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A Low Carbon Pathway for the Fertiliser Sector in the Republic of Türkiye

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List of Abbreviations

AN	Ammonium Nitrate
AS	Ammonium Sulphate
CAN	Calcium Ammonium Nitrate
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CCUS	Carbon Capture, Utilisation and Storage
DAP	Diammonium Phosphate
EBRD	European Bank for Reconstruction and Development
EGD	European Green Deal
ESG	Environmental, Social and Governance
ETS	Emissions Trading System
EU	European Union
FTS	Frontier Technologies Scenario
GHG	Greenhouse Gas
IFA	International Fertiliser Industry Association
JRC	Joint Research Centre
LCP	Low Carbon Pathway
LCPdom	LCP Domestic Production
MAP	Monoammonium Phosphate
MoAF	Ministry of Agriculture and Forestry
MoENR	Ministry of Energy and Natural Resources
MoEUCC	Ministry of Environment, Urbanisation and Climate Change
MoFA	Ministry of Foreign Affairs

MoIT	Ministry of Industry and Technology
MoLSS	Ministry of Labour and Social Security
MoT	Ministry of Trade
MoTF	Ministry of Treasury and Finance
MPP	Mission Possible Partnership
NDC	Nationally Determined Contributions
NPK	Nitrogen, Phosphorus, Potassium
OM	Organomineral
OPEX	Operational Expenditure
R&D	Research and Development
RCF	Recycled Carbon Fuel
RES	Renewable Energy Systems
SBTi	Science Based Targets Initiative
SDG	Sustainable Development Goals
SPS	Stated Policy Scenario
SteerCo	Steering Committee
ToR	Terms of Reference
TSE	Turkish Standards Institute
TÜBİTAK	The Scientific and Technological Research Council of Türkiye
UAN	Urea Ammonium Nitrate
WoM	Without Measures Scenario
WoMdom	WoM Domestic Production

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A photograph of a vast agricultural field, likely a cornfield, with rows of green crops stretching towards a distant treeline under a hazy, golden sky. The perspective is from a low angle, looking down the rows of crops. The soil is dark and appears to be recently tilled.

EXECUTIVE SUMMARY

An Overview of Türkiye's Fertiliser Sector

The "A Low Carbon Pathway for the Fertiliser Sector in the Republic of Türkiye" report provides a comprehensive and multifaceted examination of the Turkish fertiliser sector, covering its current status, challenges, and potential pathways towards sustainable and low-carbon development. The report's findings and analyses are crucial for understanding the complex interplay of economic, policy, and regulatory factors that influence the industry's trajectory.

The study underscores the importance of aligning fertiliser investments with the overarching goals of the European Green Deal (EGD) strategy, particularly the ambitious target of achieving net-zero emissions by 2050 within the framework of the Sustainable Development Goals (SDG). This alignment underscores the need for strategic coherence with international sustainability agendas to drive meaningful progress. Considering Türkiye's 2053 net-zero targets, the report highlights the critical role of implementing measures to reduce greenhouse gas (GHG) emissions and encourage technological transformation within the fertiliser sector. The proposed introduction of a carbon pricing mechanism, such as a carbon trading system akin to the European Union (EU) Emissions Trading System (ETS) as detailed in the Draft Climate Law, marks a significant policy shift with extensive implications for emissions reduction and regulatory frameworks.

Türkiye's fertiliser sector is highly dependent on imported raw materials and intermediary inputs. Approximately 95% of the materials required for fertiliser production and a third of the finished fertiliser products are imported, rendering the sector vulnerable to price shocks and supply-side issues. The primary raw materials and products used and imported in the fertiliser sector include natural gas, ammonia, and urea, all of which are dependent on energy prices.

Fertiliser consumption in Türkiye has nearly doubled between 1981 and 2001, despite a roughly 20% decrease in arable land during the same period. Key factors influencing the production/consumption dynamic in Türkiye include agricultural incentives, energy/raw material prices, new irrigation projects, exchange rates, and changes in crop types. There has been an increasing trend in fertiliser use per unit of land since 1994, with nitrogen consumption per hectare being 105 kg in 2021. In contrast, nitrogen consumption in the EU was reported as 157 kg/ha in the same year (**Figure 1**).

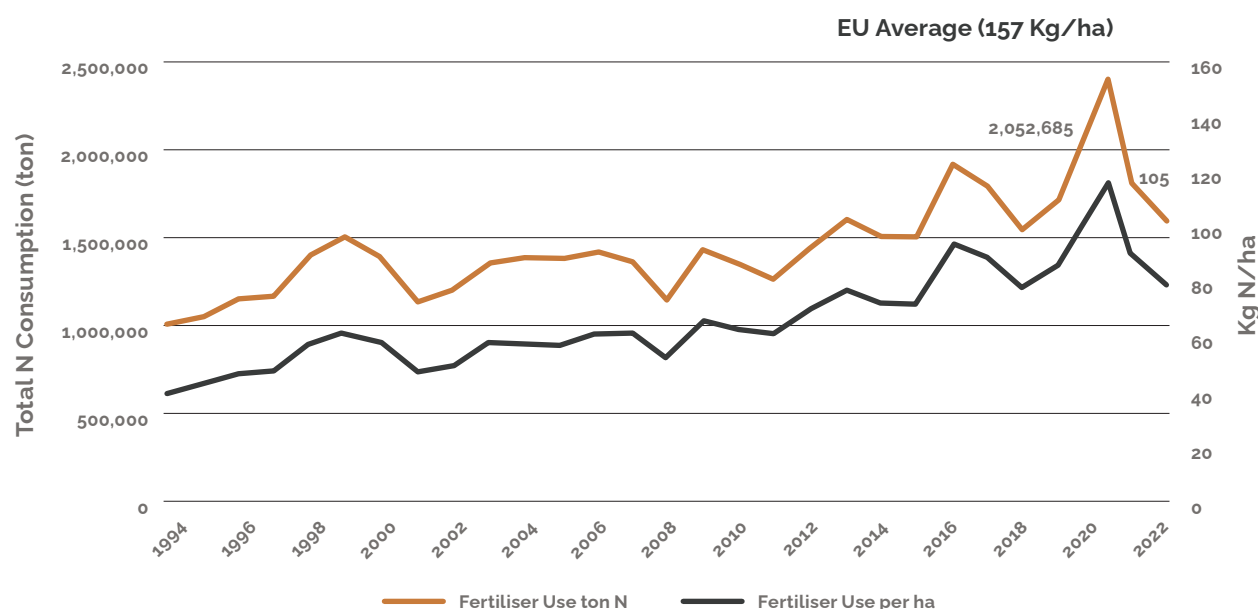


Figure 1. Total and Unit Nitrogen Consumption in Türkiye and EU¹

Based on the types of fertilisers consumed in Türkiye, the ammonia required for their production in 2020 was estimated to be 2.1 million tons, predominantly used for urea production. However, Türkiye's annual ammonia production capacity stands at only around 0.86 million tons, with actual production reaching just 0.45 million tons in 2020. Consequently, the shortfall was met through imports, comprising approximately 1.18 million tons of ammonia and 0.92 million tons of other nitrogen-containing products. Hence, nearly 75% of the ammonia consumed in Türkiye is not included in the national GHG emission inventory and imported by Türkiye as embedded emissions. Despite not being a significant exporter of fertilisers, the high emission intensity of Türkiye's fertiliser sector exposes it to vulnerabilities associated with the Carbon Border Adjustment Mechanism (CBAM). While exports constitute a small portion compared to domestic consumption, Türkiye's fertiliser exports approached nearly 300 million USD in 2023, with around 95% of these exports destined for EU countries, including Romania, Ireland, and Italy.

As illustrated in **Figure 2** and **Table 1**, fertiliser consumption in Türkiye exceeds production. While Türkiye's fertiliser production capacity surpasses the required consumption amount for types, reliance on imported materials and the dynamics of the international market sometimes make importing fertilisers more viable than domestic production. This is particularly observed during periods of rising natural gas prices, where importing ammonia and urea becomes more feasible than producing these raw materials domestically.

¹ <https://data.worldbank.org/indicator/AG.CON.FERT.ZS?locations=EU>

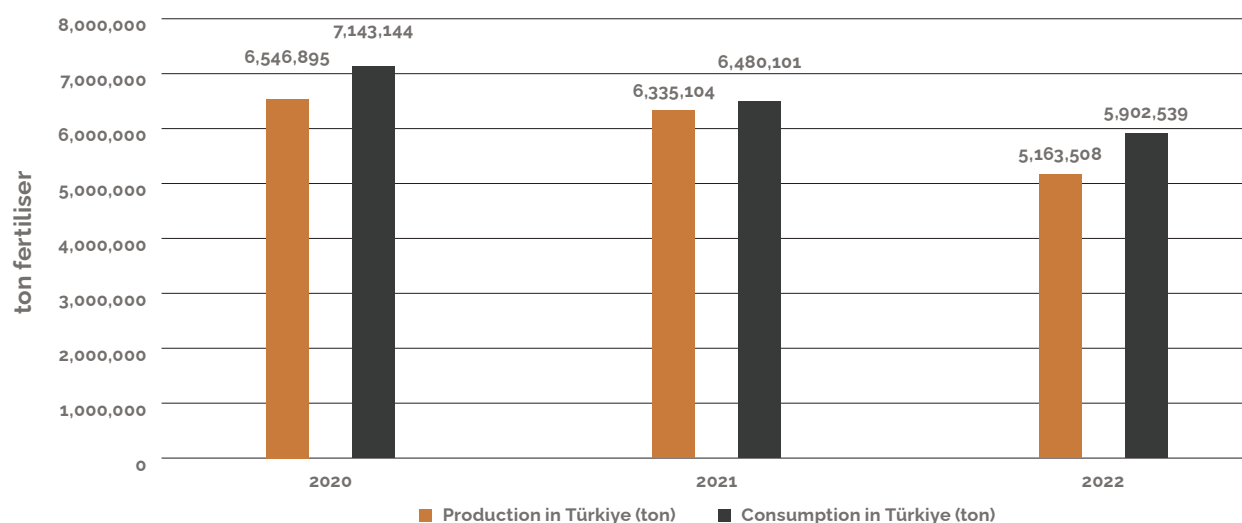


Figure 2. Fertiliser Production and Consumption Index in Türkiye

Table 1. Fertiliser Production and Consumption Data of Türkiye (2020- 2022)

Production/Consumption	2020	2021	2022
Production in Türkiye (ton)	6,546,895	6,335,104	5,163,508
Consumption in Türkiye (ton)	7,143,144	6,480,101	5,902,539
% Difference of Consumption Compared to Production	8%	2%	13%

The types of fertilisers consumed in Türkiye have varied in recent years, influenced by factors such as restrictions on high Ammonium Nitrate (AN) fertilisers, incentive programs and irrigation infrastructure. Notably, the demand for urea nearly tripled between 2000 and 2020, accounting for 35% of Türkiye's total fertiliser production. Other main fertiliser types preferred in Türkiye include NPK (Nitrogen, Phosphorus, Potassium), Calcium Ammonium Nitrate (CAN), and Diammonium Phosphate (DAP).

