2652-Fundamentals on Environment and Sustainability

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Group 14

Trans Adriatic Pipeline Report

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Contents

Executive Summary

This report focuses on the Trans Adriatic Pipeline (TAP), an infrastructure projected to transport natural gas built across Greece, Albania and Italy, and its environmental impacts.

The TAP is considered an innovative project who offers significant strategic benefits, built with the goal of supporting Europe's energy transition by offering an alternative to coal and oil by providing natural gas, that emits significantly less carbon dioxide, and it helps to shift to a low carbon economy.

Despite this, the TAP project raises important environmental and socio-economic concerns, since the construction of the infrastructure and the infrastructure itself has an impact on air quality, water resources, soil health, and biodiversity. Environmental issues are represented by greenhouse gas emissions, possible methane leaks, sediment disruption in rivers, and habitat fragmentation.

This report goes through the project's infrastructure, operational strategies, and environmental management practices. It evaluates the effectiveness of the mitigation efforts and explores future opportunities, such adapting the pipeline for hydrogen transport.

By addressing these issues, the report aims to provide a comprehensive understanding of TAP's role in Europe's energy landscape and its broader implications for the environment and local communities.

What is TAP?

The Trans Adriatic Pipeline (TAP) is part of the Southern Gas Corridor, a project designed to transport natural gas from the Shah Deniz II field in Azerbaijan to markets in Europe. It provides a direct route for transporting natural gas to European markets, diversifying energy supplies, and improving Europe's energy security. Moreover, it aims to reduce Europe's reliance on traditional gas suppliers, particularly Russia, thereby decreasing geopolitical risks associated with energy supply disruptions.

History

TAP journey began in 2003 with a study that explored the potential to transport natural gas from the Caspian Sea region to Europe. By 2006 studies confirmed TAP's technical, economic, and environmental feasibility. In 2007, basic engineering concluded and TAP

AG was established as the company overseeing the project. The Shah Deniz Consortium in Azerbaijan selected TAP as the preferred route to transport gas to Europe in 2013. This decision followed extensive intergovernmental agreements between Albania, Greece, and Italy, and environmental and technical evaluations. The construction started ufficially in 2016, completing the offshore pipeline section across the Adriatic Sea in 2020. The pipeline became operational in November 2020, delivering its first volumes of gas to Europe shortly after. In 2022 TAP had transported over 15 billion cubic meters of natural gas, strengthening its role in Europe's energy security.

Infrastructure and Operations

In the 3,500-kilometer Southern Gas Corridor, TAP spans 877 kilometers in length, with 772 kilometers onshore and 105 kilometers offshore, including an 810-meter section below the Adriatic Sea. The pipeline currently transports up to 10 billion cubic meters (bcm) of natural gas annually, with the potential to increase capacity to 20 bcm by adding compressor stations in Greece and Albania. Compressor stations, powered by 15 MW units, maintain optimal gas flow and pressure throughout the route.

To minimize its environmental footprint and to guarantee safe and effective transportation, most of the pipeline is located underground and the visible infrastructure are limited to the Pipeline Receiving Terminal (PRT) in Italy, compressor and valve stations. TAP include also horizontal directional drilling and microtunneling to overcome geographical challenges (mountainous regions, rivers, and the Adriatic Sea). Moreover, the pipeline incorporates technologies, like a SCADA (Supervisory Control and Data Acquisition) system monitors all the important real-time data such as gas pressure, temperature, and flow across the entire pipeline.

The Shareholders

The Trans Adriatic Pipeline (TAP) is owned by a consortium of major energy companies and each of them holding a 20% share:

- SOCAR (State Oil Company of Azerbaijan Republic) is an Azerbaijan's energy company, involved in oil and gas exploration, production, and transportation.
- BP is one of the world's leading oil and gas companies and operate in exploration, production, refining, and energy trading.

- Snam is a European leader in natural gas infrastructure, operating over 40,000 kilometers of pipelines. It plays a vital role in the integration of European gas networks and the promotion of natural gas as a resource for a sustainable energy mix.
- Fluxys, a Belgian company, operates an extensive network of pipelines and liquefied natural gas (LNG) terminals across Europe.
- Enagás is a Spanish Transmission System Operator with over 50 years of experience in gas infrastructure and more than 12,000 kilometers.

Environmental Impacts

Although TAP's vision is to contribute to a sustainable energy future by pursuing opportunities for transporting energy sources, reducing emissions, and aligning with the European Union's energy transition goals, the reality is that data and studies have revealed how natural gas, along with the way the pipeline infrastructure is constructed, creates problems in terms of pollution, environmental impact, and even social effects.

Air Impact

Fuel	Pounds of co2 emitted per Btu
Coal (antjracite)	228.6
Coal (bituminous)	205.7
Disel fuel and heating oil	161.3
Gasoline (without ethanol)	157.2
Propane	139.0
Natural gas	117.0

TABLE 1 - POUNDS OF CO2 EMITTED PER MILLION BRITISH THERMAL UNITS (BTU) OF ENERGY FOR VARIOUS FUELS SOUCE: U.S. ENERGY INFORMATION ADMINISTRATION (N.D.)

The Trans Adriatic Pipeline (TAP) supports Europe’s energy needs by transporting natural gas, a cleaner-burning alternative to coal. According to the U.S. Energy Information Administration, natural gas emits almost 50% less carbon dioxide (CO_2), than coal per unit of energy produced, making it a good option to reduce greenhouse gas (GHG) emissions.

However, TAP’s operations still contribute to air emissions, primarily due to the technical processes that maintain pipeline functionality and pressure. In fact, natural gas moves through pipelines under high pressure generated by compressor stations along the route. These compressors require significant amount of energy to maintain the necessary pressure for moving gas and this energy typically comes from burning the natural gas. As we said, combustion of natural gas in compressors releases CO_2, contributing to GHG emissions. Additionally, compressors may emit smaller amounts of nitrogen oxides

(NOx) because of the high-temperature combustion process. NOx is a pollutant that contributes to air quality degradation and that can lead to the formation of ground-level ozone and smog.

