Fundamental on Environment and Sustainability
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ENVIRONMENTAL IMPACT ANALYSIS

TUNNEL EURALPIN LYON - TURIN

Group 13

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INTRODUCTION

1.1 Background

Currently, **almost 50 million tons of goods** are transported annually between Italy and France through the Alps, with approximately 90% moved by road – significantly higher than the 70% in Austria and 30% in Switzerland (AECOM, 2023). Even though such reliance road transport brings substantial environmental consequences, economic trade between Italy and Fance holds significant economic value, representing a total of € 103 billion (ISTAT 2017).

Recognizing both the socioeconomic importance of this trade but also that transport emissions comprise a quarter of EU's total greenhouse gas emissions, for which the European Commission set a **target of achieving a 90% reduction by 2050**, there is a strong urgency for a solution capable of shifting transport from road to rail, cut journey times, save energy and address these environmental imbalances (AECOM, 2023). After prolonged political discussions, 2016 marked the approval of additional developments on the cross-border section of the Lyon-Turin railway line, foollowing preliminary studies and works.

1.2 The project

The Lyon-Turin is a **comprehensive railway project** designed to connect Lyon and Turin, extending over 270 km (TELT, 2024), with 80% of the railway line dedicated to freight transport and 20% to passenger transport. This line aims to guarantee a connection, south of the Alps, between Western and central-eastern Europe, while promoting economic exchanges and competitiveness of Mediterranean European countries, as a freight and passenger railway network, that intersects with the most important sea and river ports, major cities and airports.

At the core of this project is the **Tunnel Euralpin Lyon-Turin**, which belongs to the cross-border section of the track (*Figure 1*), and that will be the focus of this report. The **cross-border section** of the Lyon-Turin freight and passenger railway line extends over a stretch of 65 km, 89% of which in tunnels, **between Susa in Piedmont and Saint-Jean-de-Maurienne**, in Savoy. The major component of this section is the 57.5 km long **Mont Cenis base tunnel** (12.5 km in Italy and 45 km in France – being the longest railway tunnel in the world.), which links the international stations of Saint-Jean-de-Maurienne and Susa, these being the connection points to the respective national lines in France and Italy.

The cross-border section of the Lyon-Turin line is the central hub of the Mediterranean Corridor on of the nine Trans-European Transport Networks (*Figure 2*), which the EU conceives as the "metro railway for Europe", connecting the continent rapidly and efficiently, linking ports, intermodal hubs and large urban centers (Lyon-Turin Engagement Forum, 2024).

Currently, **over 20% of the tunnel has already been excavated**. The cost of the cross-border section is estimated at 11.1 billion euros, as certified by the International Grant Thronton Financial Advisory Services Group. From this amount, 40% is co-financed by the European Union, while the remaining is divided between France (25%) and Italy (35%). The completion of the project's main works is expected to be in 2033 (TELT, 2024).

1.3 Problem Statement

The primary reasons behind the realization of the project are mainly on the **environmental side** - reducing the polluting emissions in the Alpine region, as one of the primary objectives established by the Climate Conference held in Paris in 2015 (which set a goal of transferring 30% of freight to railway transport by 2030 and 50% of it by 2050); and on **transport and economy** - aiming to support the economic development of these territories and improve the connectivity between Italy, France and the European railway networks. Additionally, it also aims bring **advantages for freight transports** (increasing capacity and cost saving) and **for passengers**, offering more trains and less travel times – travel from Lyon-Turin will be cut to 1h 47", against the current 3h 47".

According to the TELT's project website, "The Mont Cenis base tunnel is a priority intervention in the context of the **Green Deal's decarbonization objectives**". In this sense, recognizing the urgent need of reducing emission, the projects aims to encourage rail travel, allowing to shift 25 million tons of freight annually from road to rail, a major challenge given that freight comprises most of the traffic on this route (Bellamy et al., 2023). In this regard, it is then expected to significantly reduce C02 emissions and local air pollutant emissions by shifting a significant fraction of freight and passenger traffic from road (fuel driven trucks and private cars) to electricity powered railways, also reducing reliance on air travel. Despite the **potential for energy savings,** the project has faced **strong opposition** over the past two decades. These controversies regard project's extensive environmental footprint during its 10-20 years of construction work, which implies thousands of truck trips for material transport, the disposal of millions of tons of excavated material, significant concrete usage, and the heavy impacts on both surface and groundwater (L.

Giunti, 2012). Many environmentalists argue that the project's environmental cost will in fact outweigh its usefulness in the context of the climate crisis (Bellamy et al., 2023).

In this sense, the ecological impact of the infrastructure's construction must be measured against its ecological benefits, over both the short and very long-term.

1.4 The Company

TELT is a public binational entity responsible for the realization and operation of the Tunnel Euralpin Lyon Turin, and the overall cross-border section of the railway, including the construction of the two new international stations (Saint-Jean-de-Maurienne and Susa), as well as ensuring their interconnection with the existing national lines (TELT, 2024).

Formally recognized as a French company, TELT is **50% owned by the French State**, through the Ministry of the Ecological Transition, **and 50% by the Italian State**, via the Ferrovie dello Stato Italiane Group. In fact, TELT was only founded in February 2015, with the aim to replace Lyon Turin Ferroviaire (LTF), which had overseen the project's studies and preliminary works between 2001 and 2015 (TELT, 2024).

With the specific purpose of achieving the development of this infrastructure, TELT's mission is closely aligned with the European goal of creating faster and more efficient transport networks. More specifically, the company sees the **Alps as a key node for commercial exchanges** and movement of people between European countries and, as such, is dedicated to developing the project in accordance with international agreements, ensuring compliance with legal and environmental requirements and quality standards (TELT, 2024).

1.5 Methodology

The methodology approach adopted throughout this assignment involved **in-depth research** not only of reports and papers from the **project's proponents**, namely its sustainability reports and predicted impacts, but also an analysis of **news and research papers** from other reliable sources. After analyzing the project's environmental impacts on water, air and earth, as well as its socioeconomic considerations, the implementations of three tools are proposed and, after, three concrete recommendations to the project are given.