Figure 3 and **Figure 4** below illustrate the proportions of two primary inputs/products used in the Turkish fertiliser sector ². From 2010 to 2021, approximately 58% of the Ammonia and 83% of the Urea utilized in Türkiye were imported. A relatively small portion of the ammonia, about 9%, was exported during this same period. These figures represent the products used in the form of ammonia and urea and therefore exclude ammonia and urea contained within imported final fertiliser products. Average capacity utilization for Ammonia and Urea production during this period was determined to be 70% and 76%, respectively. The capacity

² World Urea Statistics by Country 2010 – 2021, IFA

utilization of domestic production plants exhibited significant fluctuations, nearly 100% in some years, primarily due to variations in international fertiliser market prices and local energy costs. These factors often make importing these products more advantageous than domestic production.

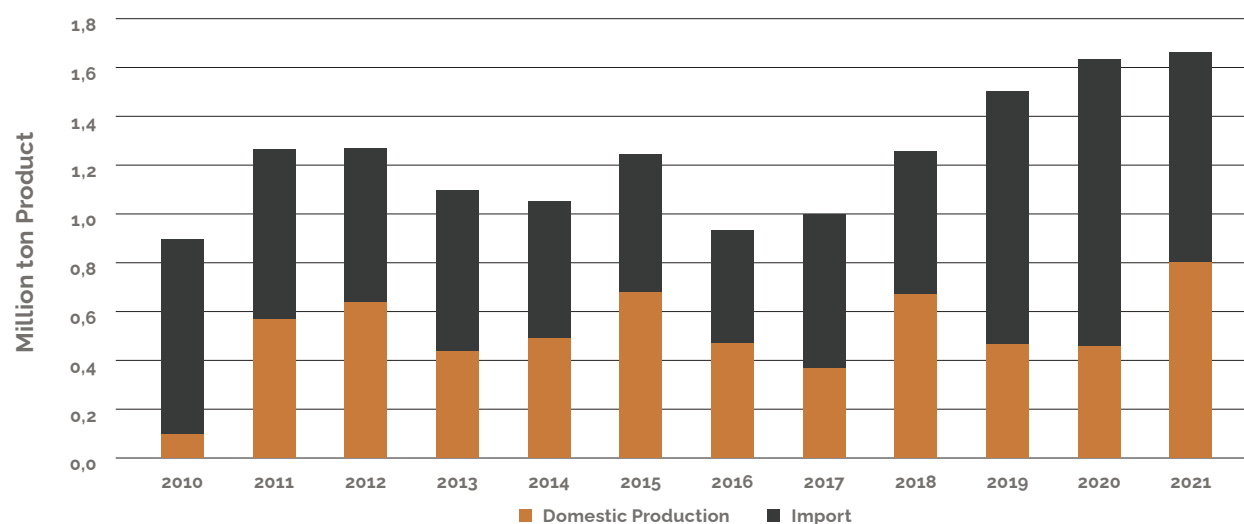


Figure 3. Ammonia Consumption in Türkiye by Source

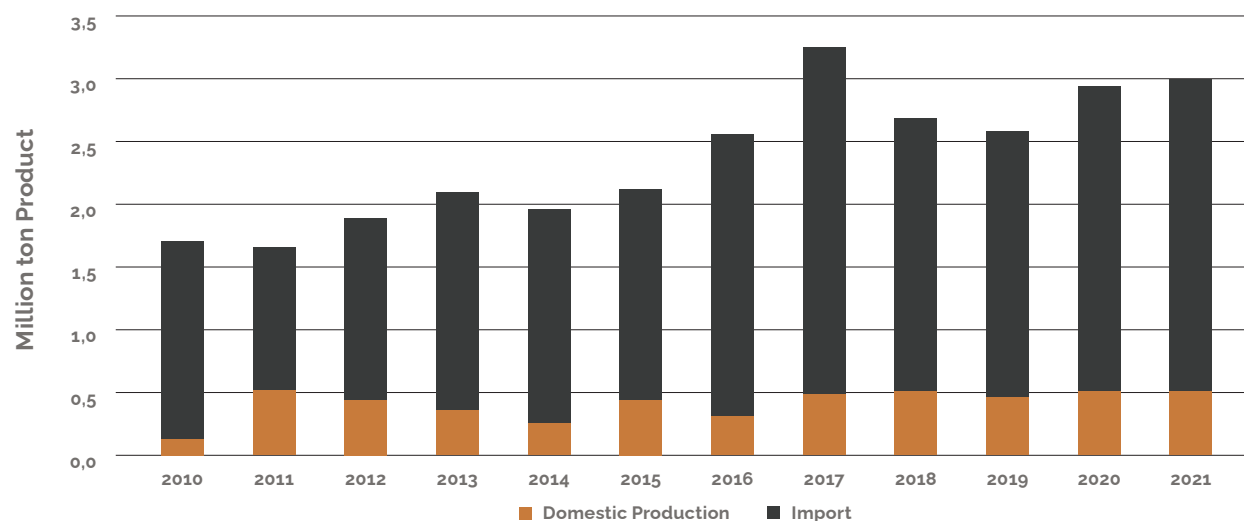


Figure 4. Urea Consumption in Türkiye by Source

In Türkiye, there are eight major chemical fertiliser producers operating across 14 different locations. Throughout this study, both face-to-face and online meetings and consultations were conducted with all these facilities to gather data and gain insights into their future and potential technology investments. Notably, among these facilities, three large companies specialize in producing organomineral (OM) fertilisers, distinct from biogas facilities, and

operate in four different locations. The overall production capacity for chemical fertilisers in Türkiye is estimated to be approximately 10.5 million tons. This figure is based on data compiled from information forms submitted by the companies, insights from actual site visits and online interviews, and information publicly shared by the companies on their official pages. A noticeable trend towards renewable energy is evident across the fertiliser sector. In terms of fertiliser production activities, there have been increases in capacity and new technology investments, particularly in nitric acid and ammonium sulphate (AS) production.

Most of the existing fertilizer factories in Türkiye are over 45 years old, established as state-owned enterprises and privatized in the 2000s. Consequently, the energy and emissions intensity of these older plants are significantly higher compared to newer facilities, which increases their vulnerability. While the share of GHG emissions from chemical fertiliser production in Türkiye is relatively low compared to other sectors and the overall emissions in the country, most of these emissions occur outside Türkiye's boundaries and are, therefore, not included in Türkiye's national GHG inventory. The majority of GHG emissions from domestic fertiliser production arise from N₂O emissions during nitric acid production, accounting for more than 50% of the fertiliser-related emissions within Türkiye. The remaining emissions primarily stem from natural gas consumption used for power generation and ammonia production.

Current Policies and Regulations

The fertiliser sector in Türkiye is regulated by multiple ministries, each playing a crucial role: The Ministry of Agriculture and Forestry (MoAF) monitors fertilizer use and sets incentives for its application, while the Ministry of Industry and Technology (MoIT) develops, implements, and supports strategies for fertilizer production; the Ministry of Industry and Technology (MoIT) is responsible for fertiliser production; the Ministry of Environment Urbanisation and Climate Change (MoEUCC) addresses emissions and environment-related issues; the Ministry of Energy and Natural Resources (MoENR) focuses on energy efficiency and renewable incentives; and the Ministry of Trade (MoT) manages import and export-related issues. Additionally, the Ministry of Labour and Social Security (MoLSS) and the Ministry of Foreign Affairs (MoFA) are also key stakeholders in the fertiliser sector. This multi-stakeholder structure necessitates intensive communication between authorities to develop effective policies.

A detailed analysis has been conducted on various topics, including plant nutrition and agricultural policy, import control, environmental management, investment incentives, Research and Development (R&D) support, renewable energy, and biogas incentives. The report also provides an in-depth exploration of ongoing studies and action plans within the

sector, covering the adoption of Environmental, Social, and Governance (ESG) reporting, the establishment of the Science Based Targets initiative (SBTi), and the disclosure of climate-related information to stakeholders. Moreover, national policy documents related to climate change mitigation and decarbonization are examined in detail, such as the 12th Development Plan, the 2021 President's Annual Program, the 2023 Industry and Technology Strategy Document of Türkiye, and the Fertiliser Sector Policy Document (2018-2022) initiated by the MoAF.

