

Final Report

Energy efficiency potentials in the Alpine transport and mobility system

**Freight transport: Development of energy efficiency
on two transalpine corridors**

**Tourism mobility: Energy efficiency of selected good
practice measures**

EUSALP AG4

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0 List of Abbreviations

AFIR	Alternative Fuels Infrastructure Regulation
ASI	Avoid-Shift-Improve
AT	Austria
BBT	Brenner Base Tunnel
BEV	battery electric vehicle
CNG	compressed natural gas
DE	Germany
GHG	Greenhouse Gas
GT	Gross ton
IPCC AR6	Intergovernmental Panel on Climate Change Sixth Assessment Report
IT	Italy
Km	kilometre
LNG	Liquefied Natural Gas
PKM	passenger-km
POI	Points of interest
TTW	Tank to Wheel
ton-km	tonne kilometre
UBA	Austrian Federal Environment Agency
VKM	vehicle-km
WTT	Well to Tank
WTW	Well to Wheel

1 Abstract

This study explores the energy efficiency and greenhouse gas (GHG) reduction potential of different mobility strategies in the Alpine region, following the Avoid-Shift-Improve (ASI) framework and the "energy efficiency first" principle promoted by the IPCC, the European Green Deal, and the Fit-for-55 package. The methodology of the present study is based on the study "Entwicklung der Energieeffizienz des transitierenden Güterverkehrs am Brennerkorridor in Tirol¹" published in February 2023. Thus the study focuses on the topic of energy efficiency in freight transport on two transport corridors. It analyzes transalpine freight transport along the Brenner and Ventimiglia corridors as well as tourism mobility in three Alpine destinations (Seefeld, Bad Hindelang, Prags). The findings show that shifting freight transport from road to rail delivers significantly higher energy savings and CO₂ reductions than merely upgrading drive technologies. Among road alternatives, battery-electric trucks perform best, while gas-powered combustion engines offer minimal climate benefits. For tourism, alternative public transport—especially when electrified—and high vehicle occupancy rates are key to reducing emissions. Train travel is more effective than car travel, even when comparing against electric vehicles. The study emphasizes the need for integrated measures that address both long-distance travel and local tourism mobility. Recommendations include improving rail infrastructure and interoperability, incentivizing clean technologies, supporting electric vehicle-based mobility solutions in tourism, enhancing charging infrastructure, and applying additional demand-side measures such as parking management and coordinated policy mixes to support modal shift and the use of new technologies. Together, these strategies can contribute significantly to decarbonising transport in the Alpine region.

¹ Development of the energy efficiency of transiting freight transport on the Brenner corridor in Tyrol.

2 Introduction and Scope of Work

According to the logic of the Avoid-Shift-Improve (ASI) approach, the *avoidance* of energy consumption through increased energy efficiency of existing technologies and energy services need to be considered as guiding principles in addition to the *shift* towards alternative transport modes and the use of new technologies ("*improve*"). The IPCC AR6 reiterates the need to take demand-side action and to consider all levels of the ASI-model (IPCC 2022a) in the frame of decarbonisation strategies. Indeed, the European Green Deal and the "Fit-for-55" package which supports its implementation are strongly based on this "energy efficiency first" principle.

In the Alpine region, two significant sources of greenhouse gas emissions from transport are transalpine freight transport and the traffic generated by tourism in the Alps (inbound and outbound journeys and local mobility). The study investigates concrete examples of both freight transport and tourism mobility to show available options for reducing greenhouse gas emissions and, looking at the "energy efficiency" first principle, what these options mean in terms of energy efficiency (energy used for the transport of goods or people).

Different approaches were chosen for freight transport and tourism mobility.

For transalpine freight transport, potential changes in greenhouse gas emissions and energy consumption through the use of different modes of transport (road or rail) and different drive types on the road (combustion engine with diesel, LNG, CNG or hydrogen; electric motor with battery or hydrogen fuel cell) were analysed for the use of the entire Brenner corridor (Munich to Verona) and the entire Ventimiglia corridor (Marseilles to Genoa). Drive types such as HVO or bio-fuels are not taken into account as they do not appear in the underlying manual for emission factors.

For tourism mobility in the Alps, three good practice examples (Seefeld, AT; Bad Hindelang, DE; Prags, IT) were selected to showcase different types of measures to improve energy efficiency related to tourism mobility. For these good practice examples, the changes in CO₂ emissions and energy consumption were analysed based on the mobility needs of a single person in a reference case (using individual motorized transportation) and in comparison, the use of the relevant offer.

Based on these analyses, the key findings are summarised in a final chapter and recommendations for measures are formulated. The measures are intended to contribute to the climate-neutral and energy-efficient handling of transalpine freight transport and mobility caused by tourism in the Alps in the future.

3 Energy efficiency of freight transport on two Alpine crossing corridors

In the study completed in 2023 on behalf of the Office of the Tyrolean Government “Development of the energy efficiency of transit freight transport on the Brenner corridor in Tyrol”, a comparative calculation of CO₂ emissions and the energy efficiency of freight transport on the Brenner corridor in Tyrol was drawn up for various scenarios.

Building on the methodology and data basis of this study, the following additional content has been developed:

- Extension of the basic study to the entire Brenner corridor (Munich - Verona via Brenner, 415 kilometres)
- Calculation and comparison of the Ventimiglia corridor (Marseilles - Genoa via Ventimiglia, 381 kilometres)

However, the methodology for illustrating relevant effects has slightly been adjusted compared to the previous Tyrolean study (https://www.tirol.gv.at/fileadmin/themen/verkehr/verkehrsplanung/Dateien/Tirol_THG_Brennerkorridortransit_V06.pdf) for reasons of data availability (detailed data regarding origin and destination of alpine crossing transport based on the Cross Alpine Freight Transport survey is not available for the Ventimiglia corridor), the approach for highlighting absolute reduction potentials with the help of modal split scenarios was not used in the new study. Instead, a relative comparison was chosen highlighting CO₂ emissions and energy consumption of one journey and the transport of one ton compared to the reference case as used in the baseline study. Based on this approach, the study analyses for both corridors the effect of a shift of 125,000 truck journeys to rail along the entire corridor (in each direction) in terms of CO₂ emissions and energy efficiency.

Finally, the results are classified, visualised and prepared for an international audience in an easily understandable form.

The following subsections summarise which data is used, how it was collected, and which estimates are made in order to derive the desired conclusions.

The following information was obtained, analysed and processed in order to be able to produce the desired results:

- Road and rail infrastructure characteristics: Sectional route lengths and gradients
- Traffic volume (road and rail) at the apex of the corridors
- Direct (tank to wheel) greenhouse gas emission factors (CO₂ equivalents/traffic performance)
- Greenhouse gas emission factors taking into account fuel, electricity or hydrogen production (well to wheel), differentiated according to drive types in road transport, gradient ratios on the road corridors and gradient ratios on the rail corridors
- Final energy demand factors differentiated according to the above criteria

3.1 Transport infrastructure of the corridors

As first step, the route lengths of the transport infrastructure relevant to the study and the average gradients must be determined, broken down by route section. This makes it possible to determine corridor-specific statements on CO₂ emissions and energy requirements.

The following sources are available for the Brenner corridor:

- ASFINAG route directory for the Inntal motorway (A12) and the Brenner motorway (A13).
- Inclination per motorway section: Herry Consult's own survey based on contour line analysis
- Various information from BBT SE on the existing infrastructure and the base tunnel (lengths and gradients)
- bbt-se.com/tunnel/projektueberblick/

The information on the infrastructure of the Brenner corridor (between Munich and Verona) relevant to the study was compiled from these sources and is presented in the

Appendix (see Table 30, Table 31 and Table 32)

The following sources are available for the Ventimiglia corridor:

- Google Maps analysis of the lengths of the motorway sections
- Gradient per motorway section: based on contour line analysis
- de.wikipedia.org/wiki/Bahnstrecke_Marseille%E2%80%93Ventimiglia
- openrailwaymap.org/

The information on the infrastructure of the Ventimiglia corridor (between Marseilles and Genoa) relevant to the study was compiled from these sources and is presented in the

Appendix (see Table 33, Table 34 and Table 35).

3.2 Greenhouse gas emission and energy demand factors

In order to determine the greenhouse gas emissions and energy demand of a journey along the corridors, corresponding emission and energy demand factors are required. The determination of these factors differs for road and rail as different data sources are used.

3.2.1 Road

The Austrian Federal Environment Agency regularly publishes transport-related emission and energy demand factors that relate to the average fleet and the average traffic situation in Austria. Similar aggregated emission factors are reported in other sources (e.g. EU external cost handbook or German Federal Environment Agency). This means that the specific situations (along the two corridors with different gradients and different vehicle compositions) for transport across the two corridors cannot be specifically mapped on the basis of such general sources.

Other data sources were therefore used.

The manual for emission factors (currently version 4.2 - see hbefa.net) allows the generation of emission factors and final energy demand factors for road transport differentiated by

- specific traffic situations,
- specific road types,
- specific topographies,
- specific truck vehicle types (differentiated according to drive type, Euro emission classes and vehicle size according to classes of maximum permissible gross weight)
- different countries (including Austria, Germany and France) and
- different points in time (year).

The following parameters were defined for determining the emission and energy requirement factors using the manual:

- traffic situation: Liquid (trucks: 80 km/h)
- road types: Motorway Interurban
- Vehicle types:
 - Articulated truck with 34t to 40t gross vehicle weight (GVW), diesel EURO VI D-E
 - Articulated truck (weight not specified), CNG Euro-VI
 - Articulated truck (weight not specified), LNG Euro-VI (CI)
 - Articulated truck (weight not specified), BEV
 - Articulated truck (weight not specified), FCEV
- Countries: Austria, Germany, France
- Date: Year 2020 (electricity mix in this year)

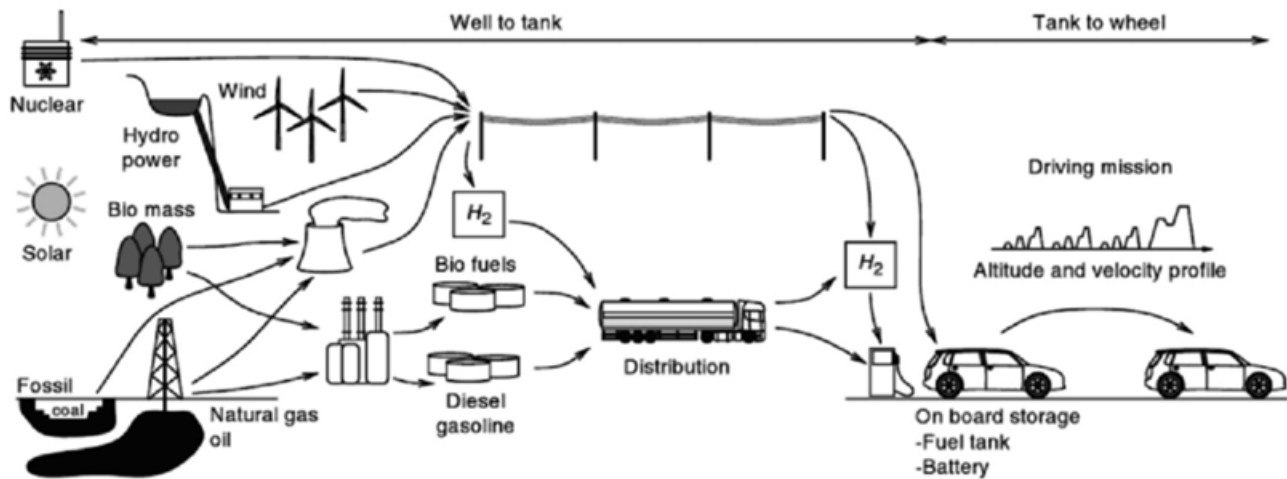
The manual does not provide specific values for Italy. Therefore, corresponding specific parameters for the determination of emissions on the Italian motorways of the two corridors cannot be used from this primary source. However, the use of other sources reduces comparability and does not make it possible to derive corresponding emissions depending on the above-mentioned parameters. For this reason, the corresponding factors from the manual for Germany were used to determine the emissions depending on the route parameters of the Italian road sections of the two corridors.

In addition to different local air pollutant emission factors, which are not in the focus here, the following parameters relevant to the study can be derived for the transport as described above:

- Greenhouse gases (CO₂ equivalents - CO₂e) produced directly during the journey (Tank to Wheel - TTW) in g/km
- Greenhouse gases resulting from the production of fuel, hydrogen or electricity (Well to Tank - WTT) in g/km
- Well to Wheel (WTW); sum of the above greenhouse gas emissions
- Final energy demand in MJ/km (or converted to kWh/km)

The following figure explains which greenhouse gas emission components are taken into account for the two approaches listed above (TTW and WTT, in total WTW).

Figure 1: Explanation of Well to wheel and Tank to Wheel



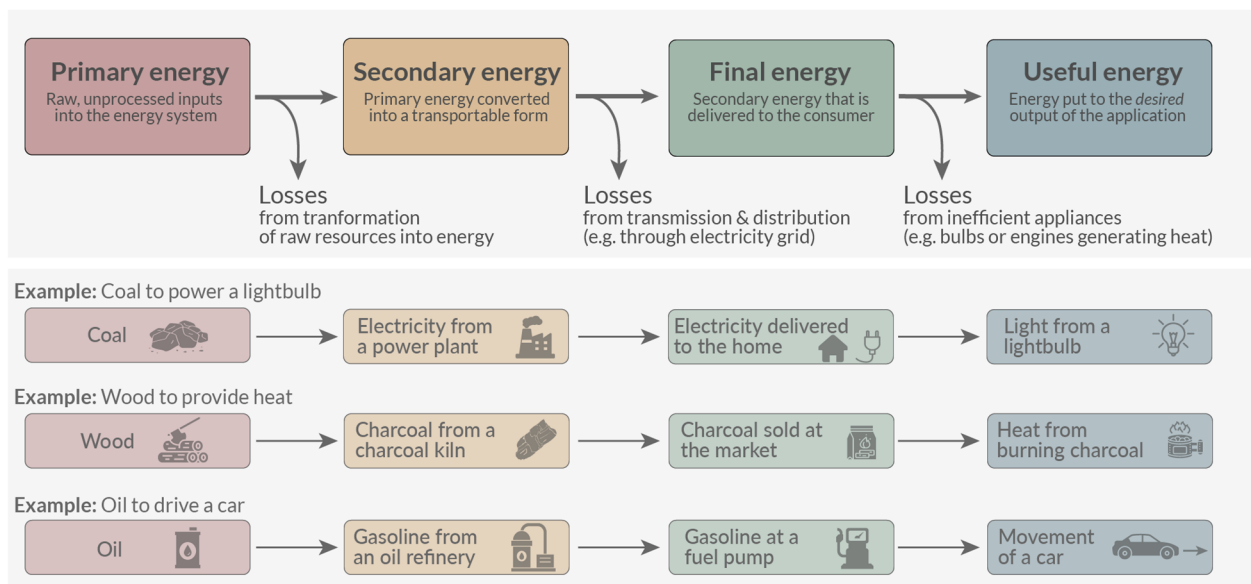
Source: Chocholac, Jan & Hyrslova, Jaroslava & Kučera, Tomáš & Machalík, Stanislav & Hruska, Roman. (2019). Freight Transport Emissions Calculators as a Tool of Sustainable Logistic Planning. Communications - Scientific letters of the University of Zilina. 21. 43-50. 10.26552/com.C.2019.4.43-50.