TAP's Greenhouse Gas Emissions

In 2023, TAP's greenhouse gas emissions were categorized under direct (Scope 1) and indirect (Scope 2) emissions. Scope 1 emissions include those from the combustion of natural gas in compressors, venting activities, and fugitive methane leaks and represent 98.94% of the total (Trans Adriatic Pipeline AG, 2023b).

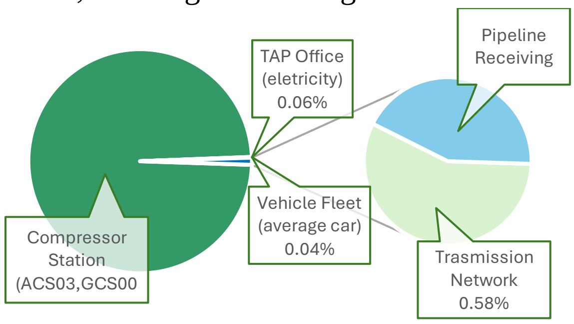

FIGURE 1 - EMISSION BY TYPE OF ISTALLATION
SOURCE: TAP GHG REPORT 2023 (TRANS ADRIATIC PIPELINE AG, 2023B)

In 2023, Scope 1 emissions amounted to approximately 173,899 tons of CO2 equivalent. The remaining 1.06% of emissions were classified as Scope 2, which accounted for 1,857 tons of CO2 equivalent and resulted from electricity consumption in TAP offices and facilities.

Most TAP's emissions originated from Greece and Albania, with Greece contributing 101,733 tons of CO2 equivalent (57.9% of the total) and Albania contributing 73,155 tons of CO2 equivalent (41.6%). Italy accounted for a smaller portion of the emissions, amounting to 868 tons of CO2 equivalent and the headquarters in Switzerland contributed a negligible 0.3 tons (Trans Adriatic Pipeline AG, 2023b).

	Unit	Greece	Albania	Italy	Swtzld.	Total 2023	Total 2022
Scope 1 (direct emissions)	Tons Co_{2e}	100,335.34	73,013.70	550.22	0.00	173,899.26 (98.93%)	186,935.07 (98.9%)
Scope 2 (indirect emissions)	Tons Co_{2e}	1,397.78	141.78	317.90	0.30	1,857.76 (1,06%)	1,971.14 (1,04%)
Total	Tons Co_{2e}	101,733.12	73,155.12	868.12	0.30	175,757.02	188,906.21
Propotion	%	57.9%	41.6%	0.5%	0.0%		

TABLE 2 - EMISSION OF TAP

SOURCE: TAP GHG REPORT 2023 (TRANS ADRIATIC PIPELINE AG, 2023B)

Methane and Fugitive Emissions

Methane emissions also occur in natural gas pipelines like TAP, as methane can escape through valves, seals, and other components, even under normal operation. Methane, the primary component of natural gas, is a potent greenhouse gas with a higher impact on global warming than CO_2 over a 20-year period. Such methane "fugitive emissions" may happen during maintenance, inspections, or when there are minor leaks along the pipeline, adding to the overall emissions footprint of TAP.

As the TAP GHG Report highlights, methane was responsible for 2.19% of the total emissions in 2023. These methane emissions mainly occurred through venting during maintenance activities and from minor leaks or fugitive emissions along the pipeline. The 53% reduction in methane release and 70% reduction in fugitive emissions specifically has been achieved mainly due to the absence of emergency venting, the implementation of a Leak Detection and Repair (LDAR) program followed by targeted leak repairs, the decision to not use the gas generator at the ACS03 station These efforts were all part of TAP's comprehensive Methane Emission Reduction Plan.

In addition to these emissions, TAP's pipeline may release volatile organic compounds (VOCs) through combustion or fugitive emissions. VOCs are organic chemicals that can contribute to ground-level ozone formation when they react with NOx in the presence of sunlight. Although TAP has systems in place to monitor and limit these emissions, VOCs are challenging to eliminate entirely in pipeline systems, as they can be present in trace amounts in natural gas and can also arise from the materials used in pipeline construction and maintenance.

TAP's Carbon Management and Future Plans

In 2022, TAP committed to developing a comprehensive Carbon Management Plan for 2022-2025 (Trans Adriatic Pipeline AG, 2023a). This plan is part of a broader Energy Transition Roadmap that outlines TAP's short-, mid-, and long-term strategies. The Carbon Management Plan includes a detailed analysis of TAP's emission sources, projections for future emissions, and specific annual targets aimed at reducing the overall carbon footprint. It focuses on decreasing Scope 1 emissions, as well as Scope 2 emissions related to electricity consumption.

In 2023, with the implementation of the Carbon Management Plan 2022-2025, measures such as shutting down the gas generator for three-quarters of the year, optimizing line pack, and effectively coordinating with adjacent Transmission System Operators (TSOs) at interconnection pressures led to a 30% overall reduction in GHG emissions compared to the forecast. This reduction was further supported by higher-than-expected ambient temperatures, which decreased the energy demand on the units, as well as an improved hydraulic configuration. (Trans Adriatic Pipeline AG, 2023b)

Water Impact

Potential Risks of Leaks

Gas pipelines can have various effects on water quality overall, with the potential for a leak representing the greatest risk. The TAP pipeline includes a section that connects Albania and Italy spanning 105 km underwater, reaching a depth of up to 810 meters. So, a potential leak would directly pollute the seawater by releasing natural gas straight into the water. A leak would therefore have a wide range of consequences. First, there would be a direct emission of natural gas into the water which would dissolve in it and alter its composition, also leading to harm to the aquatic ecosystem because of hydrocarbon contamination in water. It's necessary to have continuous monitoring and supervision to avoid accidental spills that could contaminate water resources and affect both the environment and local communities.

Environmental Protection Measures

The TAP pipeline not only passes through the Adriatic Sea, but it crosses several rivers during its path. To minimize the impact on the environment for its construction they used advanced construction techniques and demanding environmental protocols. The innovative approach is the use of trenchless river crossing methods, such as micro-tunnelling, that involve creating an underground tunnel beneath a riverbed without disrupting the surface. The goal of this method is to minimize sediment release and preserve water quality but sediment release during river crossing is unavoidable, and sedimentation in water bodies poses a risk for aquatic ecosystems by reducing light penetration.