Recommendations developed in this study consider Türkiye's Nationally Determined Contribution (NDC), the planned National ETS, impacts on the agri-food sector, energy strategy, and the sector's competitiveness. Proposed measures include fostering the implementation of low carbon technologies and improving resource efficiency in the sector through better utilization of organic materials, enhancing nutrient use efficiency and developing labour skills. The study also advocates for the development and implementation of technology-based measures such as N_2O abatement, green/blue ammonia/hydrogen production, and incentivizing renewable energy/energy efficiency to reduce emissions. The implementation timeline and the responsible and relevant institutions for implementing the measures have been determined in consultation with steering committee members and stakeholders.

Key Findings of the Study

Study includes assessment of current status of the fertiliser facilities in terms of product types, emission and energy intensity for main fertiliser types produced in Türkiye and benchmarking with other countries/regions. The benchmarking section highlights areas where the industry can reduce carbon emissions, improve energy efficiency, and align with sustainability goals. Challenges identified include market sensitivity, external factors, and agriculture's role. Opportunities are defined as alignment with green initiatives, renewable energy, and capacity expansion potential. When comparing the Turkish fertiliser sector with international commitments like the EU ETS benchmarks and SBTi, several needs become evident. Process emission from nitric acid production was identified as the main emission source in terms of absolute emissions which increases the emission intensity of all main types of fertilisers such as AN, CAN and NPK fertilisers which are produced using nitric acid. Emission intensity of nitric acid production in Türkiye was calculated as 68% higher compared to EU whereas emission intensity of CAN and AN fertilisers are calculated as 64 and 54% higher compared to EU average. Scope 2 emission intensity due to electricity consumption for fertiliser production was also calculated as around 20-36% higher than EU average.

In the Greenhouse Gas and Policy Interaction Model section, the proposed model and its assumptions are described. The 2020 operating year was used to calculate base year emissions for this study. The boundary of the emission calculations is gate-to-gate emissions of fertiliser-producing facilities in Türkiye, considering both scope 1 and scope 2 emissions. The proposed model is a long-term, large-scale linear programming model aiming to minimize the total discounted cost over the 2020-2053 planning horizon. The model covers all stages of fertiliser production, including ammonia synthesis, production of derivatives (urea, AN, nitric acid, AS), with a detailed integration of the economic and emission features of processing technologies.

As detailed in Chapter 4, six different scenarios were run within the model study, and the 2020-2053 GHG projection results of each scenario were obtained. The investment amounts required for the Low Carbon Pathway (LCP) and Frontier Technologies Scenario (FTS) scenarios, which are notable mitigation scenarios, have been determined. To present the numerical results of the model, 2020 baseline emissions for all scenarios were calculated as 3,446,621 tons of CO₂. Within the Without Measure (WoM) scenario, which represents the baseline scenario, GHG emissions in 2053 are projected to be 4,478,441 tons. In 2053, the LCP scenario is expected to reach -161,500 tons CO₂, the LCP domestic production (LCPdom) scenario -856,391 tons CO₂, and the FTS -169,170 tons CO₂. Therefore, according to the LCP, LCPdom, and FTS scenarios, by 2053, the fertiliser production sector in Türkiye has the potential to become carbon negative.

Figure 5 shows the emissions calculated for different scenarios for 2020-2053 period. The WoM domestic production (WoMdom) scenario, which refers to producing all raw materials in Türkiye without any mitigation measure, projects 2053 emissions to be 175% higher than the WoM scenario's 2020 emissions. The LCPdom scenario, also focusing on domestic production but with emissions 125% lower than the WoM scenario's 2020 emissions, offers a more significant emission reduction rate than the LCP and FTS scenarios. This is because fertiliser types have different production amounts on a scenario-by-scenario basis. Notably, the negative emissions calculated in 2053 for LCP and FTS scenarios implies that the CO₂ needed for urea production will have to be supplied from other sources if green ammonia dominates the market.

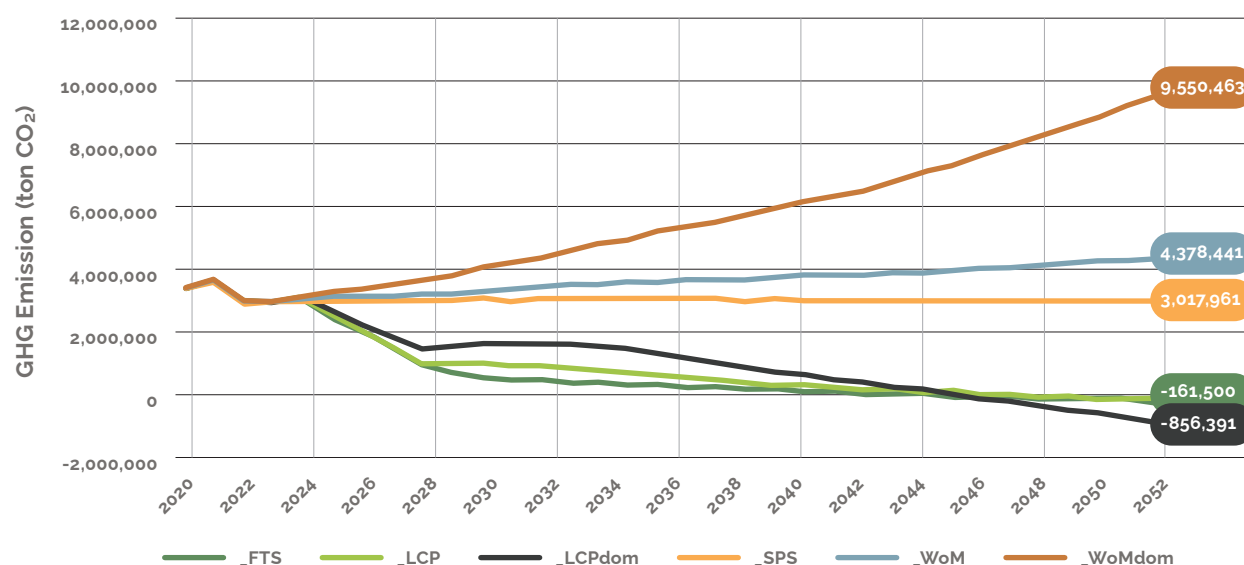


Figure 5. GHG Emission Trend by Each Scenario Between 2020-2053

In the low carbon pathway scenarios, which include both LCP and FTS, various mitigation measures were considered. However, three measures were particularly emphasized: N₂O abatement investments, green and blue ammonia use, and improving fertiliser use efficiency. These measures are scheduled in three phases: Phase 1 (2024-2025), Phase 2 (2026-2038), and Phase 3 (2039-2053). This phased approach is based on predictions about the technological maturity level of these mitigation measures.

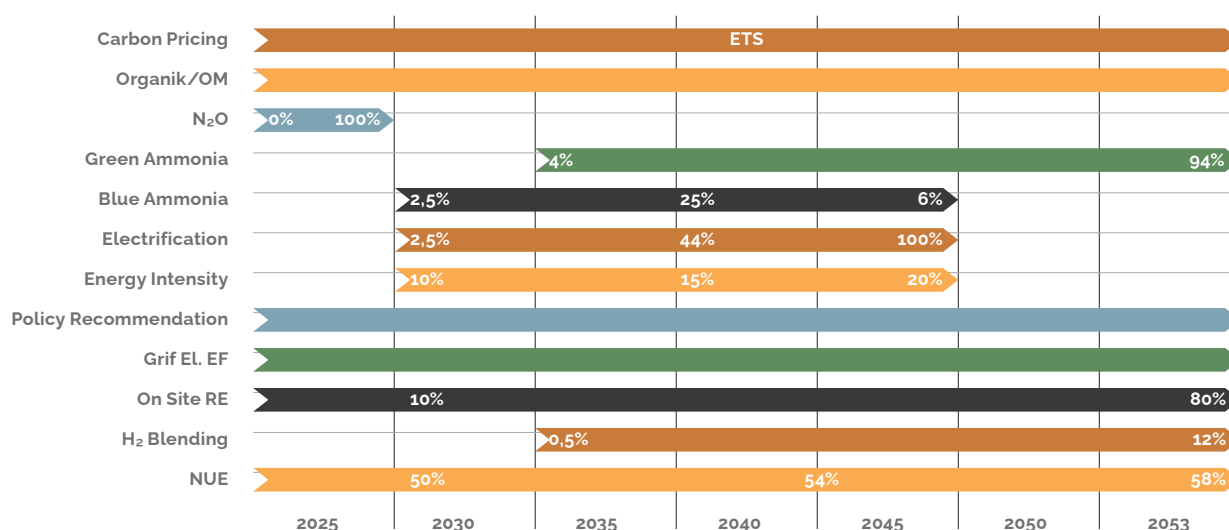


Figure 6. Timeline for Measures and Technologies Recommended

To briefly highlight the potential impact, implementing recommendations for N₂O abatement investments, green and blue ammonia use, and enhancing fertiliser use efficiency could potentially reduce cumulative emissions in the base scenario by 93-95% between 2020 and 2053. Further details on this are provided in Section 3 of the report.

The implementation penetration rates of the mitigation measures recommended for the LCP and FTS scenarios from 2020 to 2053 are detailed in **Figure 22** and **Figure 23**. The most significant contributor to emission reduction is projected to be the N₂O abatement systems. This measure is proposed for full implementation (100%) by 2028, with an annual penetration rate of 25% during the 4-year period from 2025 to 2028 in both scenarios. The available technology supports achieving full implementation by 2028. N₂O abatement investments stand out as the most important emission reduction measure, addressing the 65-69% range of the total cumulative emission reduction in both scenarios. The use of green and blue ammonia became the second most important measure, contributing to a cumulative emission reduction of 17-20%. For LCP scenario, green ammonia technology is proposed to be implemented at a rate of 5% by 2030 and reaches 30% in 2040. For FTS, this technology is proposed to be implemented at a rate of 30% by 2030 and reaches 60% in 2040. Fertiliser use efficiency also contributes to a reduction of 8-9%. The contribution of other mitigation measures is in the range of 0-1%.

