EUROFIMA
ROLLING STOCK FINANCING

ANNEX 1

IMPACT ASSESSMENT METHODOLOGY

This annex covers the detailed methodology applied to quantify the impact indicators: the assumptions, the relevant data sources and the computational steps followed.

GREEN BOND IMPACT REPORTING

MARCH 2026

METHODOLOGY OVERVIEW

The approach followed in order to derive the impact indicators is based on the comparison between:

a) the emissions and energy consumption of the green assets

and

b) the emissions and energy consumption of the alternative means of transportation (i.e., those that would be used, in case the rolling stock were not financed).

Therefore, the "baseline" for the impact assessment is the assumed "alternative means of transportation".

As the impact indicators represent in fact "estimated" impacts (ex-ante) and not on actual impact (ex-post), a number of assumptions are made in the framework.

The following paragraphs explain the assumptions made and define and quantify the baseline.

MAIN ASSUMPTIONS

The estimate of the emission savings generated by EUROFIMA green projects relies on the following assumptions:

1. The reported impact is the expected environmental impact, based on ex-ante estimates[1], as opposed to the actual[2] ex-post data.
2. The reported impact is defined as "Avoided" or "Reduced". In the former case, the green assets financed do not generate any direct savings versus the historical data, but, if the project had not been financed, the related emissions or the energy consumption would be higher[3]. In the latter case, the green assets financed reduce emissions or energy consumption compared to the historical and actual data.

These cases are described in Table 1.

3. The benefits are estimated as savings to be generated on an annual basis and not as total cumulative benefits over the entire project lifetime and they rely on the following assumptions:
   a) the operations are steady and stable and all the financed rolling stock runs at the normal and planned operating schedule; and
   b) all passengers would move to a different means of transportation, in the case such rolling stock had not been financed[4].
4. The emissions considered for the financed rolling stock are assessed based on the standards of the Greenhouse Gas Protocol Scope 1, which considers only the "Tank-to-Wheel" (TtW) values (i.e., emissions generated only by the train) and excludes the "Well-to-Tank", (WtT) values (i.e., emissions generated in the electricity grid and power stations). This is also in line with the EU Taxonomy that considers electric rail transport as a zero-direct emission means of transport.
5 The methodology is based on a number of parameters, which may change over time, both because of external environment changes and because of new and more sophisticated tools. EUROFIMA commits to using every year the latest available parameters and to highlighting the changes in the revised methodology.
6. Besides, EUROFIMA keeps the right to improve the model used to estimate the savings, in order to enhance the accuracy. Every change in the model versus the previous one will be properly highlighted.

Table 1 - Examples of projects and impact on GHG emission or energy consumption

Projects type	GHG emissions	Energy consumption	Description
Additional green rolling stock	Reduced/Avoided	Reduced/Avoided	The project provides additional rolling stock on a new or already existing line, thus increasing the ridership; partly because more people will move to train and partly to meet the increasing transport demands.
Renewal of electric with green rolling stock	Avoided	Avoided/Reduced	The project replaces old trains with new and more efficient ones; the ridership is assumed to continue along the trend of the old trains.
Renewal of diesel with green rolling stock	Reduced	Reduced	The project replaces diesel trains with green ones, thus delivering real emissions reduction compared to the past.
Retrofitting or modernization of green rolling stock	Avoided	Avoided	The project upgrades old trains, making them more efficient or comfortable; the ridership is assumed to continue along the trend of the old trains.

[1] Therefore, the actual environmental impact of the projects may diverge from initial estimates. In addition, when comparing different projects, caution should be taken because baselines, base years, and calculation methods may vary (infrastructure and cost structure may vary across countries). Finally, projects might have impact across a wider range of indicators than those captured in this report.

[2] The assessment of the impact indicators is based on assumptions; therefore the actual (ex-post) environmental impact of the projects may diverge from initial assessment and across projects. In addition, financed projects might also have other impacts than those captured in the impact assessment table.

[3] It is acknowledged that in case the trains are newly manufactured, savings in the ramp-up phase may well be overestimated, as the trains are not yet operated or are operated with limited utilization in order to finalize the commissioning phase.

However, in a long-term perspective, the assumption made is deemed to be the most appropriate to show the environmental impact of the train or project.

[4] It is acknowledged that in case of a substitution of existing rolling stock, the real flow of passengers who will stop using the old trains is very limited in the first months: it will increase as the rolling stock becomes less and less reliable or comfortable and only in the long-term all passengers will move to an alternative means of transportation. However, in a long-term perspective, the assumption made is deemed to be the most appropriate to show the environmental impact of the train or project.