Water Resource Management

There are water implications not only due to direct contamination, but also for the fact that TAP is a large infrastructure, whose realization requires a huge amount of water. To protect water resources, TAP implemented wastewater treatment facilities. The goal is to appropriately treat and safely dispose of the wastewater produced during building activities in order to keep neighboring rivers, streams and groundwater sources clean.

Hydrotesting and water usage

Additionally, hydrotesting water management was carried out with careful planning. As a matter of fact, large amounts of water are frequently needed for hydrotesting, which is an essential procedure to check the integrity of the pipeline. Hydrotesting is a process that involves filling the pipeline with water and pressurizing it to its maximum operating pressure with the goal of detecting leaks, weaknesses or structural issues. After the use they followed strict guidelines to recycle this water, but, still, the high-water demand for hydrotesting puts pressure on local water supplies, particularly in regions where water shortage is a problem, such as in southern Italy. Even though the water usage is managed responsibly, the high-water use is still a concern and for this reason TAP is demonstrating its commitment to resource efficiency, as shown in the 2023 ESG Report, where they recorded their achievement of a water consumption reduction by 41% compared to the previous year (Trans Adriatic Pipeline AG, 2023a).

In summary, TAP's approach to environmental management demonstrates a commitment to reducing water-related impacts while addressing operational challenges. Through initiatives such as wastewater treatment and efforts to lower water consumption, the pipeline has established standards for sustainable infrastructure. However, certain risks are unavoidable in a project of this scale.

Earth Impact

Biodiversity and Habitat Conservation

The TAP route crosses ecologically significant land areas within Greece, Albania, and Italy, where biodiversity conservation measures are crucial. The Biodiversity Management Framework (BMF) implemented by TAP aims to implement comprehensive reforestation efforts along its path, working closely with local forestry departments to ensure that tree planting aligns with regional environmental goals. Reforestation is one part of TAP's larger plan, which also includes ongoing habitat monitoring to assess species diversity and vegetation health along the pipeline's "right of way" (Trans Adriatic Pipeline AG, 2023a; European Investment Bank, 2023). However, the project's efforts have already yielded some measurable success. An example is the forestation sites in Greece which have achieved substantial survival rates for planted trees. This aligns with the International Finance Corporation's (IFC) Performance Standards on Environmental and Social Sustainability, emphasising restoring native vegetation and reducing habitat fragmentation (IFC, 2012).

While these efforts reflect commitment, studies show that such replanting may only partially restore ecosystems to their original state. Research on similar projects indicates that newly planted forests often lack the complexity and interspecies relationships of natural habitats that have evolved over centuries, making them less effective in supporting diverse wildlife. This concern is particularly relevant in areas with rare or specialized flora and fauna, where habitat disturbances can disrupt species' niches and interdependencies (Bull et al., 2013; Maron et al., 2012).

Aspect if Biodiversity	Pre-project status	Post-project status (expected)	Notes
Species diversity	High	Moderate	Incomplete restoration of species interactions
Habitat Connectivity	Fragmented	Limited but improved	Habitat corridors not fully restored
Ecological complexity	High	Low	Difficulty in restoring interspecies relationships
Tree density	Moderate	High	Lack of diversity in tree species

TABLE 3 - BIODIVERSITY LOSS AND RESTORATION PROJECTIONS FOR TAP.
SOURCE: ADAPTED FROM PUSCEDDU (2024), BULL ET AL. (2013)

Although TAP conducts flora and fauna monitoring with its 15-year monitoring plan, short-term monitoring periods may overlook longer-term ecological changes that could emerge decades post the disturbance (Lindenmayer et al., 2018).

Soil and Land Management

The pipeline construction often involves extensive soil excavation and alteration through compaction, erosion, affecting soil health, including nutrient loss and overall disruption of underground ecosystems. This can harm soil productivity and, thus, negatively impact the local agriculture and ecosystem functions (Sawatsky et al., 2016). TAP has taken several measures to address these issues. It applies a range of soil stabilization and erosion control techniques along its route, such as erosion barriers and vegetation cover, to limit the potential for land degradation (TAP AG, 2023). The project also commits to continuous soil monitoring and post-construction assessments to ensure that impacted areas regain productivity.

Despite these efforts, soil compaction reduces water infiltration and reduces microbial diversity and functionality, affecting nutrient cycling essential for plant growth. In regions like southern Italy, where olive trees are a major crop, it can make it difficult for plants to establish roots (Brockettet al., 2012). Soil recovery can be slow, as compacted soils often have limited aeration and water infiltration, hindering root growth and microbial activity (Hobbs et al., 2001). TAP's vegetation re-establishment efforts may successfully control erosion but may not fully restore these microbial communities, which are critical for long-term soil health and ecosystem resilience (Schloter et al., 2018).

Soil Property	Pre-construction status	Post-construction status (expected)	Notes
Soil compaction	Low	High	Compaction due to machinery and equipment
Water retention	High	Low	Reduced infiltration due to compaction
Organic matter	High	Low to moderate	May take years to recover
Agricultural yield	High	Reduced	Productivity loss in affected areas

TABLE 4 - COMPARISION OF SOIL PROPERTIES BEFORE AND AFTER TAP CONSTRUTION.
SOURCE: ADAPTED FROM BROCKETT ET AL. (2012), BEVERIDGE ET AL. (2013)

Therefore, although TAP's soil management framework meets environmental standards, it could be increased by using bioengineering solutions such as soil inoculants to restore microbial life, a practice found to be beneficial in rehabilitated soils (Beveridge et al., 2013).

Fauna Conservation and Monitoring

TAP's environmental strategies emphasize wildlife protection along the pipeline's path. Recognizing the risks to animal populations, the project monitors key species, like wolves and brown bears in Greece and Albania, that might be affected by habitat fragmentation (Trans Adriatic Pipeline AG, 2023a). Regular monitoring activities align with conservation best practices and reflect TAP's compliance with the ISO 14001 environmental standards, which promote systematic approaches to mitigating biodiversity impacts. TAP's data-driven monitoring aligns with EU conservation goals, particularly in terms of maintaining "ecological connectivity" so that animals can safely travel across regions even where the pipeline is present (European Commission, 1992).