Emissions generated during the production and scrapping of vehicles (whether ICE or BEV) are therefore not included.

The following figure explains which approach of measuring energy consumption is taken into account in the final energy considered in the manual.

Figure 2: The four ways of measuring energy

The four ways of measuring energy



Icon source: Noun Project.

OurWorldinData.org – Research and data to make progress against the world's largest problems.

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For this study the final energy is taken into account due to data availability in manual for emission factors. This manual is the main source for the calculations in order to have comparable values for the different countries and vehicle types and to be able to include the specific topology on the two corridors. Figure 2: The four ways of measuring energy explains that the final energy is the energy that the vehicle obtains by refuelling with fuel or hydrogen or charging with electricity. The final energy therefore does not take into account the energy consumed in the production or scrapping of the vehicle or the energy 'lost' through conversion and transportation of the energy sources. However it does take into account the energy that cannot be used for travelling when starting and driving (e.g. heat generated by the engine).

The use of e-fuels (synthetic fuels which are manufactured using captured carbon dioxide or carbon monoxide, together with hydrogen) is also currently being discussed as an option for climate-neutral transport. Unfortunately, the manual for emission factors does not include any greenhouse gas emission and energy demand factors for this drive option. This means that it is not possible to perform an equivalent calculation to that for the drive types listed in the handbook. A desktop research ^{2 3} on the use of e-fuels and the associated greenhouse gas emissions and energy demand allows the following qualitative statements:

- There are no direct greenhouse gas emissions (GHG).

² Martin Wietschel, Patrick Plötz, Elisabeth Dütschke, Felix Neuner, Josephine Tröger, Till Gnann: Eine kritische Diskussion der beschlossenen Maßnahmen zur E-Fuel-Förderung im Modernisierungspaket für Klimaschutz und Planungsbeschleunigung der Bundesregierung vom 28.3.2023 ([isi.fraunhofer.de/de/presse/2023/presseinfo-05-efuels-nicht-sinnvoll-fuer-pkw-und-lkw.html](https://www.fraunhofer.de/de/presse/2023/presseinfo-05-efuels-nicht-sinnvoll-fuer-pkw-und-lkw.html))

³ emobicon.de/e-fuels-vergleich-energieaufwand-kosten-nachhaltigkeit/

- The well-to-wheel greenhouse gas emissions depend on the electricity used to produce the e-fuels, the production location of the e-fuels and the mode of transport from the production location to the e-fuel sales location. As production is energy-intensive, a few per cent share of non-green electricity for production is enough to make the WTW greenhouse gas balance worse than that of a normal diesel. A reduction in greenhouse gas emissions can only be achieved with 100 % green electricity for generation.
- The final energy requirement is comparable to the use of conventional diesel.
- However, the primary energy requirement is significantly higher compared to diesel and, above all, to other drive technologies, as according to sources (e.g. adac.de/verkehr/tanken-kraftstoff-antrieb/alternative-antriebe/synthetische-kraftstoffe/) only 10 % to 15 % of the energy required reaches the vehicle as final energy.
- Conclusion: E-fuels can be climate-neutral if they are produced with 100 % 'green' electricity, but the low overall energy efficiency means a significantly higher primary energy input compared to all other drive types. In any case, energy efficiency is significantly lower than for battery-electric vehicles as renewable electricity first needs to be synthesised into liquid fuel and is then used in an internal combustion engine which is – per se – less energy-efficient compared to an electric motor.

The WTW greenhouse gas emission and final energy demand parameters (without taking cold starts into account) for the two corridors under consideration result from the manual and are presented in the Appendix (Table 36, Table 37 and Table 38).

3.2.2 Rail

For rail, too, the UBA's (Umweltbundesamt / Austrian Federal Environment Agency) emission and energy demand factors do not allow the specific situation of the two corridors – in particular the different gradients – to be taken into account. An alternative approach was therefore chosen for rail transport.

All rail freight transport along the two corridors is handled electrically. All calculations on energy demand and CO₂ emissions therefore relate exclusively to the electricity used to operate rail transport via overhead catenary.

An unpublished study by Herry Consult from 2002 for the BMVIT⁴ outlines a simplified calculation of the energy demand of freight trains as a function of train weight and gradient. This was done for the mountain route via the Brenner Pass and the Brenner Base Tunnel. The following parameters of that study have been adopted for this study (another source: eisenbahn.gerhard-obermayr.com/daten/elektrotraktion/zugkraft-reibung-leistung confirms the following information):

- Tractive force required to move (not accelerate) a gross ton in the plane: 35 Newtons (N) per total gross ton (GT)

⁴ Austrian Federal Ministry for Transport, Innovation and Technology

- Tractive force required in addition to the force in the plane per one per mill gradient to move a gross ton on this gradient (not to accelerate): 10 N/Gbt

The values only take into account the comparative energy consumption during the journey and therefore do not represent the complete energy expenditure of a train journey. This approach is comparable to that used for road transport, where cold starts are not taken into account in the presentation of emission factors and energy demand.

The values allow a simple comparison of energy consumption between rail and road on the two corridors.

Using information on the average speed on the route sections, the tractive force can be converted into power and, using the time required per section (depending on the speed and route length), into energy demand per total gross ton kilometre (kWh/GTkm) and, using volume data, also into energy demand per net ton kilometre (kWh/NTkm).

For the Brenner corridor, corresponding data is available regarding total GT and average speed (taking into account scheduled and unscheduled stops along the route) of an average goods train (1.230 GT, 50 km/h or 100 km/h through the base tunnel). For the Ventimiglia corridor, it is assumed that an average goods train has the same weight and travels at an average speed of 50 km/h.

Based on the specific final energy demand and the relevant CO₂ emission parameters in g CO₂/kWh, the specific CO₂ emissions per net ton-kilometre (g CO₂/NTkm) can be derived. As for road transport, these are shown both for direct emissions (tank to wheel - TTW) and for the generation of electricity including direct emissions (well to wheel - WTW) (see Figure 2 for an explanation). There are no direct emissions when operating purely with electricity by rail. The CO₂ emissions resulting from electricity generation depend on the type of electricity generation. ÖBB-Infrastruktur AG currently provides its customers with traction current generated 100 % from renewable energy (96 per cent of which comes from hydropower) (see infrastruktur.oebb.at/de/geschaftspartner/energieversorgung/bahnstrom/railpower-zero).

For the lines in Germany, Italy and France, the electricity mix of the respective country, or the relevant region (source – see next part of this section) is assumed due to a lack of information regarding the specific composition of traction current. Electricity Maps ApS (electricitymaps.com/) reports the CO₂ emission factors of the electricity consumed per country (and in Italy per region) per year, month and day. This data source (online query in November 2024) was used for the information on the CO₂ emissions of the respective electricity grid.

This results in the following emission and energy requirement parameters (taking into account only the journey, without starting acceleration processes) for the two corridors on the rail:

Table 1: Brenner corridor, CO₂e emission factors [g/Ntkm], final energy demand factors [kWh/Ntkm], Rail, via Mountain Line

Country	from	to	TTW CO ₂ e	WTW CO ₂ e	Final Energy Demand ⁵
DE	München Trudering	Rosenheim	0.0	7.2	0.018
DE	Rosenheim	Border DE/AT	0.0	10.5	0.026
DE	Border DE/AT	Rosenheim	0.0	11.5	0.028
DE	Rosenheim	München Trudering	0.0	14.9	0.037
AT	Border DE/AT	Wörgl	0.0	0.0	0.027
AT	Wörgl	Abzweigung Fritzens- Wattens	0.0	0.0	0.027
AT	Abzweigung Fritzens- Wattens	Abzweigung Innsbruck	0.0	0.0	0.027
AT	Abzweigung Innsbruck	Border AT/IT	0.0	0.0	0.230
AT	Border AT/IT	Abzweigung Innsbruck	0.0	0.0	-0.035
AT	Abzweigung Innsbruck	Abzweigung Fritzens- Wattens	0.0	0.0	0.027

⁵ Negative values result from energy recovery through braking when travelling downhill.

Country	from	to	TTW CO _{2e}	WTW CO _{2e}	Final Energy Demand ⁵
AT	Abzweigung Fritzens- Wattens	Wörgl	0.0	0.0	0.027
AT	Wörgl	Border DE/AT	0.0	0.0	0.027
IT	Border AT/IT	Franzens- feste	0.0	-5.8	-0.018
IT	Franzens- feste	Bozen	0.0	-3.1	-0.010
IT	Bozen	Verona Quadrante Europa	0.0	5.2	0.017
IT	Verona Quadrante Europa	Bozen	0.0	11.9	0.038
IT	Bozen	Franzens- feste	0.0	32.8	0.105
IT	Franzens- feste	Border AT/IT	0.0	45.9	0.147

Table 2: Brenner corridor, CO₂e emission factors [g/Ntkm], final energy demand factors [kWh/Ntkm], Rail, via Brenner Base Tunnel

Country	from	to	TTW CO ₂ e	WTW CO ₂ e	Final Energy Demand ⁶
DE	München Trudering	Rosenheim	0.0	7.2	0.018
DE	Rosenheim	Border DE/AT	0.0	10.5	0.026
DE	Border DE/AT	Rosenheim	0.0	11.5	0.028
DE	Rosenheim	München Trudering	0.0	14.9	0.037
AT	Border DE/AT	Wörgl	0.0	0.0	0.027
AT	Wörgl	Abzweigung Fritzens- Wattens	0.0	0.0	0.027
AT	Abzweigung Fritzens- Wattens	Abzweigung BBT	0.0	0.0	0.027
AT	Abzweigung BBT	Staatsgrenze IT	0.0	0.0	0.082
AT	Staatsgrenze IT	Abzweigung BBT	0.0	0.0	-0.005
AT	Abzweigung BBT	Abzweigung Fritzens- Wattens	0.0	0.0	0.027
AT	Abzweigung Fritzens- Wattens	Wörgl	0.0	0.0	0.027
AT	Wörgl	Border DE/AT	0.0	0.0	0.027
IT	Staatsgrenze AT/IT	Franzensfeste	0.0	-0.7	-0.002
IT	Franzensfeste	Bozen	0.0	-3.1	-0.010

⁶ Negative values result from energy recovery through braking when travelling downhill.

Country	from	to	TTW CO _{2e}	WTW CO _{2e}	Final Energy Demand ⁶
IT	Bozen	Verona Quadrante Europa	0.0	5.2	0.017
IT	Verona Quadrante Europa	Bozen	0.0	11.9	0.038
IT	Bozen	Franzensfeste	0.0	32.8	0.105
IT	Franzensfeste	Staatsgrenze AT/IT	0.0	20.7	0.066

Table 3: Ventimiglia corridor, CO_{2e} emission factors [g/Ntkm], final energy demand factors [kWh/Ntkm], Rail

Country	from	to	TTW CO _{2e}	WTW CO _{2e}	Final Energy Demand ⁷
FR	Marseilles Fos (Port)	Saint-Raphaël	0.0	1.4	0.025
FR	Saint-Raphaël	Ventimiglia (Border FR/IT)	0.0	1.5	0.027
FR	Ventimiglia (Border FR/IT)	Saint-Raphaël	0.0	1.5	0.027
FR	Saint-Raphaël	Marseilles Fos (Port)	0.0	1.5	0.027
IT	Ventimiglia (Border FR/IT)	Bordighera	0.0	11.0	0.000
IT	Bordighera	Sanremo	0.0	32.3	0.103
IT	Sanremo	Taggia-Arma	0.0	48.9	0.156
IT	Taggia-Arma	Savona	0.0	8.4	0.027
IT	Savona	Ports of Genoa	0.0	8.3	0.027

⁷ Negative values result from energy recovery through braking when travelling downhill.

Country	from	to	TTW CO _{2e}	WTW CO _{2e}	Final Energy Demand ⁷
IT	Ports of Genoa	Savona	0.0	8.3	0.027
IT	Savona	Taggia-Arma	0.0	8.3	0.027
IT	Taggia-Arma	Sanremo	0.0	-6.4	-0.020
IT	Sanremo	Bordighera	0.0	-3.0	-0.010
IT	Bordighera	Ventimiglia (Border FR/IT)	0.0	6.1	0.019

3.3 Results

Based on the procedures and input data for road and rail set out in chapters 3.1 and 3.2 the following results can be derived and presented in aggregated form for the two corridors and the drive types as well as transport modes:

- Results per ton-km on average along corridor (both directions)
- Results for a transported ton along the whole corridor (both directions)
- Change due to shift of one transported ton along the corridor (both directions) from diesel truck (EURO VI D-E) to other drive types or to rail
- Change due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive or to rail

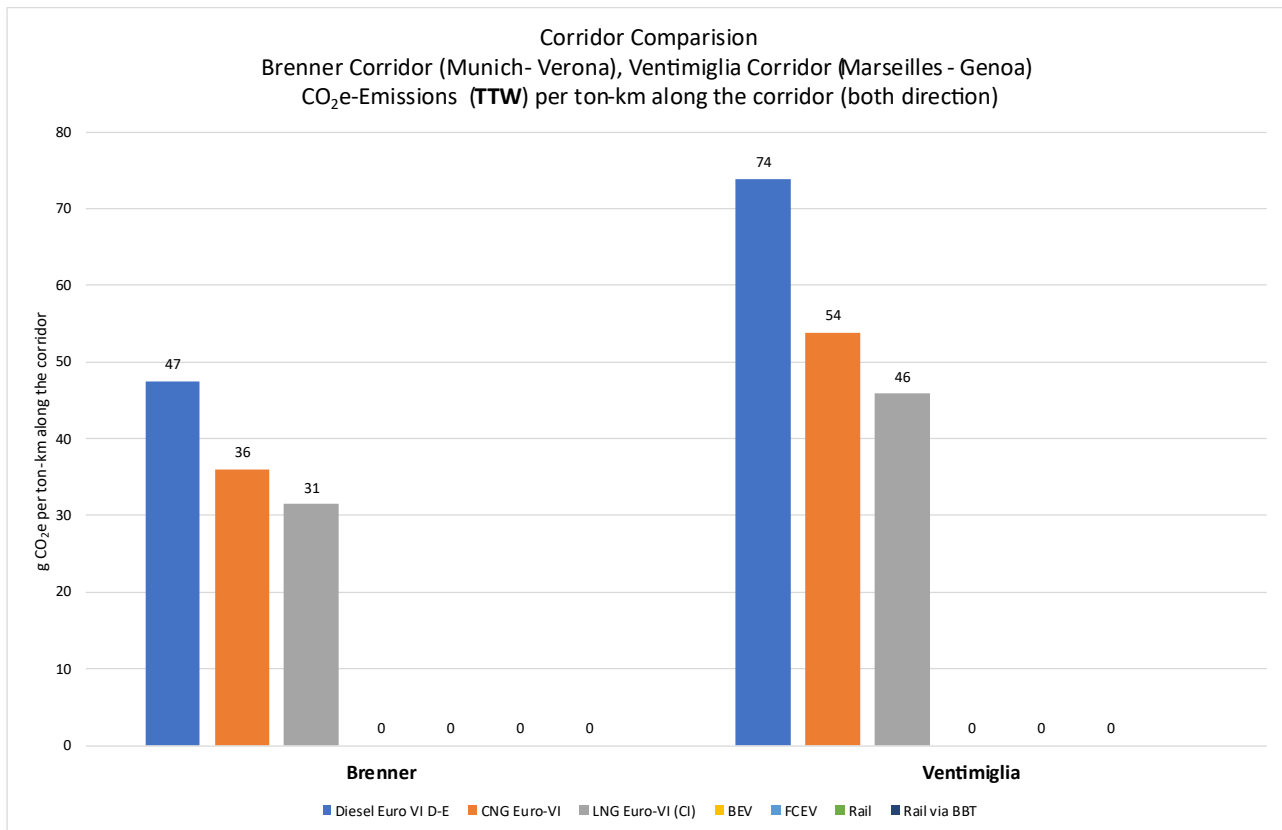
All listed results were determined for CO_{2e} emissions (TTW and WTW) and for final energy consumption.