THE BASELINE

The baseline considered to derive the environmental impact is different according to the specific project type and case:

a) For the replacement of an existing electrical train, an upgrade, or introduction of additional trains, it is assumed that all passengers would continue using a car as an alternative means of transportation, in the event that project had not been financed. The baseline is assumed to be the "average car in the current European vehicle stock" in line with the EU Taxonomy. This assumption is considered appropriate for the impact reporting purpose: despite the differences across countries and projects, in terms of mix of cars used, local habits and different mix of transportation mean (bus, plane, boat), the impact on the final estimated values is negligible.

b) For the replacement of diesel rolling stock with green rolling stock, it is assumed that all passengers would continue using the existing diesel train, in the case that the project had not been financed. Therefore, the alternative means of transportation taken as baseline is the replaced diesel equipment itself.

BASELINE VALUES FOR GHG EMISSIONS

The baseline values reflect the guidelines of EU Taxonomy[5]. The values are either passenger-kilometres (pkm) in case the alternative means of transportation is a diesel train, or vehicle-kilometres (vkm) in case of a car.

Where operator-specific data is made available, EUROFIMA reserves the right to incorporate such information in order to enhance the accuracy and robustness of the model.

Table 2 - GHG emissions baseline in the EU

Projects type	HGH emissions	Alternative means of transportation	Baseline GHG emissions
Additional green rolling stock	Reduced/Avoided	Car	290 gCO_2/vkm
Renewal of electric with green rolling stock	Avoided	Car	290 gCO_2/vkm
Renewal of diesel with green rolling stock	Reduced	Diesel train	70/90 gCO_2/pkm
Retrofitting or modernization of green rolling stock	Avoided	Car	290 gCO_2/vkm

[5] Page 329 of the EU Taxonomy Technical Report by TEG (Link)

BASELINE VALUES FOR ENERGY CONSUMPTION

The baseline values for energy consumptions are calculated based on data from several public sources, assumptions on the mode of use (motorway, rural) of the alternative means of transportation, the mix of petrol versus diesel in the European car fleet, the weight of the average car, the car occupancy rate, and using an online calculator developed by a Swiss partnership led by the Swiss government[6].

The baseline values for diesel rolling stock equipment are taken from the values assumed by UIC (the international association of railway companies)[7].

More specifically, the assumptions and data considered are as follows:

1. The average car consumption is sourced from the Eco passenger Methodology report[8], developed by UIC by type of fuel, mode of use and size of the car.

Table 3 - Car energy consumption as a function of usage in the EU

Mode of use	Average auto consumption					
	Diesel (l/100 km)			Petrol (l/100 km)		
	Small	Medium	Large	Small	Medium	Large
Motorway	4.5	5.3	6.7	6.3	7.5	9.2
Rural	3.8	4.5	5.8	4.9	5.8	7.2
Urban	5.7	6.7	8.4	7.3	8.7	10.5

2. It is assumed that all passengers would use the alternative means travelling 50% of their time along a motorway and the other 50% along rural roads and driving a medium-size car. Urban traffic is excluded, even if part of the alternative journey would happen inside a city, as the project financed do not include trams or metro. Even if the actual modal mix may be a much more complex mix of the three above modal utilization, it is deemed that a more detailed estimation at project level would not yield a material and significant increase of reliability of the final estimates. The data is summarized in Table 4.

Table 4 - Average car energy consumption for motorway and rural usage in the EU

	Average auto consumption		Travel %
	Diesel (l/100 km)	Petrol (l/100 km)	
Motorway	5.3	7.5	50%
Rural	4.5	5.8	50%
Average travel	4.9	6.7	

The average energy consumption for the travel for both petrol and diesel is calculated as follows:

Average Auto Consumption - Motorway = ACM
Average Auto Consumption - Rural = ACR
% of time traveled in a Motorway = TM% = 50%
% of time traveled in Rural roads = TR% = 50%
Average Auto Consumption - Travel = ACT

ACT = (ACM * TM% + ACR * TR%)

3. The mix diesel versus petrol cars of the European fleet is sourced from the most up-to-date date of the European cars manufacturers (ACEA) statistics[9].

Table 5 Car energy mix in the EU

	Mix % of the European fleet
Petrol	53.9%
Diesel	42.0%
Other	4.1%

4. The average consumption is calculated with the following steps, with the diesel versus petrol mix and the average travel consumption as shown in Table 3, 4 and 5.

