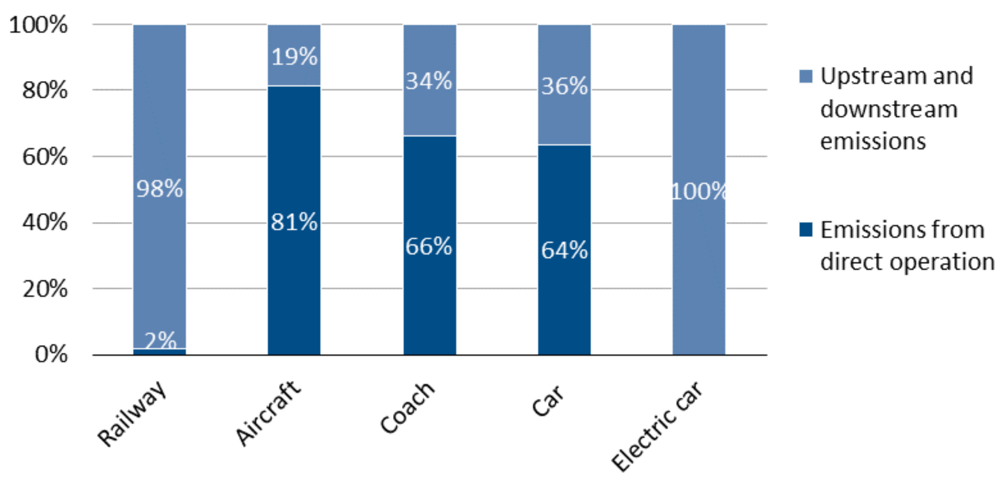


INFRAS graph.

Figure 5 shows the proportions of upstream and downstream greenhouse gas emissions in terms of all greenhouse gas emissions for a journey from Geneva to Paris (including pre and post journey). The upstream and downstream processes include production, maintenance and disposal of the vehicles, the infrastructure and the energy.

No greenhouse gas emissions are generated for electric cars during the journey. Therefore, 100% of the greenhouse gas emissions are created from upstream and downstream processes. Production, maintenance and disposal of the vehicles, the infrastructure and power are all upstream and downstream processes. With the railway, around 98% of the greenhouse gas emissions are caused by the upstream and downstream processes, and about 2% by direct operation. The emissions from direct operation all come from the pre and post journeys (e.g., bus journey to the station). The main journey by railway does not cause any greenhouse gas emissions either. With the conventional car, around 36% of the greenhouse gas emissions originate from the upstream and downstream processes. For the coach this is about 34%, and for the journey by aircraft approximately 19%.

Figure 5: Proportion of upstream and downstream greenhouse gas emissions in terms of all greenhouse gas emissions

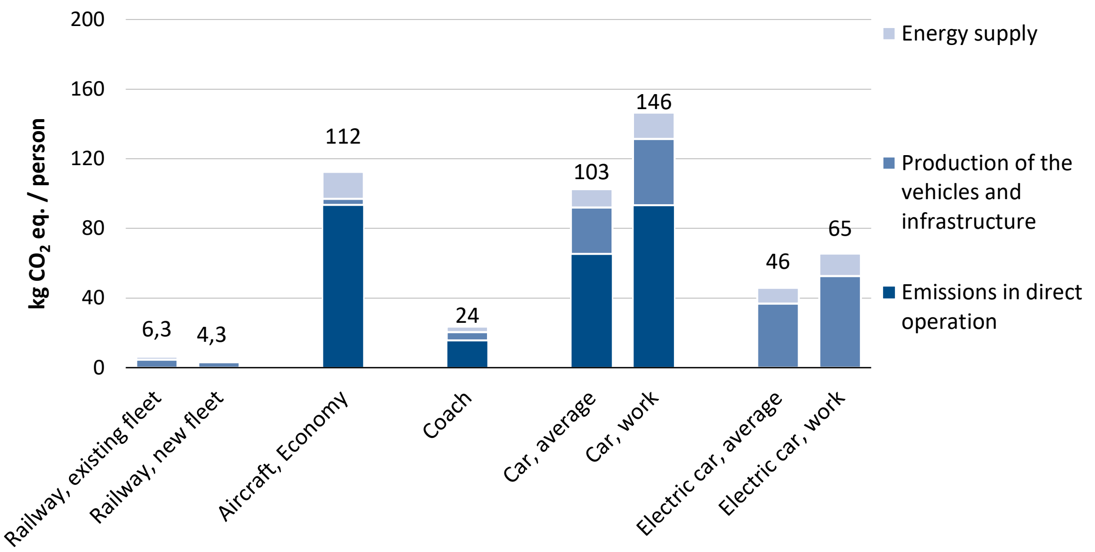


INFRAS graph.

Zurich–Paris

The journey by TGV from Zurich to Paris caused around 6.3 kg CO_2 equivalent per person and journey. Travelling on the new fleet today leads to greenhouse gas emissions of about 4.3 kg CO_2 equivalent. A journey by coach from Zurich to Paris causes somewhat higher emissions per head at approximately 24 kg CO_2 equivalent. Travelling by electric car causes around 46 kg CO_2 equivalent, and with a conventional combustion engine this is around 103 kg CO_2 equivalent. With lower occupancy (e.g., business trips), the emissions per head increase to an average of 65 kg CO_2 equivalent for an electric car, and to 146 kg CO_2 equivalent for a conventional car. The highest emissions are generated per person and journey by the aircraft at 112 kg CO_2 equivalent.

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

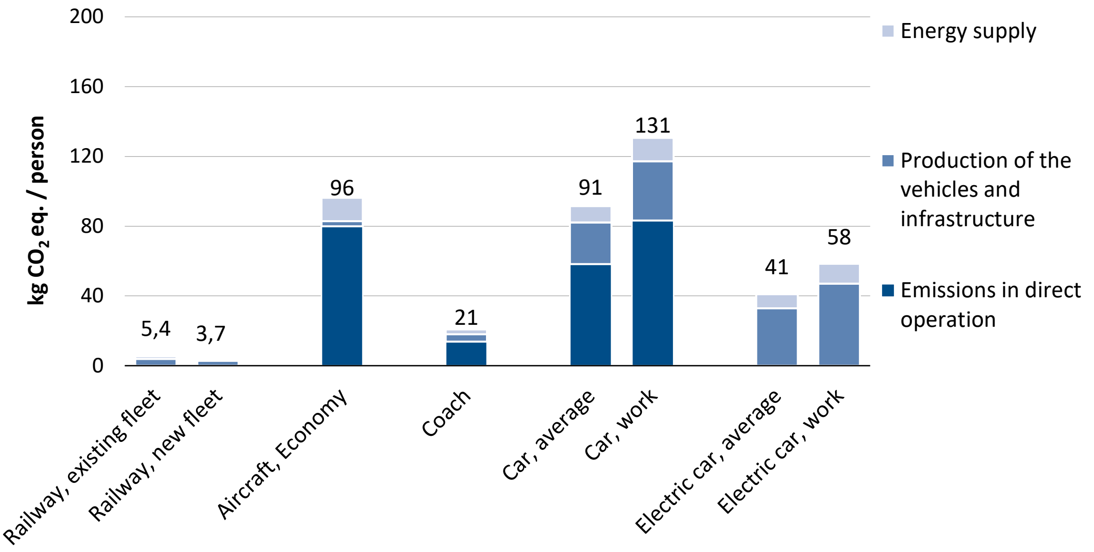


INFRAS graph.

Basel–Paris

A comparison for the journey from Basel to Paris of greenhouse gas emissions of different modes of transport, shows that the TGV causes the lowest greenhouse gas emissions per person and journey at 5.4 kg CO_2 equivalent. With the new TGV fleet, the greenhouse gas emissions per person and journey decrease to 3.7 kg CO_2 equivalent. A journey by coach gives 21 kg CO_2 equivalent per person. By car, a journey by conventional car per person generates around 91 kg CO_2 equivalent and a journey by electric car somewhat less than half of this (41 kg CO_2 equivalent). With the car occupancy for business travellers, the greenhouse gas emissions increase to 131 kg CO_2 equivalent (fossil fuel powered car) and 58 kg CO_2 equivalent (electric car). The highest greenhouse gas emissions per person are created by the aircraft at 96 kg CO_2 equivalent.

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

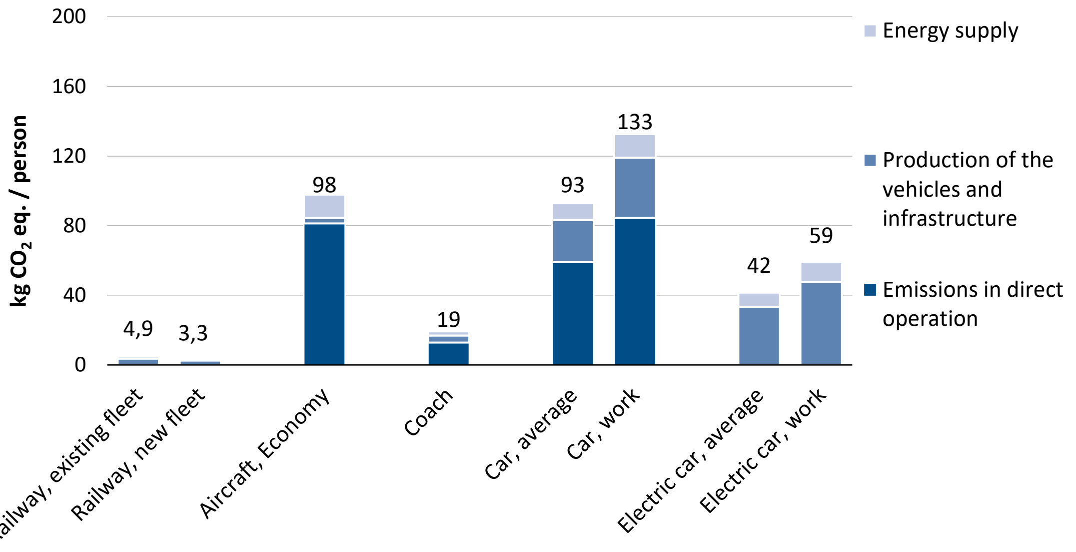


INFRAS graph.