2. IMPACT ASSESSMENT

2.1 Impact on Air

The heavy impact of the Tunnel Euralpin Lyon-Turin on Air is a topic of **significant debate**. It is known that air pollution is a major cause of premature death and illness and is the biggest environmental health risk in Europe, causing around 400,000 premature deaths a year (WHO, 2018). As already stated, the Tunnel Euralpin Lyon-Turin key objective is to have a positive environmental impact through the **decrease in the usage of motor vehicles**. "Every year, more than 45 million tons of goods travel between Italy and France along the Alpes, **92% of which are transported by road** (against 8% by rail), with important consequences on pollution and greenhouse gas emissions" (TELT, 2021)

Looking more carefully, the construction of this tunnel aims to **transfer "25 million tons of freight from road to rail every year"** (Bellamy et al., 2023). As confirmed by the European Environment Agency, **trains have a substantially lower carbon footprint** than cars and planes. In addition, fuel combustion stemming from the road traffic source is responsible for the emission of nitrogen oxides which are among the most harmful air pollutants to the environment (EEA, 2019) and aggravate greenhouse gas emissions. However, not only light and heavy diesel transport but also activities such **construction** are main sources of particles, namely PM 2.5 particles, that, once again, in European cities, are the pollutant of greatest concern due to its effects on health.

This way, the popular controversy over whether the tunnel's construction will lead to more negative environmental impacts than post-construction benefits, linked to the commitments of reducing inter-alpine road traffic of the **Alpine Convention**, which are essential for the European CO_2 emission reduction strategy, is left hanging in the air.

Regarding the **construction phase**, according to EuroNews, this is projected to generate significant carbon dioxide emissions, i.e., **10 million tons of carbon dioxide**, due to the use of heavy machinery, vehicles and construction materials. Even so, the group of companies involved in the construction is committed to a **mitigation strategy** of these effects, by using low-emission and electric vehicles and equipment, "such as shuttles for personnel transfers between accommodation and the construction site, and diesel vehicles compatible with the use of greener fuels such as HVO diesel, which has a significantly lower greenhouse gas emission factor than conventional diesel (0.03558 kg. CO2eq/L versus 2.659 kg CO2eq/L).

However, when it comes to electric vehicles, their environmental impact depends on how the energy for their use is generated (Ferreira, 2024). Therefore, implementing these measures will be beneficial **if the energy used is 100% renewable**. Consequently, it should be noted that all the electrical energy used by the equipment in the construction is **produced from renewable sources** and the use of eco-sustainable materials is also promoted. Apart from that, in the largest Italian construction site for the Lyon-Turin railway line, Chiomonte, TELT is planning to install photovoltaic panels, which will imply **carbon dioxide savings in the amount of 512 tons per year**. Also, "the excavated materials removal operations will be carried out through electrical belts, avoiding road vehicles, producing a **saving in carbon dioxide** emissions estimated in 891 tons and diesel fuel consumption in 342,346 litres" (Lyon-Turin Engagement Forum, 2024).

This way, considering these implemented measures, one can conclude that there is a great concern for mitigating the negative impacts arising as a consequence of the construction process.

The impacts have been in fact calculated through the Carbon Balance methodology of Agence de l'Environnement et de la Maîtrise de l'Energie, considering all the phases of the construction and operational work and they are expressed in terms of tons of CO2 equivalent. Analysing *Figure 3* (*from Annexes*), through the red line, it is estimated that the emissions of the construction phase **will be offset about 15 years after the tunnel starts operating** and that, after this period, the infrastructure will produce positive results in terms of carbon dioxide reduction. More precisely, it is estimated that over 120 years of its use, from the date it offsets the construction's emissions, the **railway will save more than one million tons of carbon dioxide per year** due to a reduction of heavy goods vehicles and traffic across the Alps in **40%**, also leading to a reduction in nitrogen oxides (NOx) and particulate matter (PM). The brown bars represent the tons of CO2 saved each year by transferring traffic from the road to the rail.

Still on the subject of **post-construction**, the trains running on this project will be powered mainly by **energy from the French grid**, which produces **relatively lower levels of carbon emissions** compared to other economies of the same level, with a large part of its energy production coming from nuclear power, according to the International Environment Agency. Nuclear energy is cleaner than oil, natural gas and coal in terms of emissions, not emitting pollutants such as sulphur dioxide, nitrogen oxides or particulate matter. Although its long term impact depends on the **responsibility** of its production in terms of waste management, accidents and mining, not being completely free of environmental impacts, it is nevertheless classified by the **European Union** as a “green” energy source. Despite progresses made in production safety, it is still important to keep a **critical eye** on it, since even if the possible impacts of using this energy do not directly affect the Alpine region, it is still associated with a global increase in nuclear energy production.

In conclusion, despite the controversy, the latest analysis confirms that the project is **expected to reduce drastically the emissions of greenhouse gases** in the Alpine region and that in terms of air impacts, the tunnel is projected to have **positive** impacts on the region and on the health of its inhabitants in the **long-term.**

2.2 Impact on Water

The construction of the Lyon-Turin rail tunnel has significant effects on water resources near the tunnel area, which poses a significant concern. During the construction, projections by the TELT suggest that between **600 to 1,000 liters of water per second** will be discharged from the tunnels (Bellamy et al., 2023). This is a considerable amount of water which will have consequences as it will deplete **local water supplies**, potentially **lowering groundwater levels**, further threatening the water resources that the surrounding area depend on (X. Jin et al., 2012). As by TELT, in 2022, water extracted during the excavation process will not be reused but instead will be discharged or redirected to prevent flooding, which significantly increases the risk of **water shortages** and **water stress** in already affected areas. Such depletion of local resources directly threatens the region’s long-term sustainability, especially in areas where water scarcity is a growing concern (Bellamy et al., 2023).

Furthermore, there are significant risks of **contamination** from the excavation of hazardous materials such as asbestos and uranium. The excavation of uranium-rich zones, for example, would release substantial radioactivity—approximately 3.3 billion becquerels (Bq)—into the environment, **endangering the water quality** of nearby water sources (TELT, 2022). This water contamination would severely impact both human health and local ecosystems which furthers the need for integrated water resource management that prioritizes environmental sustainability.

Moreover, the water **demand will also be increased** due to the water required for construction activities, such as concrete mixing, earthworks, and dust suppression. This will put additional strain on the already limited water supply in the region. Even though the greater threat to water supply is the disruption of the natural water resources due to excavation, there is also significant water usage from the actual construction. This is also pointed out by Albert Poggio from the Mountain Union of Val of Susa who mentions that while the water directly used for construction is significant, the **greater concern lies in the disruption of natural water sources**, which could result in more substantial water losses due to excavation (Bellamy et al., 2023). These risks show the importance of managing water resources efficiently during this large-scale tunnel project as it could have massive consequences otherwise.