3.3.1 Tank to Wheel greenhouse gas emissions

In the following, the results for tank-to-wheel greenhouse gas emissions are first presented in tabular form and then illustrated in figures to provide a quicker comparison between corridors, drive types and transport modes.

3.3.1.1 Comparison per Ton-km

Figure 3: Corridor comparison, CO₂e emissions (TTW) per ton-km on average along corridor (both direction), [g/ton-km]



Transports using electric vehicles (BEV, FCEV, rail) have no TTW CO₂ emissions, as no emissions are generated by electric engines. The emissions resulting from electricity generation are only included in the WTW (well to wheel) values (see also Figure 1). TTW-CO₂ emissions per ton-km of vehicles with combustion engines are lower on the Brenner Corridor mainly due to higher load factors (ton pr truck) on this Corridor.

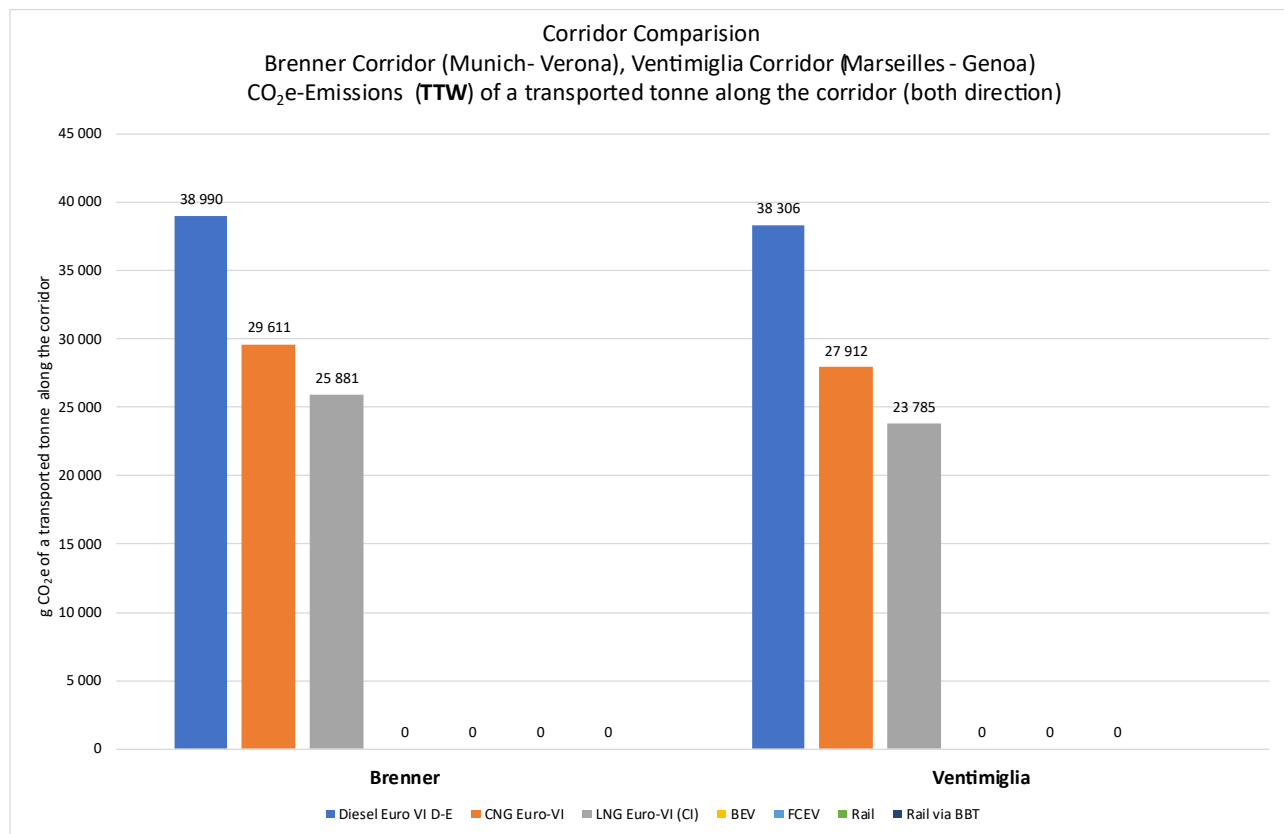
Table 4: Corridor comparison, CO₂e emissions (TTW) per ton-km on average along corridor (both direction), [g/ton-km]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, Diesel Euro VI D-E	47	74
Road, CNG Euro-VI	36	54
Road, LNG Euro-VI (CI)	31	46
Road, BEV	0	0
Road, FCEV	0	0

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Rail	0	0
Rail via BBT	0	-

3.3.1.2 Comparison per ton on overall corridor

Figure 4: Corridor comparison, CO₂e emissions (TTW) for a transported ton along the whole corridor (both direction), [g]



Despite lower TTW CO₂ emissions per ton-km on the Brenner corridor (see Figure 3), the TTW emissions of a transported tonne balance out over the entire route, as the distance between Munich and Verona is greater than that between Marseilles and Genoa.

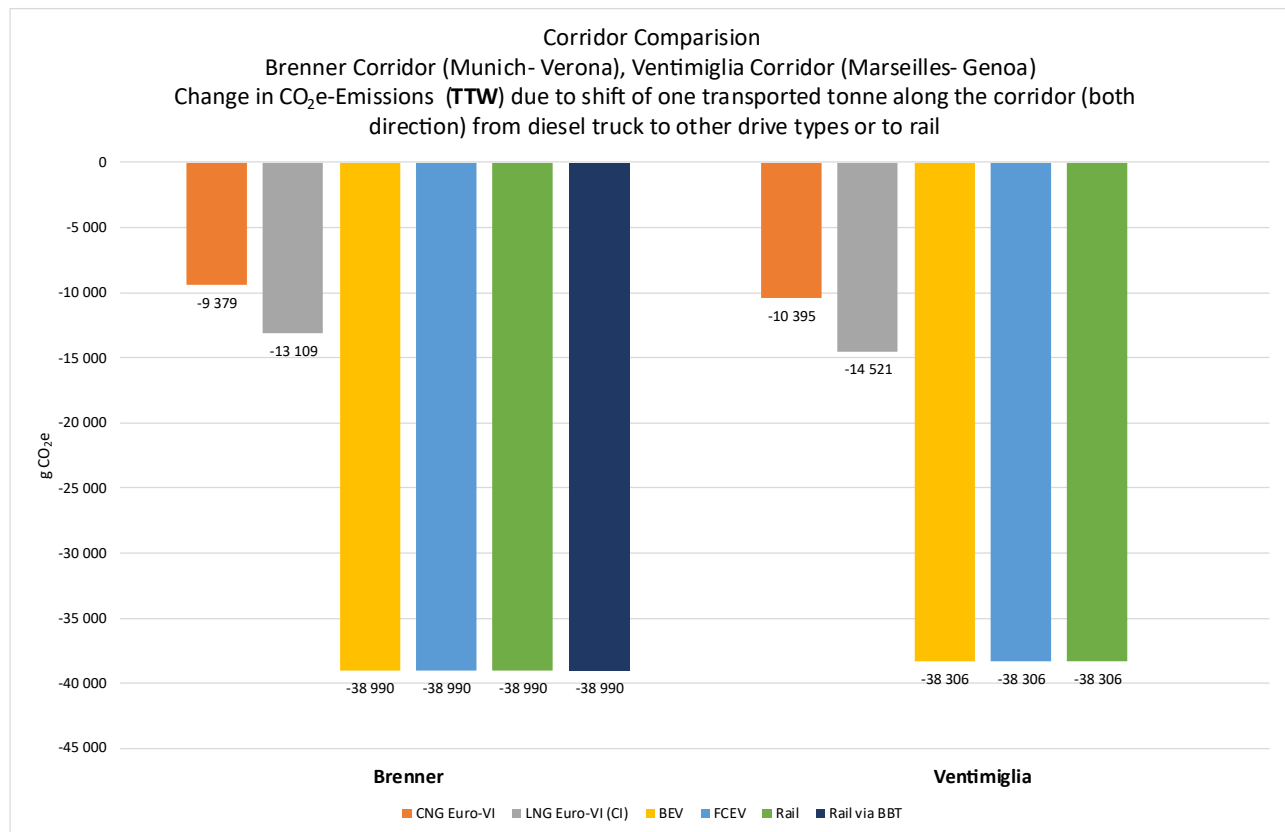
Table 5: Corridor comparison, CO₂e emissions (TTW) for a transported ton along the whole corridor (both direction), [g]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, Diesel Euro VI D-E	38,990	38,306
Road, CNG Euro-VI	29,611	27,912

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, LNG Euro-VI (CI)	25,881	23,785
Road, BEV	0	0
Road, FCEV	0	0
Rail	0	0
Rail via BBT	0	-

3.3.1.3 Comparison CO₂ reduction potentials

Figure 5: Corridor comparison, change in CO₂e emissions (TTW) due to shift of one transported ton along the corridor (both direction) from diesel truck to other drive types or to rail, [g]



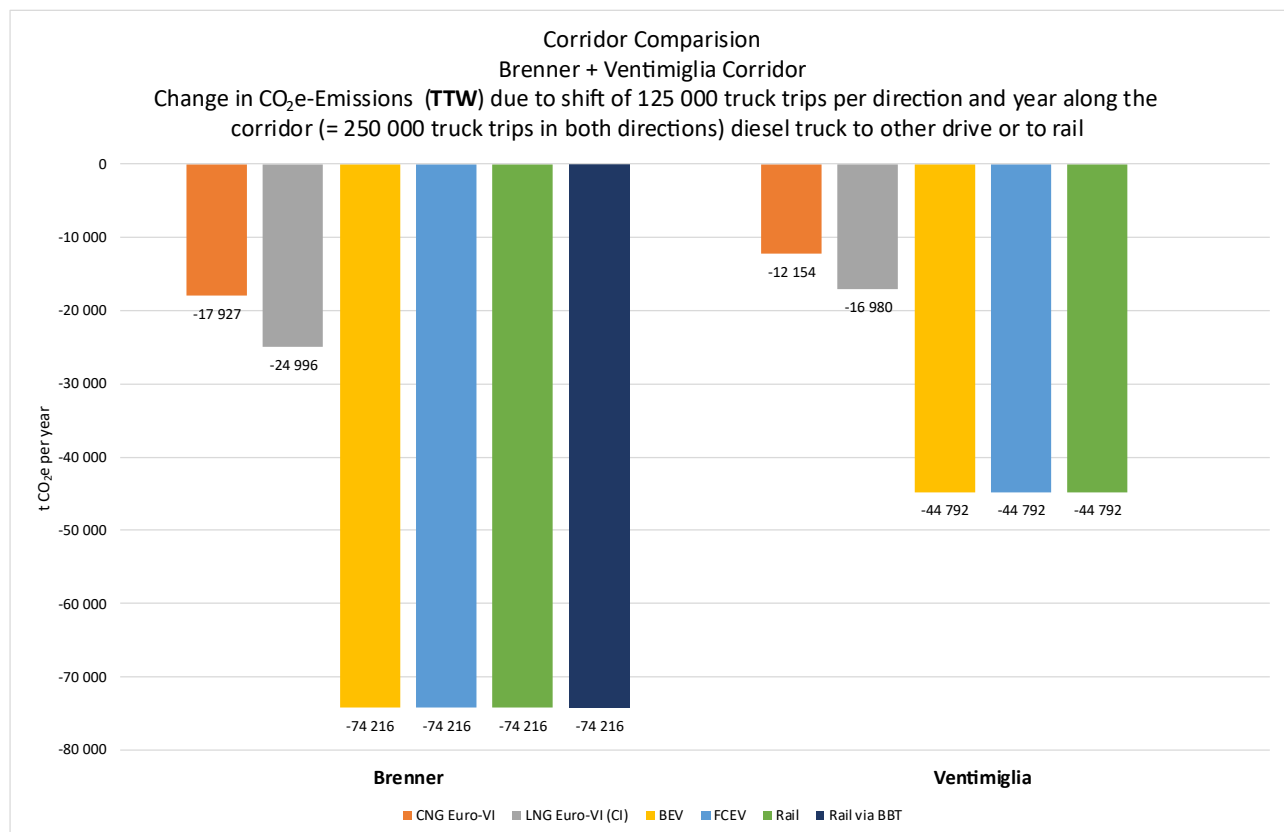
As vehicles with electric motors (BEV, FCEV, rail) have no WTW CO₂ emissions, the entire WTW CO₂ emissions can be reduced when using these vehicles compared to using a diesel truck. The savings for these vehicles per corridor are therefore the same per tonne transported along the corridor.

Table 6: Corridor comparison, change in CO₂e emissions (TTW) due to shift of one transported ton along the corridor (both direction) from diesel truck to other drive types or to rail, [g]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, CNG Euro-VI	-9,379	-10,395
Road, LNG Euro-VI (CI)	-13,109	-14,521
Road, BEV	-38,990	-38,306
Road, FCEV	-38,990	-38,306
Rail	-38,990	-38,306
Rail via BBT	-38,990	0

3.3.1.4 Comparison for shift of 125.00 trucks trips

Figure 6: Corridor comparison, change in CO₂e emissions (TTW) due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive types or to rail, [t]



The savings on the Brenner corridor due to shift of 125,000 truck trip per direction from diesel to other drive or rail are higher on the Brenner Corridor because of the longer distance of this corridor.