The penetration rates for renewable energy consumption, electrification, and green ammonia production are expected to reach 80-90% by 2053. These penetration rates are conservatively designed, considering the maturity level of the associated technologies.

The total investment needs for all low carbon scenarios have also been calculated. The investment requirement up to 2053 is estimated at 5.26 billion USD for the LCP scenario and 7.66 billion USD for the FTS scenario (**Table 2**). The LCPdom scenario, which assumes that all demand is met through production within Türkiye, is projected to require an investment of approximately 16.6 billion USD.

Table 2. Investment Needs for All Scenarios

CAPEX (Capital Expenditure)	LCP	LCPdom	FTS
Total (Billion USD)	5.26	16.6	7.66

In LCP scenario, main investment items will be renewable energy investments, heat pumps and investments for new organic and OM fertiliser production capacity. In FTS scenario, more ambitious penetration of organic/OM fertiliser consumption is needed therefore, majority of the investment needed in FTS will be for these investments whereas renewable energy investments and heat pumps will be other main investment items. Green and blue ammonia investments will be the fourth main item in both LCP and FTS scenarios. LCPdom scenario, which assumes the production of all raw materials and intermediary inputs domestically requires significantly more investments due to demand for new production capacities for ammonia and other fertilisers/intermediary inputs. In LCPdom scenario, around 39% of the investment (~6.5 billion USD) will be needed for RE investment whereas green ammonia investment cost is estimated as 4.8 billion USD. Other main investment items will be organic/OM fertiliser production costs, blue ammonia and energy efficiency investments. N₂O abatement systems have relatively low initial investment costs and high GHG reductions due to high global warming potential of N₂O. Fertiliser use efficiency is one of the critical measures in all scenarios and requires management of demand via capacity building, new fertiliser types and precision agriculture activities. Most of the measures to improve fertiliser use efficiency are assumed to be related to operational costs, therefore investment cost is not included for this measure.

Installation of N₂O abatement systems reducing demand via efficient use of fertilisers and using organic sources in fertiliser production are key measures which can allow bulk GHG emission reductions at lower costs compared to other investments (green ammonia, Renewable Energy and Heat Pumps). Considering the technology maturity levels, costs and benefits, those measures are prioritized in the recommendations list whereas green/blue ammonia and heat pump investments are foreseen at medium/long term.

In addition to measures proposed for production and demand side management, policy measures have also been developed to support low carbon pathway options. Measures have been defined under four axis including process improvements and technological transformation, sustainable supply chain, legislative measures (carbon pricing, incentives/financial mechanisms) and employment and capacity building. In consultation with steering committee and key stakeholders, 24 policy recommendations have been developed. Implementation period and steps, bottlenecks, coordinating institutions and relevant institutions have been defined for each recommendation.

Policy axis and recommendations under each axis and policy types are summarised below together with recommended implementation timeline.

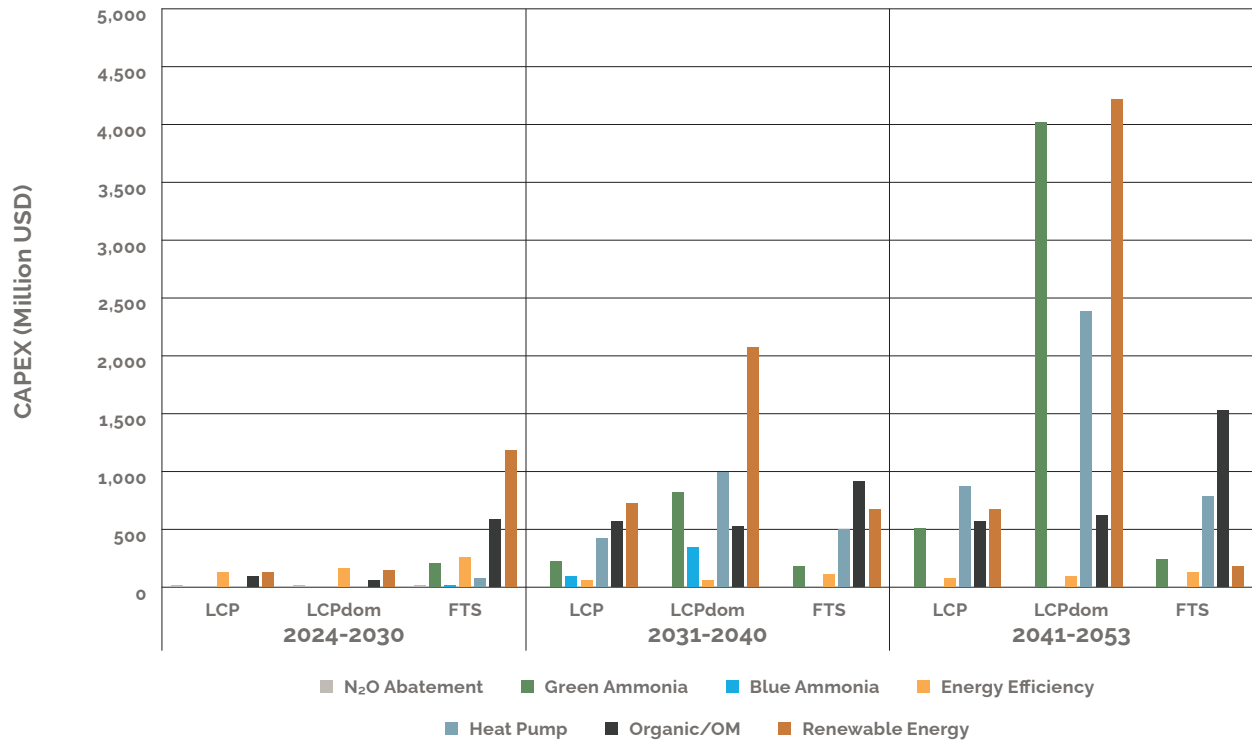


Figure 7. Breakdowns of Investment for Each Mitigation Technology and Scenario Between 2024-2030; 2031-2040 and 2041-2053

A close-up photograph of a person's hands, wearing a grey sweater, gently cupping a small green seedling with three leaves growing out of dark brown soil. Overlaid on the soil is a white digital network consisting of glowing nodes connected by thin lines, symbolizing technology and sustainability. The background is dark and out of focus.

1. INTRODUCTION

The fertiliser sector significantly contributes to global GHG emissions, with nitrogenous fertilisers production alone accounting for about 1.5% of global emissions³. In Türkiye, the fertiliser market has demonstrated growth both in terms of total and per hectare fertiliser consumption. Nearly 95% of the raw materials and intermediary inputs in the fertiliser sector, including natural gas as feedstock and energy source, ammonia, and urea, are imported. This dependency increases the sector's vulnerability, especially considering Türkiye's high reliance on imports for fertiliser production, contrasted with its status as a net exporter in the agri-food sector. The link between fertiliser, agricultural production, and food security underscores the sector's importance for Türkiye's economic and social stability. Additionally, emissions from fertiliser production and application are major sources of GHG emissions.

In 2021, Türkiye ratified the Paris Agreement and declared a net-zero emission target for 2053. At COP 27 in 2022, Türkiye increased its emission reduction target to 41% compared to a business-as-usual scenario. The Turkish government has taken several steps to address climate change, including developing a long-term low-emission development strategy, a climate law, and the 12th Development Plan (2024-2028)⁴. The 12th Development Plan, prepared for 2024-2028, is a crucial policy initiative for Türkiye's sustainable development and climate change mitigation efforts⁵. This plan aligns with Türkiye's long-term strategy towards 2053, aiming to be consistent with the 2030 Agenda for Sustainable Development. The fertiliser sector in Türkiye is integral to the economy and plays a significant role in achieving the goals of the 12th Development Plan and the Nationally Determined Contribution (NDC).

The "Green Growth Technology Roadmap for the Fertiliser Sector"⁶ published in 2022, outlines the sector's decarbonization roadmap and low-carbon technologies. This roadmap is crucial for Türkiye's fertiliser sector to reduce GHG emissions and improve energy efficiency, moving towards a sustainable and environmentally friendly industry. CBAM is also vital for Türkiye's fertiliser sector, ensuring a level playing field with countries that have already implemented carbon pricing mechanisms. The European Green Deal (EGD), approved in 2020, is a series of policy initiatives by the European Commission aimed at making the EU the first climate-neutral continent by 2050.

This project, financed by the EBRD with MoIT as the beneficiary and led by GTE and the ESCON Consortium, aims to support climate-related policy actions in line with national targets. The SteerCo, comprising MoIT, MoEUCC, MoAF, MoT, MoENR, MoTF, MoLSS, the Presidency of Strategy and Budget, Revenue Administration, The Scientific and Technological Research Council of Türkiye (TÜBİTAK), Turkish Standards Institute (TSE), and fertiliser companies, reflects diverse industry perspectives.

³ https://europa.eu/newsroom/ecpc-failover/index_en.htm

⁴ https://onikinciplan.sbb.gov.tr/wp-content/uploads/2023/11/On-ikinci-Kalkinma-Plani_2024-2028.pdf

⁵ https://unfccc.int/sites/default/files/NDC/2023-04/T%C3%99CRK%C4%B0YE_UPDATED%201st%20NDC_EN.pdf

⁶ https://www.tubitak.gov.tr/sites/default/files/yesil_tyh_gubre_16082023.pdf

During the roadmap's development for the Turkish fertiliser sector, three SteerCo meetings were organized to share project outputs with stakeholders and gather their feedback effectively. Besides these meetings, numerous other focused stakeholder discussion meetings were held to discuss model results and policy recommendations. Achieving significant reductions in emissions requires a combination of measures tailored to each fertiliser facility's specific needs. However, the roadmap presented in this report provides a data-driven transition scenario, enabling policymakers and industry leaders to benchmark their efforts. This report, prepared following the adoption of the roadmap, serves as a framework to accelerate the implementation of the proposed measures, bring together relevant stakeholders, and create an investment strategy and platform to share a common vision for the sector.