While most of problems arise during construction, there are also challenges after it has been completed. The challenges regarding **water shortages and decreased water supply** are expected to persist, and the reduced availability of water for agricultural use in surrounding areas can have huge consequences. The regions near the tunnel, classified as **"Beaufort"** zones, rely on consistent water supplies for irrigation to produce the necessary for fodder for its livestock. The decrease in water availability threatens **agricultural productivity**, risking the region's food security and economic viability (Bellamy et al., 2023). As Delhomme highlights, "with less water, irrigation won't be possible," which places the agricultural sector in jeopardy (Bellamy et al., 2023), illustrating the interconnected nature of water scarcity, food production, and economic stability.

Furthermore, groundwater **flow disturbances and contamination risks** will likely continue, even after the construction phase. There are potential concerns about the long-term effects of the TELT Tunnel on groundwater systems, emphasizing the need for **continuous monitoring**, for which TELT is working with local administrations to monitor and address these issues (TELT, 2023). These potential post-construction water disruptions showcase the need for a comprehensive, long-term strategy for water management, ensuring that resources are protected but also replenished.

Recognizing the negative consequences on the water resource, TELT has taken important steps towards **mitigating** such impacts. The company has committed to sustainable water management practices such as **rainwater collection** and **water drainage management** (TELT, 2022). Recovered water is repurposed for various uses, such as dust suppression in the tunnels, irrigation of nearby vineyards, cooling of machinery, and cleaning construction sites (Lyon-Turin Engagement Forum, 2024). These steps follow the broader concept of **reducing water waste** and **improving water efficiency**. This aligns with the sustainable development goals aimed at preserving a natural water cycle and therefore reducing water waste in the long term.

Moreover, TELT has also introduced an extensive **Environmental Monitoring Plan** to track both water quality at multiple locations around the construction area and after the construction has finished (TELT, 2022). By monitoring water quality at over a hundred locations the company tries to ensure that water quality remains stable and that the tunnel's construction does not significantly harm local water systems. According to TELT (2022), this monitoring network has not yet identified any significant impacts on water quality or local ecosystems, but the full effects of the project may not be apparent until its completion or even later so the company and the monitoring must be cautious. Such ongoing monitoring is crucial for ensuring that any changes in water availability or quality can be quickly addressed.

In addition, TELT has adopted innovative techniques to **prevent water loss**, such as full-round waterproofing systems and water membranes (Bufalini et al., 2017). These efforts are designed to minimize water leakage and protect local water resources from being contaminated or wasted. Furthermore, the geothermal properties of the water being extracted are being evaluated, which could provide a sustainable energy source for the tunnel's construction activities and a potential to reduce use the water rather than waste it (Bufalini et al., 2017). These measures demonstrate a commitment to reducing the environmental footprint of the project while also exploring sustainable alternatives to traditional construction practices.

Despite all these negative impacts on Water, the construction of the tunnel does also bring **some benefits**. The **reduction in road traffic** expected, can I fact lead to decreased road pollution, which may help protect water quality by reducing pollutants such as oil, chemicals, and particulates. As these contaminants may get into the water, worsening its quality, the tunnel could contribute to reducing this contamination.

In conclusion, the construction of the Lyon-Turin rail tunnel presents **significant challenges** to local water resources, **both during and after the project**. The large-scale discharge and redirection of water and the potential risk of contamination by hazardous materials such as asbestos or nuclear material pose serious problems to water availability and quality, which could affect ecosystems and human health. TELT has implemented some mitigation strategies such as water recovery and water quality monitoring but overall, the long-term sustainability of water resources in the region seems to **be negatively affected** by the tunnel project.

2.3 Impact on Earth

The last environmental impact analysis concerns Earth. In fact, one of the most significant environmental challenges of this infrastructure project involves managing the **large volume of excavated soils and rocks** which are removed during the works – more precisely, the tunnel construction is estimated to generate **27.2 million tons of excavated material** over a period of 10 years (TELT, 2021).

While the project is 89% underground, which minimizes surface disruption when compared to its total scale, addressing the effective management of underground materials is essential to ensuring the project's environmental feasibility. Firstly, **the presence of radioactive materials**, such as uranium, on the excavated soil, represents one of the concerns (Giunti et al., 2012). If, as was originally predicted, the disposal and consequent dispersion of materials in open-pit sites can indeed lead to an estimated 3.3 billion Bq (becquerels) of radioactivity, this would not only cause serious risks soil contamination, but also to air and water quality (as already noted previously). The **soil contamination**, together with the action of meteorological events such as wind (being capable of carrying these radioactive particles), would expose local communities to cumulative radiation levels potentially harmful over time. More specifically, the main health risks come from radon, a **radioactive gas found in uranium-bearing rocks** (Giunti et al., 2012). Its chemical reactivity and electrical properties make radon particles to attach to dust and other tiny particles in air, which can be very easily inhaled and stored in the lungs and fixed to pulmonary mucosae, eventually severely **damaging human cells in the lungs.**

Secondly, concerns have been raised regarding the **presence of asbestos in excavation materials**. Early estimates from 2012 suggested around 170,000 cubic meters of asbestos bearing rocks with relevant concentrations could be found 500 meters from the base tunnel (Giunti et al., 2012). However, this estimation may significantly underestimate the actual case. While Italian regulators define "very low levels" as those "under 5% of concentration of asbestos in rocks encountered during excavation", the legal limit is about 0.1% according to Italian law.

To prevent soil contamination, manage these hazardous materials, and **mitigate** their potential consequences, while promoting a **sustainable use of resources**, TELT had adopted a strategy focused on the principles of **circular economy** during the construction phase. They decided to set up two international sites dedicated only to the waste management and use of excavated material, one on the French side and other on the Italian side. The plan underway is to recycle over 50% of the material, which is processed in the recycling sites to be reused for construction purposes, such as concrete segments, aggregate for concrete and railway embankments (Lyon-Turin Engagement Forum, 2024). The rocks that cannot be reused due to their mechanical/chemical characteristics are directed towards morphological restoring or transported off-site to revive the natural environment in identified areas (Lyon-Turin Engagement Forum, 2024).

Despite TELT's commitment to a sustainable and responsible excavation process and to the recycling of waste materials, concerns surge as this large-scale operation can heavily **disrupt the natural soil structure.** The **removal of topsoil and disturbance of subsoil layers** can lead to soil erosion, loss of fertility, and to the destruction of plant roots, which are crucial to stabilize soil. Such disruptions and landscape alterations may contribute to the **reduction of soil permeability**, increasing surface run-off (opposed to water infiltration), damaging groundwater aquifers and affecting the availability/ variability of water for both plants and local communities.