Lausanne–Paris

For the journey from Lausanne to Paris, the TGV creates the lowest greenhouse gas emissions per person and journey at 4.9 kg CO_2 equivalent. With the new TGV fleet, the greenhouse gas emissions per person and journey decrease to 3.3 kg CO_2 equivalent. A journey by coach creates 19 kg CO_2 equivalent per person. By car, a journey in a conventional car generates around 93 kg CO_2 equivalent per person, and a journey in an electric car somewhat less than half (42 kg CO_2 equivalent). With the car occupancy of business travellers, the greenhouse gas emissions rise to 133 kg CO_2 equivalent (fossil fuel powered car) and 59 kg CO_2 equivalent (electric car). The highest greenhouse gas emissions per person are generated by the aircraft at 98 kg CO_2 equivalent.

Figure 8: Climate footprint, Lausanne–Paris: CO_2 equivalents per person and journey for different modes of transport

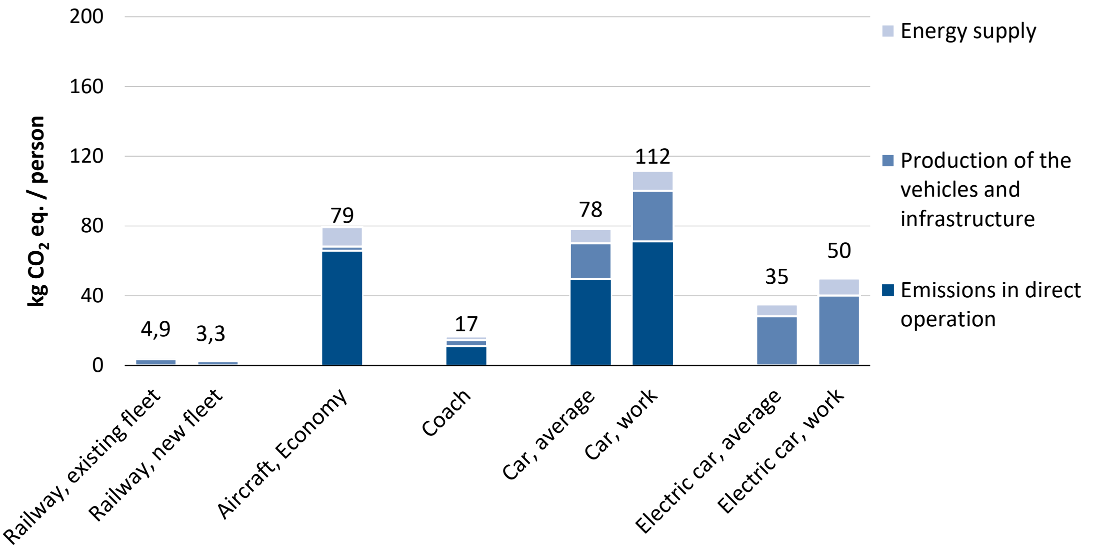


INFRAS graph.

Geneva–Marseille

For the journey from Geneva to Marseille the TGV generates the lowest greenhouse gas emissions per person and journey at 4.9 kg CO_2 equivalent. With the new TGV fleet, the greenhouse gas emissions per person and journey decrease to 3.3 kg CO_2 equivalent. A journey by coach creates 17 kg CO_2 equivalent per person. By car, a journey by conventional car produces around 78 kg CO_2 equivalent per person, and a journey by electric car somewhat less than half of this (35 kg CO_2 equivalent). With the car occupancy for business travellers, the greenhouse gas emissions increase to 112 kg CO_2 equivalent (fossil fuel powered car) and 50 kg CO_2 equivalent (electric car). The highest greenhouse gas emissions per person are caused by the aircraft at 79 kg CO_2 equivalent.

Figure 9: Climate footprint, Geneva–Marseille: CO_2 equivalents per person and journey for different modes of transport



INFRAS graph.

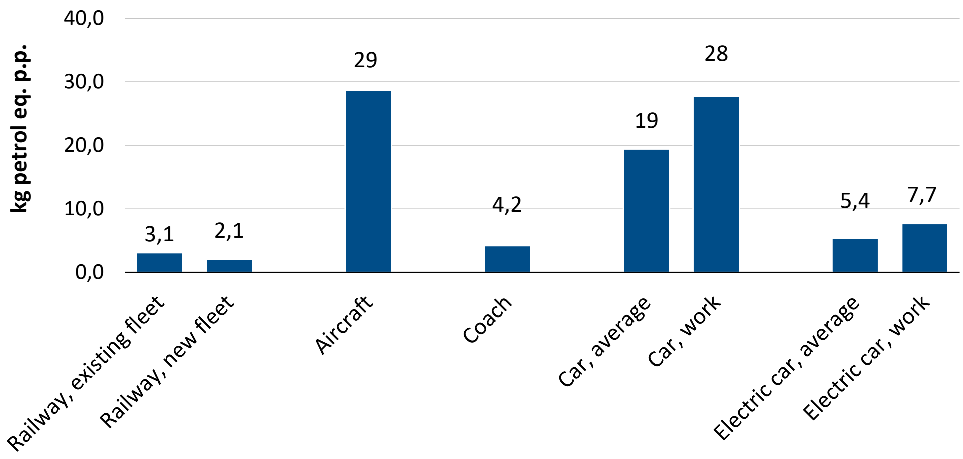
3.2. Final energy balance

The energy used per person and journey is assessed in the final energy balance. The final energy is typically converted into kilogramme 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.

Geneva–Paris

In comparison with the modes of transport surveyed, the existing TGV Lyria fleet shows the lowest final energy consumption on the Geneva–Paris route, with around 3.1 kg petrol equivalent per person and journey. With the new fleet, which has been in operation since the end of 2019, an even lower final energy consumption of around 2.1 kg petrol equivalent is to be expected. The coach consumes about 4.2 kg petrol equivalent per person and journey, and the electric car around 5.4 kg petrol equivalent. With cars, the energy consumed increases in the case of a lower occupancy for business travel at 7.7 (electric car) or 28 kg petrol equivalent (fossil fuel driven car). With final energy consumption per person and journey too, aircraft (29 kg petrol equivalent) consume the most energy.

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

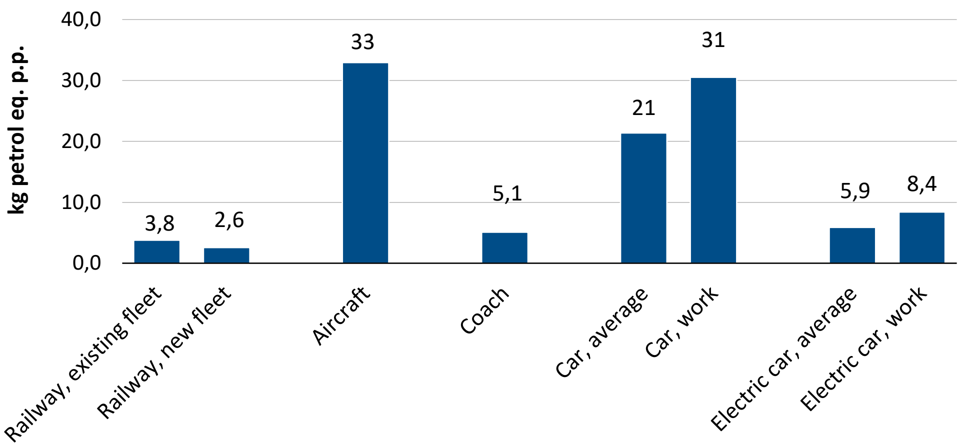


INFRAS graph.

Zurich–Paris

Figure 11 shows the final energy consumption per person and journey from Zurich to Paris. The railway journey by TGV (new fleet), at around 2.6 kg petrol equivalent, has the lowest energy consumption per person (existing fleet, about 3.8 kg petrol equivalent). The energy consumption of the coach around twice as high at 5.1 kg petrol equivalent, and the same applies to an averagely occupied electric car at almost 6 kg petrol equivalent. The conventional car consumes around 21 kg petrol equivalent and for the aircraft this is about 33 kg petrol equivalent. With the cars, the energy consumption increases; in the case of a lower occupancy for business travel to 8.4 kg (electric car) and 31 kg petrol equivalent (fossil fuel powered car).

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

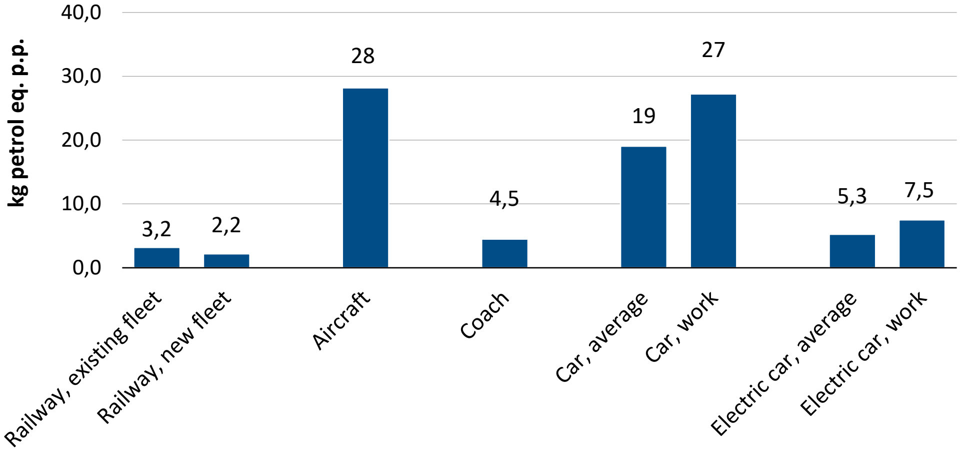


INFRAS graph.