Table 7: Corridor comparison, change in CO₂e emissions (TTW) due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive types or to rail, [t]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, CNG Euro-VI	-17,927	-12,154
Road, LNG Euro-VI (CI)	-24,996	-16,980
Road, BEV	-74,216	-44,792
Road, FCEV	-74,216	-44,792
Rail	-74,216	-44,792
Rail via BBT	-74,216	-

3.3.2 Well to Wheel greenhouse gas emissions

In the following, the results for well-to-wheel greenhouse gas emissions are first presented in tabular form and then illustrated in figures to provide a quicker overview of the relationships between corridors, drive types and transport modes.

3.3.2.1 Comparison per Ton-km

Figure 7: Corridor comparison, CO₂e emissions (WTW) per ton-km on average along corridor (both direction), [g/ton-km]

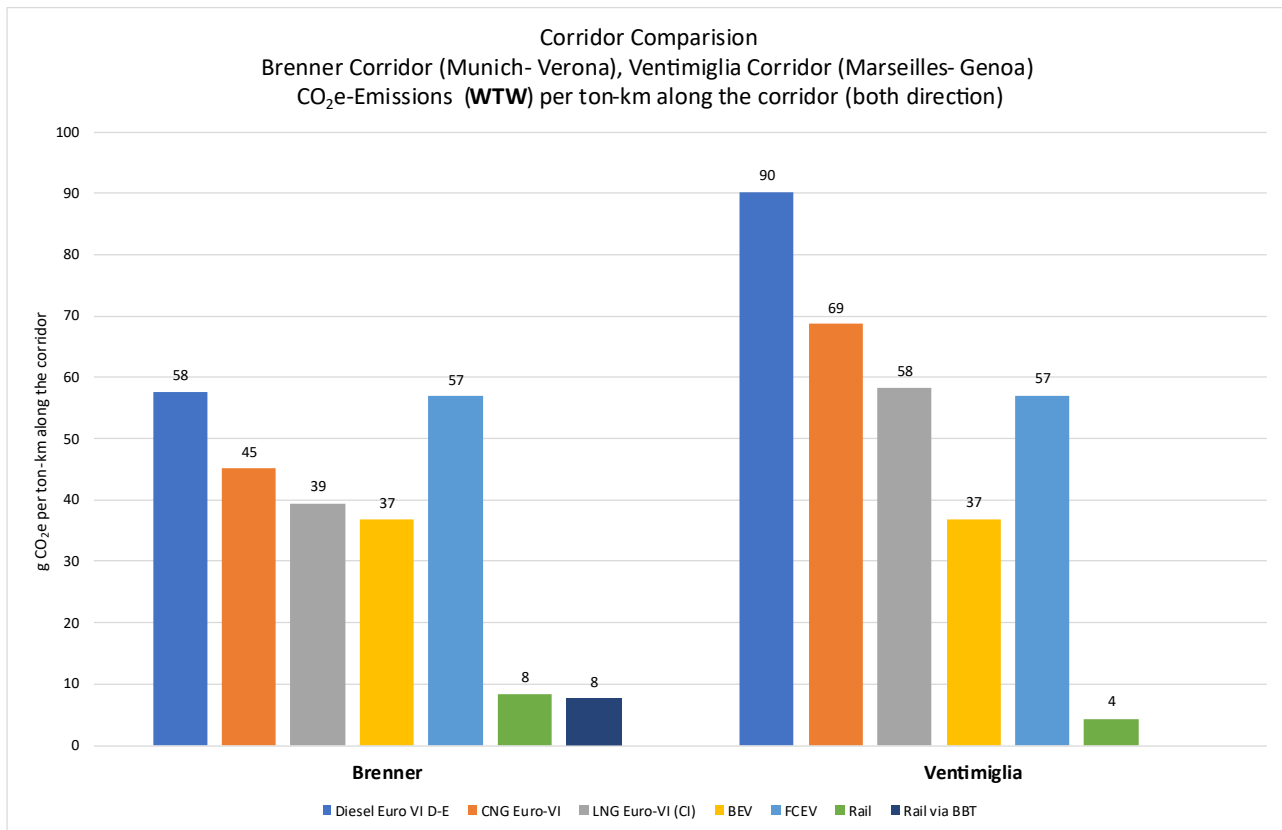


Figure 7 shows the CO₂ emissions not only of the engine but includes also the CO₂ emissions resulting from the production of fuel, hydrogen or electricity (explanation see Figure 1). This leads to CO₂ emissions also from vehicles with electric engines. One can see that the WTW CO₂ emissions from rail are significantly lower than those from BEV. Are the emissions per tonne-kilometre for trucks powered by combustion engines lower on the Brenner corridor due to the higher load factor, this can be offset for trucks powered by electric motors on the Ventimiglia corridor. This is due to the high proportion of nuclear power in France (which causes hardly any CO₂ emissions during generation).

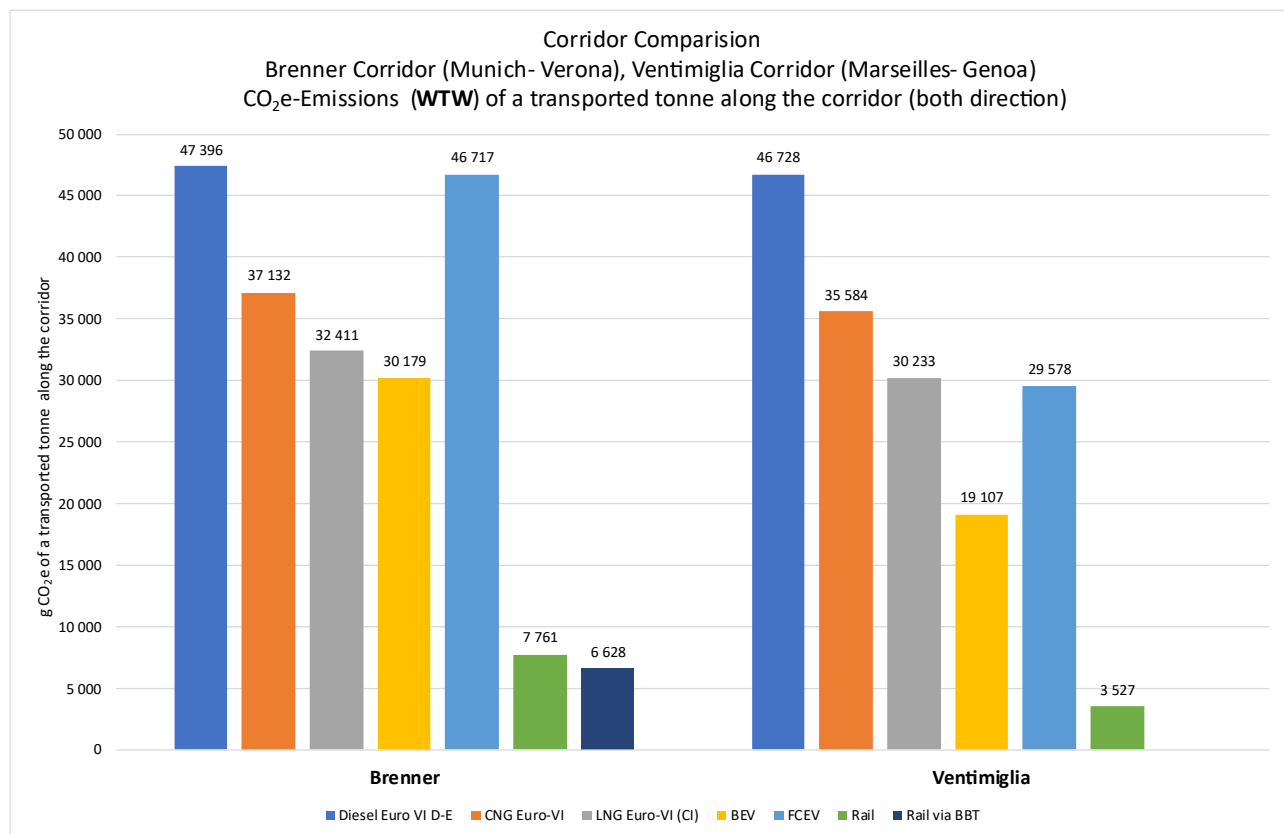
Table 8: Corridor comparison, CO₂e emissions (WTW) per ton-km on average along corridor (both direction), [g/ton-km]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, Diesel Euro VI D-E	58	90
Road, CNG Euro-VI	45	69
Road, LNG Euro-VI (CI)	81	58

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, BEV	37	37
Road, FCEV	57	57
Rail	8	4
Rail via BBT	8	-

3.3.2.2 Comparison per ton on overall corridor

Figure 8: Corridor comparison, CO₂e emissions (WTW) for a transported ton along the whole corridor (both direction), [g]



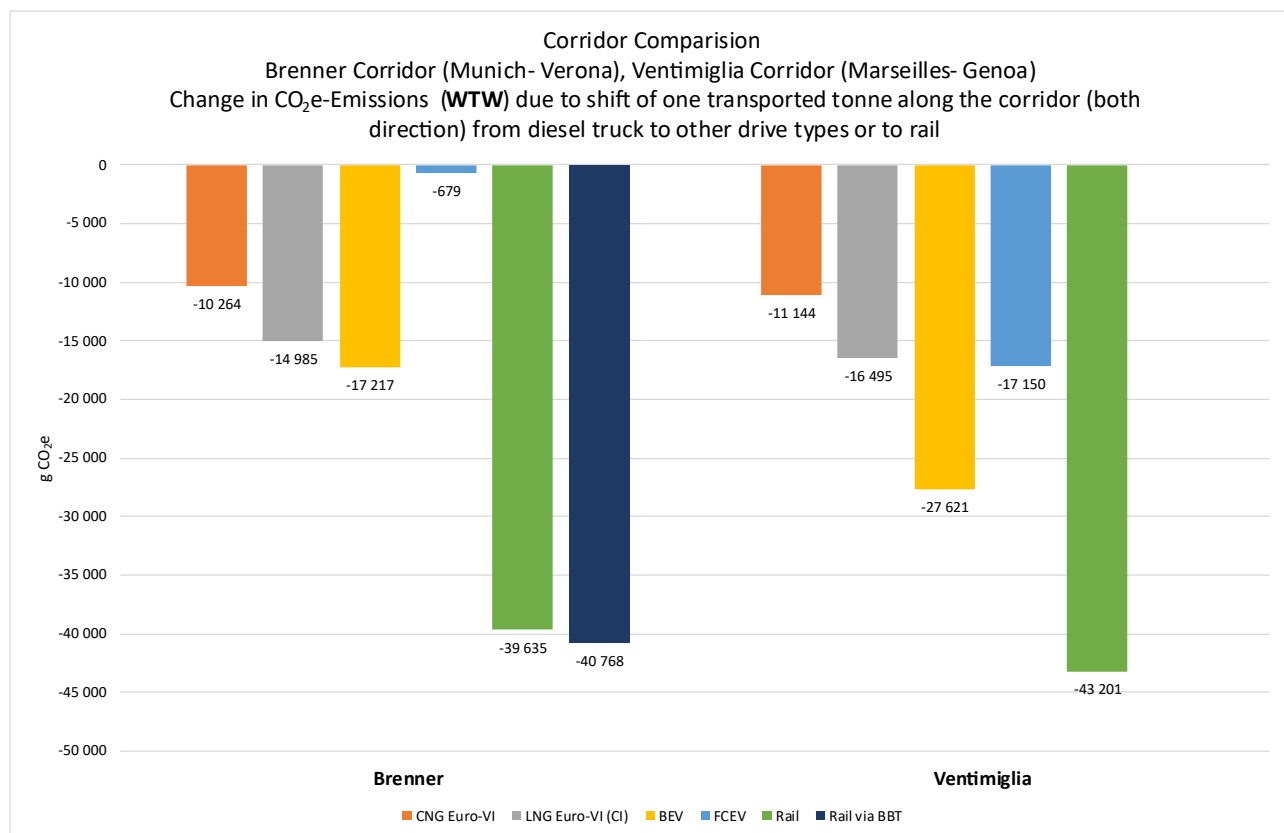
The same applies to WTW emissions (as for TTW emissions): the higher values per ton-km are offset by the greater distance along the Brenner corridor and the emissions per tonne transported are equalised along the two corridors. The differences between the individual truck drive types are due to the respective CO₂ emission figures shown in the manual for emission factors. These take into account the different electricity mixes in the individual countries and the different energy requirements and resulting CO₂ emissions for fuel production and fuel transport.) For this reason, FCEVs perform worse due to the high energy intensity in production of the hydrogen and the costly transport (due to the large volume).

Table 9: Corridor comparison, CO₂e emissions (WTW) for a transported ton along the whole corridor (both direction), [g]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, Diesel Euro VI D-E	47,396	46,728
Road, CNG Euro-VI	37,132	35,584
Road, LNG Euro-VI (CI)	32,411	30,233
Road, BEV	30,179	19,107
Road, FCEV	46,717	29,578
Rail	7,761	3,527
Rail via BBT	6,628	-

3.3.2.3 Comparison CO₂ reduction potentials

Figure 9: Corridor comparison, change in CO₂e emissions (WTW) due to shift of one transported ton along the corridor (both direction) from diesel truck to other drive types or to rail, [g]



The theoretical shift of a transported tonne from a diesel truck to other drive types or rail clearly shows that a shift to rail has the greatest potential for reducing emissions. This applies

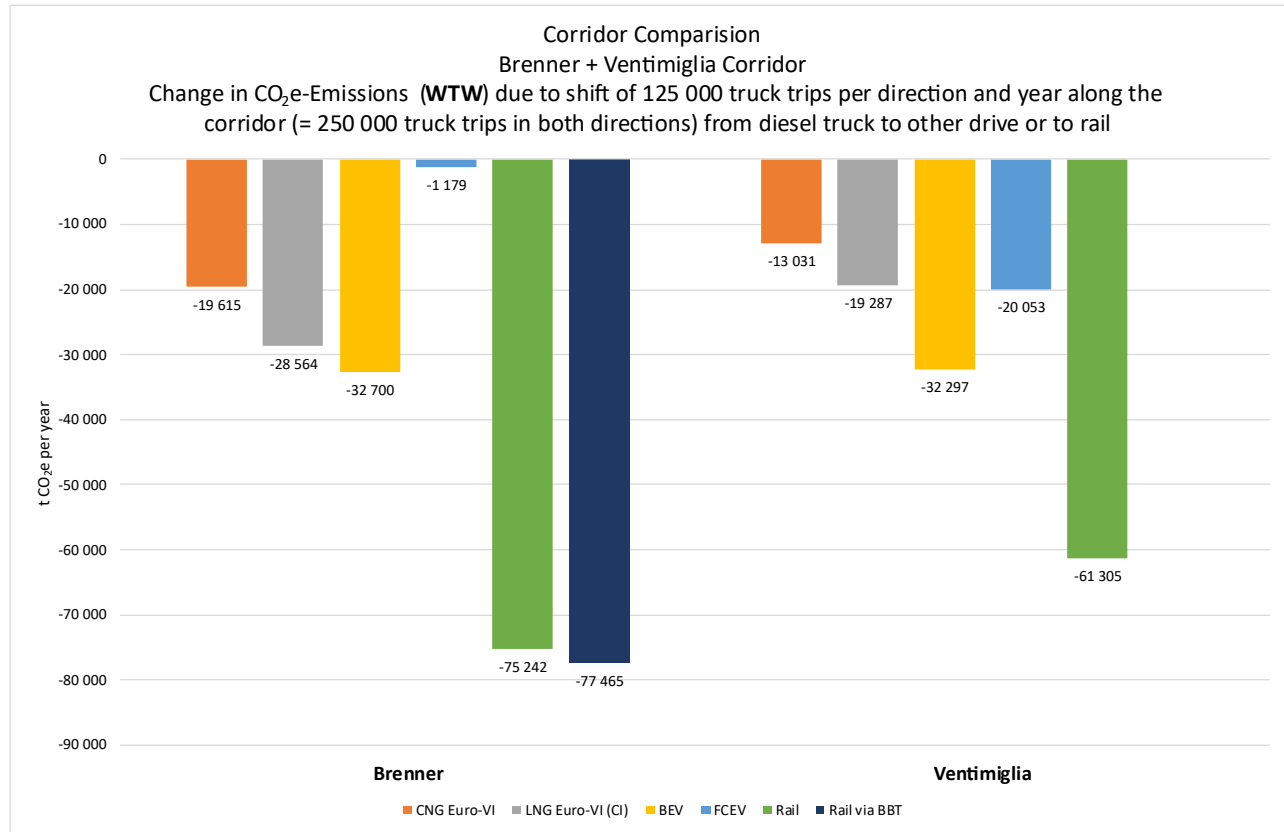
to both corridors. In a comparison of truck drive types, BEV clearly performs best. Due to the high proportion of nuclear power in France, the difference between BEV and FCEV on the Ventimiglia corridor is not as high as on the Brenner corridor.