Furthermore, the recognition of the impact associated with an infrastructure project of this scale in the Alps, characterized by its rich, unique and varied ecosystem (TELT, 2021), is of crucial importance, due to its potential to **heavily impact the local biodiversity**. As an example, The Susa Valley, part of the EU's Natura 2000 network, is a designated **area of ecological significance**, being home to species protected under the EU Habitats Directive and Birds Directive, such as certain bats, amphibians, and bird species (Natura 2000 Network, n.d.). The current disturbance from noise and human activity from the construction process can heavily disrupt breeding, feeding, and migration patterns in such places, while the construction zones and supporting infrastructure can disrupt wildlife corridors crucial for movement of species.

Protecting such **complex Alps ecosystem** implies not only a deep understanding of its characteristics, but an active avoidance of habitat disruption, impact minimization on the numerous protected species, and the investment in rewilding projects and ecological restorations. In this sense, in addition to complying with the statutory environmental requirements for the establishment of its construction sites, TELT has implemented diverse **biodiversity protection initiatives**, rewilding projects and restructuring ecological functions in order not to harm the conservation status of Alpine biodiversity, in compliance with SGD 15. In terms of biodiversity, the considered affected areas by the project are significantly higher in France than in Italy, accounting for 71% of the total (*Table 1*). However, one should note that, in both countries, more than 50% of the predicted impacted areas are not natural environments, but rather artificial and ruderal zones, which confirms that ecological consideration played a role when choosing the location of work sites. Despite this, on each side of the border, over 55% of the impacted areas are subject to ecological rehabilitation, which corresponds to an area larger than the truly natural environment negatively affected.

More particularly, firstly, **on the Italian side**, the protected areas are mainly located in the lower Susa Valley, already stated as a region characterized by its alpine climate which is home to a vast natural heritage with a **rich variety of fauna and flora**. Since 2022, TELT, together with several universities and institutes, has been developing several field activities to assess the effectiveness of its **restoration measures and interventions**. Such field studies had in fact showed that the implementation of forest clearing interventions, in this case a built ecological corridor, have successfully improved the presence of determined animal species in the areas closed to the construction sites, such as the **Southern Festoon butterfly** (Zerynthia polyxena) population in the municipalities of Giaglione, Chiomonte and Salbertrand - a protected species at European level (Piccini et al., 2022). Another ongoing project, this at binational level, involves research on Erica Carnea, a native plant of the Susa and Maurienne, which is often threatened by the opening of forest tracks, roads, quarries and agricultural expansion. The project wants then to propose new approaches for the safeguard of its habitat through the promotion of applied botany, which is of particular interest to the local regions (TELT, 2021).

Secondly, **the French territory** is currently in the process of implementing 26 areas (covering a target of 150 hectares) subject to measures designed to: protect endangered species and to improve the attractiveness of these sites for the biodiversity created around them – one examples include the establishment and management of a network of habitats that support **amphibian reproduction** in valley areas (*Figure 5*). Once established, these areas are supposed to be maintained through the implementation of long-term management places that require the direct involvement of local actors for at least 30 to 60 years (TELT, 2021). As analyzed, in both countries, the new project aims to minimize impacts and **preserve ecosystems, habitats and biodiversity**. However compensatory measures for the fauna and flora are clearly unbalanced on the French side – which has over 20 projects covering more than170 hectares, while the Italian side has just one project of 20 hectares.

It can therefore be concluded that this project is **unlikely to bring any significant positive effects** to the Earth dimension, particularly in terms of soil health and biodiversity. Instead, it is expected to pose considerable threats: the challenges in managing construction and excavated waste; the soil contamination from to the presence of radioactive materials and asbestos and its impact on ecological corridors and habitats, affecting biodiversity. **Despite the mitigation efforts,** it remains uncertain whether the planned measures will effectively offset the project's long-term environmental impacts on the Earth's ecosystems.

2.4 Socioeconomic Impacts

Given the project’s scale and relevance, its results extend beyond environmental impacts, but affects entire **regions, communities and international relationships**.

Firstly, to provide some context and ascertain the satisfaction of the citizens with this project, a French market research and opinion polling company, BVA, conducted surveys to assess public opinion about the project in both France and Italy. The results showed that the project is **supported by a majority** in all age and social groups and electorates in France (93%) and in Italy (86%), with only the region of Susa Valley in Italy being the most divided, according to TELT (2019).

On a **global level**, the transfer of road traffic from road to rail **reduces health risks and mortality** linked to the high levels of pollution. In fact, TELT’s first Health Impact Assessment in 2017, showed that, as well as helping to reduce the negative health impacts caused by road traffic pollution, the efforts made through the measures implemented to minimize the externalities of construction on health are also yielding important results.

In addition to the environmental costs, the construction of the tunnel can also mitigate the consequences of **motorway congestion, which entails significant economic and social costs**, which is behind significant spending time and loss of quality of life for citizens, while also damaging the quality of road infrastructures due to the great pressure on them. Furthermore, **transport accidents** are also a **European emergency**, with significant external economic and social costs (TELT, 2021). Indicators specifically tied to the construction site suggest that **unemployment decreased**. The construction of the tunnel has generated thousands of jobs, providing employment opportunities in the construction sector, engineering, logistics and related services. “In 2021, the Lyon-Turin line was the **leading employer** in the Maurienne (on the French side) with more than 800 employees on all construction sites” (TELT, 2021).

The project attributes importance to several **Sustainable Development Goals** related with well-being. TELT is committed with the development of employment opportunities that value health and safety at work in both countries involved, considering the **SDG 8 "Decent Work and Economic Growth"** and, promoting **gender equality (SDG 5)**, carefully addressing gender quotas among its employees. Furthermore, it exists a **"Diversity and Inclusion" policy** that intends to create a favorable environment, enhance skills of all employees as well as motivate them. This is also a way of supporting **Human Rights in the workplace**. Moreover, **SDG 17 "Partnership for the Goals"** is addressed through the cooperation and dialogue between Italy and France with support of Europe towards a common goal.

Besides, specific policies were implemented both on the French and Italian side. On the French side, in 2003, was created the Démarche Grand Chantier Lyon-Turin in the region of Maurienne, as a tool for the **development of the territory** with the aim of transforming the construction of the tunnel and promoting technical and financial support to boost future projects in the region, improving the social condition of its inhabitants. It was also created the "Mon employ Lyon-Turin" to promote the employment in the regions involved and the "Appui Lyon Turin Entreprises (ALTE)", designed to **connect local and regional businesses** with opportunities arising from the Lyon-Turin railway project. On the Italian side, the Piedmont region implemented the Regional Law 4/2011 and with its application, it also emerged the "Territorial Pact" that in collaboration with entities including TELT, also promoted local employment and businesses.