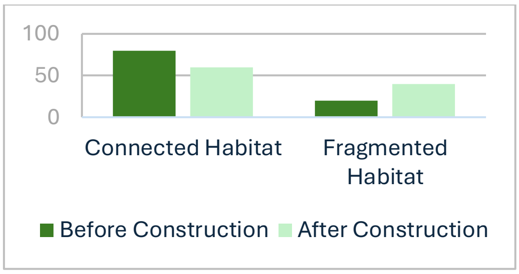

FIGURE 2 - HABITAT CONNECTIVITY BEFORE AND AFTER PIPELINE CONSTRUCTION.
SOURCE: ADAPTED FROM PUSCEDDU (2024), (TRANS ADRIATIC PIPELINE AG, 2023A).

Nevertheless, pipeline projects like TAP can disrupt wildlife corridors and introduce permanent obstacles for animals to travel. This restriction disrupts migration patterns and genetic diversity, especially for species with larger ranges, like the brown bear (Forman & Alexander, 1998). Research on infrastructure impacts has also noted that such disruptions can lead to increased mortality for species attempting to cross barriers or adapt to altered environments (Benitez-Lopez et al., 2010). Wildlife overpasses or underpasses can reduce these impacts, a measure that TAP could consider for enhancing ecological connectivity and allowing for safer wildlife movement (Clevenger & Huijser, 2011). Additionally, TAP's monitoring could be extended to include multi-year studies to capture the long-term effects of habitat fragmentation on species population dynamics, addressing the need for a more comprehensive understanding of post-disturbance recovery (Gaston et al., 2008).

Long-term Ecological Impacts and Carbon Management

TAP's commitment to reducing environmental impacts extends to minimizing disruptions to soil carbon storage and supporting natural carbon sequestration in terrestrial ecosystems. When soils are disturbed by large-scale construction, like pipeline installation, significant amounts of carbon stored in soil layers can be released, contributing to overall carbon loss in the ecosystem. Studies show that soil disruption through digging, compaction, and vegetation removal decreases soil organic carbon (SOC), a critical element for soil health and fertility (Don et al., 2011). SOC acts as a long-term carbon sink, and its reduction not only impacts the immediate soil quality but also diminishes the landscape's ability to capture and store carbon in the future.

In TAP's case, soil carbon impacts are managed through strategies to rehabilitate disturbed soils along the pipeline's "right of way" (ROW). TAP's ESG report outlines that replanting and erosion control measures aim to restore the soil structure and increase vegetation, which can eventually help reestablish carbon stores over time (Trans Adriatic

Pipeline AG, 2023a). TAP's reforestation and bio-restoration plans are significant steps in this direction, as they support re-establishing vegetation that can gradually sequester carbon within the affected regions' soils (European Investment Bank, 2023). A critical concern, however, is the slow pace at which soil carbon levels recover once disturbed. According to research, soil organic carbon levels can take years or even decades to rebuild following heavy compaction and vegetation removal, meaning that immediate restoration efforts may not fully offset carbon loss (Schloter et al., 2018). In particular, the heavy machinery used during the pipeline's installation, compacts soil layers reducing root growth potential and water infiltration, which are both essential for re-establishing the soil's productivity that support carbon capture (Hobbs & Harris, 2001). By implementing additional strategies related to soil's health, such as using bio-engineered soil inoculants to replenish microbial life, TAP could further improve the rate of soil carbon recovery (Beveridge et al., 2013).

TAP's soil management includes maintaining vegetative ground cover to prevent erosion, which is essential as exposed soil can accelerate organic carbon loss. Soil exposed to wind and water erosion loses organic matter and other nutrients, making it more challenging to support vegetation that can rebuild soil carbon stocks (Brockett et al., 2012). This erosion control approach not only aids in protecting soil carbon stores but also contributes to the stabilization of the ROW, reducing the risk of further disturbances that would perpetuate carbon loss.

While TAP's carbon management plan emphasizes the importance of ecosystem restoration, effectively achieving long-term soil carbon recovery requires continuous monitoring and adaptive management. Considering the slow nature of soil carbon accumulation, TAP's ongoing assessments of soil and vegetative health will be essential to track progress and implement measures as needed. A potential way to enhance carbon capture and ensure that the land can function effectively as a carbon sink over the coming decades is to adopt adaptive soil health practices, such as adding organic material to soil and encouraging native plant regrowth (Beveridge et al., 2013).

Impacted Area	TAP actions	Expected Outcomes
Soil erosion control	Erosion barriers and vegetation covers	Minimizations of soil erosion and stabilization of soil structure
Soil compaction recovery	Regular monitoring and land reconditioning efforts post-construction	Restoration of soil productivity and support of plant growth

Reforestation and afforestation	Replanting trees along the ROW	Gradual restoration of vegetation cover, contributing to carbon sequestration
Carbon management	Methane leak detection and repair program; Carbon Management Plan 2022-2025	Reduced carbon emissions through operational adjustments and methane management
Long-term monitoring	15-year monitoring plan to track vegetation recovery and soil health	Ensure compliance with "No Net Loss" biodiversity goals and assess soil recovery effectiveness

TABLE 5 - TAP'S SOIL RESTORATION AND CARBON MANAGEMENT ACTIONS.
SOURCE: ADAPTED FROM TAP'S 2023 ESG REPORT AND ESCS (EUROPEAN INVESTMENT BANK, 2023).

Socio-Economic Impacts

The Trans Adriatic Pipeline (TAP) operations' success is largely related to the communities who live along the pipeline route and to the effort of its employees. Therefore, in addition to its physical and environmental impacts, the socio-economic implications for the regions it traverses, Greece, Albania and Italy, must be considered.

In the matter in question, the 2023 TAP's ESG report focuses both on the relevance of local communities, for which TAP has initiated programmes aimed at fostering long-term, trust-based partnerships with local stakeholders, and the organization's people, pointing an accent on cultural diversity as a TAP's strength and on their commitment to prioritise employee well-being, learning and offering opportunities for personal and professional growth (Trans Adriatic Pipeline, 2023a) .

From the 2023 ESG Report, it is possible to recognize how TAP values the social aspects of the ESG paradigm, thanks to the introduction of the *Social & Environmental Investments* (SEI) programme, which has the objective to engage with the regional and local officials, as well as other stakeholders, in order to identify the areas in which these investments, which reached a total of €50,012,744 in 2023, could effectively benefit the affected communities. The following paragraphs will cover various social welfare and infrastructure initiatives that the investments support, as well as their economic impacts, the geopolitical context and the project's controversies.