Table 10: Corridor comparison, change in CO₂e emissions (WTW) due to shift of one transported ton along the corridor (both direction) from diesel truck to other drive types or to rail, [g]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, CNG Euro-VI	-10,264	-11,144
Road, LNG Euro-VI (CI)	-14,985	-16,495
Road, BEV	-17,217	-27,621
Road, FCEV	-679	-17,150
Rail	-39,635	-43,201
Rail via BBT	-40,768	-

3.3.2.4 Comparison shift of 125,000 truck trips

Figure 10: Corridor comparison, change in CO₂e emissions (WTW) due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive or to rail, [t]



This figure shows the WTW CO₂ emission reduction potential due to the shift of 125,000 diesel truck trips per direction and year along the two corridors to other drives or to rail. On the Brenner corridor the reduction potential is higher due to longer the distance of the corridor. The reasons for the differences between the drive types and rail are the same as describes for Figure 9.

Table 11: Corridor comparison, change in CO₂e emissions (WTW) due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive or to rail, [t]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, CNG Euro-VI	-19,615	-13,031
Road, LNG Euro-VI (CI)	-28,564	-19,287
Road, BEV	-32,700	-32,297

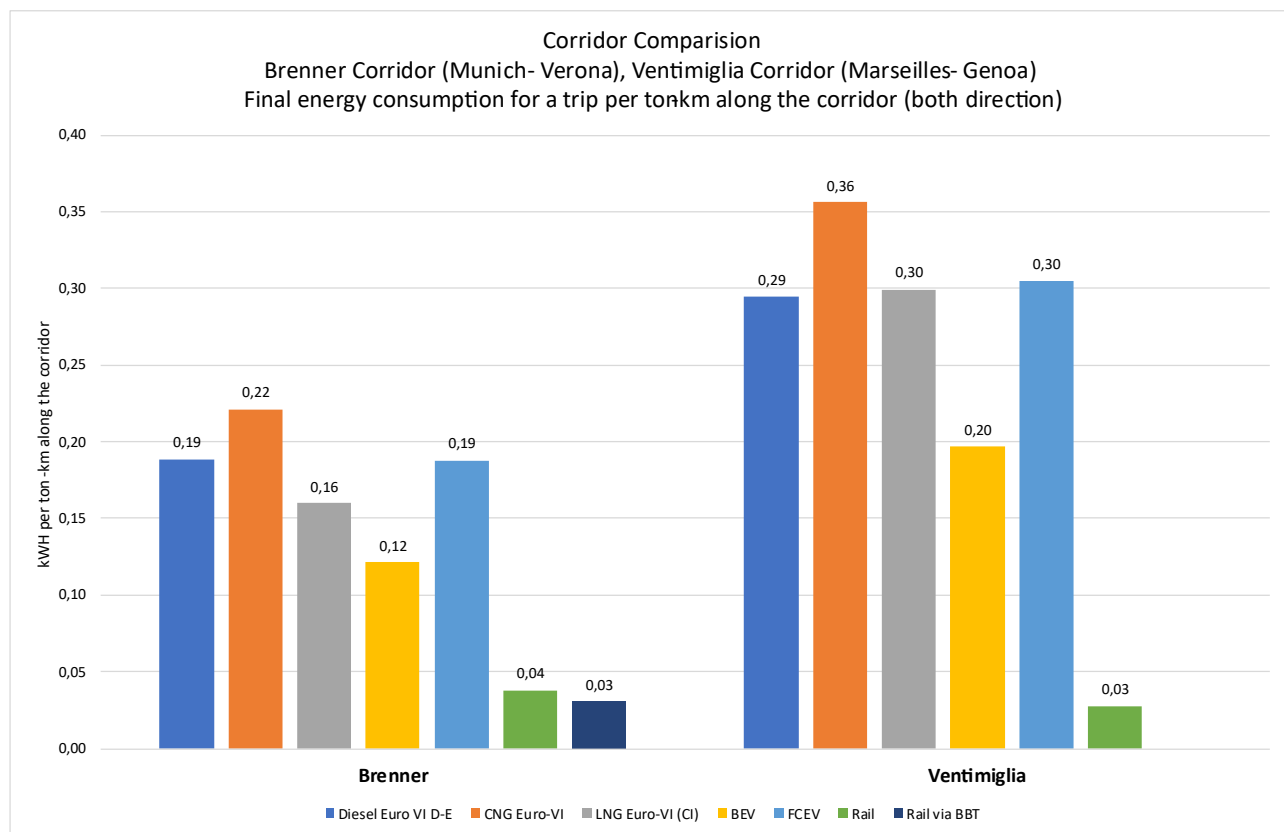
Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, FCEV	-1,179	-20,053
Rail	-75,242	-61,305
Rail via BBT	-77,465	-

3.3.3 Final energy consumption

In the following, the results for the final energy consumption are first presented in tabular form and then illustrated in figures to provide a quicker overview of the relationships between corridors, drive types and transport modes.

3.3.3.1 Comparison per kWh/Ton-km

Figure 11: Corridor comparison, final energy consumption per ton-km on average along corridor (both direction), kWh/ton-km]



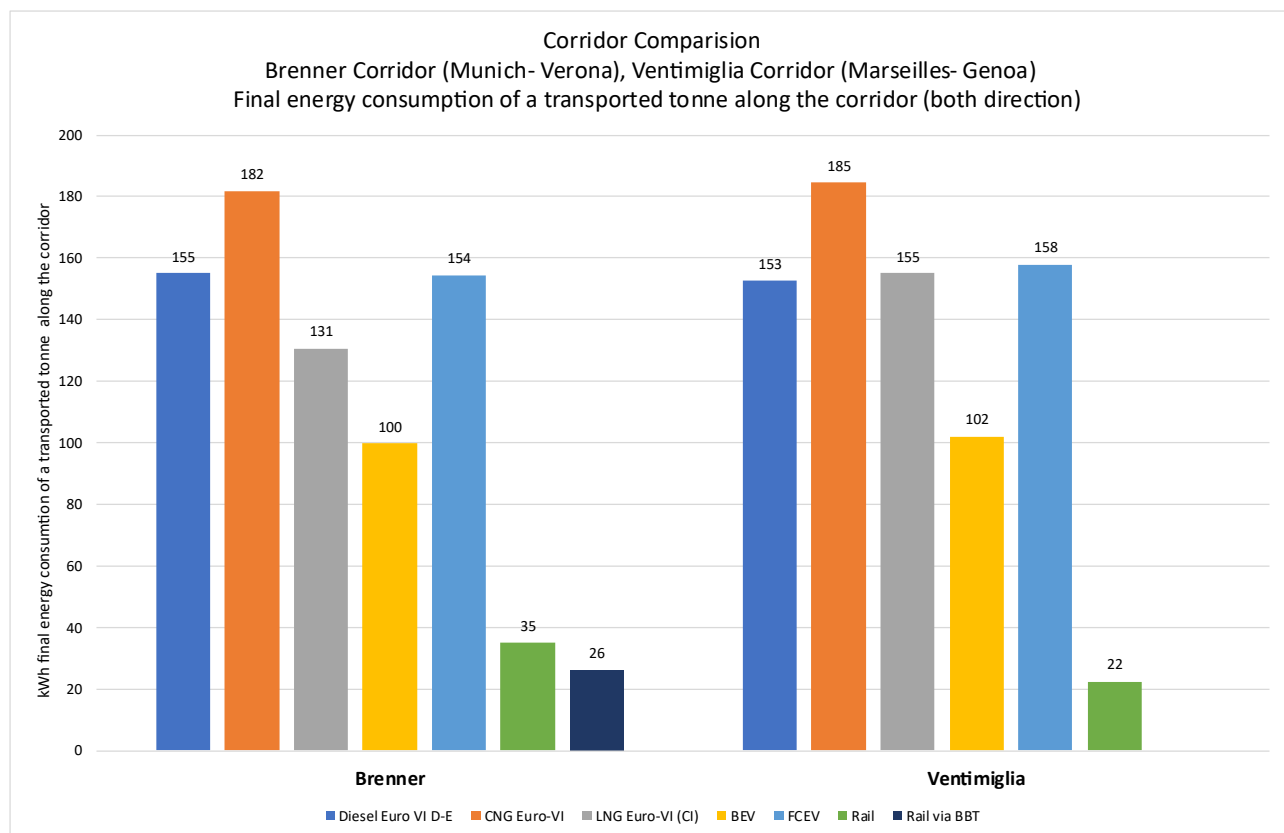
The final energy demand per ton-km is higher on the Ventimiglia corridor than on the Brenner corridor, as the average load factor on the Brenner is significantly higher than along the Ventimiglia corridor. The differences between the drive types are due to the final energy demand factors from the manual for emission factors. These take into account the different electricity mixes in the individual countries and the different energy requirements and for fuel production and fuel transport between drive types and countries.

Table 12: Corridor comparison, final energy consumption per ton-km on average along corridor (both direction), kWh/ton-km]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, Diesel Euro VI D-E	0.19	0.29
Road, CNG Euro-VI	0.22	0.36
Road, LNG Euro-VI (CI)	0.16	0.30
Road, BEV	0.12	0.20
Road, FCEV	0.19	0.30
Rail	0.04	0.03
Rail via BBT	0.03	-

3.3.3.2 Comparison per kWh on overall corridor

Figure 12: Corridor comparison, final energy consumption for a transported ton along the whole corridor (both direction), [kWh]



The results presented in Figure 12 for the transport of one tonne with the different truck types along the two corridors give a very similar picture for each truck type for the two corridors.

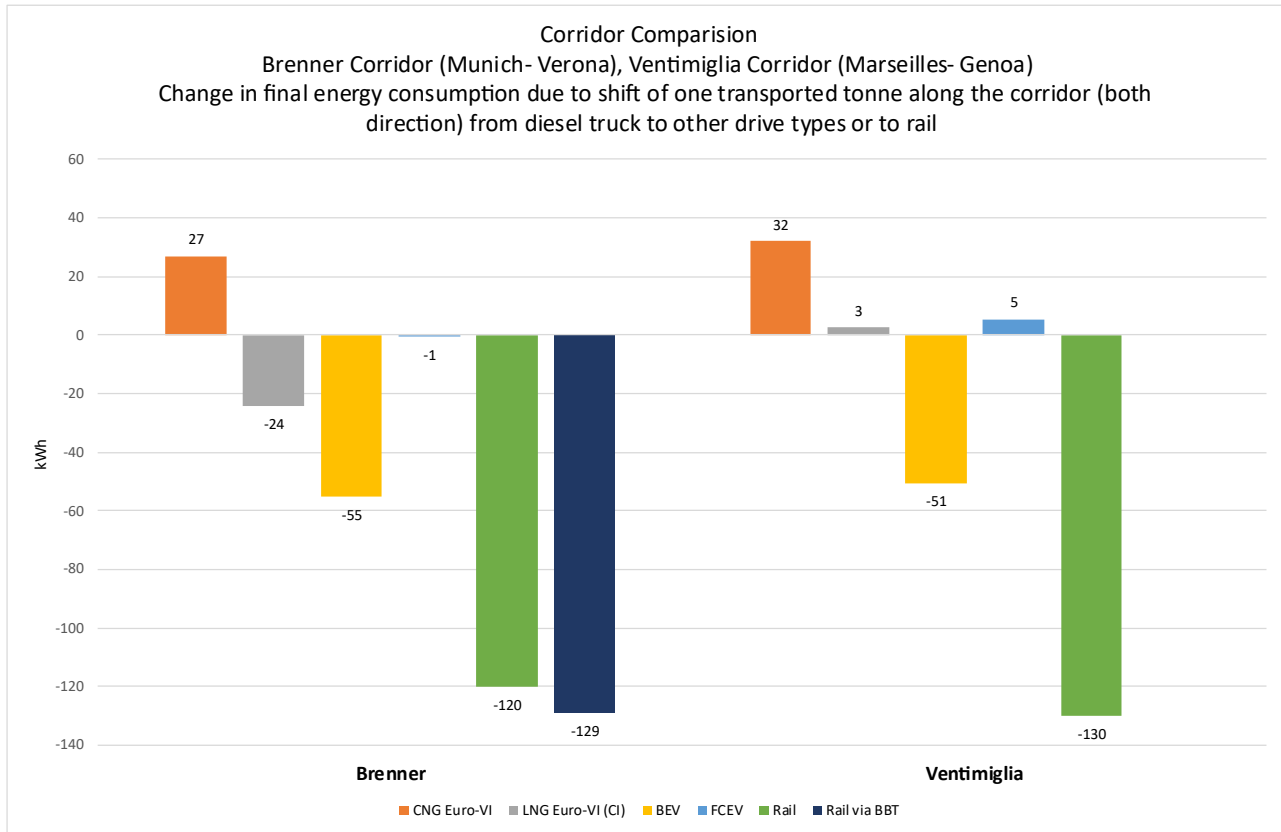
The results are based on the energy demand factors from the manual for emission factors combined with the different load factors and distances per corridor. This means that the very similar values presented for each corridor are 'coincidentally' similar. Figure 11 provides more comparative information, showing the differences per ton-km between the two corridors.

