Republic of Serbia
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#ЕУ ЗА ТЕБЕ

RAILWAY LINE BELGRADE–NIŠ, SECTION III PARAĆIN-TRUPALE (NIŠ)

Environmental and Social Impact Assessment, Annex 2: GREENHOUSE GAS ASSESSMENT

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Key Contacts			
EUD	Anthony Robert	Programme Manager	Delegation of the European Union to the Republic of Serbia Vladimira Popovica 40/V, 11070 New Belgrade, Republic of Serbia Phone: +381 11 3083200 Anthony.ROBERT@eeas.europa.eu
MEI	Aleksandra Todorović	MEI's Representative	Ministry of European Integration Nemanjina 34, 11000 Belgrade, Republic of Serbia atodorovic@mei.gov.rs
	Branko Budimir	Advisor to the Minister of European Integration	Ministry of European Integration Nemanjina 34, 11000 Belgrade, Republic of Serbia branko.budimir@mei.gov.rs
SUEZ Consulting (SAFEGE) Office in Serbia	Željko Tmušić	Project Director	Ul. Beogradska 27, 11000 Belgrade, Republic of Serbia Phone: +381 11 32 34 730 zeljko.tmusic@suez.com
	Dušan Rakić	Project Manager	Ul. Beogradska 27, 11000 Belgrade, Republic of Serbia Phone: +381 11 32 34 730 dusan.rakic@suez.com
	Darko Jakšić	Team Leader	Ul. Beogradska 27, 11000 Belgrade, Republic of Serbia Phone: +381 11 32 34 730 jaksic@zeelandnet.nl
	Miodrag Uljarević	Deputy Team Leader	Ul. Beogradska 27, 11000 Belgrade, Republic of Serbia Phone: +381 11 32 34 730 miodrag.uljarevic@suez.com

LIST OF ABBREVIATIONS AND ACRONYMS

BEV	Battery electric vehicles
CO_2	Carbon Dioxide
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
GHG	Greenhouse Gases
km	kilometre
PFS	Pre-Feasibility Study
RoS	Republic of Serbia

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. BASELINE GHG EMISSIONS

In 2023, carbon dioxide (CO_2) emissions from fossil fuels and industry in the Republic of Serbia (RoS) were estimated to be 42.36 million tonnes, showing a decrease of 0.91% compared to 2021 and a decrease of 3.67% compared to 2020. CO_2 emissions per capita were equivalent to 6 tonnes per person[1].

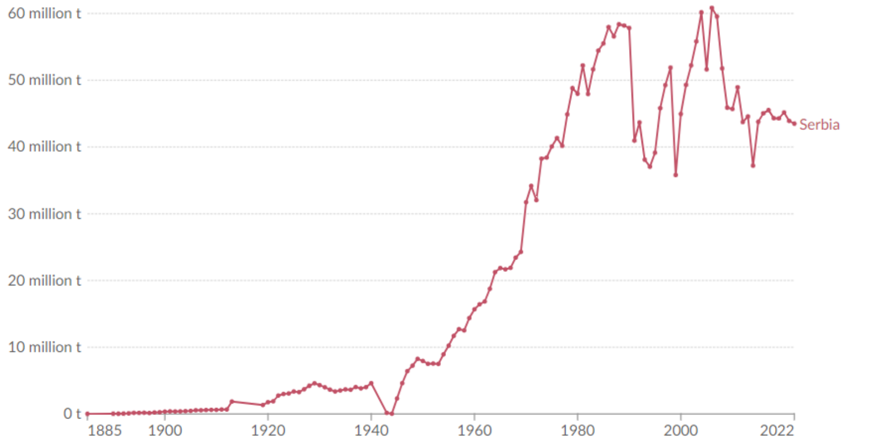

Figure 1-1. Annual CO_2 emissions from fossil fuels and industry in RoS

According to the latest available data on CO_2 emissions from different sectors (in 2020), the transport sector accounted for 14.83% of total CO_2 emissions, showing a growth trend compared to previous years[2].