Basel–Paris

12 shows the final energy consumption per person and journey from Basel to Paris. The railway journey (new fleet), at around 2.2 kg petrol equivalent, has the lowest energy consumption per person (existing fleet, around 3.2 kg petrol equivalent). The energy consumption of the coach is around twice as high at 4.5 kg petrol equivalent, and the same applies to an averagely occupied electric car at about 5.3 kg petrol equivalent. The conventional car consumes approximately 19 kg petrol equivalent, and for the aircraft this is about 27 kg petrol equivalent. With the cars, the energy consumption increases; in the case of lower occupancy for business travel to 7.5 kg (electric car) and 27 kg petrol equivalent (fossil fuel powered car).

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

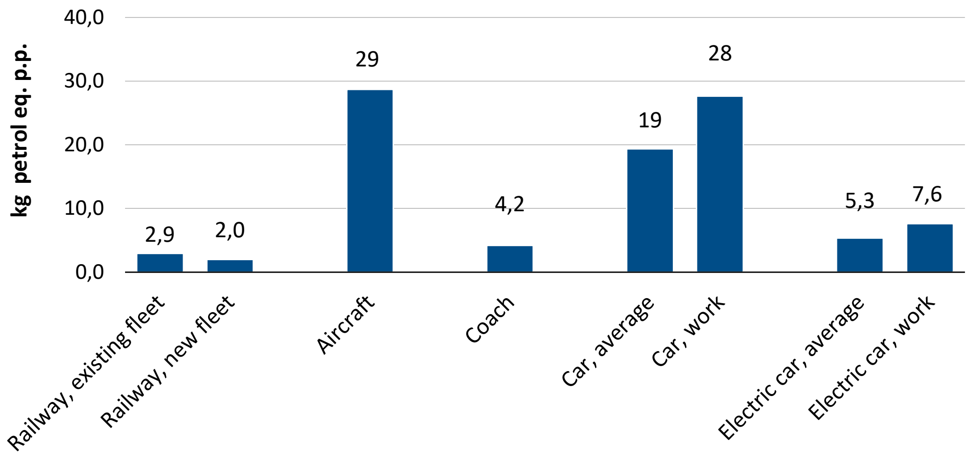


INFRAS graph.

Lausanne–Paris

Figure 13 shows the final energy consumption per person and journey from Lausanne to Paris. The railway journey (new fleet), at around 2.0 kg petrol equivalent, has the lowest energy consumption per person (existing fleet, around 2.9 kg petrol equivalent). The energy consumption of the coach is about double this at 4.2 kg petrol equivalent, and the same applies to an averagely occupied electric car at around 5.3 kg petrol equivalent. The conventional car consumes around 19 kg petrol equivalent, and for the aircraft this is about 29 kg petrol equivalent. For the cars, the energy consumption increases; in the case of lower occupancy for business travel to 7.6 kg (electric car) and 28 kg petrol equivalent (fossil fuel powered car).

Figure 13: Final energy consumption per person and journey of different modes of transport on the Lausanne–Paris route

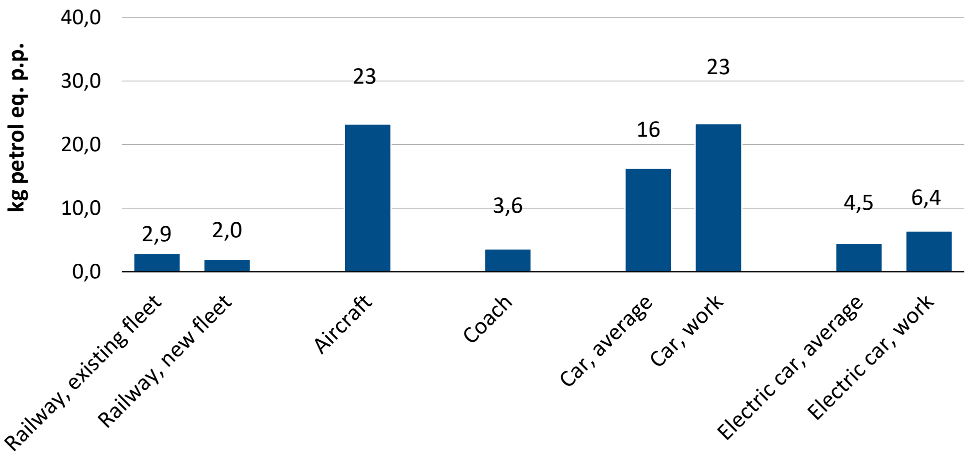


INFRAS graph.

Geneva–Marseille

Figure 14 shows the final energy consumption per person and journey from Geneva to Marseille. The railway journey (new fleet), at around 2.0 kg petrol equivalent, has the lowest energy consumption per person (existing fleet, around 2.9 kg petrol equivalent). The energy consumption of the coach is not quite double this at 3.6 kg petrol equivalent, and the same applies to an averagely occupied electric car, at around 4.5 kg petrol equivalent. The conventional car consumes around 16 kg petrol equivalent, and for the aircraft this is approximately 23 kg petrol equivalent. For the cars, the energy consumption increases; in the case of lower occupancy for business travel to 6.4 (electric car) and 23 kg petrol equivalent (fossil fuel powered car).

Figure 14: Final energy consumption per person and journey of different modes of transport on the Geneva–Marseille route



INFRAS graph.

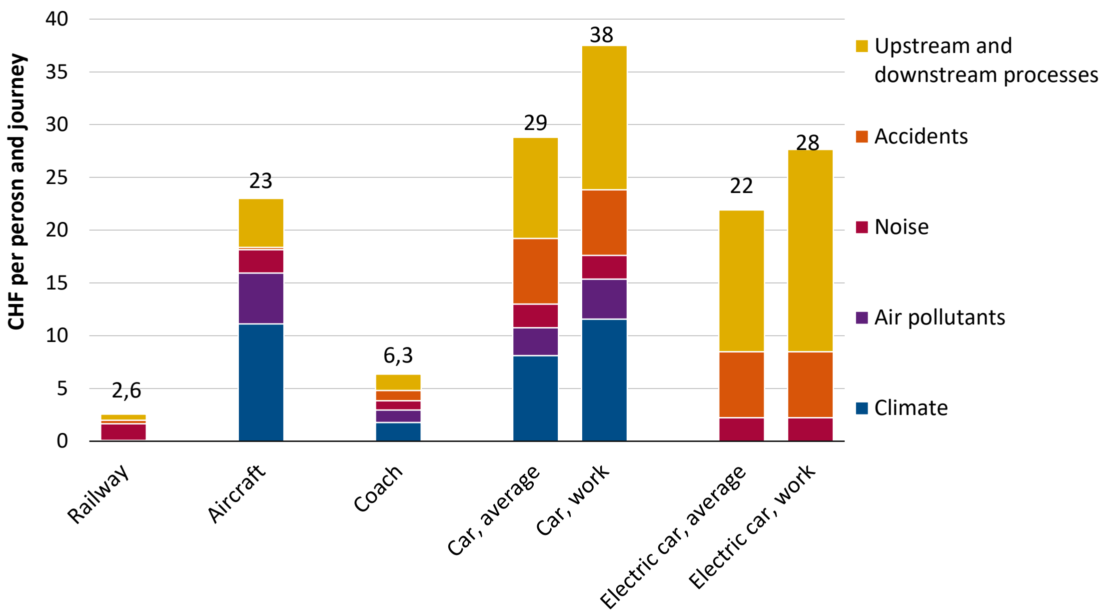
3.3. Environmental and accident costs

In this section, the environmental and accident costs of the modes of transport under consideration are shown for all five routes. The results are presented in CHF per person and journey. On the first route, Geneva–Paris, an additional graph and analysis are shown, which gives the proportions of the individual cost categories in terms of the overall environmental and accident costs. For the other routes, the graphs have been assigned to the Annex for reasons of clarity.

Geneva–Paris

Figure 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 per person and journey, followed by the coach at CHF 6.3 per person and journey. If an electric car is selected for the journey, average costs come out at CHF 22 per person for environmental and accident costs (occupancy of 1.6 people per car). With the lower occupancy for business travellers, the costs increase to CHF 28. For conventional cars with a combustion engine with average occupancy, the costs are around CHF 29 per person. With lower occupancy for business travellers, the costs increase to CHF 38 per person. A journey by aircraft from Zurich to Paris generates environmental and accident costs of around CHF 23 per person.

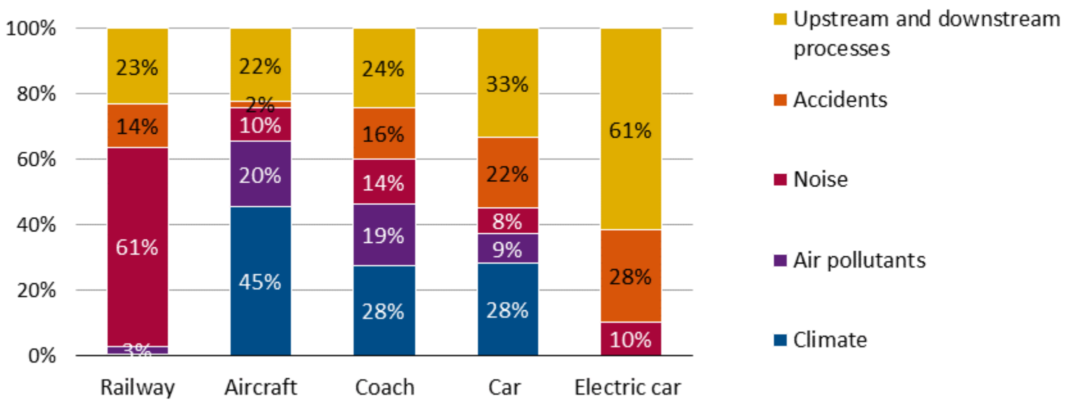
Figure 5: Average environmental and accident costs per person and journey on the Geneva–Paris route



INFRAS graph.