This way, the tunnel's construction will bring an **increase in local population** and will in particularly **low the average age in the communities** in what concerns the arrival of employees, which will cause social and economic impacts such as an increase in demand for housing, services and goods, **stimulating the economy** that will consequently **improve social conditions**.

On another dimension, studies provided that **real estate values**, including both residential and luxury properties, there is a **continuous upward trend**, in line with broader national patterns. However, focusing on a specific valley in Italy, Chiomonte, where the main construction site is located, there was a reduction of almost 30% in real estate value due to **disturbances** and land expropriations that caused a wave of protests (Cottafava, Corazza, & Torchia, 2024).

Also, by **linking key economic hubs**, the tunnel will make regions more attractive to investors and will make the local economies more competitive on a European and global scale. The connectivity provided by this infrastructure is of great importance to the main centers of Europe, since it impacts **“18 per cent of the European population, in regions that account for 17 per cent of European GDP”** (Virano, 2021), which will see trade between them made easier and more productive, as well as bringing France and Italy closer together. This type of cross-border projects **“are those that give the greatest benefit to the European economy”** and the cross-border between Italy and France represents a “multiplier 3 times higher than the average of the 9 TEN-T corridors” (TELT, 2023). Moreover, this project will provide a greater capacity to the interchange between both countries, since the trains that will be used have a capacity of “up to 1500 tons, compared to the 600-700 tons seen today” on the road (TELT, 2023).

The perception of the **creation of necessary infrastructure** and the **improvements in travel conditions and mobility** are also among the reasons for support the project by citizens. There will be more long-distance trains providing **less travel time**, i.e., according to TELT, that there will be 22 long-distance trains a day “compared to the 6 TGVs travelling today on the historic line between Turin and Lyon” (TELT, 2023), that will reduce travel time between these cities from 3 hours and 47 minutes to 1 hour and 47 minutes.

Thus, despite some short-term socioeconomic challenges, the construction of the Tunnel Euralpin Lyon-Turin is **expected to bring long-term positive impacts,** positioning this huge investment as essential for economic and social development of the regions involved.

TOOLS APPLICATION

To finish the impact assessment the three following tools were applied: **The Environmental Impact Assessment (EIA)**, **the Life Cycle Assessment (LCA)** and **the Strategic Sustainability Assessment (SSA)**.

The **EIA** evaluates the **project’s direct environmental impacts during its construction and operational phases**, focusing on critical concerns such as carbon emissions, water resource depletion, and biodiversity disruption. This evaluation begins by estimating the **extent of the impacts** which should occur, followed by the development of mitigation strategies. For example, the project incorporates renewable energy sources and advanced water recovery systems as a mitigation strategy to minimize the environmental harm of the project during the construction phase (TELT, 2022). Furthermore, ongoing environmental monitoring, such as the monitoring of the groundwater levels, ensures compliance with the environmental goals of the project. **EIAs** are typically conducted before the start of a project, but by continuously performing them throughout the construction phase, the project can assess whether the initial objectives are still being met. If any objectives are not being achieved, **appropriate countermeasures** can be implemented. Therefore, it is recommended to conduct **EIAs** throughout the project's construction to ensure ongoing environmental compliance and adaptability.

LCA complements the **EIA** by evaluating t**he environmental impacts of the project across its entire lifecycle**. While TELT estimates that the emissions of the construction phase will be offset 15 years after the tunnel starts operating, other significant impacts, such as the reduction in water quality and habitat disturbances, are not adequately addressed. By employing an **LCA** approach, which considers a broader range of factors such as **resource depletion**, **ecosystem disruptions**, and **waste management**, the overall environmental footprint of the tunnel can be more accurately understood. This tool can be further developed by integrating dynamic models to track impacts over time, simulating alternative construction scenarios, and incorporating a circular economy perspective to reduce waste and enhance resource recovery. Additionally, linking LCA insights directly with **EIA** findings can ensure that **immediate and long-term environmental trade-offs** are better communicated, leading to a more informed decision-making process. Moreover, the **SSA** evaluates the b**roader alignment of a project with international sustainability goals**, including the United Nations **SDGs**. The TELT project contributes to the following SDGs, including **SDG 7** (Affordable and Clean Energy) through the integration of renewable energy and energy-efficient rail systems, and **SDG 8** (Decent Work and Economic Growth) by creating thousands of jobs and fostering inclusive employment. It supports **SDG 9** (Industry, Innovation, and Infrastructure) by developing sustainable transport infrastructure and boosting connectivity, and **SDG 12** (Responsible Consumption and Production) by adopting circular economy principles, such as reusing excavated materials. Additionally, the project contributes to **SDG 13** (Climate Action) by reducing greenhouse gas emissions through shifting freight from road to rail and to **SDG 15** (Life on Land) by implementing biodiversity restoration programs to preserve Alpine ecosystems.

In conclusion, the application of the **EIA**, **LCA**, and **SSA** tools ensures a comprehensive evaluation of the TELT project’s environmental and sustainability impacts. By **continuously assessing its environmental performance**, lifecycle impacts, and **alignment with global**

sustainability goals, TELT can effectively mitigate potential harm while contributing to long-term sustainable development.

FINAL RECOMMENDATIONS

After assessing in detail the environmental impacts of TELT's project, on Air, Water, and Earth, as well as its Socioeconomic effects, the following practical and reliable recommendations are proposed to address not just the most significant and damaging impacts but those with not sufficient current mitigation strategies. In this regard, they give respect to the reduction of tons of C02 emission expected during the construction phase; an efficient use of energy and soil and the prevention and monitoring of soil and water contamination.

4.1 Direct Air Capture Technique

Regarding the impact on Air, it is proposed the implementation of **carbon dioxide absorption centres,** as a feasible and robust strategy. The Direct Air Capture (DAC) technique extracts carbon dioxide "directly from the atmosphere at any location for carbon dioxide storage or utilisation". In this sense, "**the carbon dioxide can be safely and permanently stored** in deep geological formations or used for a variety of applications", through a process that ensures that this is done far from the water table (International Energy Agency, n.d.).

This is a strategy already developed by 1PointFive, a carbon capture storage company, with the aim of **reducing the carbon dioxide emitted into the atmosphere** by sectors where emissions are difficult to abate despite operational changes that try to mitigate the effects of their activity (1PointFive, n.d.), such as the TELT project activity which involves a significantly heavy machinery over such a long period of time. This technique can be integrated into both the construction and post-construction phases of TELT. During construction, it can be implemented in sites with the highest carbon emissions such as construction machinery zones and transport routes. However, it must be borne in mind that this technique requires a significant use of energy and **must be used with renewable energy sources** such as solar panels or geothermal setups. Even so, a **synergy** can be created with railway electrification that uses low carbon electricity from the French grid. This captured carbon can also have **industrial applications**, as it can be used in the manufacture of construction materials, helping to reduce the project's carbon footprint.