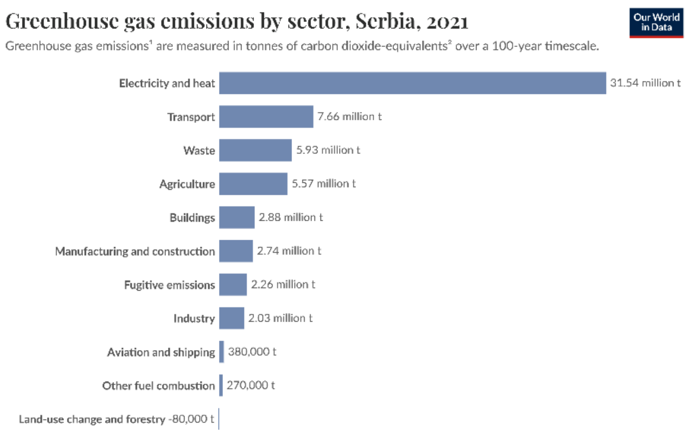

Figure 1-2. Fossil CO_2 emissions by sector in RoS in 2021

[1] https://ourworldindata.org/co2/country/serbia
[2] Ibid.

2. PROJECT GHG EMISSIONS

2.1. Approach and methodology

The possible impacts of railway reconstruction on climate are related to the emissions of greenhouse gases (GHG) from the vehicles and equipment expected to be used during the construction phase, and rail transport during the operation phase. The assessment has been undertaken in line with European Investment Bank (EIB) and European Bank for Reconstruction and Development (EBRD) assessment tools and has incorporated the already developed Corridor Assessment methodology, including the EBRD Protocol for Assessment of Greenhouse Gas Emissions (2017). The calculation of Project-related CO_2 emissions for the construction and operation phases is presented in the sections below.

In general, GHG calculations distinguish 3 types of emissions:

- Scope 1 emissions: Direct GHG emissions from sources owned or controlled by the investee.
- Scope 2 emissions: Indirect GHG emissions generated from purchased electricity, heating, cooling, and steam consumed by the project but not produced by the investee. Scope 2 emissions physically occur at facilities where electricity, heat, or cooling energy is generated.
- Scope 3 emissions: All other indirect emissions caused by the project but originating from sources not owned or controlled by the investee. For example, emissions from the production or extraction of raw materials, use of sold products and services, etc.

The following types of emissions were specifically considered for this Project:

- <u>Construction phase:</u> Scope 1 emissions that occur directly on the construction site due to the operation of construction equipment/vehicles and machinery that burn fossil fuels. Scope 2 emissions from the consumption of electricity, heating, and cooling energy during construction activities are considered negligible, so are omitted from the assessment.
- <u>Operation phase:</u> Scope 2 emissions resulting from the consumption of electricity for train operations (as the railway will be fully electrified), stations, lighting for underpasses etc. Scope 1 emissions resulting from railway maintenance vehicles/machinery/equipment that burn fossil fuels are considered negligible, and therefore omitted from the assessment.

Note: Scope 3 emissions are related to the production of steel and concrete for new railway infrastructure. Considering that these emissions are not directly related to the Project, as well as that the reconstructed railway is planned to be used for many years, and that steel and concrete can be reused upon decommissioning, Scope 3 emissions were not included in the assessment presented below to simplify the calculations.

2.2. Construction phase

The most significant CO_{2e} emissions during the construction phase are expected to come from the burning of fossil fuels in vehicles/machinery used for soil and sub-structure excavations, dismantling the existing railway infrastructure (where necessary) and the transport of that material, as well as materials needed for railway (re)construction.

2.2.1. Calculation of Scope 1 GHG emissions arising from the excavation and transport of materials

Table 2-1. Materials that should be removed and materials needed for railway construction

Material	Quantity
Materials/structures to be removed	
Excavation (land removal) on the open railway	1,100,000 m^3
Materials needed for railway (re)construction*	
Embankment	742,201 m^3
Gravel	915,887 m^3

*Note: The quantities of materials expected be removed and needed for railway reconstruction are based on the Conceptual Design for Section 3 (Paraćin – Trupale).

For the purpose of calculating emissions resulting from the dismantling of existing structures, materials removal and the use of materials for reconstruction activities, the online software 'LIFE HULLEAS199' was used. This software has been developed to evaluate the sustainability of railway projects. Figure 2-1 shows the results.