2. Current Situation Analysis of Turkish Fertiliser Sector



2.1 Capacity and Production

Fertiliser consumption in Türkiye has almost doubled between 1981 and 2001, despite a roughly 20% decrease in arable land during the same period. Although the production capacity of fertiliser facilities is sufficient to meet domestic demand, due to market conditions and high import dependence, the capacity utilization of these facilities in Türkiye has been around 60% of production capacity⁷.

According to data collected from stakeholders, the chemical fertiliser production capacity in Türkiye is approximately 7.3 million tons annually, with a raw material production capacity of 5.49 million tons. Of particular note in terms of GHG emissions are the production capacities of nitric acid and ammonia, which are 1.5 million tons and 775 thousand tons, respectively.

Furthermore, the total fertiliser production capacity recorded in industrial registry records is about 12.6 million tons. These records include chemical, organic and OM fertilisers combined, providing only aggregate figures without detailed breakdowns. Additionally, these records encompass all fertiliser producers in Türkiye, both large and small.

Discrepancies exist between the industrial registry records and MoAF data regarding raw material production. For instance, MoAF reports nitric acid production capacity at about 1.5 million tons, whereas industrial registry records indicate a capacity of 1.27 million tons. This discrepancy raises questions about the accuracy of these figures. According to MoEUCC data in Türkiye's 2021 national emission inventory, nitric acid production was 1.35 million tons, with N₂O emissions of 6,790 tons (National Inventory Report of Türkiye 2021, submitted in 2023). Additionally, the ammonia capacity information in industrial registry records, which specifically pertains to aqueous solutions, is not directly comparable to the ammonia production capacity data from MoAF.

In Türkiye, there are eight major chemical fertiliser producers with production facilities across 14 different locations, as shown in **Figure 8**. Among these facilities, three large companies produce OM fertilisers, in addition to biogas facilities, operating in four different locations. The chemical fertilisers production capacity in Türkiye is approximately 10.5 million tons, based on data from company submissions, site visits, online interviews, and official company information. Furthermore, if utilized to full capacity, it is feasible to produce approximately 1 million tons of OM fertiliser.

⁷ <https://www.tarimorman.gov.tr/BUGEM/Belgeler/Bitkisel%20C3%9Cretim/Bitki%20Besleme%20ve%20Tar%C4%B1msal%20Teknolojiler/%C4%B0statistikler/Y%C4%B1llar%20Baz%C4%B1nda%20Kimyevi%20G%C3%BCbre%20T%C3%BCketim%20ve%20C3%9Cretim%20%C4%B0statistikleri.xlsx>

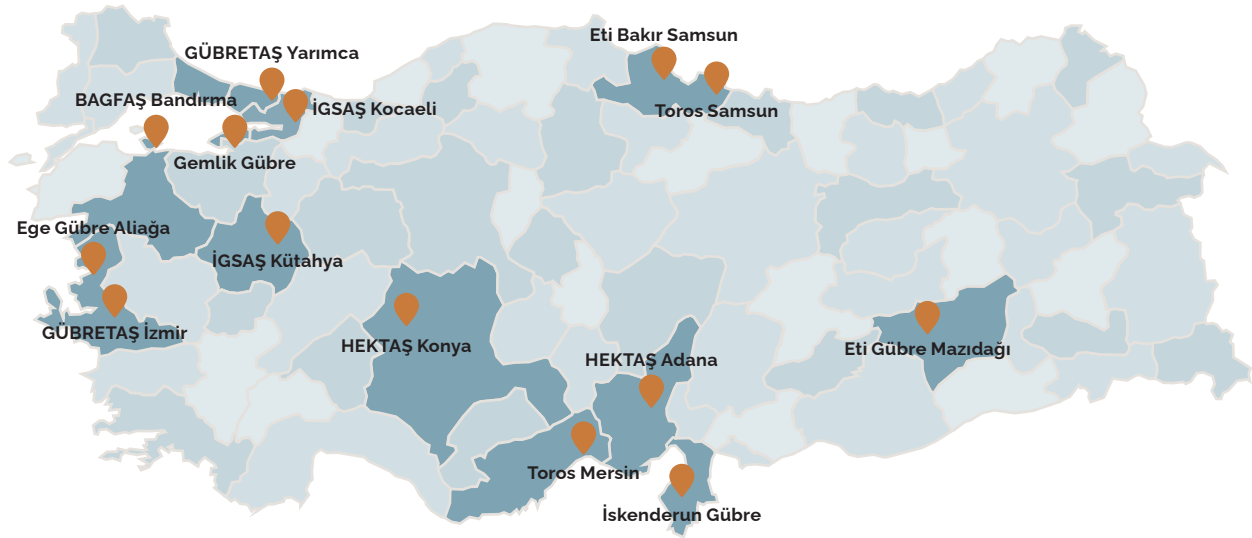


Figure 8. Fertiliser Production Facilities in Türkiye

2.2 Fertiliser Trade of Türkiye

Fertiliser consumption in Türkiye has nearly doubled between 1981 and 2001, despite a 20% decrease in arable land during the same period. Despite having sufficient production capacity, the fertiliser sector in Türkiye experiences only about 60% capacity utilization, primarily due to market conditions and high import dependence. Various factors such as agricultural incentives, energy/raw material prices, new irrigation projects, exchange rates, and changes in crop types significantly impact the production and consumption dynamics in Türkiye. The use of fertiliser per unit of land has been on an increasing trend since 1994, with nitrogen consumption per hectare reaching 105 kg in 2021. In comparison, nitrogen consumption in the EU was higher, recorded at 157 kg/ha in the same year.

Data published by the MoAF in 2022⁸ provides detailed information on the production, consumption, import, and export values for the years 2017, 2018, and 2019 (Table 3 and Figure 9).

Table 3. Production, Export, Consumption and Import Data for between 2017-2019

Year	Production (ton)	Export (ton)	Consumption (ton)	Import (ton)
2017	3,841,645	5,353,780	6,332,872	594,560
2018	4,027,004	4,331,739	5,411,881	924,796
2019	4,661,491	4,929,081	6,087,714	1,270,676

⁸ Report "SÜRDÜRÜLEBİLİR GIDA SİSTEMLERİ ÜLKE RAPORU TÜRKİYE 2021"
<https://www.tarimorman.gov.tr/ABDGM/Belgeler/Uluslararası%C4%B1%20Kurulu%C5%9Flar/Su%C5%9Flu%20Sistemleri%20G%C4%B1da%20Sistemleri%20Ülke%20Raporu%20-%20T%C3%BCrkiye%202021.pdf>

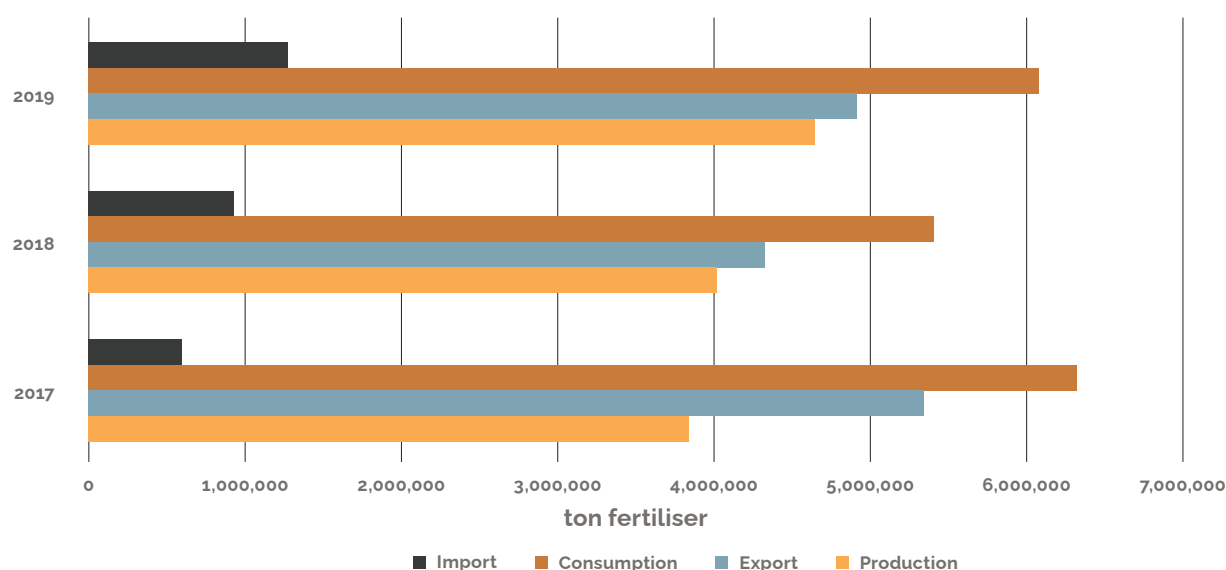


Figure 9. Production, Export, Consumption and Import Data for Between 2017-2019

2.3 Benchmarking

This section summarizes the dynamic structure of the Turkish fertiliser sector, underlining both its challenges and opportunities. Key challenges include market sensitivity and external factors such as geopolitical events, as well as the sector's dependence on agricultural demand. Opportunities are emerging from alignment with green initiatives, the adoption of renewable energy, and the potential for capacity building. The fertiliser sector has the capacity to transition to cleaner production models by adopting energy-efficient technologies, reducing emissions, and exploring sustainable raw material sources. Collaboration with public institutions and international organizations can aid in meeting the EU ETS criteria and achieving the objectives of the EGD. To comply with international standards, the sector should focus on data transparency, emission reduction strategies, energy efficiency improvements, transition to renewable energy, flexible supply chains, technology upgrades, and stakeholder engagement.