Post-construction, this technology can be installed near the railway line's terminals, which can be a target for increased traffic, to capture these emissions or even emissions from residual construction maintenance activities. Thus, despite being a costly operation, this could be a feasible and robust recommendation as far as air quality and greenhouse gas emissions are concerned.

4.2 Geothermal energy utilization

Following to the second recommendation, to provide some context, **geothermal energy** is an alternative form of energy generated by the Earth's natural heat, providing a sustainable, renewable, and cost-effective resource capable of generating electricity (Geothermal Basics, n.d.). In fact, unlike other renewable sources, geothermal energy has the potential to provide reliable, "baseload" power, not being dependent on changing factors such as wind or sun. If managed properly, geothermal plants can last for decades or centuries, as the amount of extracted energy can be balanced with the rock's rate of renewing its heat (Geothermal Energy, n.d.)

The opportunities offered by geothermal energy have been already explored in a study undertaken by TELT together with the Polytechnic of Turin, which found that the water collected during excavations of the Chiomonte base tunnel (an exploratory and access tunnel for the larger Mont Cenis Base Tunnel) can serves as a reliable source of clean and sustainable energy for the construction site. **The geological and geothermal conditions featured** of the Lyon-Turin base tunnel - high temperature rock masses, particularly in the Ambin massif, where overburden make temperatures to reach 47ºC, combined with intercepted groundwater - present significant potential for further energy exploitation. Additionally, numerical models already developed showed that over a 10-year period, energy yields of up to 0.26 kW/m of tunnel have been predicted, making this a viable closed-loop system (Alvi et al., 2022). Therefore, this report recommends a detailed assessment of the potential geothermal resources **for broader energy needs.**

Instead of being only utilized during the initial construction stages (which has been done, with low focus and importance), the drained water and head could be used **for long-term operational needs**. For instance, by supporting post-construction requirements such as tunnel ventilation systems and lighting, while helping to regulate internal tunnel temperatures, reducing reliance on additional cooling systems. Even though the direct application of geothermal energy for train electricity is very limited, due to the scale of energy required for high speed and freight trains, provided by high-voltage electricity network, the **surplus energy is still advantageous**. It can be leveraged for meeting district heating, powering greenhouses for horticulture, supporting the electricity demand of the international railway station with its offices, as well as other local energy needs in areas such as Susa and Chiomonte, feeding into the local grids. This would heavily contribute to the **regional energy sustainability**, **reducing dependence on external resources** and providing a **reliable renewable energy source**.

Therefore, it is recommended that the TELT project explores the use of geothermal energy from the Lyon-Turin tunnel's drained water for long-term operational needs, which can **reduce reliance on external energy source**s and partially offset project's negative environmental impacts regarding energy consumption. Despite challenges such as the **initial investment required** and energy variability, leveraging this geothermal potential can enhance regional sustainability and contribute to the project's environmental goals.

4.3 Water and Soil Contamination Prevention & Monitoring

Relatively to the last concrete recommendation, even though soil and water contamination has not yet transpired, there is a real expectation that this may still occur over the next years. Therefore, it is recommended an **improvement of the measures for contamination prevention**, as soil and water contamination can lead to disastrous consequences. More specifically, the project could improve its prevention strategy in several areas such as **improved monitoring**. Sensors with **Internet of Things (IoT)** capabilities and **AI algorithms** can detect high risk contamination areas with very high precision and would help detect **areas where construction would need to be more careful** (Ullo & Sinha, 2020).

Furthermore, in regions with **high contamination risk** the project could utilize **Geosynthetic Clay Liners (GCL)**, which provide a high level of impermeability. This is crucial for zones with high amounts of **chemical or nuclear material** as it would stop the seepage of these contaminants (Kong et al., 2017). The implementation of **IoT sensors** and **AI algorithms** for real-time monitoring, as well as the use of **GCLs**, are highly feasible for the TELT project. **IoT-based sensors** are increasingly cost-effective and adaptable, with proven success in large-scale infrastructure projects (Ullo & Sinha, 2020). Similarly, **GCLs** have been widely used in environmental protection projects due to their durability and effectiveness in containing contaminants like uranium (Kong et al., 2017). These materials are relatively easy to implement and maintain, and **their long-term performance** is well-documented, ensuring that these solutions are both practical and effective for the TELT tunnel. Therefore, it is recommended to implement these prevention methods to further secure water and soil against contamination.

4.4 Final note on recommendations

There are further recommendations that, if implemented, can strengthen the environmental feasibility of the Lyon-Turin tunnel. These include increasing **efforts to restore soil layers** post-construction to prevent soil erosion and loss of fertility; **improving habitat wildlife restoration** especially on the Italian side of the tunnel; and **establishing a regional water management authority** to monitor water extraction, its reuse and contamination patterns - designing an integrated water resource management plan.

However, it is crucial to consider the **socio-economic consequences** of the project. Despite its benefits in reducing costs, promoting international relations, stimulating and supporting business development, further measures could be taken to address potential challenges. Developing **housing price schemes** to prevent local populations from being affected by the rising housing demand/ pricing; and continuously **monitor air quality and radiation** exposure to identify and mitigate any collateral effects on public health are some of the recommended measures. Additionally, it is important to consider that the effectiveness of this infrastructure construction is contingent on promoting the population's transition to more sustainable transportation (compared to road) for both passengers and freight. In this sense, **creating intermodal transport options**, including **efficient bus services** to complement the rail extension and creating incentive **pricing schemes** for passenger and companies engaged in freight transport will **increase awareness** and promote the **adoption rate** of such transport options.

It is of biggest importance that the provided recommendations, along with other measures and policies, are implemented to guarantee the mitigation of the assessed negative environmental impacts and reinforce the positive ones.

CONCLUSION

It can be concluded that one of the main concerns of the Lyon Turin Tunnel is to go **hand in hand with the SDGs**, emphasising the growing complementarity between environmental sustainability and socio-economic well-being, rather than treating them as independent of each other.