Strengthening Livelihoods and Supporting Community Quality of Life

As written in the report, TAP invested a huge amount in community infrastructure projects in order to enhance the quality of life for the local residents, for instance through the refurbishment of the Cultural Centre Library in Chiliodendro municipality of Kastoria and the construction of sport facilities, like the new 5x5 soccer field in Mesopotamia-Kastoria. Such initiatives not only serve as primary community focal points but help to create social cohesion and healthy physical activity. Another is the "On the same boat" initiative in Melendugno which furnished equipment and technical support for local fishermen—a scheme providing a clear parallel with economic sustainability and effective industrial endeavor.

Supporting Education and Training

TAP has also emphasized supporting educational and training undertakings. It equipped vocational high schools with laboratory centers in five cities of East Macedonia and Thrace, improving the infrastructure of education and enhancing local talent. In such a way, under this action, practical training for students, especially in the oil and gas industry, is enhanced, boosting their employability and supporting local economic development.

Enhancing Environmental Management

TAP is committed to restore the lands to their original conditions and, if required, also through financial compensation for the landowners affected. In this regard, it is important to mention the Livelihood Assistance and Transitional Support (LATS) programme, which has the objective to improve the agricultural productivity on the affected lands and support the households impacted by the construction. This brings to the long-term sustainability of local ecosystems, as well as an improvement of the economy due to the financial investments on the areas.

Geopolitical Context

Besides the ESG report, it is possible to identify other socio-economic impacts related to the geopolitical context. As a matter of fact, TAP is part of the Southern Gas Corridor and is in line with the EU necessity to diversify and secure natural gas supply, also due to its aim to reduce the dependency on Russian gas by diversifying its energy sources (S&P Global Commodity Insights, 2020). Amidst the backdrop of entrenched geopolitical rivalries and the recurrent disputes between Russia and transit nations such as Ukraine — disputes that have, on occasion, culminated in significant interruptions to European energy supplies (Stern et al., 2009) —the European Union has intensified its pursuit of alternative natural gas sources. Within this perspective the linkage of European energy markets to Azerbaijan's Shah Deniz gas reserves through the Southern Gas Corridor turns out to be a strategic response to reduce the EU's overdependence on Russian gas, presenting itself as a move designed to bolster the continent's energy resilience and to reduce the geopolitical influence that Moscow might otherwise exercise (European Commission, 2020). As a matter of fact, the urgency of this diversification strategy was highlighted starkly by the severe supply interruptions of 2006 and 2009 which has led to the exposure of both the acute risks tied to political tensions with Russia and the deeper fragility of relying so heavily on a single dominant source, thus spurring accelerated initiatives to establish alternative supply routes and diversify partnerships within the energy sector (De Jong, Wouters, & Sterkx, 2010).

Controversies Surrounding TAP

TAP was meant to be a bold step forward for Europe’s energy strategy by offering a crucial piece in the puzzle of the Southern Gas Corridor. However, the reality on the ground is far more complicated, since across Greece, Albania and Italy the project has stirred frustration and resistance, as people grapple with what they see as deep socio-economic and environmental costs. From disputes over land to the loss of cultural landmarks, TAP’s promises of progress have often seemed overshadowed by the challenges it brings (Counter Balance, 2021).

In Greece, farmers like Themis Kalpakidis from Kavala have been vocal about their struggles. For them, this isn’t just a pipeline—it’s a direct threat to their way of life. Farmlands that have been cultivated for generations are now disrupted, and livelihoods that were already hanging by a thread are under even greater strain. What happened is similar for the Albanian landowners like Agim Bendo in Turan, because these farmers are demanding something many would consider basic fairness: proper compensation for the land they’ve sacrificed. These are not isolated complaints; they echo a shared sense of being overlooked in the face of corporate ambition (Balkan Insight, 2018).

Moving on Italy, in the town of Melendugno (Puglia), things hit a deeply personal note: over 1,500 olive trees—many of them centuries old—were uprooted to clear the way for the pipeline, and for the locals these trees weren’t just agricultural assets but were symbols of history, identity, and pride. Protests erupted, and for years, the pipeline became a flashpoint for larger concerns. Allegations of aquifer contamination, poor waterproofing during construction, and an Environmental Impact Assessment (EIA) that critics argue failed to see the bigger picture only added fuel to the fire (Navach & Jewkes, 2016; Counter Balance, 2021).

Zooming out, even TAP's broader purpose has sparked debate. Officially recognized as an EU Project of Common Interest (Trans Adriatic Pipeline AG, n.d.) and backed by a €1.5 billion loan from the European Investment Bank, the pipeline was supposed to bolster energy security. Detractors argue it does little on that front, while raising serious moral controversies: among these is the question of whether it is justifiable for the EU to invest in a project that many believe props up Azerbaijan's authoritarian regime. It's a tough conversation—one that forces us to look closely at the cost of progress (Counter Balance, 2021).

Reflecting on the pipeline's socio-economic consequences, it's important to consider its complexity: on one hand, this analysis has shown how the program has made clear improvements in infrastructure, education, and environmental protection and offered opportunities for growth and development in the transitional areas; on the other, it has also shown the existence of profound tensions between local communities and corporate ambitions, raising questions about justice, cultural preservation, and the ethics of progress.

From this dual reality of TAP we can reflect on how the challenges faced by modern infrastructure projects need to reckon with the coexistence of global goals and local realities. As the project progresses, its ability to navigate conflicting interests will be critical since, nowadays, also and especially large-scale projects need to prioritize sustainability, equity and genuine community well-being in a world increasingly defined by interconnected challenges.

Recommendations

TAP contributes significantly to Europe's energy landscape by providing greener substitutes for conventional fossil fuels and energy security. Its activities do, however, pose a number of socioeconomic and environmental issues such as emissions of greenhouse gases, especially carbon dioxide and methane. Due to TAP's passage through environmentally sensitive areas, which disrupts wildlife corridors and affects species connectivity, biodiversity loss and habitat fragmentation are also pressing consequences that need to be addressed. Besides, it is worth noting how the pipeline affects the nearby communities which includes issues ranging from land use disputes to guaranteeing fair socioeconomic advantages for the areas it passes through. To address these challenges and help make TAP a more sustainable project, we suggest the following recommendations.