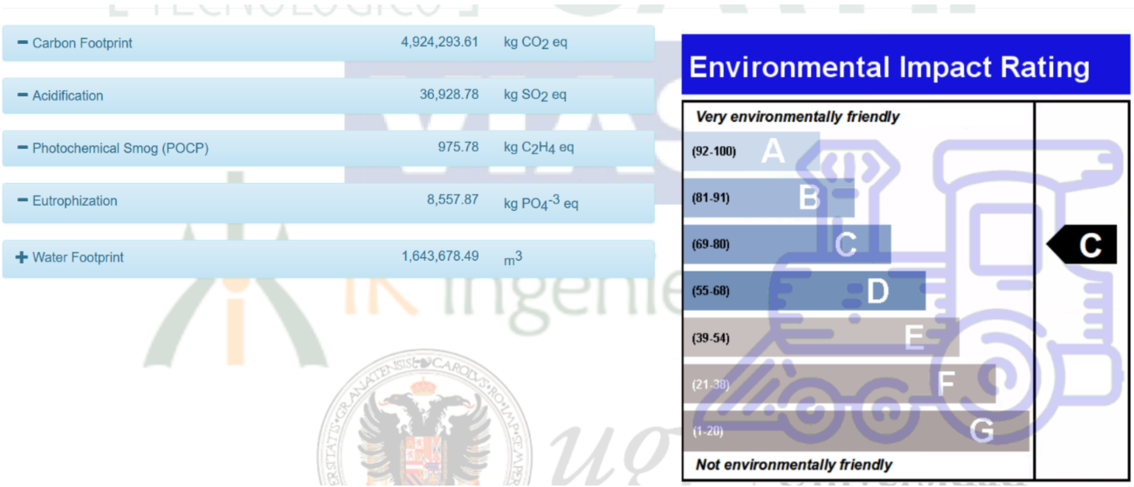

Figure 2-1. GHG emissions caused by material removal and material used for (re)construction of the railway, calculated through the LIFE HULLEAS online calculator

Dismantling of existing structures, removal of existing materials and use of materials for the (re)construction activities on the sections with the double-track railway is calculated to generate approx. 4,924 tonnes of CO_2 emissions per year, which is approx. 0.011% of total annual CO_2 emissions in RoS. Considering that these are total generated emissions, and the estimated duration of the construction works is about 4 years, the estimated total CO_2 emissions amounts to 19,696 tonnes (assuming an equal volume of CO_2 emissions will be generated each year during the construction phase).

2.2.2. Calculation of Scope 1 GHG Emissions from the operation of Construction Equipment

Input data related to the operation of construction equipment (including machinery and vehicles) includes the anticipated type of equipment, the number of units in operation and operational hours for all other construction activities (not including those covered in Section 2.2.1). The type of equipment and number of units have been taken from the Conceptual Design for Section 3 and draft Corridor-level Traffic Study. The assumption has been made that construction equipment will be utilised 8 hours a day, five days a week (as a worst-case scenario). In addition, it has been assumed that the type of fuel used will be diesel, as is typically the case in railway construction[3]. The average fuel consumption for each type of construction equipment was determined based on manufacturers' catalogues or available scientific research (Table 2-2).

Table 2-2. Input data for calculating CO2 emissions from construction equipment

Equipment used in the construction phase		
Type of equipment	**Number of units**	**Fuel Consumption [l/h]**
Loader	4	15[4]
Bulldozer	2	33.16[5]
Grader	3	8[6]
Rollers	4	4[7]
Sheepfoot vibrating roller	2	8[8]

[3] M. H. Alzard, M. A. Maraqa, R. Chowdhury, Q. Khan, F. D. B. Albuquerque, T. I. Mauga & K. N. Aljunadi, Estimation of Greenhouse Gas Emissions Produced by Road Projects in Abu Dhabi, United Arab Emirates, 2019
[4] Mario Klanfar, Tomislav Korman, Tripmir Kujundzic, Fuel consumption and engine load factors of equipment in quarrying of crushed stone, 2016
[5] Ibid.
[6] https://www.scribd.com/document/271103107/Fuel-Consumption
[7] https://www.scribd.com/document/321246669/Fuel-Consumption-Sheet
[8] https://www.scribd.com/document/321246669/Fuel-Consumption-Sheet

Tank truck	4	33[9]
Tipper truck	26	15.2[10]

The CO_2 emissions factor per litre of diesel fuel is 2.49[11]. Based on input data, using the following formula, CO_2 emissions generated as a result of the use of construction equipment were calculated:

$$E_{equipment} = Number\ of\ units\ (-) \cdot Consumption\left(\frac{l}{h}\right) \cdot Number\ of\ working\ hours\ per\ day\left(\frac{h}{day}\right) \cdot Number\ of\ working\ days\ per\ year\ \left(\frac{day}{year}\right) \cdot Emission\ factor\ \left(\frac{kgCO_{2e}}{l}\right)$$