Figure 16 shows the proportions of the individual cost categories in terms of the total environmental and accident costs for each mode of transport. With the railway, the noise costs constitute around 61%, followed by the upstream and downstream processes at around 23% (for power production, rolling material and infrastructure) and the accident costs at 14%. The direct air pollution costs and the climate costs make up the rest. For air traffic, the climate costs account for the largest percentage of environmental and accident costs of a flight at approximately 45%. The air pollutant costs generate around 20%, the costs of upstream and downstream processes 22% and the accident costs another 2%. For the coach, the proportions look as follows: climate costs represent the largest proportion of the overall costs at 28%, the upstream and downstream processes 24%, air pollution 19%, accident costs 16% and noise costs about 14%. The picture is similar to the coach for conventional, fossil fuel powered cars. Climate costs account for 28%, upstream and downstream processes 33%, accident costs around 22%, the costs of air pollution around 9% and noise costs 8%. The electric car does not create any climate and air pollution costs in direct operation. 61% of the costs arise from the upstream and downstream processes, and another 28% from accidents, while 10% comes from noise costs.

Figure 6: Proportion of individual cost categories in terms of total environmental and accident costs (Geneva–Paris)

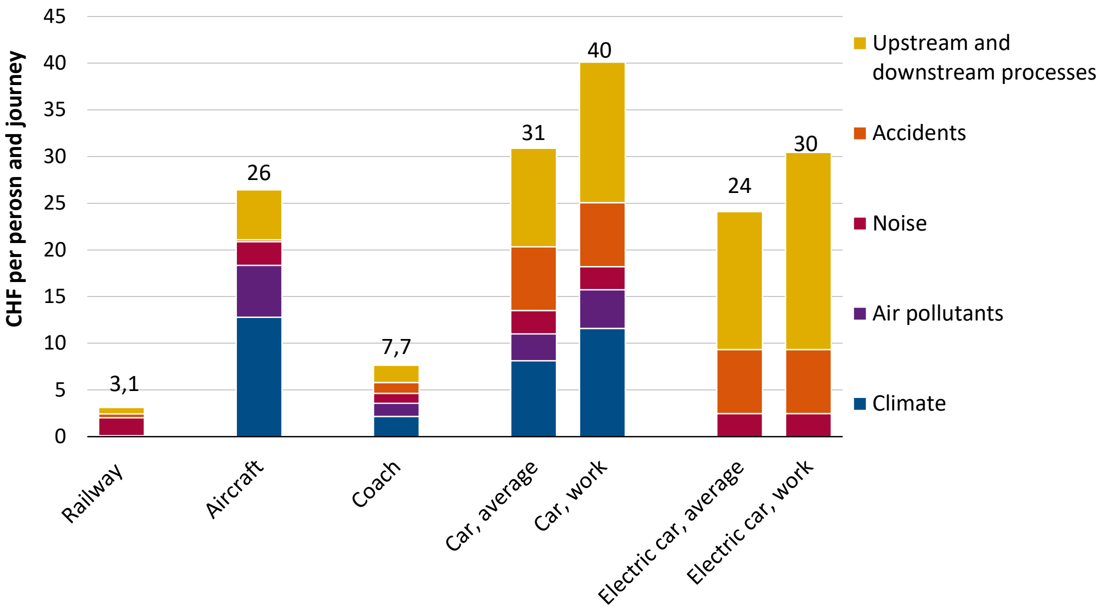


INFRAS graph.

Zurich–Paris

Figure 77 shows the total environmental and accident costs for the individual modes of transport, differentiated by the cost categories to be considered. A journey by TGV from Zurich to Paris in 2nd class creates environmental and accident costs of around CHF 3.1 per person. A journey by coach generates around CHF 7.7 per person. Selecting an electric car for the journey leads to an average (occupancy of 1.6 persons per car) of CHF 24 per person in environmental and accident costs. With the lower occupancy by business travellers, the costs rise to CHF 30. For a conventional car with a combustion engine, for average occupancy this is around CHF 31 per person. With the lower occupancy for business travellers, the environmental and accident costs increase to CHF 40 per person. For all cars, it should be mentioned that the costs would be considerably reduced by increasing the occupancy (2 to 5 persons per vehicle). A journey by aircraft from Zurich to Paris generates environmental and accident costs of about CHF 26 per person.

Figure 77: Environmental and accident costs per person and journey by mode of transport on the Zurich–Paris route

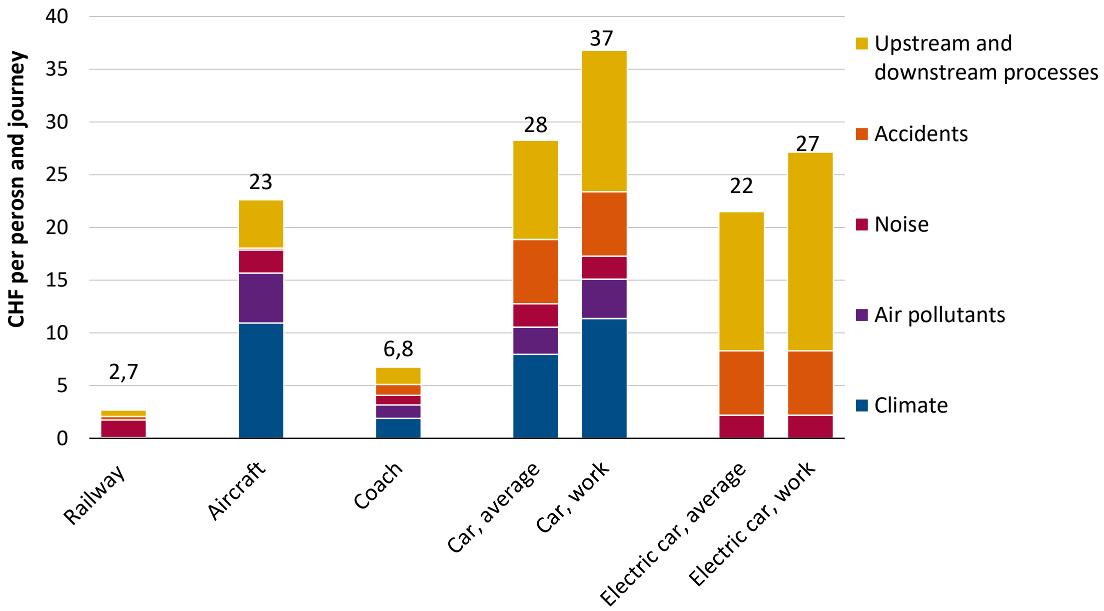


INFRAS graph.

Basel–Paris

A railway journey by TGV from Basel to Paris generates environmental and accident costs of around CHF 2.7 per person. A journey by coach generates about CHF 6.8 per person. Choosing to travel by electric car (occupancy of 1.6 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 27. For a conventional car with a combustion engine with average occupancy, it is about CHF 28 per person. With lower occupancy for business travellers, the costs rise to CHF 37 per person. A journey by aircraft from Zurich to Paris creates environmental and accident costs of around CHF 23 per person.

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

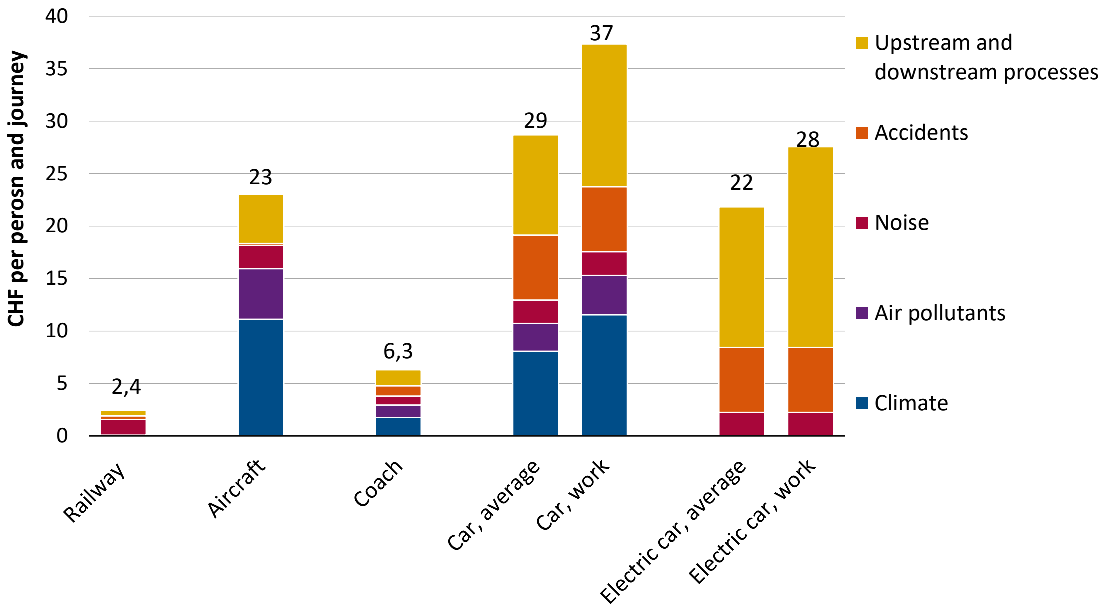


INFRAS graph.