Enhance Long-term Ecosystem Monitoring Using Strategic Environmental Assessment (SEA)

To guarantee that the TAP meets its biodiversity conservation and restoration goals, long-term ecosystem monitoring should be improved through the use of Strategic Environmental Assessment (SEA). SEA provides a structured framework for incorporating environmental issues into decision-making, especially for large-scale infrastructure projects with considerable ecological consequences (Joanaz de Melo, 2024).

While TAP presently uses a 15-year monitoring plan, expanding monitoring to at least 30 years conforms with the prevention principle and addresses long-term ecological effects that frequently surface decades after disturbances (Lindenmayer & Likens, 2018). SEA is more complete since it incorporates broader regional and temporal assessment. It also promotes adaptative intervention that is beneficial, e.g. if monitoring reveals that the recovery of soil microbial diversity is slower than expected or there is ongoing fragmentation of wildlife corridors. It would allow TAP to refine its reforestation plans or construct additional wildlife crossings to mitigate these impacts (Clevenger & Huijser, 2011). Furthermore, SEA aligns with EU environmental directives, such as the Habitats Directive, and ensures that TAP's monitoring and mitigation efforts meet international standards for biodiversity conservation (European Commission, 1992).
To ensure the correct implementation of a SEA the following steps should be considered:

- Baseline assessment: establish extensive baseline data for biodiversity, soil health, and water quality along the pipeline route to serve as a reference point for detecting long-term changes (Joanaz de Melo, 2024).
- Stakeholder engagement: SEA mandates transparent processes, involving local communities, environmental NGOs, and experts to prioritize ecological values and maximize the chance of identifying potential problems (OECD, 2011).

- Scenario analysis: develop scenarios to predict the potential cumulative impacts of the project (European Commission, 2019).
- Adaptive monitoring framework: implement iterative monitoring processes to allow adjustments as new data becomes available (Lindenmayer & Likens, 2018).

TAP's existing frameworks, including its adherence to ISO 14001 standards and its 15-year monitoring plan, provide a strong foundation for integrating SEA. SEA would, however, broaden TAP's monitoring to address even longer-term ecological concerns, emphasize participatory methodologies, and be consistent with TAP's dedication to stakeholder participation. This could be possible by leveraging its current expertise and partnerships.

Adapt TAP to Transport Hydrogen

Using the current infrastructure and strategically adapting TAP to transport hydrogen will help the pipeline meet Europe's decarbonization goals. Hydrogen, particularly green hydrogen produced via renewable energy, offers significant environmental advantages. Compared to natural gas, it eliminates methane emissions and, thus, reduces the carbon footprint of energy transport (Züttel et al., 2010). This shift would support the European Green Deal's objectives to achieve climate neutrality and strengthens TAP's relevance as an energy supplier in the region (European Commission, 2019).

Having said that, to ensure this adaptation is feasible, TAP must address technical challenges such as hydrogen embrittlement (a phenomenon that weakens steel pipelines) (Bockris, 2002). Retrofitting the pipeline with hydrogen-compatible materials or coatings is essential for addressing this question and guaranteeing safety and longevity. The conversion to hydrogen avoids the environmental costs of constructing new pipelines, thus, reducing land-use changes and minimizing impacts on biodiversity (Scholten et al., 2020). Since there would be temporary disturbances from retrofitting activities, SEA would be helpful in guiding the process by mapping sensitive areas and scheduling construction to minimize further disruptions. For example, regions with endangered species or high ecological significance should have retrofitting work scheduled outside of breeding or migration seasons. Bioengineering solutions, such as applying microbial soil inoculants, can expedite the recovery of soil health and enhance ecosystem services in affected areas, lessening long-term concerns about soil compaction and nutrient cycling (Beveridge et al., 2013).

Changing to the transportation of hydrogen also offers advantages in water and air quality management. Unlike natural gas, hydrogen leaks do not result in long-term groundwater contamination due to its rapid dissipation (Züttel et al., 2010). However, the erosion related to construction poses short-term risks to aquatic ecosystems. Nevertheless, these could be mitigated with erosion control techniques and the use of biodegradable. These measures are aligned with the circular economy principles that aim to minimize waste and regenerate natural systems, which makes them more attainable (Ellen MacArthur Foundation, 2013). By replacing natural gas, adapting TAP to transport hydrogen eliminates methane emissions from the pipeline system contributing to the improvement of the impacts on air. To maximize these benefits, the project should prioritize green hydrogen, produced with electrolysis using renewable energy, or blue hydrogen, produced with carbon capture and storage technologies. This would ensure it's on par with EU policies and international climate commitments like the ISO 14001 standards (International Energy Agency, 2021).

From an economic point of view, the adaptation of TAP to hydrogen is feasible, given there is an increasing demand for hydrogen in Europe. It's a key energy source in the renewable energy transition. The collaboration with hydrogen producers, renewable energy stakeholders, and governmental bodies is essential to ensure an efficient transition and secure the funding and technical expertise needed for retrofitting to potentially make TAP an important green energy supplier to its region (International Energy Agency, 2021) (TAP AG, 2023).

Improving Water Resource Management through Circular Practices

The TAP has a considerable water demand for operations, like hydrotesting, and poses some impacts on water, like potential contamination risks. Hydrotesting alone consumes vast quantities of water and exerts pressure on local water supplies, particularly in arid regions like southern Italy (TAP AG, 2023). Circular economy principles for water use and reuse would help mitigate these. According to Our Future Water (2023), a circular approach to water management focuses on reducing water waste, reusing treated water, and maintaining the integrity of natural water cycles. By implementing such practices, TAP can mitigate its operational impact on local water resources. TAP can implement modular water treatment systems that allow for the recycling and reuse of hydrotesting water which reduces the demand for freshwater extraction. These systems can also treat wastewater from construction and maintenance activities, ensuring that water released back into the environment meets the quality standards (Beveridge et al., 2013). Furthermore, there should be collaboration with local authorities to manage shared water sustainably since we can't forget the availability of water for agricultural and domestic use (Our Future Water, 2023).