The number of tipper trucks used to transport materials to the construction site is taken from Table 2-2 (i.e. 26). Based on the empirical data, an average distance from the material collection site to the unloading site of 50 km was assumed, and transportation frequency of 270 days per year. CO_2 emissions generated from using tipper trucks for material transport is calculated as:

$$E_{transport} = Number\ of\ units\ (-) \cdot Consumption\left(\frac{l}{h}\right) \cdot Distance\ of\ the\ material\ collection\ site\ to\ the\ unloading\ site(km) \cdot Number\ of\ working\ days\ per\ year\ \left(\frac{day}{year}\right) \cdot Emission\ factor\ \left(\frac{kgCO_{2e}}{l}\right)$$

Using these two formulas, the total annual CO_2 emissions generated from the operation of construction equipment are approx.16.300 tonnes.

Taking into account that CO_2 emissions in RoS from the transport sector in 2023 amounted to 42.36 million tonnes[12], the use of construction equipment for the construction of this subsection would contribute to an increase in total annual emissions from the transport sector by 0.04%.

2.3. Operation phase

Since the railway will be fully electrified, direct (Scope 1) sources of CO_2 emissions in the operation phase (i.e. related to maintenance vehicles and equipment) are considered to be negligible and have not been included in this assessment.). The main source of indirect (scope 2) emissions in the operation phase is the use of electricity to power the trains and railway-related infrastructure (stations, signalling equipment, track switches, lighting of underpasses

[9] Calculated based on average consumption: https://www.webfleet.com/en_gb/webfleet/blog/do-you-know-the-diesel-consumption-of- a-lorry-per-km/ and average speed: https://www.matec-conferences.org/articles/matecconf/pdf/2017/01/matecconf_encon2017_02022.pdf
[10] https://postconflict.unep.ch/humanitarianaction/documents/02_08-04_06-04_02-22.pdf
[11] https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf
[12] https://ourworldindata.org/co2/country/serbia

etc.). Indirect (Scope 2) CO_2 emissions have been calculated for the base year (2024) and for three future Project scenarios:

- Project scenario 1 – 2028, assuming the railway has not been reconstructed (no Project scenario)
- Project scenario 2 – 2028, assuming the railway has been reconstructed (Project implementation scenario)
- Project scenario 3 – 2040, incorporating projected changes in the use of the railway instead of road vehicles and energy use, assuming the Project has been implemented.

The first two are for the sake of comparison between the 'Project' and 'no Project' scenarios, and the second and third are to quantify actual avoided emissions arising mainly from changes in the Serbian electricity mix until 2040.

The calculation of emissions was based on energy consumption, the current electricity grid emission factor and projected future electricity grid emission factor (considering planned increases in the share of renewable energy sources). Direct data on energy consumption from trains is difficult to collect, due to the large number of companies that use the existing infrastructure. Therefore, energy consumption is calculated using the appropriate mathematical formulas outlined below. Input data for the calculation of CO_2 emissions from railway operation is shown in Table 2-3.

Table 2-3. Input data for calculation of Scope 2 CO_2 emissions in the operation phase

Inputs required		Current railway alignment (base year: 2024)		Future railway alignment 2028 (Project implementation)
N_{stops}	Number of intermediate stops	20		9
L	Trip length [km]	58.1		58.1
v_{ave}	Average speed [km/h][13]	100		180
V_{max}	Maximum speed [km/h]	100		200
B_0	Constant equating to rolling resistance[14]	2024.	2025.	0.001
		0.003	0.004	
B_1	Constant equating to friction resistance[15]	2024.	2025.	0.15
		0.5	0.6	
B_2	Constant equating to aerodynamic resistance	0.95[16]		0.36[17]
g	Gravitational constant [m/s²]	9.81		

[13] Project Description chapter
[14] http://coachrobmuller.blogspot.com/2017/11/rolling-resistance-revisited.html
[15] https://www.iitg.ac.in/rkbc/me101/Presentation/L09-12.pdf
[16] https://www.simscale.com/blog/2017/06/air-resistance-vehicle-design/
[17] https://www.computer.org/csdl/magazine/cs/2019/03/08656573/187Q8FqILxC

D_h	Change in height [m][18]	3.8	3.6
Trains			
N_p	Number of trains in passenger services	26	106
N_f	Number of trains in freight services	62	90[19]
m_p	Average passenger train weight [ton]	380[20]	400[21]
m_f	Average freight train weight [ton]	650[22]	700[23]
Average carbon emission factors (e) [gCO_2/kWh]:			
2024[24]	512		
2028[25]	462		
2040[26]	359		