Average Diesel Auto Consumption – Travel = ACTD = 4.9 l/100km
Average Petrol Auto Consumption – Travel = ACTP = 6.7 l/100km
% of Diesel cars in the European Fleet = DC% = 42%
% of Petrol cars in the European Fleet = PC% = 53,9%
Average Auto Consumption = AC

AC = (ACTD * DC% + ACTP * PC%)/(PC% + DC%) = (4.9*42%+6.7*53.9%)/(53.9%+42%) = 5.9 l/100km

5. To calculate journey savings, the average European car utilization is assumed to be 1.5 passengers/car, as set by UIC[10], with an average car weight of 1395 Kg., as per the European Vehicle Market Statistics pocketbook[11] .

6 https://www.mobitool.ch/fr/info/a-propos-de-mobitool-9.html
7 https://uic.org/
8 http://ecopassenger.hafas.de/bin/help.exe/en?L=vs_uic&tpl=methodology
9 https://www.acea.be/statistics/tag/category/passenger-car-fleet-by-fuel-type
10 http://ecopassenger.org/bin/query.exe/en?ld=uic-eco&L=vs_uic&OK#focus
11 https://theicct.org/sites/default/files/publications/ICCT_Pocketbook_2018_Final_20181205.pdf

6. The online Mobitool[12], developed by the Swiss federal government and other public institutions, is used to set the baseline of the average car in the current stock, along with the above parameters in Table 6.

Table 6 - Inputs into Mobitool

Inputs to Mobitool	Values
Car occupancy	1.5 person per car
Consumption	5.9 l/100km
Weight	1395 Kg

If the baseline for a specific project is the transportation by car, to be consistent with the Scope 1 definition, only the consumption for the car itself and not any other side-costs (e.g., road construction, etc.) is considered in Mobitool (referred as "Direkter Betrieb"), 1.30 MJ/pkm.

7. If the baseline for a specific project is a diesel train, the corresponding value (25.2 g/pkm) assumed by UIC from the Eco passenger Methodology[8] is translated in MJ/pkm, assuming a diesel heating value 45.5 MJ/Kg[13].

(25.2 g/pkm)*(45.5 MJ/1000g) = 1.15 MJ/pkm

As above for the GHG emissions baseline, where operator-specific data is made available, EUROFIMA reserves the right to incorporate such information in order to enhance the accuracy and robustness of the model.