Another area for improvement is sediment control during river crossings. Although TAP employs trenchless methods, like micro-tunneling, there is still sedimentation in water bodies (Joanaz de Melo, 2024). To further mitigate these impacts, the project can expand erosion control measures and using biodegradable materials in construction to preserve aquatic ecosystems and water quality. TAP has already demonstrated a significant commitment to conservate water which is highlighted by its 41% reduction in water usage in 2023 providing a strong foundation for further integrating circular practices (TAP AG, 2023). By expanding these efforts, TAP not only strengthens its environmental commitments but also aligns with innovative water management techniques that allow the project to be more sustainable. The circular economy model ensures that water resources are used efficiently, waste is minimized, and ecosystems are preserved, making it an essential strategy for TAP's long-term sustainability goals.

Alignment with the Sustainable Development Goals (SDGs)

The recommendations align TAP's operations with key SDGs, promoting sustainability across multiple dimensions. Adapting TAP to transport hydrogen supports SDG 7 (Affordable and Clean Energy) by advancing the clean energy transition, while enhanced carbon management aligns with SDG 13 (Climate Action) to mitigate climate risks. Biodiversity conservation and ecosystem restoration address SDG 15 (Life on Land), and circular water practices ensure compliance with SDG 6 (Clean Water and Sanitation) by protecting water resources. Integrating circular economy principles advances SDG 12 (Responsible Consumption and Production), while infrastructure modernization and innovative restoration techniques support SDG 9 (Industry, Innovation, and Infrastructure). Investments in community development align with SDG 11 (Sustainable Cities and Communities), improving local resilience, and stakeholder collaboration reinforces SDG 17 (Partnerships for the Goals).

Conclusions

The Trans Adriatic Pipeline represents a significant contribution to Europe's energy diversification and security. By providing an alternative to traditional fossil fuels, it has demonstrated its role in supporting the transition to a lower-carbon economy, while striving to balance its impact on local ecosystems and communities. However, as this report has highlighted, TAP's journey is emblematic of the duality inherent in large-scale infrastructure projects. The project has made demonstrable strides in the measurement of water consumed, soil regeneration, and biodiversity conservation. The adoption of more sophisticated tracking systems, replanting projects, and community engagement efforts demonstrates a dedication to environmental sustainability and inclusive development. However, there are still challenges on, especially due to the concerns about water resource management, risk of contamination and long-term ecological recovery, which show the inherent difficulties of projects of this scale. Moreover, the project is not fully aligned with the EU's ambitious climate objectives, because although natural gas is less polluting than coal, it is by no means a zero-impact solution. This dual reality calls for a sustained effort to bridge the gap between global objectives and local realities. TAP's management has taken commendable steps, but these must evolve further. Enhanced monitoring, integration of circular practices in resource use, and adaptive management frameworks will be critical to ensuring that the pipeline's operations continue to minimize environmental impacts while maximizing socio-economic benefits. Moreover, future-proofing the infrastructure by adapting it for hydrogen transport could align TAP more closely with Europe's long-term decarbonization goals.

We can state that TAP is a critical contributor to the EU's diversification strategy, but its story is also a cautionary example that big infrastructure projects aren't just about energy or economics, they're fundamentally about people. As highlighted on the 2023 TAP ESG Report, it is recognized that people cannot be regarded merely as a rhetorical construct but are fundamental for the long-term success of the project. Stricter environmental oversight, fairer treatment of communities and a commitment to social responsibility are essential prerequisites and considering socio-economic impacts is equally crucial to building a future that genuinely benefits everyone and aligns with the principles of the UE 2030 Agenda for Sustainable Development.

References

Balkan Insight. (2018). Greek, *Albanian farmers unite against Adriatic pipeline*. Retrieved from https://balkaninsight.com

Benitez-Lopez, A., Alkemade, R., & Verweij, P. A. (2010). The impacts of roads and other infrastructure on mammal and bird populations: A meta-analysis. *Biological Conservation*, *143(*6), 1307–1316. https://doi.org/10.1016/j.biocon.2010.02.009

Beveridge, T. J., Focht, D. D., Scholl, D. M., Ellis, K. R., Webb, R. I., & Power, M. (2013). Bioengineering solutions for soil rehabilitation. *Soil Biology & Biochemistry, 47*, 97–107. https://doi.org/10.1016/j.soilbio.2012.09.012

Brockett, B. F. T., Prescott, C. E., & Grayston, S. J. (2012). Soil moisture and degradation impact on microbial communities. *Forest Ecology and Management*, *266*, 120–130. https://doi.org/10.1016/j.foreco.2011.11.024

Bull, J. W., Suttle, K. B., Gordon, A., Singh, N. J., & Milner-Gulland, E. J. (2013). Biodiversity offsets in theory and practice. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *368*(1621), 20120491. https://doi.org/10.1098/rstb.2012.0491

Clevenger, A. P., & Huijser, M. P. (2011). *Wildlife crossing structure handbook: Design and evaluation in North America*. U.S. Department of Transportation Federal Highway Administration. Retrieved from https://www.fhwa.dot.gov/

Costanza, R., & Daly, H. E. (1992). Natural capital and sustainable development. *Conservation Biology*, *6*(1), 37–46. https://doi.org/10.1046/j.1523-1739.1992.610037.x

Counter Balance. (2021). *Press briefing: Trans-Adriatic Pipeline (TAP)*. Retrieved from https://counter-balance.org/uploads/files/Documents/Briefings-and-Policy-Files/2021-Press-Briefing-TAP.pdf

De Jong, S., Wouters, J., & Sterkx, S. (2010). The 2009 Russian-Ukrainian gas dispute: Lessons for European energy crisis management after Lisbon. *European Foreign Affairs Review*, *15*, *511–538*. Retrieved from https://cris.unu.edu/sites/cris.unu.edu/files/EUGRASP%20De%20Jong%20-%20Wouters%20-%20Sterkx.pdf

Don, A., Schumacher, J., & Freibauer, A. (2011). Impact of tropical land-use change on soil organic carbon stocks—a meta-analysis. *Global Change Biology, 17*(4), 1658–1670. https://doi.org/10.1111/j.1365-2486.2010.02336.x