The Joint Research Centre (JRC) 2023 Technical Report⁹ provides data on the emission intensity of main raw materials and fertiliser types for Türkiye and the EU27 average (Table 4). The reason for the 50-65% higher direct emission intensity in TR compared to the EU mainly stems from direct emissions during the ammonia and nitric acid production processes, which are the main raw materials for various fertiliser types. Moreover, the indirect emission intensity in Türkiye is also higher, indicating opportunities for improved energy efficiency and suggesting that the renewable energy consumption ratio might be lower than the EU27 average.

⁹ Vidovic, D., Marmier, A., Zore, L. and Moya, J., Greenhouse gas emission intensities of the steel, fertilisers, aluminium and cement industries in the EU and its main trading partners, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/359533, JRC134682

Table 4. Emission Intensity per ton of Product

Fertiliser or Raw Material	Emission Intensity ton CO ₂ /ton product (Türkiye)			Emission Intensity ton CO ₂ /ton product (Average of EU 27)			Comparison Between Türkiye and EU27		
	Direct	Indirect (Electricity)	Total	Direct	Indirect (Electricity)	Total	Direct Emission Difference per ton of Product	Indirect Emission Difference Due to Electricity Consumption per ton of Product	Difference in Emission Intensity per ton of Product
Ammonia	2.07	0.11	2.18	1.91	0.07	1.98	8%	36%	9%
Nitric Acid	2.4	0.04	2.44	0.74	0.03	0.77	69%	25%	68%
AS	0.64	0.07	0.71	0.58	0.05	0.62	9%	29%	13%
AN	2.32	0.09	2.41	1.03	0.06	1.1	56%	33%	54%
Urea	1.4	0.09	1.49	1.27	0.07	1.33	9%	22%	11%
DAP	0.54	0.05	0.59	0.48	0.04	0.51	11%	20%	14%
NPK	0.97	0.08	1.05	0.48	0.06	0.53	51%	25%	50%
CAN	1.62	0.06	1.68	0.56	0.04	0.6	65%	33%	64%

Table 5 Emphasizes the importance of setting interim targets for global fertilizer and chemical producers by 2030 and achieving carbon neutrality by 2050. It also includes various solutions and practices adopted in the sector. The chapter concludes by emphasizing the potential for Turkish fertiliser companies to advance in decarbonization. It highlights the importance of addressing the needs identified in the context of international developments and practices adopted by global firms.

Table 5. Decarbonization Targets and Applications of Global Fertiliser Companies

Company	CF Industries ¹⁰
Targets	25% reduction in emission intensity (tCO ₂ e/ton product) of products by 2030 Achieving carbon neutrality by 2050
Activities	Blue/Green Ammonia Utilizing electricity from renewable sources. Reducing carbon emissions intensity Ensuring the proper use of their products in agricultural production.
Company	ICL ¹¹
Targets	30% reduction in Scope 1-2 emissions by 2030 (Base year: 2018) Achieving carbon neutrality by 2050
Activities	Using digital tools for GHG emissions monitoring. Assessing Scope 3 emissions. Phasing out oil shale-firing and transitioning to gas-fired power generation. Electricity sourcing from strategic power purchase agreements. Increasing energy efficiency, streamlining production facilities. Installing solar photovoltaic systems for electricity generation.
Company	Mosaic ¹²
Targets	20% reduction in emission intensity (tCO ₂ e/ton product) of products by 2025
Activities	Emphasizing operating efficiency. Investing in energy-efficient technologies and evaluating alternative energy sources. Leveraging agronomic expertise to promote efficiencies in agricultural systems. Advocating for a balanced clean energy policy. Reporting energy and GHG performance and communicating with stakeholders.
Company	Nutrien ¹³
Targets	30% reduction in Scope 1-2 emissions by 2030 (Base year: 2018)
Activities	Using multiple initiatives to improve energy efficiency and emissions performance across their manufacturing facilities. Exploring additional carbon capture, utilization, and storage (CCUS) projects. Renewable energy procurement. Generating low-carbon ammonia opportunities by leading in low-carbon markets and platforms.

¹⁰ <https://sustainability.cfindustries.com/energy-emissions-and-climate-change/decarbonizing-our-network>

¹¹ <https://icl-group-sustainability.com/reports/ghg-climate-change/>

¹² <https://www.mosaicco.com/Air>

¹³ <https://www.nutrien.com/sustainability/strategy/emissions-reduction>

Company	OCI ¹⁴
Targets	20% reduction in Scope 1-2 emissions by 2030 (Base year: 2019) Achieving carbon neutrality by 2050
Activities	Sustainable Agriculture: OCI Agro app to optimize farmers' activity planning and optimal nutrition application. Developing fertilisers with urease and/or inhibitors for better nutrient use efficiency. Train farmers on fertiliser application, provide digital resources. Decarbonizing their Sites: N ₂ O and NO _x abatement. Implementing Best Available Technologies. Waste heat capture and recovery. CO ₂ capture, recycling, and sale. Cleaner Fuels: E-methanol / Green methanol. Recycled carbon fuel (RCF) methanol.
Company	Phosagro ¹⁵
Targets	14% reduction in Scope 1-2-3 emissions by 2028 (Base year: 2018)
Activities	Value Chain Collaboration Plan Climate Risk Mitigation Strategies Ecological Impact and Quality Assessment Eco-Friendly Fertiliser Production Commitment to Environmental Stewardship Air Quality Enhancement Initiatives Facility Modernization and Upgrades
Company	Yara ¹⁶
Targets	30% reduction in Scope 1-2 emissions by 2030 (Base year: 2019) Achieving carbon neutrality by 2050
Activities	Yara Clean Ammonia (YCA) Initiative Agoro Carbon Alliance to develop farm-based carbon credits. Clean Technology Opportunities Focus on Regenerative Agriculture Development of Green Fertiliser HEGRA Project (Herøya Green Ammonia)

¹⁴ <https://oci-global.com/sustainability/>

¹⁵ <https://www.phosagro.com/sustainability/ecology/>

¹⁶ <https://www.yara.com/sustainability/sustainability-performance/planet/>

2.4 Strengths and Weaknesses of the Turkish Fertiliser Sector

The Turkish fertiliser sector is clearly evolving and receptive to progress, though it faces a number of strengths and weaknesses.

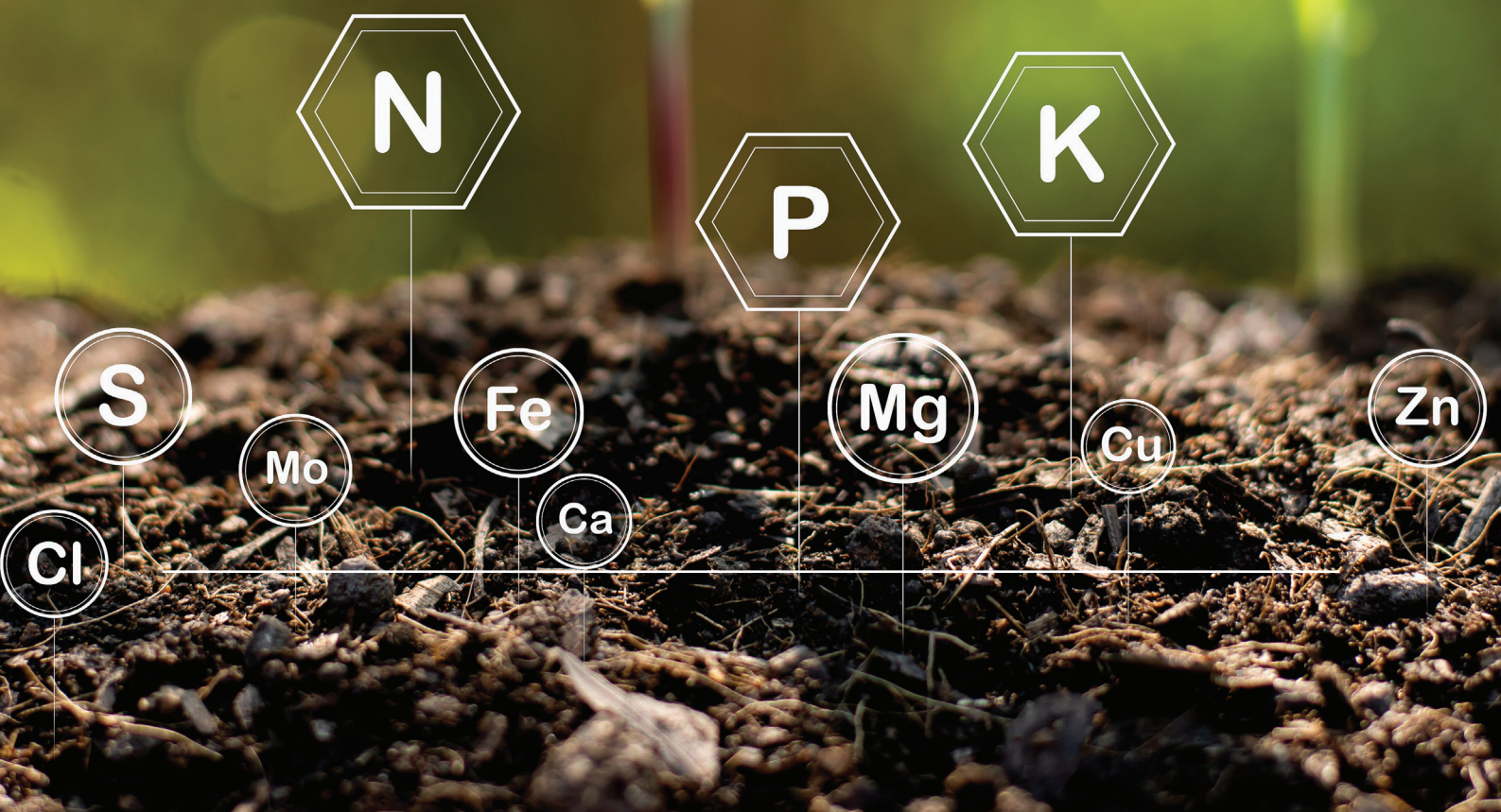
Strengths:

- **Alignment with Green Initiatives:** Many fertiliser companies are increasingly acknowledging the importance of sustainability. This is evident in their interest in green ammonia, OM fertilisers, and striving for net-zero emissions.
- **Renewable Energy:** The shift towards renewable energy and waste heat potential is an advantage for minimizing the carbon footprint associated with production.
- **Capacity Expansion:** Investments in capacity expansion and the adoption of new technologies demonstrate a commitment to growth and the potential for efficiency improvements.