Firstly, the energy consumption of each train was calculated using the following formula[27]:

$$E' = \frac{(N_{stops} + 1)}{L} \cdot \frac{v_{max}^2}{2} + B_0 + B_1 \cdot v_{ave} + B_2 \cdot v_{ave}^2 + \frac{g \cdot D_h}{L}$$

Then the total energy consumption was determined, based on the number of trains, their weight and the length of the Project (Section 3 Paraćin – Trupale):

$$E = E' \cdot L \cdot (N_p \cdot m_p + N_f \cdot m_f)$$

Multiplying the total energy consumption by the emissions factor, the total emissions for different scenarios were calculated using the following formula:

$$Total\ emissions = E \cdot e$$

The results are presented in Table 2-4.

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[18] Height reduction in modern trains has been taken into account. http://www.railway-technical.com/trains/rolling-stock-manufacture.html; https://www.researchgate.net/figure/Train-model-a-different-lengths-of-trains-b-train-cross-section-c-CRH380A- and_fig1_320774107
[19] Transport Study within Feasibility Study – draft (PPF9 2024)
[20] https://socialcompare.com/en/comparison/high-speed-trains
[21] It was assumed that there would be a minor increase in the train weight due to the expected increase in their length
[22] Average value based on Preliminary Feasibility Study – Reconstruction and Modernisation of the Railway Line Belgrade-Nis, 2022
[23] It was assumed that there would be a minor increase in the train weight due to the expected increase in their length
[24] Considering the average value in 2023: https://app.electricitymap.org/zone/RS
[25] Based on the difference in the share of renewable energy sources between 2016 and 2021: https://www.worldometers.info/electricity/serbia-electricity/ https://www.statista.com/statistics/1237596/serbia-distribution-of-electricity-production-by-source/#:~:text=Much%20of%20Serbia's%20electricity%20generation,of%20the%20country's%20power%20mix
[26] https://balkangreenenergynews.com/rs/srbija-planira-da-duplira-udeo-obnovljive-energije-i-dostigne-40-odsto-do-2040/
[27] India GHG Program, India Specific Rail Transport Emission Factors for Passenger Travel and Material Transport, 2015

Table 2-4. Scope 2 CO_2 emissions as a result of train operation

Total Scope 2 CO_2 emissions – train operation [tons CO_2]			
Baseline	2024	Base case (current railway)	4,709.2
Scenario 1	2028	Project is not implemented	4,253.92
Scenario 2	2028	Project is implemented	11,873.49
Scenario 3	2040	Project is implemented	9,226.37

*Note: The calculation is made for the worst (general) scenario – i.e. the maximum estimated number of trains is used for each year.

In order to account for an expected reduction in emissions due to an increase in number of passengers using the railway and the consequent decrease in the number of journeys taken by road, a projection of the number of passengers using the railway was taken into consideration, as presented in the Traffic Study.

Table 2-5. Number of passengers – projections[28]

Number of passengers using the railway		
2024	Base case (current railway)	980,000
2028	Project is not implemented	1,000,000
2028	Project is implemented	1,300,000
2040	Project is implemented	1,500,000

A shift from fossil fuel-powered vehicles to BEV (battery electric vehicles) is not considered because of the large uncertainty connected with this scenario.

Additionally, following the implementation of the Project, the use of the railway for the transport of goods is expected to increase, as calculated and presented in the Pre-Feasibility Study (PFS.)[29] The calculated quantities of goods expected to be transported by rail under the various scenarios being assessed is presented in Table 2-6.

Table 2-6. Quantity of goods transported by the railway – projections[30]

Goods transported [ton]		
2024	Base case (current railway)	7,449,282
2028	Project is not implemented	8,876,012

[28] Source Traffic Study PPF9 2024
[29] Source Pre-Feasibility Study PPF9 2024
[30] Projections of the number of transported goods by years were calculated on the basis of data on the quantity of goods transported in the first quarter of 2022 and the quantity of goods transported in 2006 (source: General Design) and taking into account the length of the Belgrade–Niš railway section. Projections of the goods transported in the future years are calculated based on the calculations within Traffic Study PPF9 2024.

2028	Project is implemented	9,691,000
2040	Project is implemented	10,746,000

In order to calculate the potential decrease in emissions due to a reduction in passenger road traffic due to Project implementation, the assumed input data shown in Table 2-7 were used.