Edwards, P., & Smith, G. (2016). Assessing construction-related emissions. *Environmental Science & Technology, 50*(10), 5063–5070. https://doi.org/10.1021/acs.est.5b05808

Ellen MacArthur Foundation. (2013). Towards the circular economy: *Economic and business rationale for an accelerated transition.* Retrieved from https://ellenmacarthurfoundation.org/

European Commission. (1992). *Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043

European Commission. (2019). *The European Green Deal.* Retrieved from https://ec.europa.eu/

European Commission. (2021). *Diversification of gas supply sources and routes.* Retrieved from https://energy.ec.europa.eu/topics/energy-security/diversification-gas-supply-sources-and-routes_en

European Investment Bank. (2023). *TAP Trans Adriatic Pipeline.* Retrieved from https://www.eib.org/en/registers/all/185779194

Forman, R. T., & Alexander, L. E. (1998). Roads and their major ecological effects. *Annual Review of Ecology and Systematics, 29,* 207–231. https://doi.org/10.1146/annurev.ecolsys.29.1.207

Gaston, K. J., Jackson, S. F., Cantú-Salazar, L., & Cruz-Piñón, G. (2008). The ecological performance of protected areas. *Annual Review of Ecology, Evolution, and Systematics, 39,* 93–113. https://doi.org/10.1146/annurev.ecolsys.39.110707.173529

Hobbs, R. J., & Harris, J. A. (2001). Restoration ecology: Repairing the Earth's ecosystems in the new millennium. *Restoration Ecology, 9*(2), 239–246. https://doi.org/10.1046/j.1526-100x.2001.009002239.x

International Energy Agency (IEA). (2021). *Hydrogen in a changing energy landscape.* Retrieved from https://www.iea.org/

International Finance Corporation (IFC). (2012). *IFC Performance Standards on Environmental and Social Sustainability.* World Bank Group. Retrieved from https://www.ifc.org/

Joanaz de Melo, J. (2024). *Concepts in environmental assessment.* NOVA University Lisbon.

Lindenmayer, D. B., & Likens, G. E. (2018). Adaptive monitoring: A new paradigm for long-term research and monitoring. *Trends in Ecology & Evolution, 33*(6), 461–473. https://doi.org/10.1016/j.tree.2018.03.005

Lopes, R. (2024). *Sustainability pathways and assessment.* FCT NOVA.

Maron, M., Hobbs, R. J., Moilanen, A., Matthews, J. W., & Christie, P. (2012). Faustian bargains? Restoration realities in the face of biodiversity offset policies. *Environmental Research Letters*, 7(4), 044004. https://doi.org/10.1088/1748-9326/7/4/044004

Nair, N. G., & Sen, P. K. (2018). Hydrogen transport in pipelines: A materials perspective. *International Journal of Hydrogen Energy*, 43(27), 12318–12330. https://doi.org/10.1016/j.ijhydene.2018.04.013

Navach, G., & Jewkes, S. (2016). *Italian olive grove stands in way of European energy security.* Reuters. Retrieved from https://web.archive.org/web/20180315070636/https://uk.reuters.com/article/uk-italy-energy-trees-insight/italian-olive-grove-stands-in-way-of-european-energy-security-idUKKCN1240GE

Our Future Water. (2023). *The circular economy in water management: Cultivating a sustainable water future.* Retrieved from https://www.ourfuturewater.com/2023/06/28/the-circular-economy-in-water-management-cultivating-a-sustainable-water-future/

Pusceddu, A. M. (2024). Pipelines, flows and roots: Power struggles over the TAP. *In Disenchanted Modernities* (pp. 399–427).

S&P Global Commodity Insights. (2020). *Turning on the tap: A shift in the European gas landscape.* Retrieved from https://www.spglobal.com/commodityinsights/PlattsContent/_assets/_files/en/specialreports/naturalgas/turning-on-tap-a-shift-in-the-european-gas-landscape.pdf

Schaltegger, S., & Burritt, R. L. (2018). Business strategies for managing carbon emissions. Journal of Cleaner Production, 172, 4157–4166. https://doi.org/10.1016/j.jclepro.2017.08.019

Schloter, M., Nannipieri, P., Sørensen, S. J., & Elsas, J. D. (2018). Microbial indicators for soil restoration. *Soil Biology and Biochemistry, 123*, 214–226. https://doi.org/10.1016/j.soilbio.2018.03.021

Southern Gas Corridor. (n.d.). *About us.* Retrieved from https://www.sgc.az/en/about

Stern, J., Pirani, S., & Yafimava, K. (2009). *The Russo-Ukrainian gas dispute of January 2009: A comprehensive assessment.* Oxford Institute for Energy Studies. Retrieved from https://www.oxfordenergy.org/wpcms/wp-content/uploads/2010/11/NG27-TheRussoUkrainianGasDisputeofJanuary2009AComprehensiveAssessment-JonathanSternSimonPiraniKatjaYafimava-2009.pdf

United Nations. (n.d.). *The 17 goals*. United Nations Department of Economic and Social Affairs: Sustainable Development. Retrieved December 6, 2024, from https://sdgs.un.org/goals

Trans Adriatic Pipeline AG. (2023a). *Committed to a sustainable energy future: ESG report 2023*. Retrieved from https://www.tap-ag.com

Trans Adriatic Pipeline AG. (2023b). *Greenhouse Gases (GHG) Report 2023* https://www.tap-ag.com/sustainability/lenders-requirements/esch-management-operations/$18964/$18963/$30066

Trans Adriatic Pipeline AG. (n.d.). *EU status: The big picture*. Retrieved December 9, 2024, from https://www.tap-ag.com/about-tap/the-big-picture/eu-status

United Nations Environment Programme (UNEP). (2019). *Oil and Gas Methane Partnership: A voluntary initiative to reduce methane emissions.* Retrieved from https://www.unep.org/resources/report/oil-and-gas-methane-partnership-voluntary-initiative-reduce-methane-emissions

Züttel, A., Borgschulte, A., & Schlapbach, L. (2010). Hydrogen as a future energy carrier. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 368*(1923), 3329–3342. https://doi.org/10.1098/rsta.2010.0006