8. The energy consumption baseline values are summarized in Table 7.

Figure 1 - Mobitool Energy consumption of a car in the EU

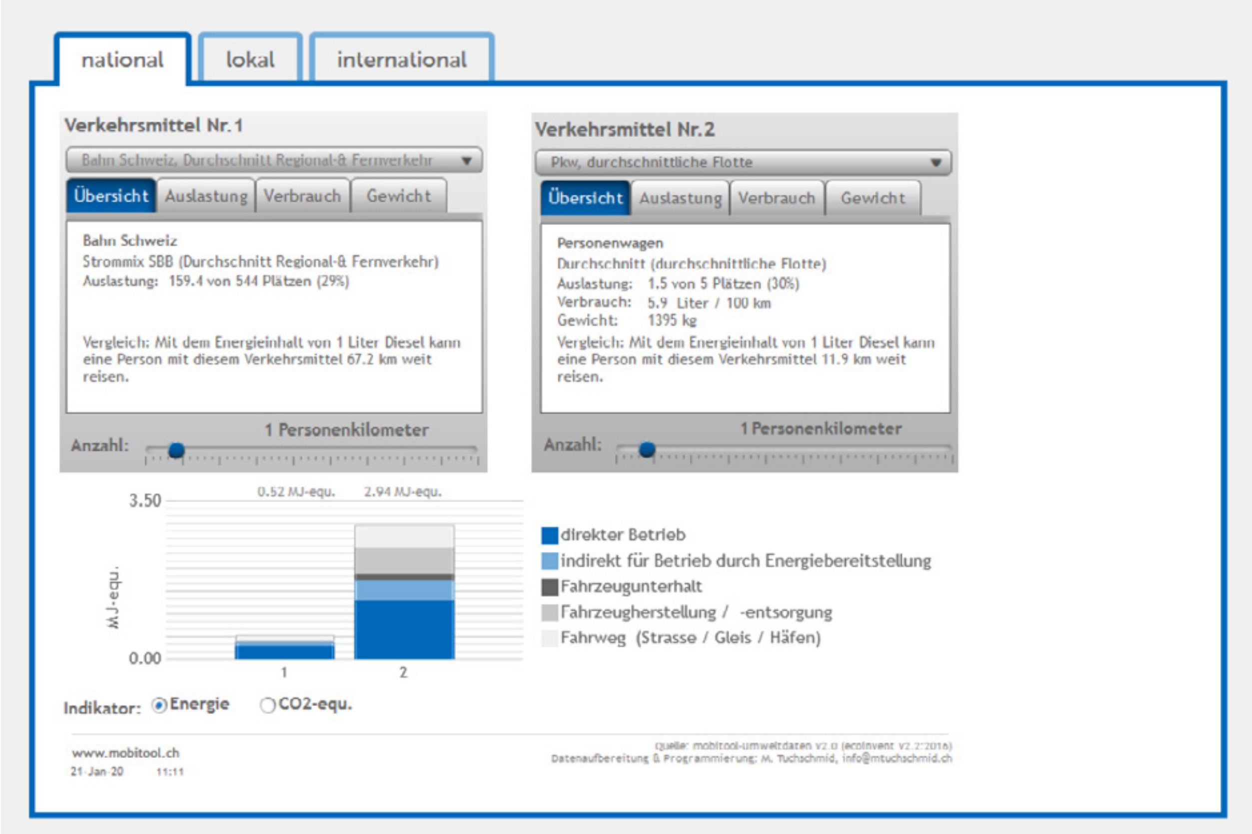


Table 7 - Energy consumption baselines

Projects denomination	Energy consumption	Alternative means of transportation	Baseline energy consumption
Additional green rolling stock	Reduced/Avoided	Car	1.30 MJ/pkm
Renewal of electric with green rolling stock	Avoided	Car	1.30 MJ/pkm
Renewal of diesel with green rolling stock	Reduced	Diesel train	1.15 MJ/pkm
Retrofitting/modernization of green rolling stock	Avoided	Car	1.30 MJ/pkm

[12] https://www.mobitool.ch/de/tools/vergleichsrechner-15.html

[13] https://www.acea.be/news/article/differences-between-diesel-and-petrol

ESTIMATION MODEL

Based on the assumptions above, the following model estimates the GHG emissions and energy savings.

A) CO_2 emissions savings

For an estimate of CO_2 savings, it is considered that the emissions of the financed rolling stock, if electric trains, are assumed to be zero and they need to be compared to an estimate of the annual pollutant emissions of the baseline, for which the corresponding standard value per passenger-kilometre is publicly available.

The annual passenger-kilometre relevant to a specific item of equipment, either a train, a coach or a locomotive, is not publicly available data, therefore requiring a separate estimate[14].

The individual factors and assumptions for the above estimate are as follows:

1. The latest estimate of the passenger-kilometre by country from the European pocketbook on transportation[15]
2. The split of the traffic by mode of operation (Regional&Commuter and Intercity&High-Speed[16]) from SCI Verkehr GmbH[17]
3. Available seats by country and by mode of operations (Regional&Commuter and Intercity&HighSpeed) from SCI Verkehr GmbH
4. The value [(Passengers*km)/(Available Seats)] by country and by mode of operations (Regional&Commuter and Intercity&HighSpeed); this value is assumed the same for all trains and lines in the relevant countries
5. The available seats of the single item of equipment is sourced from the rolling stock manufacturer or the corresponding railway operator[18], the coaches carried, in terms of type, number and seats of the single coach.
6. In case of a locomotive, as in itself such a vehicle carries no passengers, the number of available seats will be estimated and depends on several factors[19]:
   a. the passenger cars carried, in terms of class,type, number and seats of the single coach.
   b. the frequency of utilization of each formation that is used.
   c. the value of the locomotives as % of the value of the entire configuration.
7. In case of passenger car, as in itself it has no power and is always coupled with a locomotive, the number of available seats will be properly weighted and depends on several factors[19]:
   a. the most frequent formation, in terms of type, number, seats and locomotive class, the passenger car is operated under
   b. the value of the single passenger car type as % of the value of the entire configuration
8. The [Passengers*km] by item of equipment, and then the corresponding savings are derived as follows:

Passengers*kilometer by Item = pkmT
Passengers*kilometer by country/mode of operations = pkmC
Available seats by country/mode of operations = AvSC
Available seats by specific item = AvST

pkmT = [pkmC / AvSC] * AvST

The "Avoided" emissions can be calculated as a difference between the emissions of the alternative means of transportation taken as baseline and the emissions of the green asset (which are zero, by definition, as defined in Scope 1):