Lausanne–Paris

A railway journey by TGV from Lausanne–Paris generates environmental and accident costs of around CHF 2.4 per person. A journey by coach leads to around CHF 6.3 per person. For a journey by electric car (occupancy of 1.6 persons per car) the cost averages CHF 22 per person for environmental and accident costs. With the lower occupancy of business travellers, the costs increase to CHF 28. For a conventional car with a combustion engine, the costs incurred for average occupancy are about CHF 29 per person. With the lower occupancy for business travellers, the costs rise to CHF 37 per person. A journey by aircraft from Zurich to Paris creates environmental and accident costs per person of around CHF 23.

Figure 19: Environmental and accident costs per person and journey by mode of transport on the Lausanne–Paris route

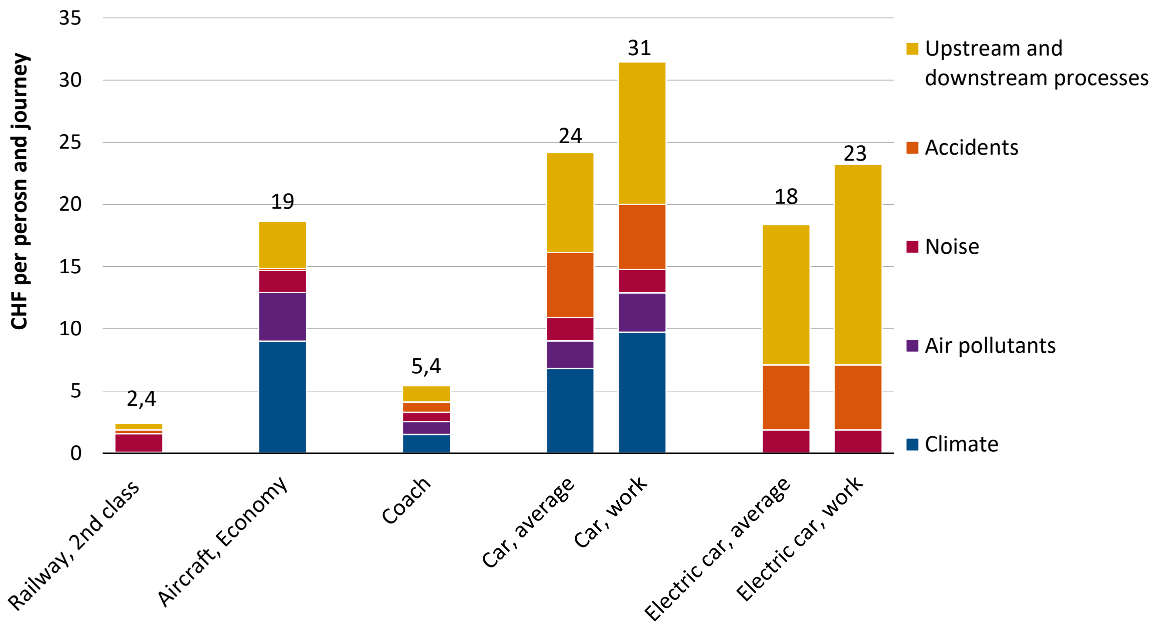


INFRAS graph.

Geneva–Marseille

A railway journey by TGV from Geneva–Marseille generates environmental and accident costs of around CHF 2.4 per person. A journey by coach creates about CHF 5.4 per person. Choosing to travel by electric car (occupancy of 1.6 persons per car), average costs of CHF 18 per person arise for environmental and accident costs. With the lower occupancy of business travellers, the costs go up to CHF 23. For a conventional car with a combustion engine, it is around CHF 24 per person for average occupancy. With the lower occupancy of business travellers, the costs rise to CHF 31 per person. A journey by aircraft from Geneva to Marseille leads to environmental and accident costs of around CHF 19 per person.

Figure 8: Environmental and accident costs per person and journey by mode of transport on the Geneva–Marseille route



INFRAS graph.

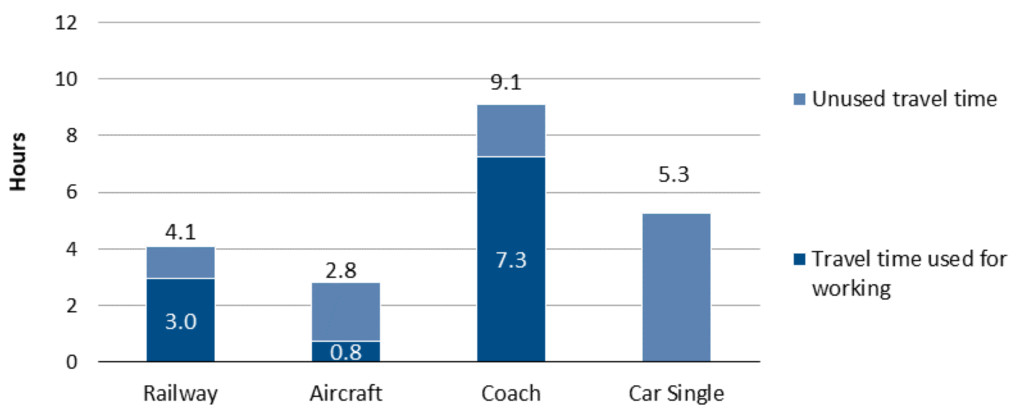
3.4. Travel time and working time

For business travellers, travel time that can be used to work may be an important criterion for selecting modes of transport. It should also be noted that usable travel time has a benefit from an economic perspective. For this reason, travel time that can be used for work in the case of each mode of transport will be presented in this chapter. The pre and post journeys are also taken into account in the calculations. However, realistically, no usable working time has been calculated for this. Working when travelling is defined as working on a technical device (e.g., a laptop) which goes beyond telephoning. The coach is a special case. Many coaches travel overnight. Work can be done in principle but in reality, it is unlikely that this time will be used for working. There are also some connections during the day. You sometimes have to change services. It is therefore not straightforward to calculate an average value for coaches. The following examples are based on the ideal case, that the coach travels during the day and there is a maximum of only one change.

Geneva–Paris

Three hours of the total journey time of around 4 hours from Geneva to Paris (Annemasse to Versailles) are available for TGV passengers to work. On the aircraft, barely an hour of around 3 hours of travel time can be used productively. On the coach, around 7 hours of the total 9 hours can theoretically be used for working but in reality, this is less. The car journeys on this route take about 5 hours. None of the time can be used for working.

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

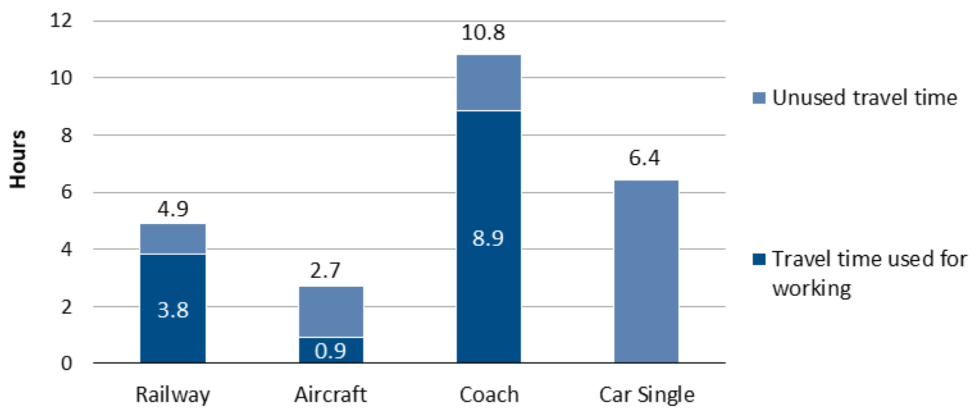


INFRAS graph.

Zurich–Paris

Proportionately, a traveller experiences the most productive working time on the railway. Almost 4 hours of the total 5-hour journey time from Zurich city centre to Boulogne-Billancourt is available for travellers to work. Travel time by aircraft gives the shortest title on this route; only barely an hour can be used for working here. On the coach, it is theoretically possible to work for almost 9 hours of the total 11 hours. In reality, however, this could be less. The car journeys on this route take around 6.4 hours. None of this time can be used for working.

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

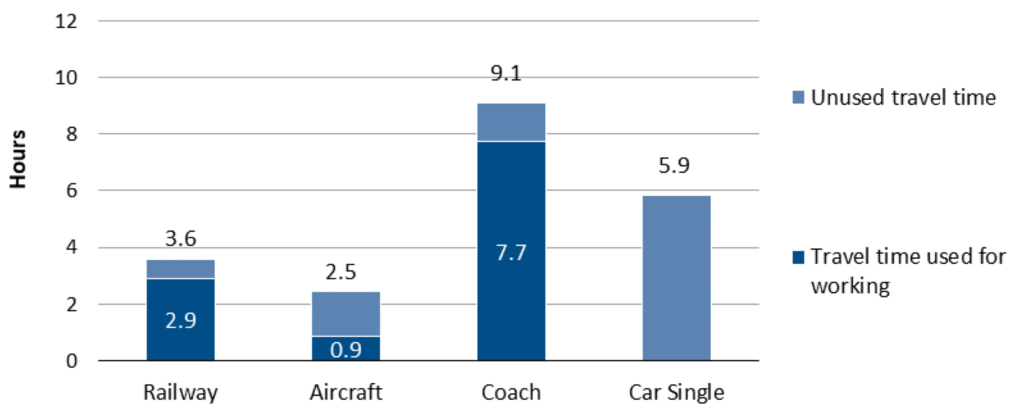


INFRAS graph.

Basel–Paris

Almost 3 hours of the total 3.6-hour journey time from Reinach BL to Paris city centre are available for TGV passengers to work. On the aircraft, barely one hour of the total 2.5 hours of travel time can be used productively. On the coach, almost 8 hours of the total 9 hours can be used for working in theory; in practice, this is less. The car journeys on this route take about 6 hours. None of this time can be used for working.