Table 13: Corridor comparison, final energy consumption for a transported ton along the whole corridor (both direction), [kWh]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, Diesel Euro VI D-E	155	153
Road, CNG Euro-VI	182	185
Road, LNG Euro-VI (CI)	131	155
Road, BEV	100	102
Road, FCEV	154	158
Rail	35	22
Rail via BBT	26	-

3.3.3.3 Comparison kWh reduction potentials

Figure 13: Corridor comparison, change in Final energy consumption due to shift of one transported ton along the corridor (both direction) from diesel truck to other drive types or to rail, [kWh]



While the use of CNG instead of diesel increases the final energy demand and no change in energy consumption is achieved with hydrogen, the final energy demand can be reduced with the other truck drive types. In both corridors, however, it can be seen that a significantly higher reduction in final energy demand can be achieved by shifting transport to rail - more than twice as much as when transport is handled with BEVs.

Table 14: Corridor comparison, change in Final energy consumption due to shift of one transported ton along the corridor (both direction) from diesel truck to other drive types or to rail, [kWh]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, CNG Euro-VI	27	32
Road, LNG Euro-VI (CI)	-24	3
Road, BEV	-55	-51

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, FCEV	-1	5
Rail	-120	-130
Rail via BBT	-129	-

3.3.3.4 Comparison shift of 125,000 truck trips

Figure 14: Corridor comparison, change in Final energy consumption due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive or to rail, [GWh]

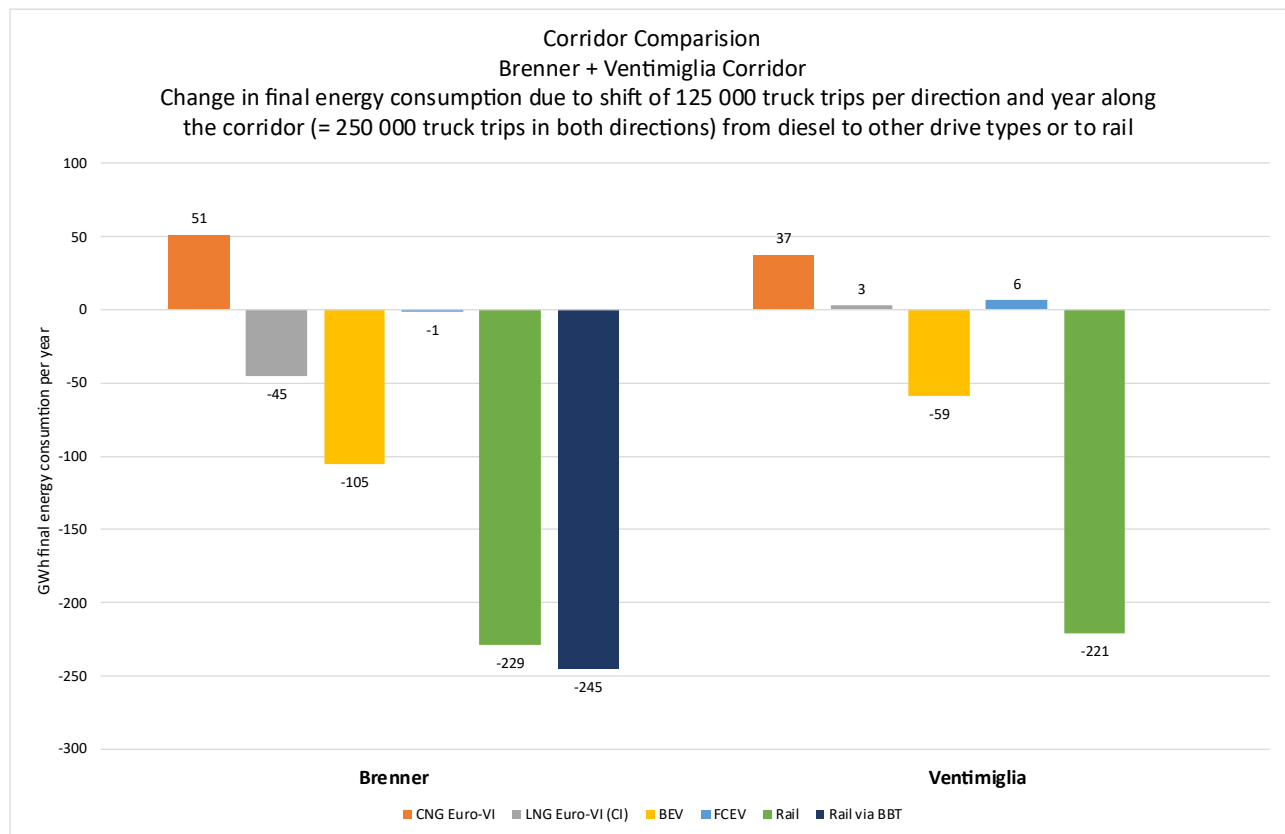


Figure 14 shows the same results as Figure 13, only not in the dimension of one displaced tonne, but in the dimension of 125,000 displaced truck journeys per corridor and direction. The ratios are therefore the same in both figures per corridor.

Table 15: Corridor comparison, change in Final energy consumption due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive or to rail, [GWh]

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
Road, CNG Euro-VI	51	37
Road, LNG Euro-VI (CI)	-45	3
Road, BEV	-105	-59
Road, FCEV	-1	6
Rail	-229	-221
Rail via BBT	-245	-

3.4 Classification of results

The results on final energy demand and the differences in final energy demand between road and rail modes of transport and the various drive types on the road are presented in this chapter using suitable comparative values to make it easier for interested readers to categorise the results.

The following comparative parameters are used for this purpose:

- Average electricity consumption per one average European person and year (2022)
- Electricity production per year of the hydropower plant Langkampfen in Tyrol (2021)
- Electricity production per year of an average nuclear power plant in France (2023)
- Electricity production per year of an average coal power plant Germany (2022)
- Electricity production per year of the Novel gas-fired cogenerative power plant in Italy near Milano (2023)

The different powerplants have been chosen to have information for the different countries relevant for the two corridors and to have different types of power plants.

The following table show the selected information for the classification.

Table 16: Base values for classification of the results

Type of classification	year	unit	value
average electricity consumption per European person and year	2022	kWh	1,584
electricity production per year (hydropower plant Langkampfen Tyrol)	2021	GWh	169
electricity production per year (average nuclear power plant France)	2023	GWh	5,714
electricity production per year (average coal power plant Germany)	2022	GWh	1,304
electricity production per year (Novel gas-fired cogenerative power plant Italy near Milano)	2023	GWh	600

The results presented in chapter 3.3.3 on the final energy demand of the different variants compared to the actual state are linked with the above-mentioned average values regarding the electricity consumption of one European person or the energy production of the different power plants listed. In this way, the potential for change in terms of final energy demand is expressed in outlined comparative figures.

Table 17: Corridor comparison, change in final energy consumption due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive types or to rail, presented as a change in **number of EU persons and their electricity consumption**

Drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
CNG Euro-VI	32,086	23,581
LNG Euro-VI (CI)	-28,622	1,852
BEV	-66,518	-37,320
FCEV	-807	3,962
Rail	-144,270	-139,546
Rail via BBT	-154,658	-

Table 17 shows that the final energy consumption saved by shifting 125,000 diesel truck trips per direction and year to rail on the Brenner corridor (with future use of the Brenner base tunnel) could supply almost 155,000 average European persons with electricity for a year. In

comparison, if these 250,000 trips (both directions) per year and would be transported by BEV instead of diesel, only about 66,000 persons could be supplied with the final energy saved.

Table 18: Corridor comparison, change in final energy consumption due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive types or to rail, presented as a change in **number of Tyrolian hydro power plants Langkampfen**

drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
CNG Euro-VI	0.30	0.22
LNG Euro-VI (CI)	-0.27	0.02
BEV	-0.62	-0.35
FCEV	-0.01	0.04
Rail	-1.35	-1.31
Rail via BBT	-1.45	-

Table 18 shows that a shift of 250,000 truck trips per year (both directions) via the Brenner Corridor would theoretically make it possible to build 1.45 fewer Inn power plants of the same size as the Langkampfen power plant.

Table 19: Corridor comparison, change in final energy consumption due to shift of 125 000 truck trips per direction and year along the corridor (= 250 000 truck trips in both directions) from diesel truck to other drive types or to rail, presented as a change in **number of average French nuclear power plants**

drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
CNG Euro-VI	0.009	0.007
LNG Euro-VI (CI)	-0.008	0.001
BEV	-0.018	-0.010
FCEV	0.000	0.001
Rail	-0.040	-0.039
Rail via BBT	-0.043	-

If 250,000 truck trips (in both directions) per year on the Ventimiglia corridor were shifted to rail, the resulting reduction in energy demand would have almost no effect on the electricity consumption of an average French nuclear power plant, as these power plants have a very high energy output and therefore the savings achievable through the shift would hardly be significant in relative terms.

The same applies to the two comparisons with an average German coal-fired power plant and the selected gas-fired power plant in Italy near Milan (see Table 20 and Table 21).

Table 20: Corridor comparison, change in final energy consumption due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive types or to rail, presented as a change in **number of average German coal power plants**

drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
CNG Euro-VI	0.039	0.029
LNG Euro-VI (CI)	-0.035	0.002
BEV	-0.081	-0.045
FCEV	-0.001	0.005
Rail	-0.175	-0.170
Rail via BBT	-0.188	-

Table 21: Corridor comparison, change in final energy consumption due to shift of 125,000 truck trips per direction and year along the corridor (= 250,000 truck trips in both directions) from diesel truck to other drive types or to rail, presented as a change in **number of the Italian gas fired power plant Novel** (near Milano)

drive type or mode	Brenner (Munich - Verona)	Ventimiglia (Marseilles - Genoa)
CNG Euro-VI	0.085	0.062
LNG Euro-VI (CI)	-0.076	0.005
BEV	-0.176	-0.099
FCEV	-0.002	0.010
Rail	-0.381	-0.368
Rail via BBT	-0.408	-

3.5 Summary

This chapter investigates CO₂ emissions and energy efficiency in cross-border freight transport along the Brenner corridor from Munich to Verona and along the Ventimiglia corridor from Marseilles to Genoa. The figures show that the conversion of drive technology towards innovative solutions in road freight transport can contribute to CO₂ emissions reduction and to a reduction in the final energy consumption of the transport system. However, even more effective in reducing CO₂ emissions and especially in lowering the final energy consumption is shifting transported tons from road to rail. Hence, the greater the modal shift, the more the final energy consumption of cross-border freight transport on the two corridors can be reduced.

CO₂ emissions (including the emissions generated during the production and transport of energy and fuel) can be reduced by 85 % (Brenner corridor, mountain route) or 95 % (Ventimiglia corridor) per ton-km if freight transport is shifted from diesel trucks to rail. In contrast, a shift from diesel trucks to battery-electric trucks can only reduce CO₂ emissions by 36 % and 59 % respectively.

A similar picture emerges with regard to the final energy saving potential: shifting one ton-km from a diesel truck to a battery-electric truck can reduce the final energy consumption by 36 % (Brenner) or 33 % (Ventimiglia). Shifting to rail, however, has significantly more than twice the savings potential on both corridors.

Comparing the energy-saving potential of the various possible drive types that can replace diesel engines on the road, battery-based systems perform best, and gas-powered combustion engines perform worst. The use of combustion engines that run on gas (LNG or CNG) or synthetic fuels makes little or no contribution to achieving the CO₂ reduction targets, as gas is not climate-neutral and combustion engines are less efficient than electricity-based drive solutions.

Once the Brenner Base Tunnel (BBT) is completed, a shift to rail transport on the Brenner corridor will result in even greater energy savings compared to using the mountain route due to the lower difference in altitude that needs to be overcome.

Following the principle of energy efficiency first and foremost, freight transport by rail should therefore be clearly favoured over road transport. Rail transport offers the most significant lever for reducing final energy consumption and greenhouse gas emissions.

4 Energy efficiency of good practice mobility measures of tourism destinations

In the further course of the project, good practice examples of energy efficiency in tourist passenger transport were analysed. The examples were selected and harmonised in cooperation with the client. The analysis was carried out on the basis of a tourist or visitor and included the calculation of the change in CO₂ emissions and final energy consumption (see Figure 2) resulting from the use of the alternative offer. The calculation of emissions includes all emissions, both direct and indirect. The initial values for the calculations for Austria come from the Austrian UBA (umweltbundesamt.at/fileadmin/site/themen/mobilitaet/daten/ekz_fzkm_verkehrsmittel.pdf) and for Germany and Italy from Electricity Maps ApS (electricitymaps.com/). This reports on the CO₂ emission factors of the electricity consumed per country (and in Italy per region) per year, month and day. This data source (online query in November 2024) was used for the information on the CO₂ emissions of the respective electricity grid.

4.1 Seefeld (AT) “Freifahrt ins Urlaubsglück”

4.1.1 Description of the good practice measure

The example of “Seefeld - Freifahrt ins Urlaubsglück” focuses on travelling to the holiday destination of Seefeld by sustainable means of transport. In 2022/23, a total of over 500,000 guest arrivals were recorded in Seefeld, a significant proportion of which travelling by private car. The tourism association is responding to this situation with a subsidy programme that offers all travellers who book at least five nights in Seefeld a reimbursement of up to EUR 150 for adults and up to EUR 75 for children when travelling to and from Seefeld by public transport (long-distance bus or train). However, it should be noted that package holidays are excluded from this promotion. In addition, a direct booking via the hotel or the local tourism service is required to ensure added value in the region.

4.1.2 Method

Calculations were carried out for the following three sample journeys:

- Hamburg - Seefeld
- Cologne - Seefeld
- Vienna - Seefeld

First, the respective route kilometres for the three example cases were determined. The distances were determined for the car journeys using a Google Maps query. The resulting distances for the journeys from Hamburg, Cologne and Vienna were 1,792 km, 1,332 km and 996 km respectively (both directions).

The distances travelled by train were also recorded. In addition, the train category (ICE, Railjet, regional train or S-Bahn) was determined for the respective sections of the journey. This data is relevant for analysing electricity consumption, as a distinction can be made between local and long-distance transport in Germany and Austria.

In Austria, the railway is operated with 100 % sustainably produced electricity, meaning that CO₂ emissions are zero for both long-distance and local transport. Final energy consumption in long-distance transport is 0.08 kWh and in local transport 0.098 kWh per passenger kilometre⁸.

Due to lack of data for Germany regarding energy consumption it is assumed that final energy consumption is identical in Germany and Austria. For the CO₂ emissions in the German rail network, it is assumed that the German electricity mix is used (CO₂ equivalent 32.6 g for long-distance transport and 39.8 g for local transport per passenger kilometre⁹).

To determine the underlying electricity mix, the route sections travelled on German and Austrian territory were surveyed.

The total distance from Hamburg Hbf. to Seefeld in Tirol Bf. is 1,836 km, of which 1,447.5 km are travelled by ICE, 343.7 km by Railjet and 44.8 km by S-Bahn. Of this total, 1,834.4 km are on German territory and 195.1 km on Austrian territory.