Number of specific green items = #ST
Baseline GhG emissions per pkm, avoided = EBA = 290 gCO_2/vkm
Baseline GhG emissions per pkm, reduced = EBR = 90 gCO_2/pkm
Passenger per vehicle = PV = 1.5
Project savings (CO2) as reduced emissions = PSCDR
Project savings (CO2) as avoided emission = PSCDA

$$PSCDA = \Sigma\, [pkmT * (EBA/PV)]_{\#ST} - 0$$

In case of "Reduced" emissions, they are quantified as follows:

$$PSCDR = \Sigma\, [pkmT * EBR]_{\#ST} - 0$$

For enhanced clarity, an illustrative example is provided based on the EUR 91.5 million project financed in 2019, with a duration of 9.4 years, for SBB. The associated CO_2 savings are generated by 13 trains operating on the Zurich S-Bahn network (Siemens RABe 514) and 6 trains serving the Lenzburg–Luzern line (Stadler RABe 520). The other examples presented refer to the same project.

pkmC (CH) = 5'015 MpkmAvSC (CH) = 354'100
AvST (Rabe 514) = 384
AvST (Rabe 520) = 128
PkmT (Rabe 514) = (5'015/354'100)*384 = 5.44 Mpkm
PkmT (Rabe 520) = (5'015/354'100)*128 = 1.81 Mpkm
#ST (Rabe 514) = 13
#ST (Rabe 520) = 6
EBA = 290 gCO2/vkm
PV = 1.5

PSCDA = {5.44*106*[(290/1.5)/106]*13}+{1.81*106*[(290/1.5)/106]*6}– 0 = 15'772 tCO_2

[14] The estimation of the passenger-kilometre of an item of equipment has been improved and made more realistic; instead of using the Pkm and available seats per country, we use the values specific both to the country and to the mode of Operation, Regional&Commuter or Intercity&High-Speed.

[15] https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2020_en

[16] Regional&Commuter refers to the short and mid distance rail traffic, such as suburban, commuting in and out the main cities and regional areas. Intercity&High-Speed refers to long distance rail traffic, such us links between main cities, along important mainline or high-speed line connections.

[17] This is a rail consulting company and specific values cannot be disclosed due to confidentiality.

[18] The single values by Asset Class can be found in Annex 3 of the Impact report [Link]

[19] More details on the model utilized to estimate the "weighted seats" of passenger cars and locomotives are provided in the Annex 3 of the impact report [Link]

B) CH_4 and N_2O emissions savings

For an estimate of the CH_4 and N_2O savings, we make the same assumptions and follow almost the same methodology as for the CO_2 savings estimation: the emissions of the financed rolling stock (electric trains) are assumed to be zero and they need to be compared to an estimate of the annual pollutant emissions of the baseline. Differently from CO_2 savings estimation, we derived the savings from energy consumption, as we could find more reliable sources of emissions by energy unit of measurement and type of fuel[20].

The values are summarized on this table, where we add the estimated % of usage between petrol and diesel (in Table 5).

Table 8 -Emission factors for CH_4 and N_2O by type of fuel and by unity of energy

Fuel	Energy unit	kg/kWh (CH_4)	kg/kWh (N_2O)	% diesel/petrol
Petrol	kWh (Gross CV)	0.00071	0.00064	53.9%
Diesel	kWh (Gross CV)	0.00002	0.00331	42.0%

The estimation is based on the following definitions and steps:

Energy consumption baseline per pkm, car = JBC = 1.30 MJ/pkm
Energy consumption baseline per pkm, diesel equipment = JBD = 1.15 MJ/pkm
Passengers*kilometer by green item = pkmT
Number of specific green items = #ST
CH_4 emitted by energy unit- Petrol = CKwhP = 0.00071 Kg/kwh
CH_4 emitted by energy unit- Diesel = CKwhD = 0.0002 Kg/kwh
N_2O emitted by energy unit- Petrol = NKwhP = 0.00064 Kg/kwh
N_2O emitted by energy unit- Diesel = NKwhD = 0.00331 Kg/kwh
% of Diesel cars in the European Fleet =DC% = 42%
% of Petrol cars in the European Fleet = PC% = 53,9%
Project savings (CH_4) as avoided emission = PSMHA
Project savings (CH_4) as reduced emissions = PSMHR
Project savings (N_2O) as avoided emission = PSNOA
Project savings (N_2O) as reduced emissions = PSNOR

Avoided emissions

1) We calculate the Energy consumption of the average car taken as baseline, as the product of JBC and pkmT.
2) We assume that the energy is split by Diesel and Petrol based on the % of the numbers of vehicles[21].
3) We calculate then the emissions avoided based on parameter above, with the following formulas:

PSMHA = Σ [pkmT *JBC* (CKwhP*PC%+ CKwhD*DC%)]#ST – 0
PSNOA = Σ [pkmT *JBC* (NKwhP*PC%+ NKwhD*DC%)]#ST - 0

Reduced emissions

1) We calculate the Energy consumption of the diesel train as baseline, as the product of JBD and pkmT.
2) We calculate then the emissions avoided based on parameters above, with the following formulas:

PSMHR = Σ [pkmT *JBD*CKwhD]#ST – 0
PSNOR = Σ [pkmT *JBD*NKwhD]#ST - 0

An illustrative example is provided below, based on the same SBB project referenced above.