Figure 23: Basel–Paris: Proportion of travel time that can be used to work

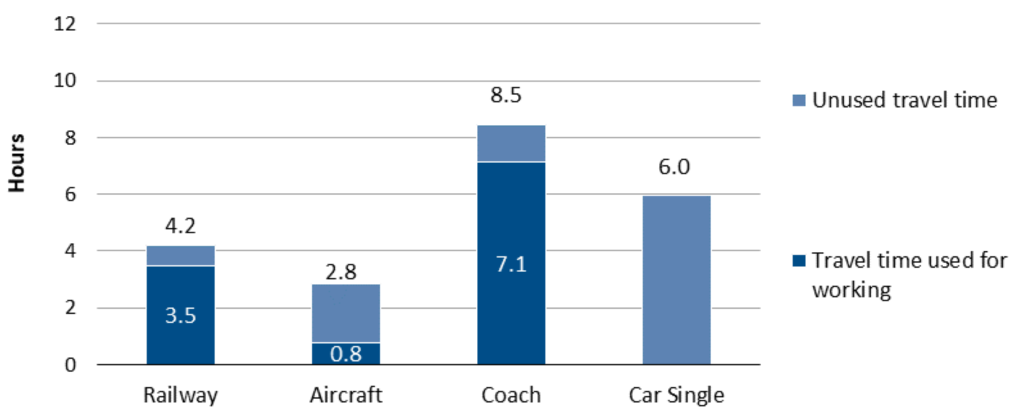


INFRAS graph.

Lausanne–Paris

Around 3.5 hours of the journey time of over 4 hours from Lausanne to Paris (Montreux to Paris city centre) are available to TGV passengers for working. On the aircraft, barely an hour of about 3 hours of travel time can be used productively. On the coach, around 7 hours of a total 8.5 hours can be used for working in theory, but in reality, this is less. The car journeys on this route take around 6 hours. None of this time can be used for working.

Figure 24: Lausanne–Paris: Proportion of travel time that can be used to work

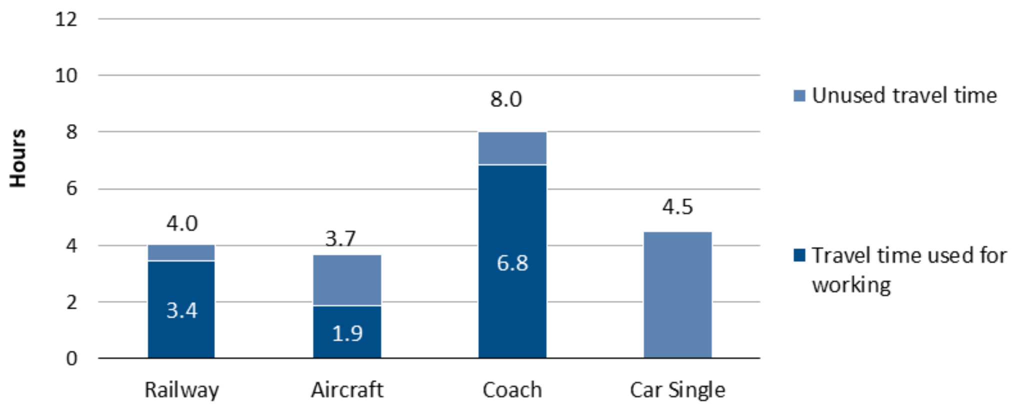


INFRAS graph.

Geneva–Marseille

Around 3.5 hours of the 4-hour journey time from Geneva to Marseille (Nyon to Marseille city centre) are available for TGV passengers for working. On the aircraft, about 2 hours of almost 4 hours of travel time can be used productively. On the coach, around 7 hours of a total of 8 hours can theoretically be used for working but in reality, this is less. The car journeys on this route take about 4.5 hours. None of this time can be used for working.

Figure 25: Geneva–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., railway (TGV Lyria), car, coach and aircraft 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, coach and aircraft are well occupied on average, while the car has a lower occupancy (1.6 persons per vehicle) on average. A significant increase in occupancy, e.g., the new TGV double deck trains, will considerably improve the balance of the railway.
- With the current average occupancies of the modes of transport surveyed (old and new TGV fleets), the environmental advantage in terms of the **climate footprint** is clearly with the railway, that is the TGV. With small differences on each route, the greenhouse gas emissions per person (including preliminary processes) for a journey by TGV on the main route are around 3 to 6 times lower than for the coach, about 7 to 12 times lower than for the electric car, approximately 16 to 27 times lower than for the conventional, fossil fuel powered car, and around 16 to 28 times lower than for the aircraft. From the perspective of climate protection, a railway journey by TGV 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 terms of the **energy balance**, the final energy of the various modes of transport is assessed because the energy efficiency of the modes of transport and not the efficiency of the various energy systems behind them were compared in the study. This means that the efficiency of an electric engine is compared with that of a combustion engine and not electricity production with that of diesel. On this basis, the comparison of the final energy consumptions shows that the railway (TGV) demonstrates the highest energy efficiency. The next highest are the coach (+30% to 70%) and electric car (+40% to 90%). The conventional car with a combustion engine has an energy efficiency that is about 4 to 5 times lower, and the aircraft around 7 to 10 times lower per person and journey.
- 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 also generate the lowest environmental and accident costs per person and journey here on all routes surveyed. This is largely due to the fact that the TGV generates almost no direct climate, air pollutant and accident costs

in operation, whereas these are in the highest cost categories for other modes of transport. The environmental and accident costs for coaches are a little more than double those of the TGV, those of the electric car almost 7 times as high, and those of the aircraft around 7 times as high. The costs for the conventional car (petrol / diesel) are around 9 times higher than those of the TGV.

- For companies in particular, the **productive use of travel time as working time** should be a criterion for 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 with regard to 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 railway, i.e., TGV Lyria, comes out best in all areas and for all routes. In terms of the climate footprint as well as the environmental and accident costs, the TGV is clearly in the lead. With respect to the environment, the coach comes after the railway, however, this still generates greenhouse gas emissions and environmental costs that are 2 to 4 times higher. Cars and aircraft demonstrate 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 7 times poorer than those of the TGV on the routes surveyed. The railway therefore currently has a clear environmental advantage in comparison with the car, even with the progressive electrification of the car, 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 7: Greenhouse gases, Zurich–Paris, based on source of emissions

kg CO_2 eq. / person	Railway, existing fleet	Railway, new fleet	Aircraft	Coach	Car, average	Car, work	Electric car, average	Electric car, work
Emissions in direct operation	0	0	93,4	15,7	65,3	93,2	0	0
Energy supply	1,7	1,2	16	3,0	10,5	15	9	13
Production of the vehicles and infrastructure	4,6	3,2	3,5	4,8	27	38	37	53
Total	**6,3**	**4,3**	**112**	**24**	**103**	**146**	**46**	**65**
Total according to the standard SN EN 16258	*1,7*	*1,2*	*109*	*19*	*76*	*108*	*9*	*13*

Basel–Paris

Table 8: Greenhouse gases, Basel–Paris, based on source of emissions

kg CO_2 eq. / person	Railway, existing fleet	Railway, new fleet	Aircraft	Coach	Car, average	Car, work	Electric car, average	Electric car, work
Emissions in direct operation	0	0	80	14	58	83	0	0
Energy supply	1,4	1,0	13	2,7	9,4	13	8	11
Production of the vehicles and infrastructure	4,0	2,7	3,0	4,2	24	34	33	47
Total	**5,4**	**3,7**	**96**	**21**	**91**	**131**	**41**	**58**
Total according to the standard SN EN 16258	*1,4*	*1,0*	*93*	*16*	*68*	*97*	*8*	*11*

Lausanne–Paris

Table 9: Greenhouse gases, Lausanne–Paris, based on source of emissions

kg CO_2 eq. / person	Railway, existing fleet	Railway, new fleet	Aircraft	Coach	Car, average	Car, work	Electric car, average	Electric car, work
Emissions in direct operation	0	0	81	13	59	84	0	0
Energy supply	1,3	0,9	14	2,5	9,5	14	8	12
Production of the vehicles and infrastructure	3,6	2,5	3,1	3,9	24	35	33	48
Total	**4,9**	**3,3**	**98**	**19**	**93**	**133**	**42**	**59**
Total according to the standard SN EN 16258	*1,3*	*0,9*	*95*	*15*	*69*	*98*	*8*	*12*