The train route from Cologne main station to Seefeld in Tirol main station is 1,325.7 km. Of this, 1,165.1 km is long distance and 160.6 km is local traffic. Of the 1,325.7 km, 1,139.4 km are in Germany and 186.3 km in Austria.

For the Vienna main station - Seefeld in Tirol station route, this results in a train distance of 1,172.8 km, of which 1,128 km is by Railjet and 44.8 km by S-Bahn. Only the Austrian electricity mix was used for the calculations. The short distance over the "Großes Deutsches Eck" was not included in the calculation.

The kilometres refer to the outward and return journey.

In a further step, the consumption was calculated for a person travelling by diesel car, battery electric vehicle (BEV) or train. The calculation for the diesel car was based on the consumption figures given by the UBA for a Golf-class vehicle. According to this, the vehicle consumes 6.9 l of diesel per 100 km, which corresponds to 248.7 g total CO₂ equivalents and 0.67 kWh per vehicle kilometre.

The UBA values for a Golf-class vehicle were also used for the BEV car. The German electricity mix (source: Electricity Maps ApS - electricitymaps.com/) was used to calculate the CO₂ equivalents for journeys from Hamburg and Cologne, as most of the electricity used for charging comes from Germany. This is 70.3 g CO₂ equivalents per vehicle kilometre. The energy consumption is 0.21 kWh/km. The Austrian electricity mix (source: Electricity Maps ApS - electricitymaps.com/) was used for the Vienna - Seefeld route¹⁰. This results in 29.5 g CO₂ equivalents and also 0.21 kWh/km.

⁸ Values for kWh/passenger km are calculated by kWh/train km (Source not published data from ÖBB Infrastructure) and average Persons per train (Source: Statistik Austria, Schiene Kontroll, ÖBB: Leistungs- und Aufkommensdaten Schiene Personenverkehr)

⁹ Electricity Maps ApS (electricitymaps.com/)

¹⁰ Source: Austrian UBA: https://www.umweltbundesamt.at/fileadmin/site/themen/mobilitaet/daten/ekz_fzkkm_verkehrsmittel.pdf

As described above, both the train category and the country-specific electricity mix were taken into account when calculating train consumption.

The following values were used for car journeys (per vehicle kilometre):

Table 22: Energy consumption and CO₂ equivalents of different vehicle types

Vehicle type	Energy consumption (kWh/VKM)	CO ₂ equivalent (g/VKM)
Diesel	0.67	248.7
BEV (AT electricity mix)	0.21	29.5
BEV (DE electricity mix)	0.21	70.3

The following values apply to rail (data per passenger kilometre):

Table 23: Energy consumption and CO₂ equivalents of different train categories and countries

Train category	Energy consumption (kWh/PKT)	CO ₂ equivalent (g/PKM)
Local transport AT	0.098	0.0
Long-distance transport AT	0.080	0.0
Local transport DE	0.098	32.8
Long-distance transport DE	0.080	26.9

In a final step, the corresponding CO₂ equivalent or energy consumption was multiplied by the distances. For the railways, the corresponding values per kilometre length per national territory and train category were used.

4.1.3 Results

The following results relate to a single person travelling to and from Seefeld from Hamburg:

Table 24: Energy consumption and CO₂ equivalents of various means of transport for a journey of one person from Hamburg to Seefeld and back

Arrival and departure with	total CO ₂ emissions in g	Energy consumption in kWh
Diesel	445,722	1,206
BEV	126,054	377
Train	49,269	164

The following findings can be derived from this table: Compared to travelling by diesel car, travelling by BEV results in a reduction in CO₂ emissions of around 72 % and a reduction in energy consumption of around 69 %.

Travelling by train shows even clearer advantages: Compared to the diesel car, CO₂ emissions fall by around 89 % and energy consumption is even reduced by around 86 %.

The train is also the most energy-efficient and lowest-emission option compared to the BEV: CO₂ emissions are around 61 % lower and energy consumption is around 57 % lower.

The following results are obtained for the journey from Cologne to Seefeld:

Table 25: Energy consumption and CO₂ equivalents of various means of transport for a journey of one person from Cologne to Seefeld and back

Arrival and departure with	total CO ₂ emissions in g	Energy consumption in kWh
Diesel	331,307	897
BEV	93,696	281
Train	37,414	114

Compared to the diesel variant, using a BEV reduces CO₂ emissions by around 66 % and energy consumption by around 72 %. The train journey is even more favourable in both categories: CO₂ emissions are around 89 % lower compared to diesel cars, while energy consumption can be reduced by a good 87 %.

A direct comparison between BEV and rail also shows a significant difference: emissions are reduced by around 60 % when travelling by train, while energy consumption is reduced by around 59 %.

Travelling from Vienna to Seefeld produces the following results:

Table 26: Energy consumption and CO₂ equivalents of various means of transport for a journey of one person from Vienna to Seefeld and back

Arrival and departure with	total CO ₂ emissions in g	Energy consumption in kWh
Diesel	247,734	670
BEV	29,367	210
Train	0	95

While CO₂ emissions are already reduced by about 88 % and energy consumption by around 69 % when using a BEV compared to a diesel car, the train is an even more environmentally friendly option:

In contrast to the car, the train does not cause any CO₂ emissions on this route, as 100 % of the traction current in Austria comes from renewable sources. Compared to diesel cars, the energy consumption of trains is around 86 % lower, and around 55 % lower than that of BEVs.

4.2 Bad Hindelang (DE) Emmi mobil

4.2.1 Description of measure

Another type of good practice measure is represented by “Emmi mobil - on-demand shuttle service in Bad Hindelang”. This focusses on local mobility in connection with tourism and leisure mobility, but also mobility in everyday life. EMMI-MOBIL complements the free bus service that is available in Bad Hindelang with the guest card. Two electric minibuses cover the need for on-demand transport in the municipal area. They operate without a fixed timetable but are connected to fixed stops in the municipal area. It takes passengers either to the nearest bus connection or directly to their destination. The service is free of charge with the local guest card.

4.2.2 Method

The data from the Umweltbundesamt for a standard Golf-sized vehicle was used to calculate the consumption of diesel cars and BEVs (see Table 22). When calculating BEV energy consumption, the German electricity supply was taken into account.

The “Emmi mobil” consists of two electrically powered Mercedes-Benz eVito Tourer Pro 129 extra-long minibuses. According to the manufacturer, these vehicles have an output of 150 kW, with an average power consumption of 28.8 kWh per 100 km.

The operator also states that the average occupancy rate of the “Emmi mobil” is 2.4 persons. The average journey distance per direction is 5.3 km, resulting in a total length for the outward and return journey of 10.6 km per trip.

For comparability, the respective consumption values (diesel car, BEV, “Emmi mobil”) were based on this average distance of 10.6 km. In the case of “Emmi mobil”, the calculated

consumption was additionally divided by the average occupancy rate of 2.4 persons in order to obtain the consumption-related value per person.

4.2.3 Results

The calculation produces the following results for a diesel car, a BEV and the electrically powered 'Emmi mobil' shared taxi:

Table 27: Comparison of energy consumption and CO₂ equivalents of one person between a diesel car, BEV and the Emmi mobil

Journey (10.6 km) with	total CO ₂ emissions in g	Energy consumption in kWh
Diesel	2,637	7
BEV	746	2
Emmi mobil	425	1

The analysis shows that switching from a diesel car to a battery electric vehicle (BEV) reduces CO₂ emissions by around 72 % and energy consumption by around 69 %.

However, due to its approach of ride pooling, the 'Emmi mobil' is even more efficient, producing over 84 % less CO₂ emissions and reducing energy consumption by around 82 % compared to a diesel car. Compared to the BEV, there is also an additional efficiency gain of around 43 % in emissions and 43 % in energy consumption.

4.3 Prags (IT) Mobility concept "Plan Prags"

4.3.1 Description of measure

The third example is the "Plan Prags" mobility concept in South Tyrol. Pragser Wildsee Lake is located in a protected UNESCO World nature heritage site. Due to the large numbers of visitors in the holiday peak season, a specific visitor guidance concept has been implemented. The concept includes a traffic regulation system to access the area and the lake and car park regulations, also by use of digital means. During summer months access is only possible by public transport (shuttle service), on foot, by bike or upon presentation of an online reservation or a valid transit permit. The booking system avoids a large proportion of superfluous circulation traffic after car park capacity has been exhausted.

4.3.2 Method

For the comparison of CO₂ emissions and energy consumption, the data from the Umweltbundesamt for a standard Golf-class vehicle was again used (see Table 22). Deviating from this, an electricity mix from northern Italy was used to calculate the battery electric vehicle.

There are currently two shuttle connections for visitors to Lake Braies:

- Line 439 runs on a route of around 12 km between Monguelfo/Welsberg and Lago di Braies/Pragser Wildsee.
- Line 442 connects Dobbiaco/Toblach with the lake, which is around 18 km away.

Line 439 has an average occupancy rate of 23 passengers, while line 442 has an average occupancy rate of 20 passengers.

The vehicle currently in use is a Mercedes Citaro (2-door, diesel). According to the manufacturer, this bus consumes 35 l diesel per 100 vehicle km, which corresponds to CO₂ emissions of 1,261.7 g and energy consumption of 3.4 kWh per vehicle km.

Comparative values were also calculated for the battery-electric Mercedes Citaro (2-door, BEV). This results in 275.8 g CO₂ equivalents and an energy consumption of 0.8 kWh per vehicle kilometre.

For the assessment, the respective consumption values were multiplied by the full distance travelled (outward and return journey). In order to obtain a consumption-related value per person, the result for shuttle transport was also divided by the respective average occupancy rate.

4.3.3 Results

This produces the following results for the 'Plan Braies' example:

Line 439 - Monguelfo/Welsberg - Lago di Braies/Pragser Wildsee (24 m)

Table 28: Comparison of energy consumption and CO₂ equivalents of one person between a diesel car, BEV, diesel bus and BEV bus on route 439

Line 439 (24 km)	total CO ₂ emissions in g	Energy consumption in kWh
Diesel	5,969	16
BEV	1,582	5
Mercedes Citaro 2 (diesel)	1,305	4
Mercedes Citaro 2 (BEV, 285 northern IT electricity mix)		1

Line 442 - Dobbiaco/Toblach - Lago di Braies/Pragser Wildsee (36 km)

Table 29: Comparison of energy consumption and CO₂ equivalents of one person between a diesel car, BEV, diesel bus and BEV bus on route 442

Line 442 (36 km)	total CO ₂ emissions in g	Energy consumption in kWh
Diesel	8,954	24

Line 442 (36 km)	total CO ₂ emissions in g	Energy consumption in kWh
BEV	2,373	8
Mercedes Citaro 2 (diesel)	2,271	6
Mercedes Citaro 2 (BEV, 496 northern IT electricity mix)		2

The results clearly show that public transport - especially battery-electric versions - have considerable advantages over individual motorised transport in terms of CO₂ emissions and energy consumption.

- On line 439, the trip of one person with electric bus produces around 95 % less CO₂ than the diesel car and only requires around 6 % of the energy (considering the occupancy rate of the bus).
- The electric bus is also significantly more economical than the BEV car: emissions are reduced by approx. 82 %, energy savings by 80 % for the trip of one person (considering the occupancy rate of the bus).
- The picture is similar on the longer route of line 442.

4.4 Summary

The empirical evidence from the good practice examples shows that a significant reduction in CO₂ emissions and energy consumption in tourist regions can be achieved by using alternative, preferably electric, means of public transport. The study shows that travelling by train is particularly effective compared to travelling by car, even compared to electric cars.

Using rail (for the trip to and from the tourism destination) or (alternative) public transport offers (for onsite trips) instead of a diesel car can reduce CO₂ emissions (including the emissions generated during the production and transport of energy and fuel) by about 75 % to 100 % (depending on the specific case study and the prevailing electricity generation mix at the national level). Compared to this a shift of one passenger trip from a diesel car to a BEV reduces CO₂ emissions only by 50 % to 70 % (again depending on the specific case study and the prevailing electricity generation mix at the national level).

A similar picture emerges with regard to the final energy saving potential: shifting one passenger trip from diesel car to rail (for the trip to and from the tourism destination) or (alternative) public transport offers (for onsite trips) reduces the final energy demand by about 80 % to 90 %. A shift to BEV enables significantly less reduction of energy demand (about 70 %).

The high utilisation of shuttles and buses that can be observed locally also contributes to the reduction of emissions. Empirical studies show that the combination of measures for travelling to and from the event and mobility on site is one of the most effective approaches.

5 Recommendations

5.1 Energy efficiency of freight transport on two Alpine crossing corridors

The following key findings can be summarised for cross-border, transalpine freight transport. Basis for this are the results generated in this study for the Brenner Corridor and the Ventimiglia Corridor with regards to CO₂ emissions and final energy consumption when using different drive types and modes of transport:

- The conversion of drive technology alone achieves significantly lower CO₂ emission reductions and final energy demand reductions than shifting transport from road to rail
- Rail offers the most significant level for reducing final energy consumption and greenhouse gas emissions
- This difference between the potential CO₂ emission reduction and energy savings between the shift from Diesel truck to BEV or to rail can be highlighted with the following comparison:
 - CO₂ emissions (including the emissions generated during the production and transport of energy and fuel) can be reduced by 85 % (Brenner corridor, mountain route) or 95 % (Ventimiglia corridor) per ton-km if freight transport is shifted from diesel trucks to rail.
 - In contrast, a shift from diesel trucks to battery-electric trucks can only reduce CO₂ emissions by 36 % and 59 % respectively.
 - Shifting one ton-km from a diesel truck to a battery-electric truck can reduce the final energy consumption by 26 % (Brenner) or 33 % (Ventimiglia).
 - Shifting to rail, however, has significantly more than twice the savings potential on both corridors.
- Battery-based systems for trucks show the highest energy saving potentials of the possible drive types for road
- Transalpine freight transport can achieve a significant contribution to the CO₂ emission reduction goals only
 - If goods are shifted from road to rail by fully exploiting the existing and future rail infrastructure capacities and
 - If the remaining truck trips are operated with the most energy-efficient and in any case climate-neutral drives possible

Based on these findings, the following **recommendations for measures** can be derived in order to achieve the emission reduction targets in **transalpine freight transport** and to reduce final energy consumption:

- Release the full potential of new cross-border infrastructure like the Brenner Base Tunnel by realising its access routes and terminal infrastructure

- Increase of interoperability along the border crossing rail freight corridors over the Alps (eradicate the need for border stops or reduce the time spent on borders due to administrative and technical reasons)
- Provision of high priority train paths for long distance rail freight transport to increase reliability and punctuality for long-distance rail freight transport
- Coordinated border crossing development of charging points along the whole corridors (distance between charging points, technology of charging points for super charging of trucks) along the European Alternative Fuels Infrastructure Regulation (AFIR)
- Realisation of an accompanying policy mix to further support the shift from road to rail (beside above listed Infrastructure measures) and to set incentives for the uptake of new technologies (especially BEV trucks) (e.g.: targeted road pricing models to incentivise modal shift and the use of clean technologies on road; increase combined transport support measures (infrastructure as well as operational and financial support).