PkmT (Rabe 514) = 5.44 Mpkm
PkmT (Rabe 520) = 1.81 Mpkm
JBA = 1.30 MJ/pkm
#ST (Rabe 514) = 13
#ST (Rabe 520) = 6
CKwhP = 0.00071 Kg/kwh
CKwhD = 0.0002 Kg/kwh
DC% = 42%
PC% = 53.9%

PSMHA = (5.44*106*13+1.81*106*6)*1,30/3,6*(0.00071*53.9/100+0.0002*42/100)/1000 = 11.5 tCH_4

[20] The data are taken from the following table: Conversion factors 2020: condensed set (for most users) https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020

[21] This assumption does not consider that the diesel cars have a better efficiency and generate less consumption, which means the Methane is overestimated and the Nitrous Oxide underestimated; however, we deem the margin of error as minimal and with a negligible impact on the magnitude of the savings.

C) Energy consumption savings

In this case the energy consumed by the green asset is not zero and must be estimated as well through publicly available data: in the case the green asset is a passenger coach, we assume the consumption of the locomotive(s) that pull/push them. The energy consumption of the alternative means of transportation is calculated based on other available data (i.e., pkm by item of equipment and energy consumed by pkm).

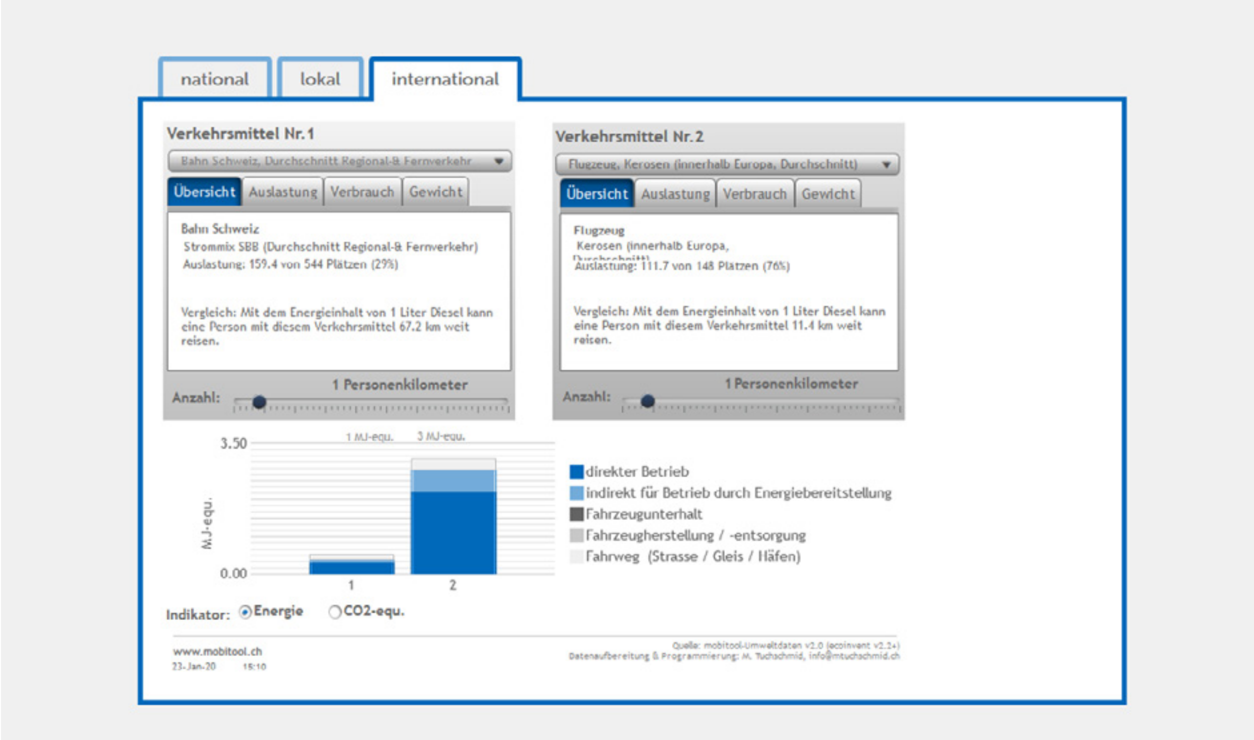
The methodology to estimate the energy saved by the train or project is as follows:

1. When specific rail rolling stock data is not available, the average values by country or the European average are taken, even if there may be differences across specific rolling stock items[22].
2. The energy consumption data for Austria, Switzerland, Germany, France and Italy is available in Mobitool as well as the average load factors (actual passengers per available seat) per country. The consumption considered is that of the train ("direkter Betrieb") only as in Figure 2.

Table 8 - Average Load factor defined in Mobitool as default parameters

Country	Mode	Load factor
Germany	Average Regional/Intercity	43%
France	Average Regional/Intercity	38%
Italy	Average Regional/Intercity	31%
Austria	Average Regional/Intercity	37%
Switzerland	Average Regional/Intercity	29%

Figure 2 - Mobitool example for Switzerland



[22] This simplification is deemed to have no significant or material impact on the final impact estimation at a portfolio level.

3. The average energy consumption of rail rolling stock in other countries is based on the average value of 88.2 Wh/pkm, as in the Eco passenger Methodology[8].

   (88.2 Wh/pkm) * 3.6/1000 = 0.32 MJ/pkm

4. The energy consumed by the green asset is summarized in Table 9.

Table 9 - Energy consumed by the green asset by country

Country	Green Asset average energy consumption (MJ/pkm)	Source
Germany	0.42	Mobitool.ch
France	0.32	Mobitool.ch
Italy	0.39	Mobitool.ch
Austria	0.42	Mobitool.ch
Switzerland	0.29	Mobitool.ch
Others	0.32	UIC Ecopassengers

5. The energy saved in a year is derived, both as "Reduced" and as "Avoided", as a difference between the energy consumed by the alternative means of transportation taken as baseline and the energy consumed by the green asset.

Numbers of specific green items = #ST
Energy consumption baseline per pkm, car = JBC = 1.30 MJ/pkm
Energy consumption baseline per pkm, diesel equipment = JBD = 1.15 MJ/pkm
Average Energy Consumption of the Green Asset per pkm = JGA
Passengers per kilometer by item = pkmT
Project savings as avoided energy consumption = PSJA
Project savings as reduced energy consumption = PSJR

$PSJA = \Sigma\ [(JBC - JGA) * pkmT]_{\#ST}$
$PSJR = \Sigma\ [(JBD - JGA) * pkmT]_{\#ST}$

An illustrative example is provided below, based on the same SBB project referenced above.

JBC = 1.30 MJ/pkm
JGA = 0.29 MJ/pkm
pkmC (CH) = 5'015 Mpkm
AvSC (CH) = 354'100
AvST (Rabe 514) = 384
AvST (Rabe 520) = 128
PkmT (Rabe 514) = (5'015/354'100)*384 = 5.44 Mpkm
PkmT (Rabe 520) = (5'015/354'100)*128 = 1.81 Mpkm
#ST (Rabe 514) = 13
#ST (Rabe 520) = 6

PSJA = {[(1.3-0.29)/(3600*103)]*5.44*106}*13 +{[(1.3-0.29)/(3600*103)]*1.81*106}*6 = 22.9 GWh

D) Estimated reduction in fuel consumption.

We derived this data from the energy consumption, using the Heating values[23] and the % of diesel and petrol vehicles in Table 5, to translate the energy into liters of fuel.

The Heating values are in the following Table 14.

Table 14 – Average Heating values of diesel and petrol fuel

Fuel	Heating Value (MJ/l)	% diesel/petrol
Petrol	33.9	53.9%
Diesel	36.7	42.0%

The assumptions, the steps to estimate the reduction of liters of fuels and relevant formulas are the following:

1) Take the savings in terms of energy consumption of the single project.
2) Divide the savings by the heating value, weighting diesel and petrol with the relevant % in terms of numbers of vehicle, in case of avoided energy consumption[24].
3) Divide the savings by the diesel heating value, in case of reduced energy consumption:

Project savings as avoided energy consumption = PSJA
Project savings as reduced energy consumption = PSJR
% of Diesel cars in the European Fleet = DC% = 42%
% of Petrol cars in the European Fleet = PC% = 53,9%
Heating value by liter Petrol=HVP = 33.9 MJ/l
Heating value by liter Diesel=HVD = 36.7 MJ/l
Reduction in fuel consumption- Avoided = RFCA
Reduction in fuel consumption- Reduced = RFCR

RFCA = PSJA/(HVP*PC%+HVD*DC%)
RFCR = PSJR/HVD

An illustrative example is provided below, based on the same SBB project referenced above.