Geneva–Marseille

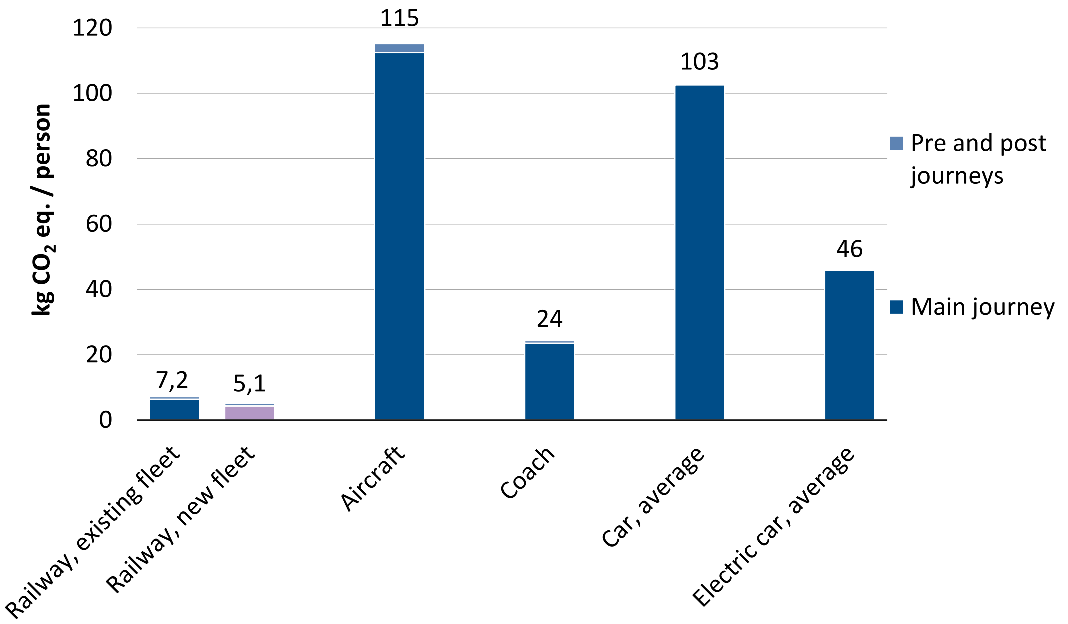
Table 10: Greenhouse gases, Geneva–Marseille, based on source of emissions

kg CO_2 eq. / person	Railway, existing fleet	Railway, new fleet	Aircraft	Coach	Car, average	Car, work	Electric car, average	Electric car, work
Emissions in direct operation	0	0	66	11	50	71	0	0
Energy supply	1,3	0,9	11	2,1	8,0	11	7	10
Production of the vehicles and infrastructure	3,6	2,4	2,5	3,4	20	29	28	40
Total	**4,9**	**3,3**	**79**	**17**	**78**	**112**	**35**	**50**
Total according to the standard SN EN 16258	*1,3*	*0,9*	*77*	*13*	*58*	*83*	*7*	*10*

Climate footprints per route with pre and post journeys

Zurich–Paris

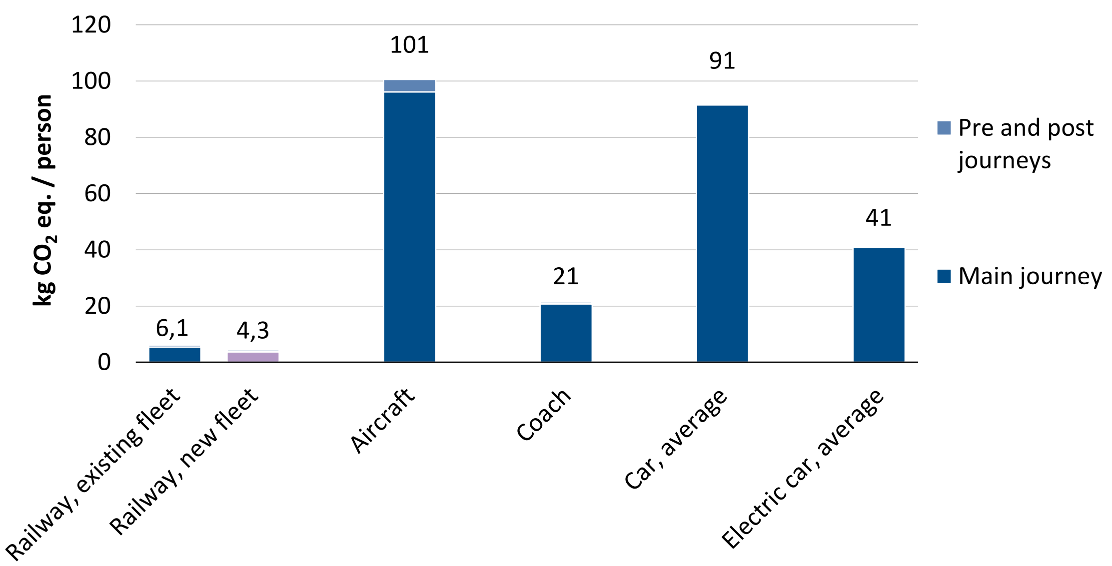
Figure 26: Average values per mode of transport (climate balance in CO2 eq. per person and journey)



INFRAS graph.

Basel–Paris

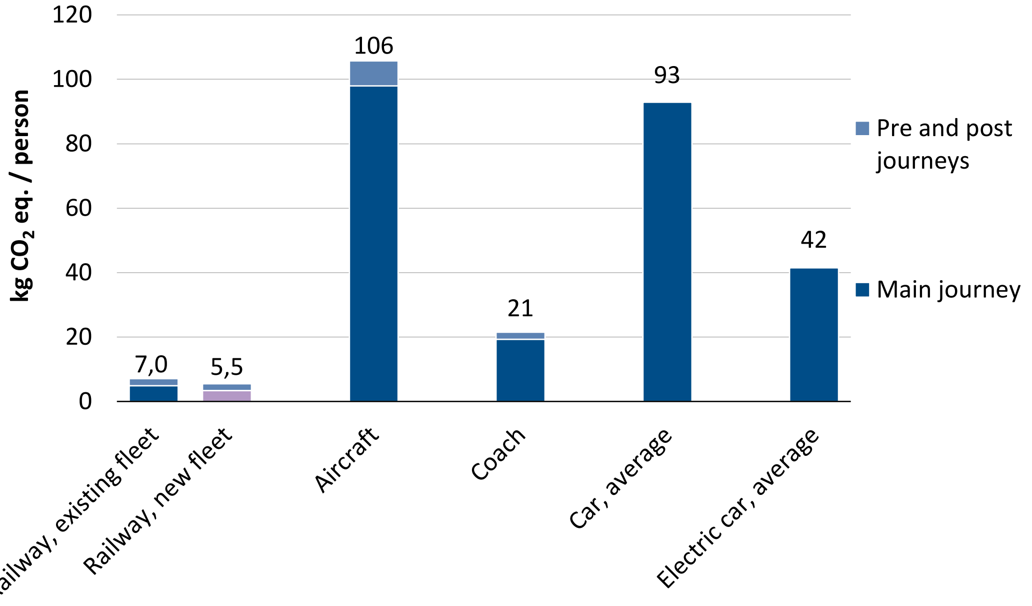
Figure 27: Average values per mode of transport (climate balance in CO_2 eq. per person and journey)



INFRAS graph.

Lausanne–Paris

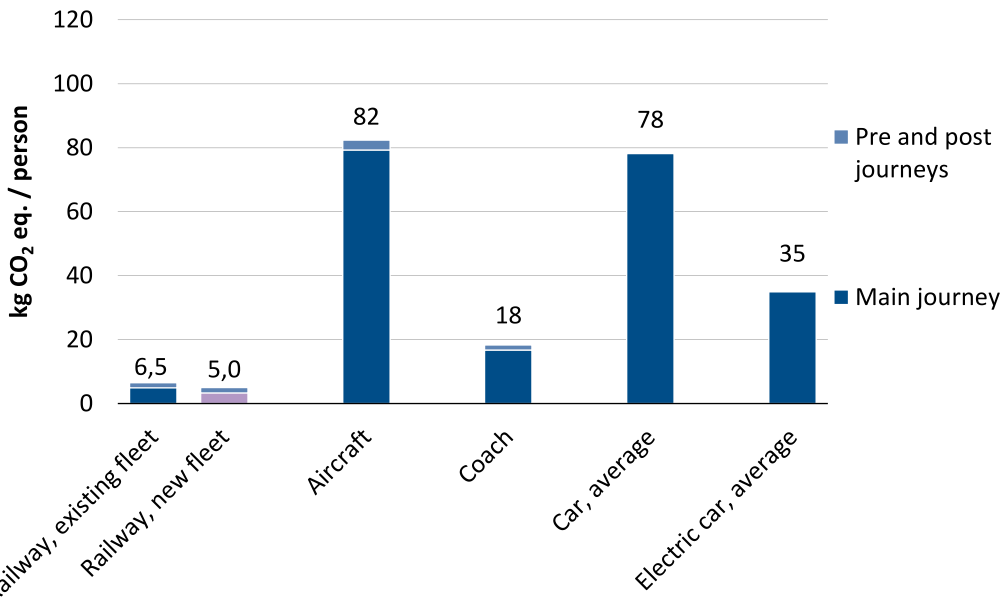
Figure 28: Average values per mode of transport (climate balance in CO_2 eq. per person and journey)



INFRAS graph.

Geneva–Marseille

Figure 29: Average values per mode of transport (climate balance in CO2 eq. per person and journey)

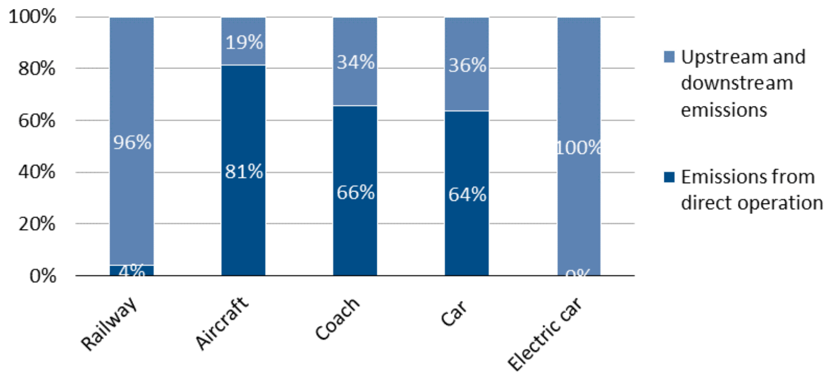


INFRAS graph.