Table 2-7. Inputs required to calculate emissions from passenger road traffic

Inputs required to calculate emissions from passenger road traffic	
Average car CO_2 emissions per passenger per kilometre [g CO_2/passenger-km]	182[31]
The shortest road distance Paraćin - Trupale [km]	65
Average number of people in the car[32]	3

In order to calculate the potential reduction in emissions resulting from a reduction in freight road transport due to Project implementation, the assumed input data shown in Table 2-8 were used.

Table 2-8. Inputs required to calculate emissions from freight road traffic

Inputs required to calculate emissions from freight road traffic	
Average truck CO_2 emissions per kilometre [g CO_2/ km]	307[33]
Shortest road distance Velika Plana-Paraćin [km]	65
Average truck capacity [ton]	10[34]

The potential decrease in emissions was then calculated using the following formula for passenger road transport:

$$\Delta e = \frac{number\ of\ passenger\ in\ the\ baseline\ year - number\ of\ passenger\ in\ projected\ year}{average\ number\ of\ people\ in\ the\ car} * average\ car\ CO_2 emissions\ per\ passenger\ per\ kilometre * the\ shortest\ road\ distance\ Paraćin - Trupale$$

And the following formula for freight road traffic:

31 https://www.statista.com/statistics/1185559/carbon-footprint-of-travel-per-kilometer-by-mode-of-transport/
32 Considering that most people use this section to transport to work.
33 https://theicct.org/publication/co2-emissions-from-trucks-in-the-eu-an-analysis-of-the-heavy-duty-co2-standards-baseline-data/
34 https://www.lynchtruckcenter.com/how-much-can-a-dump-truck-carry/

$$\Delta e = \frac{goods\ transported\ in\ the\ baseline\ year - goods\ transported\ in\ projected\ year}{average\ truck\ capacity}$$
$$* \ average\ truck\ CO_2 emissions\ per\ kilometre$$

$$* \ the\ shortest\ road\ distance\ Paraćin - Trupale$$

The results of the predicted potential changes in emissions (relating to passenger and freight road traffic) are shown in Table 2-9.

Table 2-9. Changes in CO_2 emissions as a result of Project implementation

Changes is CO_2 emissions [tons CO_2]			
		Passenger road traffic	Freight road traffic
2024	Base case (current railway)	0.00	0.00
2028	Project is not implemented	-78.87	-2,847.04
2028	Project is implemented	-1,261.87	-4,473.35
2040	Project is implemented	-2,050.53	-6,578.60

These data follow directly from the previous two formulas (passenger and freight road traffic). Since the number of passengers/the amount of goods is higher in 2028 than in 2024, and in both equations data for 2028 are the second (negative) term, then the results are also negative.

Emissions as a result of train operations and a potential modal shift from road to rail traffic are shown in Table 2-10.

Table 2-10. CO_2 emissions as a result of train operations and potential modal shift from road to rail transport

Total CO_2 emissions – trains operation and modal shift from road to rail transport [tons CO_2]			
Baseline	2024	Base case (current railway)	4,709.2
Scenario 1	2028	Project is not implemented	1,328.01
Scenario 2	2028	Project is implemented	6,138.27
Scenario 3	2040	Project is implemented	597,24

Therefore, if the Project is not implemented, this assessment has indicated that there will be a potential increase in CO2 emissions. Conversely, Project implementation could potentially result in a reduction in CO_2 emissions of 87.1% by 2040 (compared to the base case).

3. CONCLUSION

According to the calculations outlined in Section 2 of this Chapter, Project implementation will potentially contribute to a reduction in total GHG emissions from the transport sector in RoS, by allowing for a significant modal shift from road to railway. Negative impacts on CO_2 emissions are only expected during the construction phase because of the use of fossil fuel- powered vehicles/machinery/equipment. Although construction-phase emissions may appear significant when compared to operational GHG emissions (Table 2-4), they are minor in the context of long-term avoided emissions resulting from modal shift (Table 2-10).

While GHG emissions during the construction phase are not avoidable, they can be partially mitigated through good construction practices and emissions reduction measures. These include, among others, efficient use of machinery, maintenance of equipment to reduce fuel consumption, minimization of material transport distances, and dust suppression measures. These measures are outlined in detail in Chapter 6 of this ESIS: Air Quality and form part of the overall environmental mitigation strategy for the Project.