PSJA = 22.9 GWh

RFCA = (22.9*103*3600/(33.9*53.9/100+36.7*42/100))/106
= 2.5 Ml

[23] https://www.acea.be/news/article/differences-between-diesel-and-petrol

[24] This assumption does not consider that the diesel cars have a better efficiency, therefore they need less liters to generate the same energy: which means the liters reduced are slightly overestimated. However, we deem the margin of error as minimal and with a negligible impact on the magnitude of the reduction of fuel

E) Tri-mode Multiple Units- Ferrovie dello Stato Italiane (FS)

The estimation of emissions and energy reductions associated with the Hitachi HTR 312 (5 units) and HTR 412 (20 units) requires a dedicated methodological section. The calculation model applied in this case was developed in cooperation with Trenitalia (TI), the subsidiary of FS responsible for rail operations, which provided detailed fleet-level operational data. As a result, the approach differs from the general model described above.

The HTR 312 and HTR 412 are tri-mode multiple units equipped with systems that allow operation either under electric catenary or via an onboard diesel engine on non-electrified lines. In addition, they are fitted with a small battery enabling emission-free entry into stations. Unlike fully electric EMUs, these units generate direct emissions when operating in diesel mode.

These trains contribute to both avoided and reduced emissions:

- Avoided emissions are calculated in line with the general methodology described above, by comparing performance against relevant alternative transport modes.
- Reduced emissions are estimated using a dedicated model developed jointly with TI, reflecting the specific operational characteristics of these assets.

Emission reductions arise because these trains operate on routes that are only partially electrified and were previously served entirely by diesel rolling stock. The improved energy efficiency of the new units, combined with partial operation under catenary, results in lower overall energy consumption and, consequently, reduced emissions compared to the legacy diesel trains they replace.

To estimate the emission reductions, it is necessary to compare the emissions generated by the tri-mode trains with those produced by the diesel trains they effectively replace. As these new units do not substitute a specific, identifiable fleet, the Class Minuetto has been selected as the baseline, as it represents the most widely used diesel multiple unit (DMU) in regional passenger services operated by FS.

However, the comparison cannot be performed by simply contrasting the total emissions generated by the 25 tri-mode units with those of the Minuetto trains. The tri-mode multiple units are larger, more technologically advanced, and heavier; consequently, their absolute energy consumption may be higher. A meaningful comparison therefore requires controlling for operational factors so that the two train types are assessed under equivalent service conditions.

To ensure comparability, the analysis relies on emissions per seat-kilometers (seat-km) as the key parameter. This metric provides a more accurate representation of the relative performance of the two train types, as it reflects both their emissions intensity and their respective passenger-carrying capacity.

Below is a summary table presenting the model applied in the analysis; all underlying data has been provided by Trenitalia.

Once the specific emissions of the two train types were calculated, the difference between the two emission intensities was multiplied by the relevant annual mileage and the number of total seats of the trimodal trains fleet. This calculation provides the estimated annual emissions reduction attributable to the deployment of the tri-mode units.

Asset Model	Specific consumption- Diesel (l/km)	Specific consumption-electric (kWh/km)	Mileage (Km) - Diesel	Mileage (Km) - Electric	Emission factor-Diesel (gCO_2 eq/l)	Emission factor-Electric (gCO_2 eq/kWh)	Seats and standing room	Number of trains	Specific emissions (gCO_2eq/seats-km)	Total reduced emissions (tCO_2eq)
Minuetto Diesel	1.67		2'160'948		2'960		286	25	0.69	5'527.3
HTR Blues	2.1	7.22	1'617'015	543'933	2'960	217.7	440	25	0.46	

The energy reduction model follows the same methodology and underlying principles as described above. The table below provides a summary of the approach used to estimate energy savings.

Asset Model	Specific consumption- Diesel (l/km)	Specific consumption-electric (kWh/km)	Mileage (Km) - Diesel	Mileage (Km) - Electric	Calorifc value (kWh/l)	Seats and standing room	Number of trains	Specific energy consumption (kWh/ seats-km)	Total reduced Energy (gWh)
Minuetto Diesel	1.67		2'160'948		10	286	25	0.0023	17.7
HTR Blues	2.1	7.22	1'617'015	543'933	10	440	25	0.0016