From an environmental perspective, the **construction phase** of the project is expected to **mainly have negative impacts**, including the release of 10 million tons of carbon dioxide and nitrogen oxides; threats to local water supplies and groundwater levels, increasing water stress; and lastly, the potential for soil contamination from radioactive materials and other hazardous substances, the loss of fertility and the heavy impact on the relevant local biodiversity. Considering this, the project has been implementing **mitigation strategies** and is **committed** to minimising these negative effects: The use of low-emission electric vehicles and other equipment, powered by 100% renewable energy, and the installation of photovoltaic panels will imply **carbon dioxide savings in the amount of 512 tons per year**; while the removal of excavation materials through electric belts will **save 891 tons of carbon dioxide** emissions and thousands of litters of diesel fuel. However**, long-term benefits** are expected. After construction, the new infrastructure will allow an **improvement in air quality and a reduction in greenhouse gases** as a result of the **transfer of millions** of domestic cars and freight transport from the road to the rail (*see Table 2*).

On a **socio-economic level**, the benefits are expected to outweigh the negative externalities. Such benefits include the increased employment and local trade, as well a boom in tourism, complemented by European economic and cultural connectivity at a regional level.

Hence, despite the controversies, the key factor for the tunnel construction is the **long term**. Giving priority to prevention and to implementing effective mitigation strategies during construction, it is hoped that the final balance will be that of an infrastructure that fosters sustainable development, in line with the principles of the 1987 Bruntland Report, still a cornerstone of sustainability discussions today. Nevertheless, it should be emphasised that greater efforts are needed: **concrete impact assessment tools** should be chosen and applied (Environmental Impact Assessment, the Life Cycle Assessment and the Strategic Sustainability Assessment) to ensure the project's sustainability alignment both during construction and post-construction and, with the same objective, further measures, such as direct air capture techniques, geothermal utilization and contamination prevention, should be considered and put into practice.