Weakness:

- **Market Sensitivity:** The sector's production and supply are heavily influenced by market conditions and price fluctuations, which can lead to potential production stoppages.
- **External Factors:** The impact of external factors, such as geopolitical events and economic fluctuations, significantly affects raw material supply, production planning, and sales operations.
- **Agriculture's Role:** There is a need to recognize the critical role of farmers and agriculture in the fertiliser sector. The industry's success is closely tied to agricultural demand for its products.

3. Greenhouse Gas and Policy Interaction Model



The proposed model in this study is a long-term, large-scale linear programming and bottom-up type model, aimed at minimizing the total discounted cost over the planning horizon of 2020-2053. The Terms of Reference (ToR) are designed to assess the impacts of various decarbonization pathways under different scenarios. These pathways represent different technological profiles or transition structures based on the processes/technologies employed throughout the horizon. Consequently, the model is developed to represent all process details comprehensively, from input composition to meeting the projected demands (Figure 10).

The model encompasses all stages of fertiliser production, including ammonia synthesis and the production of derivatives such as urea, AN, nitric acid, and AS. It integrates economic and emission features of processing technologies in detail (Figure 11). Therefore, the most crucial aspect of the model, in line with the ToR objectives, is technological explicitness. This entails a detailed representation of current, transitional, and frontier processes and technologies in the sector.

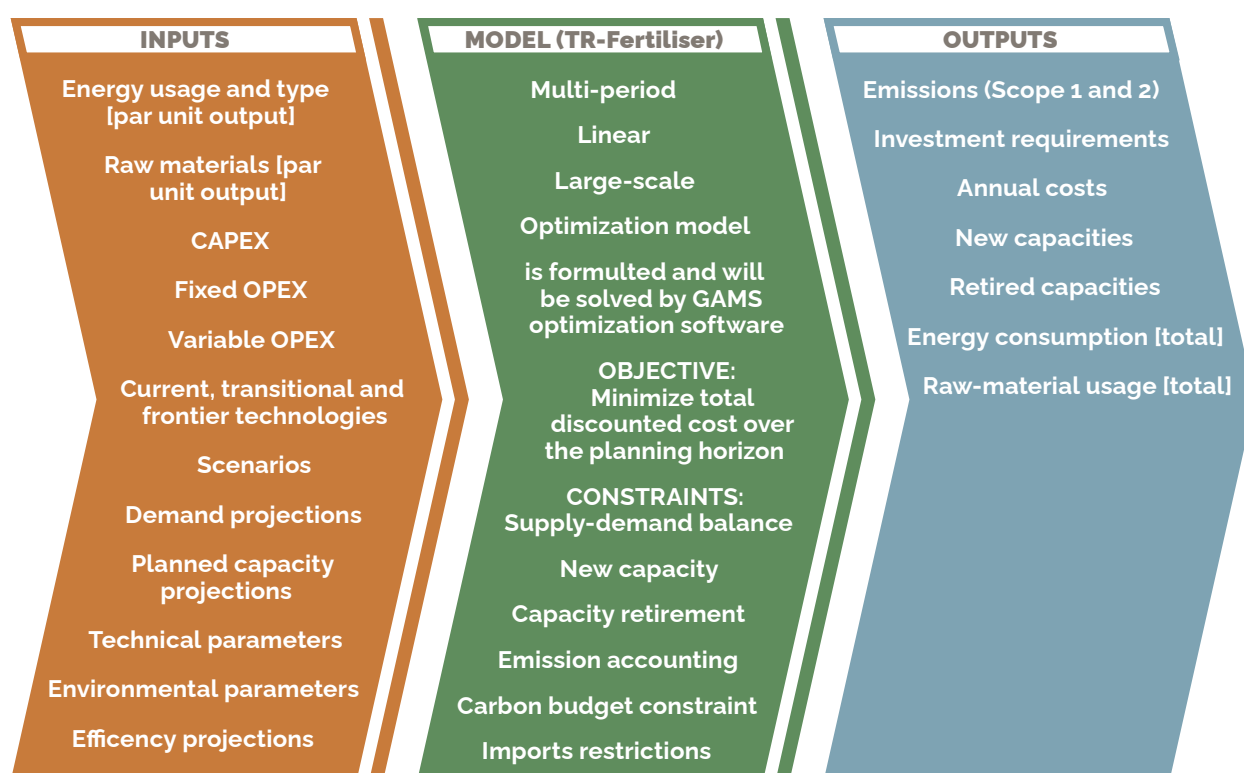


Figure 10. TR-Fertiliser: Modelling Framework

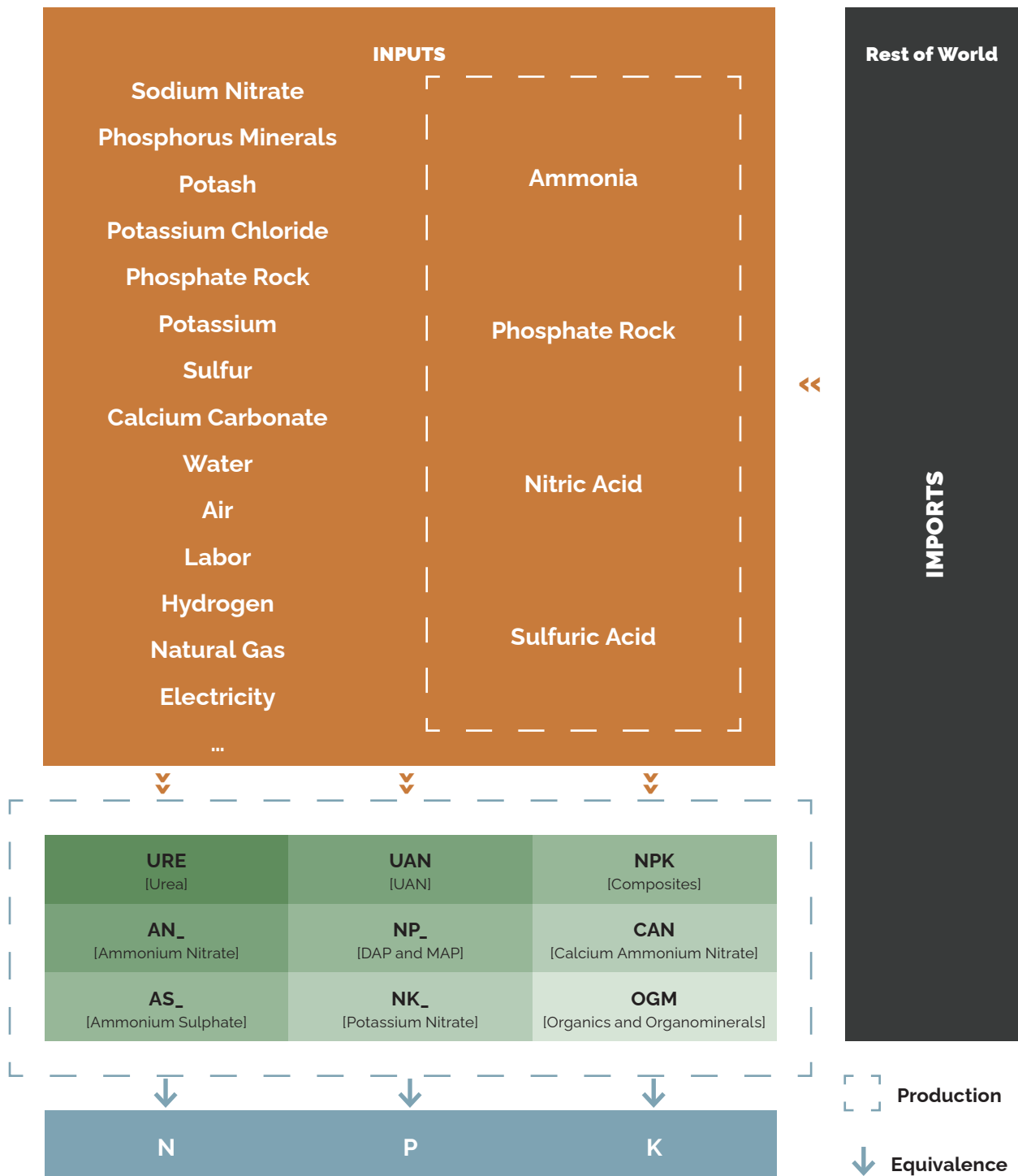


Figure 11. TR-Fertiliser: Input-output and Production Structure

3.1 Results of the Model

As illustrated in **Figure 12**, the baseline emissions for all scenarios in 2020 were 3,446,621 tons of CO₂. Examining the emissions projected for 2053, the WoM scenario is expected to result in 4,378,441 tons of CO₂. By contrast, in 2053, the LCP scenario is anticipated to reach -161,500 tons CO₂, the LCPdom scenario -856,391 tons CO₂, and the FTS -169,170 tons CO₂. Therefore, according to the LCP, LCPdom, and FTS scenarios by 2053, the fertiliser production sector in Türkiye has the potential to become carbon negative.