5.2 Energy efficiency of good practice mobility measures of tourism destinations

The following key findings can be summarised for mobility measures of tourism destinations. Basis for this are the results generated in this study for three best practice mobility measures in three different tourism destinations (Seefeld, Bad Hindelang, Prags) with regard to CO₂ emissions and final energy consumption when using different drive types and modes of transport:

- Alternative public transport options in tourism regions help to reduce greenhouse gas emissions. If these are not offered with combustion engines but with electric vehicles, the impact is significantly higher.
- The use of the train for long distance travels to and from the tourism destination instead of the use of private cars decreases the CO₂ emissions and energy demand significantly also compared to the use of BEV instead of cars with combustion engines for the journey.
- This difference between the potential CO₂ emission reduction and energy savings between the shift from Diesel car to BEV or to rail and other public transport offers can be highlighted with the following comparison:
 - CO₂ emissions (including the emissions generated during the production and transport of energy and fuel) can be reduced by 75 % to 100 % (depending on the specific case study and the prevailing electricity generation mix at the national level) if a passenger trip is shifted from diesel car to rail (for the trip to and from the tourism destination) or (alternative) public transport offers (for onsite trips).
 - In contrast, a shift from diesel car to battery-electric car can only reduce CO₂ emissions by 50 % to 70 %.
 - Shifting one passenger trip from a diesel car to a battery-electric car can reduce the final energy consumption by about 70 %.

- Shifting to rail (for the trip to and from the tourism destination) or (alternative) public transport offers (for onsite trips), however, enables a higher reduction (80 % to 90 %)
- A high occupancy rate of the vehicles used for local transport offers (such as on demand shuttles or busses) increases the CO₂ emission-reduction and decreases energy demand compared to the use of private cars.
- To achieve optimal results, measures focusing both on trips to and from the tourism region and on local mobility should be combined.

To contribute to emission reduction goals following **measures** are **recommended regarding tourism mobility of Alpine tourism destinations**

- A combination of offers for the use of train for the travel to and from the tourism destinations and local transport offers at the destination is important to push both travel to, from and at the destination with public transport.
- Financial Support to enable the offer of BEV-based alternative mobility solution (instead of combustion engine-based solutions)
- Establishment, expansion and provision of e-charging infrastructure (in addition to implementation of AFIR targets) in the tourism regions (at accommodation establishments and POIs)
- Additional measures such as parking management at touristic points of interest (POI) are necessary to increase the attractiveness of public transport offers for tourists to these POIs. This increases the CO₂ emission reduction possibilities of such offers. A higher usage of these offers enables a higher occupancy rate which is again an important step to further reduction of CO₂ emissions of local transport activities of tourists at tourism destinations.
- Better promotion of available good practices through joint communication, campaigns, etc
- Integration of measures focusing on sustainable transport with other related measures in the regions → towards climate-neutral tourism packages

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8 Appendix

Table 30: Brenner corridor, route information, road

Country	"motor-way"	from	to	length (km)	gradient (%) direction south ¹¹
DE	A8	Kreuz München Süd (A99)	km 37	27	0 %
DE	A8	km 37	Leitzachbrücke	2	-2 %
DE	A8	Leitzachbrücke	AS Irschenberg	4	2 %
DE	A8	AS Irschenberg	Dreieck Inntal (A93)	13	-2 %
DE	A93	Dreieck Inntal (A93)	Border Kufstein	26	0 %
AT	A12	Border Kufstein	Kn Innsbruck- Amras (A13)	77	0 %
AT	A13	Kn Innsbruck- Amras (A12)	Border Brennerpass	36	3 %
IT	A22	Border Brennerpass	Bozen	87	-2 %
IT	A22	Bozen	km 112	118	0 %
IT	A22	km 112	km 110	2	4 %
IT	A22	km 110	Verona - Kn A4	20	0 %

¹¹ The reverse gradient is used in the opposite direction.

Table 31: Brenner corridor, route information, rail, via mountain line

Country	from	to	length (km)	gradient (%) direction south ¹²
DE	München Trudering	Rosenheim	64.9	-0.1 %
DE	Rosenheim	Border DE/AT	31.9	0.0 %
AT	Border DE/AT	Wörgl	13	0.0 %
AT	Wörgl	Abzweigung Fritzens- Wattens	60.6	0.0 %
AT	Abzweigung Fritzens- Wattens	Abzweigung Innsbruck	15.4	0.0 %
AT	Abzweigung Innsbruck	Border AT/IT	35.5	2.6 %
IT	Border AT/IT	Franzensfeste	40.7	-1.5 %
IT	Franzensfeste	Bozen	48.3	-1.0 %
IT	Bozen	Verona Quadrante Europa	150.2	-0.1 %

Table 32: Brenner corridor, route information, rail, via BBT

Country	from	to	length (km)	gradient (%) direction south ¹³
DE	München Trudering	Rosenheim	64.9	-0.1 %
DE	Rosenheim	Border DE/AT	31.9	0.0 %
AT	Border DE/AT	Wörgl	13	0.0 %

¹² The reverse gradient is used in the opposite direction.¹³ The reverse gradient is used in the opposite direction.

Country	from	to	length (km)	gradient (%) direction south ¹³
AT	Wörgl	Abzweigung Fritzens- Wattens	60.7	0.0 %
AT	Abzweigung Fritzens- Wattens	Abzweigung BBT	10.1	0.0 %
AT	Abzweigung BBT	Border AT/IT	27.6	0.7 %
IT	Border AT/IT	Franzensfeste	25	-0.5 %
IT	Franzensfeste	Bozen	48.3	-1.0 %
IT	Bozen	Verona Quadrante Europa	150.2	-0.1 %

Table 33: Ventimiglia corridor, route information, road

Country	"motor-way	from	to	length (km)	gradient (%) direction east ¹⁴
FR	A8	Marseilles (A8/A52 near Marseilles)	Nice ouest	160.4	0 %
FR	A8	Nice ouest	AS Monaco	25	2 %
FR	A8	AS Monaco	Ventimiglia (Border FR/IT)	21	-2 %
IT	A10	Ventimiglia (Border FR/IT)	Savona (A6)	105	0 %
IT	A10	Savona (A6)	Genoa (A7)	28	0 %

¹⁴ The reverse gradient is used in the opposite direction.

Table 34: Ventimiglia corridor, route information, rail

Country	from	to	length (km)	gradient (%) direction south ¹⁵
FR	Marseilles (Port)	Fos Saint-Raphaël	161.1	0.0 %
FR	Saint-Raphaël	Ventimiglia (Border FR/IT)	98.2	0.0 %
IT	Ventimiglia (Border FR/IT)	Bordighera	4.7	0,1 %
IT	Bordighera	Sanremo	11.6	1.0 %
IT	Sanremo	Taggia-Arma	6.1	1.7 %
IT	Taggia-Arma	Savona	85.8	0.0 %
IT	Savona	Ports of Genoa	39.1	0.0 %

Table 35: Brenner corridor, WTW CO₂e emission factors, electricity mix 2021 per country, road [g/truck-km]

Country	motor - way	from	to	Diesel Euro VI D-E	CNG Euro-VI	LNG Euro-VI (CI)	BEV ¹⁶	FCEV ¹⁷
DE	A8	Kreuz München Süd (A99)	km 37	806	569	484	745	1,153
DE	A8	km 37	Leitzach- brücke	109	65	55	-45	-70
DE	A8	Leitzach- brücke	AS Irschenber g	1,867	1,325	1,127	1,545	2,392
DE	A8	AS Irschenberg	Dreieck Inntal (A93)	109	65	55	-45	-70

¹⁵ The reverse gradient is used in the opposite direction.¹⁶ Negative values result from energy recovery through braking when travelling downhill.¹⁷ Negative values result from energy recovery through braking when travelling downhill.

Countr y	motor - way	from	to	Diesel Euro VI D-E	CNG Euro-VI	LNG Euro-VI (CI)	BEV¹⁶	FCEV¹⁷
DE	A93	Dreieck Inntal (A93)	Border Kufstein	806	569	484	745	1,153
DE	A93	Border Kufstein	Dreieck Inntal (A93)	806	569	484	745	1,153
DE	A8	Dreieck Inntal (A93)	AS Irschenber g	1,867	1,325	1,127	1,545	2,392
DE	A8	AS Irschenberg	Leitzach- brücke	109	65	55	-45	-70
DE	A8	Leitzach- brücke	km 37	1,867	1,325	1,127	1,545	2,392
DE	A8	km 37	Kreuz München Süd (A99)	806	569	484	745	1,153
AT	A12	Border Kufstein	Kn Innsbruck- Amras (A13)	820	809	685	401	621
AT	A13	Kn Innsbruck- Amras (A12)	Border Brenner- pass	1,900	1,883	1,597	832	1,288
AT	A13	Border Brenner- pass	Kn Innsbruck- Amras (A12)	110	92	78	-24	-38
IT	A22	Border Brennerpas s	Bozen	109	65	55	-35	-54
IT	A22	Bozen	km 112	806	569	484	576	891
IT	A22	km 112	km 110	2,886	2,084	1,773	1,732	2,681

Country	motor-way	from	to	Diesel Euro VI D-E	CNG Euro-VI	LNG Euro-VI (CI)	BEV ¹⁶	FCEV ¹⁷
IT	A22	km 110	Verona - Kn A4	806	569	569	576	891
IT	A22	Verona - Kn mit A4	km 110	806	569	569	576	891
IT	A22	km 110	km 112	17	1	1	-541	-838
IT	A22	km 112	Bozen	806	569	569	576	891
IT	A22	Bozen	Border Brenner-pass	1,867	1,325	1,127	1,194	1,849

Table 36: Brenner corridor, final energy demand factors, road [kWh/truck-km]

Country	motor-way	from	to	Diesel Euro VI D-E	CNG Euro-VI	LNG Euro-VI (CI)	BEV ¹⁸	FCEV ¹⁹
DE	A8	Kreuz München Süd (A99)	km 37	2.6	3.0	2.5	1.8	2.8
DE	A8	km 37	Leitzachbrücke	0.3	0.3	0.3	-0.1	-0.2
DE	A8	Leitzachbrücke	AS Irschenberg	6.2	7.0	5.9	3.8	5.9
DE	A8	AS Irschenberg	Dreieck Inntal (A93)	0.3	0.3	0.3	-0.1	-0.2
DE	A93	Dreieck (A93)	Inntal Border Kufstein	2.6	3.0	2.5	1.8	2.8
DE	A93	Border Kufstein	Dreieck Inntal (A93)	2.6	3.0	2.5	1.8	2.8

¹⁸ Negative values result from energy recovery through braking when travelling downhill.¹⁹ Negative values result from energy recovery through braking when travelling downhill.

Country	motor-way	from	to	Diesel Euro VI D-E	CNG Euro- VI	LNG Euro- VI (CI)	BEV ¹⁸	FCEV ¹⁹
DE	A8	Dreieck Inntal (A93)	AS Irschenberg	6.2	7.0	5.9	3.8	5.9
DE	A8	AS Irschenberg	Leitzachbrücke	0.3	0.3	0.3	-0.1	-0.2
DE	A8	Leitzachbrücke	km 37	6.2	7.0	5.9	3.8	5.9
DE	A8	km 37	Kreuz München Süd (A99)	2.6	3.0	2.5	1.8	2.8
AT	A12	Border Kufstein	Kn Innsbruck- Amras (A13)	2.6	3.3	0.3	1.8	2.8
AT	A13	Kn Innsbruck- Amras (A12)	Border Brennerpass	6.2	7.8	1.8	3.8	5.9
AT	A13	Border Brennerpass	Kn Innsbruck- Amras (A12)	0.3	0.4	6.5	-0.1	-0.2
AT	A12	Kn Innsbruck- Amras (A13)	Border Brennerpass	2.6	3.3	0.3	1.8	2.8
IT	A22	Border Brennerpass	Bozen	0.3	0.3	0.3	-0.1	-0.2
IT	A22	Bozen	km 112	2.6	3.0	2.5	1.8	2.8

Table 37: Ventimiglia corridor, WTW CO₂e emission factors, electricity mix 2021 per country,

road [g/truck-km]

Country	motor-way	from	to	Diesel Euro VI D-E	CNG Euro- VI	LNG Euro- VI (CI)	BEV ²⁰	FCEV ²¹
FR	A8	Marseilles (A8/A52 near Marseilles)	Nice ouest	816	666	565	101	157
FR	A8	Nice Quest	AS Monaco	1,890	1,550	1,317	210	325
FR	A8	AS Monaco	Ventimiglia (Border FR/IT)	110	76	64	-6	-10
FR	A8	Ventimiglia (Border FR/IT)	km 173	1,890	1,550	1,317	210	325
FR	A8	km 173	Nice ouest	110	76	64	-6	-10
FR	A8	Nice ouest	Marseilles (A8/A52 near Marseilles)	816	666	565	101	157
IT	A10	Ventimiglia (Border FR/IT)	Savona (A6)	806	569	484	576	891
IT	A10	Savona (A6)	Genoa (A7)	806	569	484	576	891
IT	A10	Genoa (A7)	Savona (A6)	806	569	484	576	891
IT	A10	Savona (A6)	Ventimiglia (Border FR/IT)	806	569	484	576	891

²⁰ Negative values result from energy recovery through braking when travelling downhill.

²¹ Negative values result from energy recovery through braking when travelling downhill.

Table 38: Ventimiglia corridor, final energy demand factors, road [kWh/truck-km]

Country	motor-way	from	to	Diesel Euro VI D-E	CNG Euro- VI	LNG Euro- VI (CI)	BEV ²²	FCEV ²³
FR	A8	Marseilles (A8/A52 near Marseilles)	Nice ouest	2.6	3.4	2.8	1.8	2.8
FR	A8	Nice Ouest	AS Monaco	6.2	7.9	6.6	3.8	5.9
FR	A8	AS Monaco	Ventimiglia (Border FR/IT)	0.3	0.4	0.3	-0.1	-0.2
FR	A8	Ventimiglia (Border FR/IT)	km 173	6.2	7.9	6.6	3.8	5.9
FR	A8	km 173	Nice ouest	0.3	0.4	0.3	-0.1	-0.2
FR	A8	Nice ouest	Marseilles (A8/A52 near Marseilles)	2.6	3.4	2.8	1.8	2.8
IT	A10	Ventimiglia (Border FR/IT)	Savona (A6)	2.6	3.0	2.5	1.8	2.8
IT	A10	Savona (A6)	Genoa (A7)	2.6	3.0	2.5	1.8	2.8
IT	A10	Genoa (A7)	Savona (A6)	2.6	3.0	2.5	1.8	2.8
IT	A10	Savona (A6)	Ventimiglia (Border FR/IT)	2.6	3.0	2.5	1.8	2.8

²² Negative values result from energy recovery through braking when travelling downhill.²³ Negative values result from energy recovery through braking when travelling downhill.