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ANNEXES

Figures

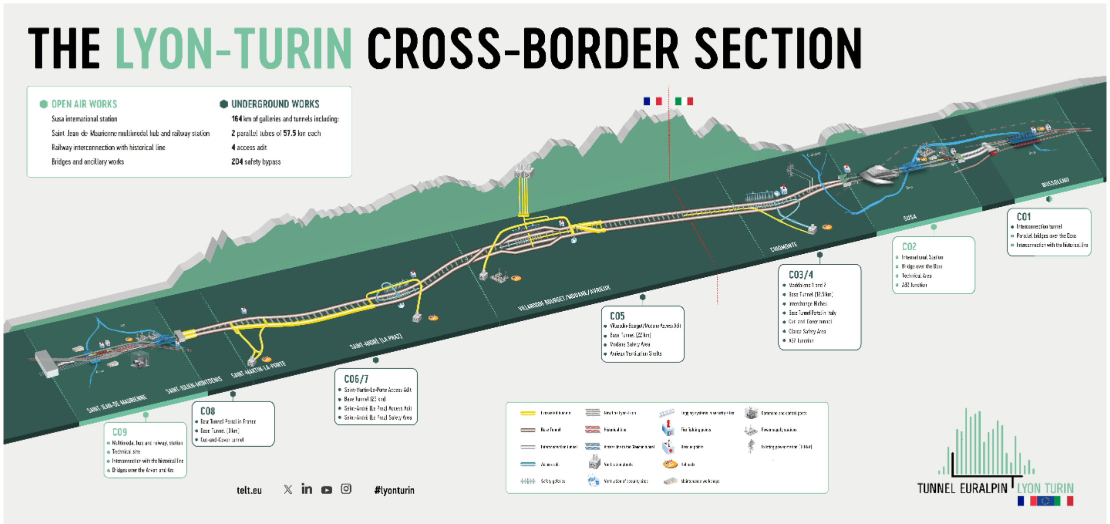


Figure 1: *TELT project & current updates*

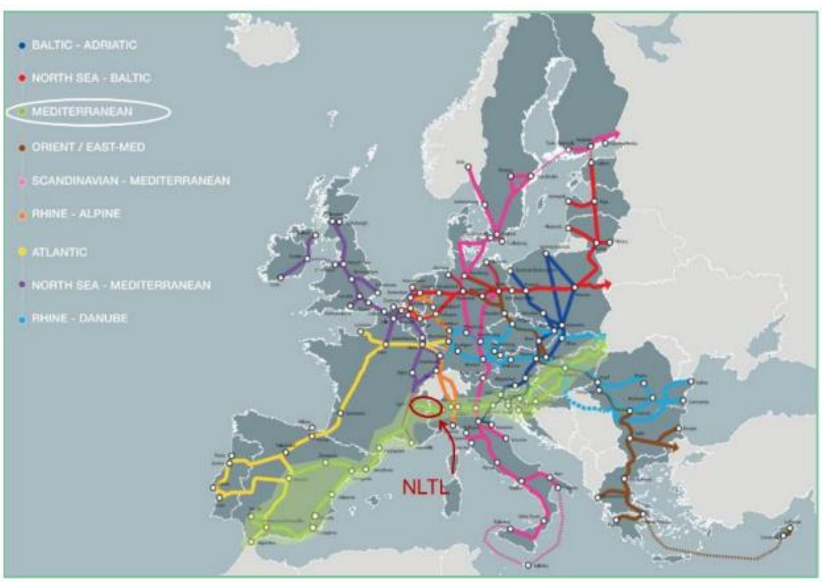


Figure 2: *TEN-T Networks Map*

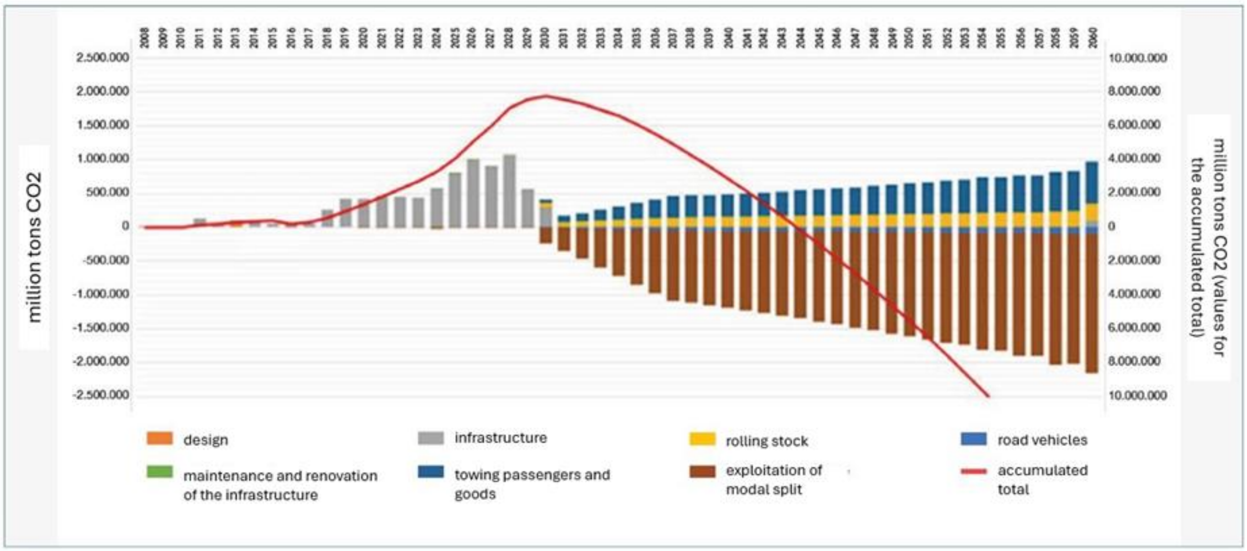
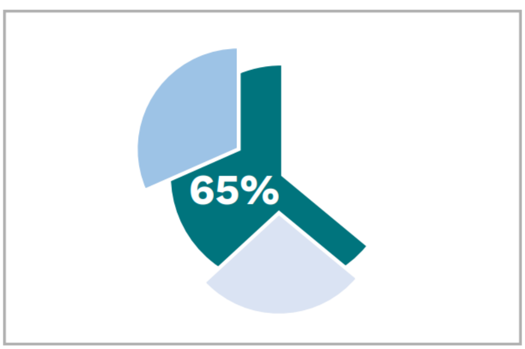
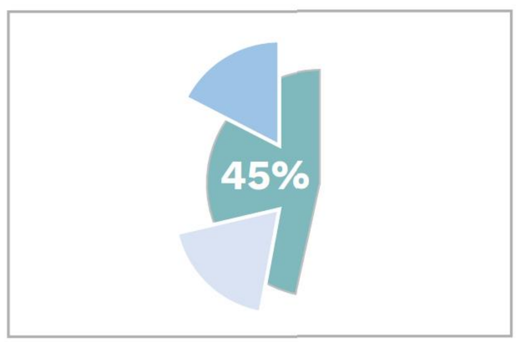


Figure 3: *Carbon Balance, values expressed in millions of tons of CO2 (Lyon-Turin Engagement Forum, 2024)*



In Italy, **65% of the materials** are used within the same work, of which 42% for embankments and 23% as aggregates for concrete.



In France, **45% of the materials** are used within the same work, of which 19% for infilling and 26% as aggregates for concrete.

***Figure 4*:** Material re-usage & purpose

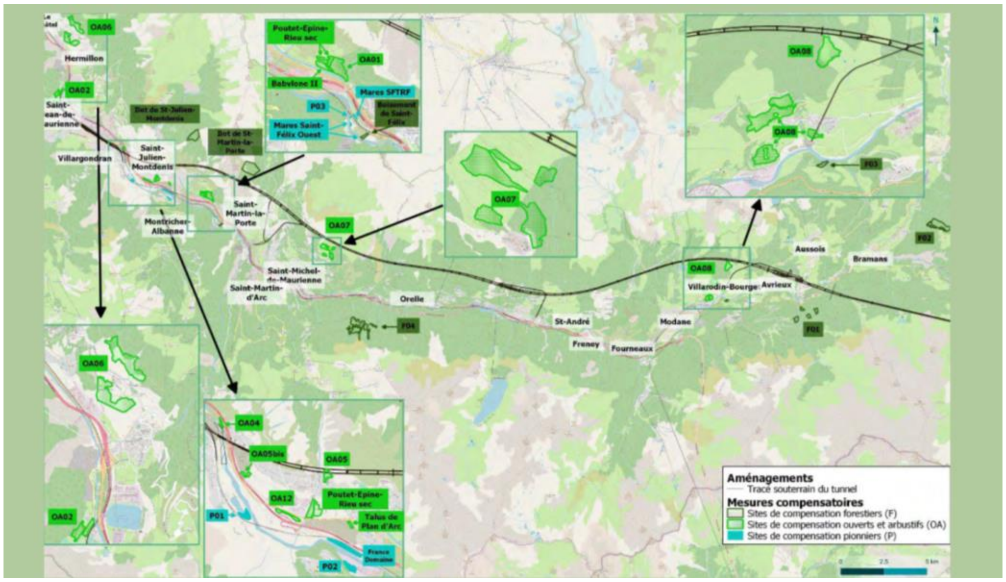


Figure 5:*Fauna and Flora Compensatory Measures Map (in France)*

Tables

Major types of environment	France		Italy		Total	
	Affected Surface	Restored Surface	Affected Surface	Restored Surface	Affected Surface	Restored Surface
Woodland	49		23		72	
Open / shrubby environments	33	94	5	38	38	132
Artificialized and ruderal environments	84		37		121	
Total	167	94	65	38	232	132

Table 1: *The number of hectares affected and restored by the project*

<table>
<tr><th></th><th>Negative Impacts</th><th>Mitigation Strategies</th><th>Positive Impacts</th><th>Overall Impact</th></tr>
<tr><td rowspan="3">Water</td><td>Water discharge</td><td rowspan="3">Improve monitoring and utilize GCLs to further prevent contamination</td><td rowspan="3">Long term improvement in water quality</td><td rowspan="3">Overall negative, due to the large potential risks</td></tr>
<tr><td>Water contamination</td></tr>
<tr><td>Reduced agricultural water supply</td></tr>
<tr><td rowspan="3">Air</td><td>Carbon dioxide emissions</td><td rowspan="3">Use of low-emission and electric vehicles; renewable energy usage, photovoltaic panels and electrical belts to avoid diesel fuel</td><td>Reduction of Road Traffic Emissions</td><td rowspan="3">Overall positive, saving over one million tons of CO2 annually after offsetting construction emissions</td></tr>
<tr><td>Emission of PM 2.5</td><td rowspan="2">Decrease in NOx and PM2.5 Levels</td></tr>
<tr><td>Nitrogen oxides</td></tr>
<tr><td rowspan="3">Earth</td><td>Volume of excavation waste</td><td rowspan="2">2 international sites dedicated to the waste management and use of excavated material</td><td rowspan="3"></td><td rowspan="3">Overall negative, but high potential for continuous effective mitigation (especially in terms of biodiversity)</td></tr>
<tr><td>Contamination from radioactive materials and asbestos</td></tr>
<tr><td>Impact on biodiversity</td><td>Diverse biodiversity protection initiatives; rewilding projects</td></tr>
</table>

Most Prejudicial Moderate Prejudicial Least Prejudicial

Table 2: *Impact Analysis Table (developed by our group)*