Proportions of upstream and downstream greenhouse gas emissions

Zurich–Paris

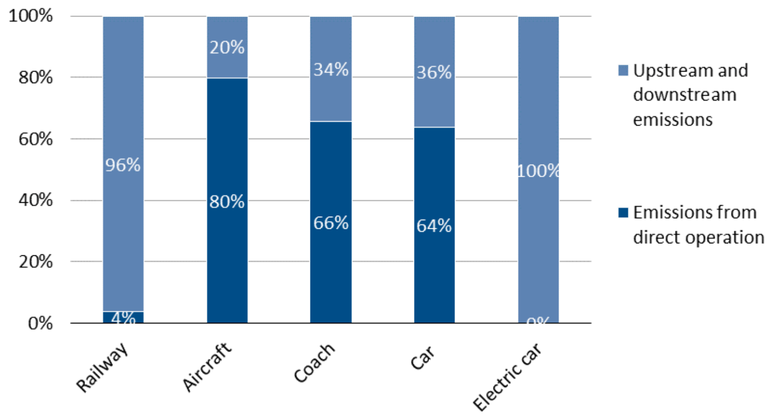
Figure 30: Zurich–Paris: Proportion of upstream and downstream greenhouse gas emissions in terms of overall greenhouse gas emissions



INFRAS graph.

Basel–Paris

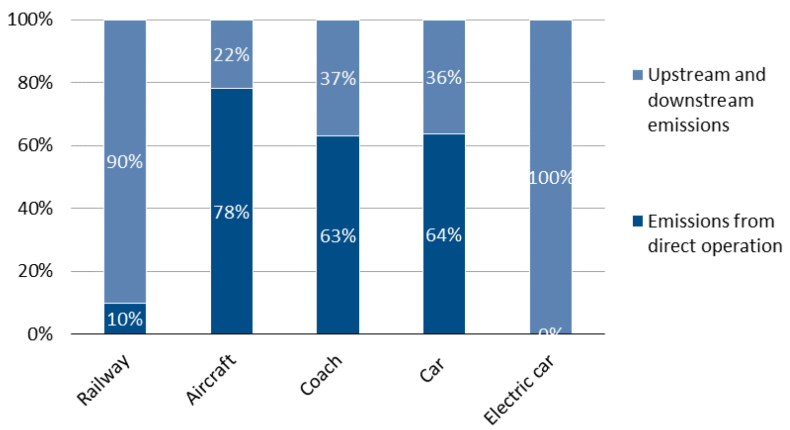
Figure 31: Basel–Paris: Proportion of upstream and downstream greenhouse gas emissions in terms of over-all greenhouse gas emissions



INFRAS graph.

Lausanne–Paris

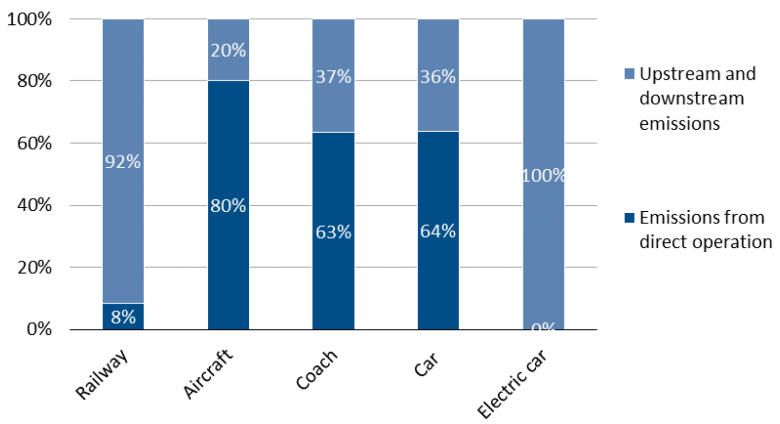
Figure 32: Lausanne–Paris: Proportion of upstream and downstream greenhouse gas emissions in terms of overall greenhouse gas emissions



INFRAS graph.

Geneva–Marseille

Figure 33: Geneva–Marseille: Proportion of upstream and downstream greenhouse gas emissions in terms of overall greenhouse gas emissions

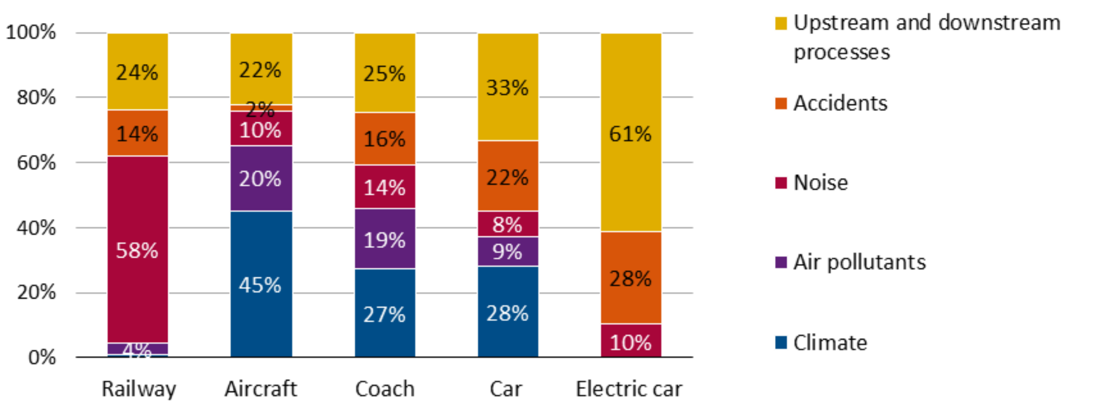


INFRAS graph.

Proportions for individual cost categories

Zurich–Paris

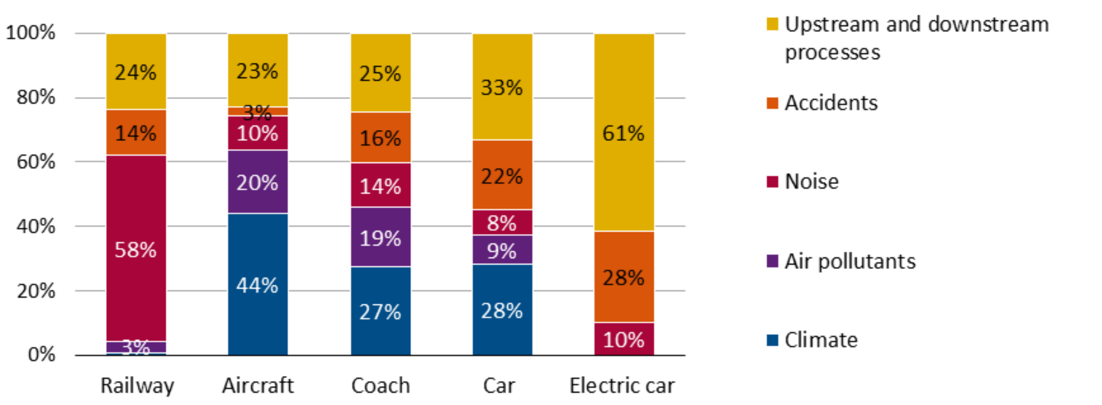
Figure 34: Zurich–Paris: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

Basel–Paris

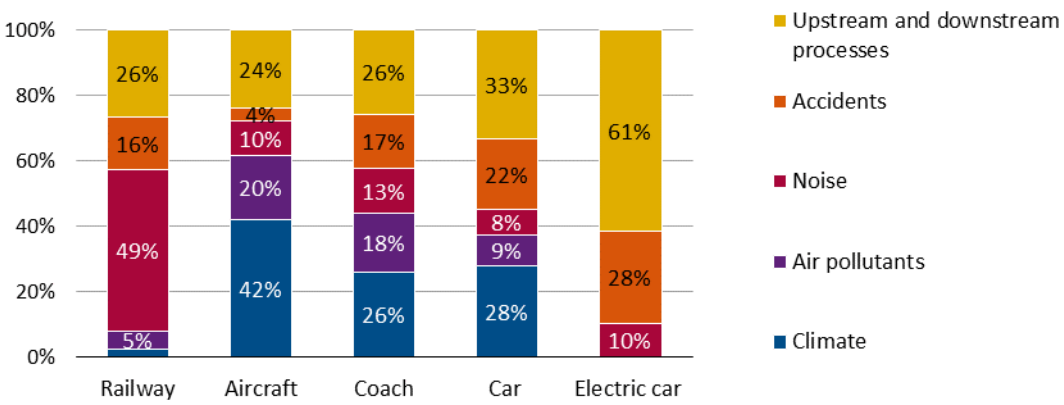
Figure 35: Basel–Paris: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

Lausanne–Paris

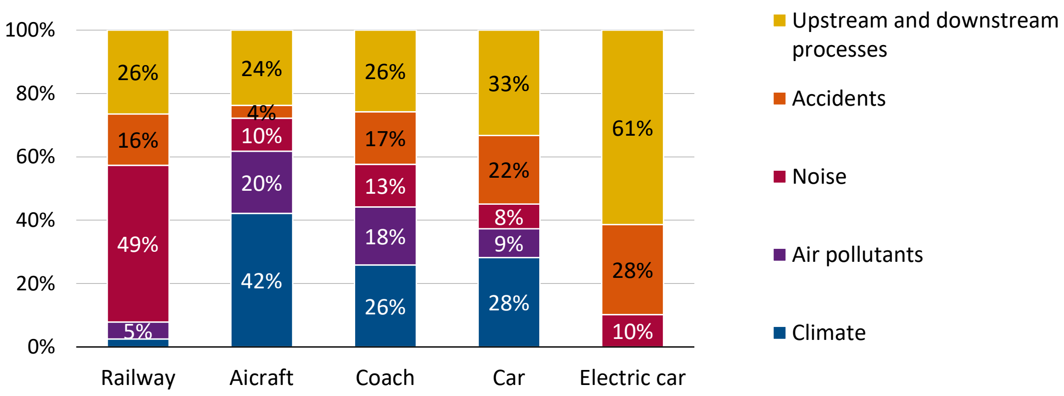
Figure 36: Lausanne–Paris: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

Geneva–Marseille

Figure 37: Geneva–Marseille: Proportion for individual cost categories in terms of the overall environmental costs



INFRAS graph.

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