While interpreting these carbon negative results, it is important to note that the model results represent only the sector's gate-to-gate emissions. In other words, the results do not encompass upstream and downstream, or Scope 3, emissions.

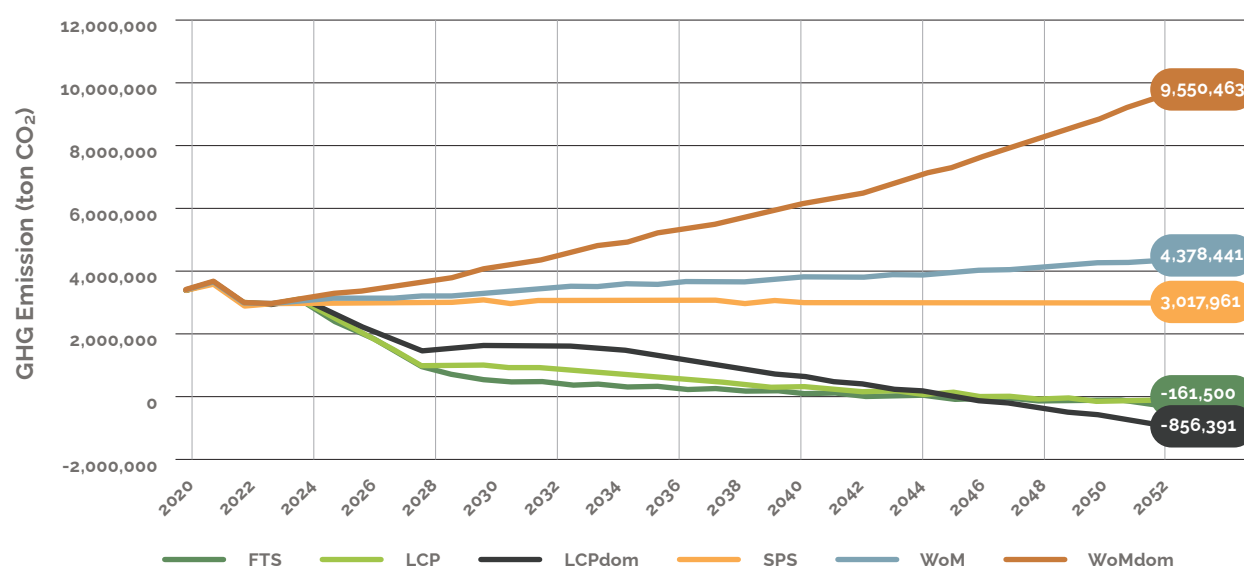


Figure 12. GHG Emission Trend by Each Scenario Between 2020-2053

The contribution of mitigation measures implemented in the LCP and FTS scenarios to the cumulative emission reduction compared to the WoM scenario between 2020-2053 are given in **Figure 13** and **Figure 14**. As clearly stated in the relevant tables and graphs, N₂O abatement investments are the most important emission reduction measure, accounting for 65-69% of the total cumulative reduction in both scenarios. The use of green and blue ammonia is the second most important measure, contributing to a reduction of 17-20%. Fertiliser use efficiency also contributes to a reduction of 8-9%. The contribution of other mitigation measures is in the range of 0-1%. In summary, if the recommendations/measures regarding N₂O abatement investments, green and blue ammonia use, and fertiliser use efficiency are implemented, it

seems possible to reduce the cumulative emissions in the base scenario by 93-95% between 2020-2053.

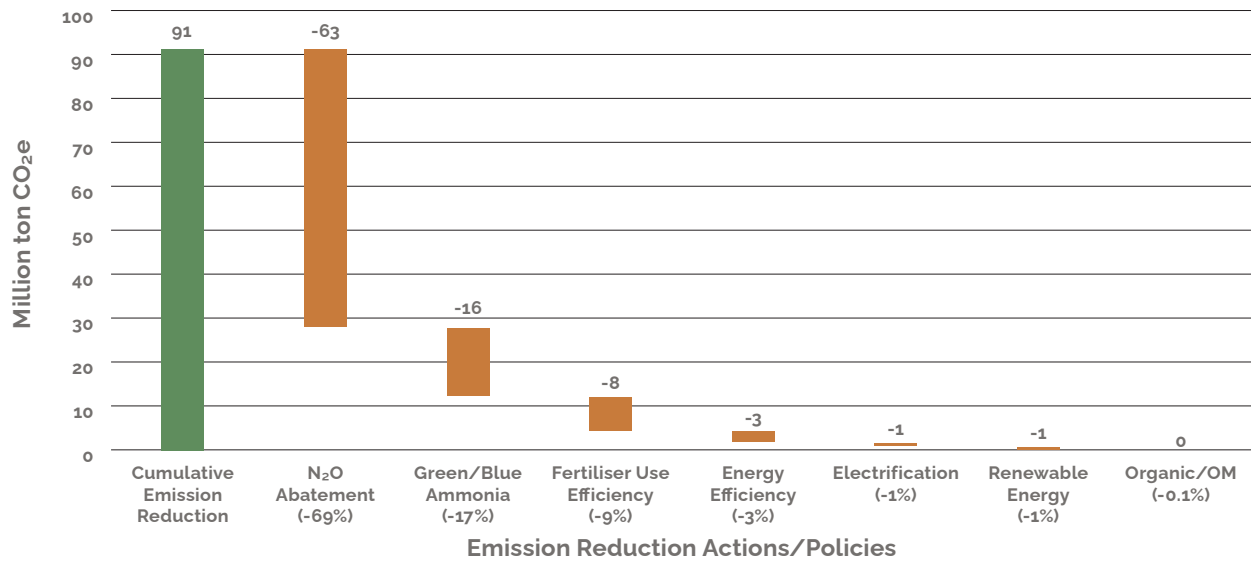


Figure 13. Contribution of Mitigation Measures Implemented in the LCP Scenario to the Cumulative Reduction Compared to the WoM Scenario Between 2020-2053

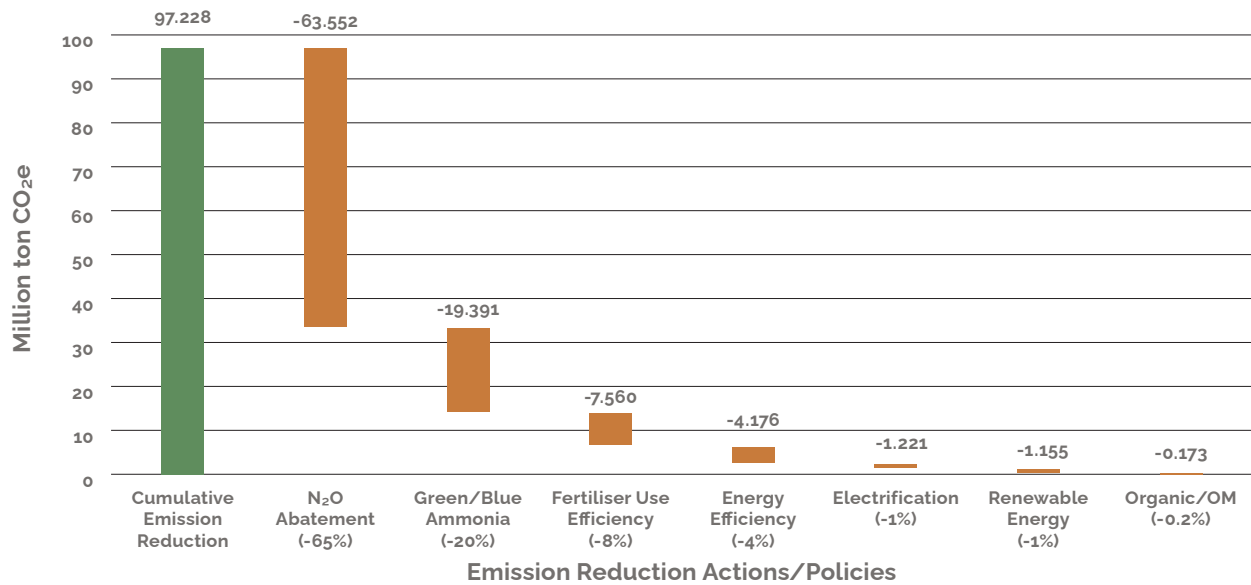


Figure 14. Contribution of Mitigation Measures Implemented in the FTS Scenario to the Cumulative Reduction Compared to the WoM Scenario Between 2020-2053

3.2 Sector Growth Methodology and Demand Projections

Fertiliser demand is influenced by a variety of factors such as price, crop type, crop price, irrigation infrastructure, changes in cultivated land, and climate. These agro-economic factors typically fluctuate annually and are challenging to predict, as evidenced by the historical trends in fertiliser demand shown in **Figure 15**. In Türkiye, the production of fertilisers is further complicated by supply and demand dynamics in international markets. Despite a decrease in the size of cultivated land, the demand for fertiliser has continued to increase both in absolute terms and in terms of consumption per unit area.

To assess GHG emissions from fertiliser production, projections were made using two scenarios from the IFA, as well as a trend study of the most recent twenty-year period. The figure below displays the domestic demand in terms of Nitrogen equivalent under three scenarios. S3 and S2 correspond to the IFA's demand projections for global (S3) and West Asia region (S2) demand for Nitrogen, where Türkiye is classified in the IFA's system. S1 is based on Türkiye's historical demand, projected using a twenty-year rolling average. Following discussions with SteerCo members and key stakeholders, S1 was determined to be the most reasonable scenario and has been adopted for use in the subsequent phases of this study.

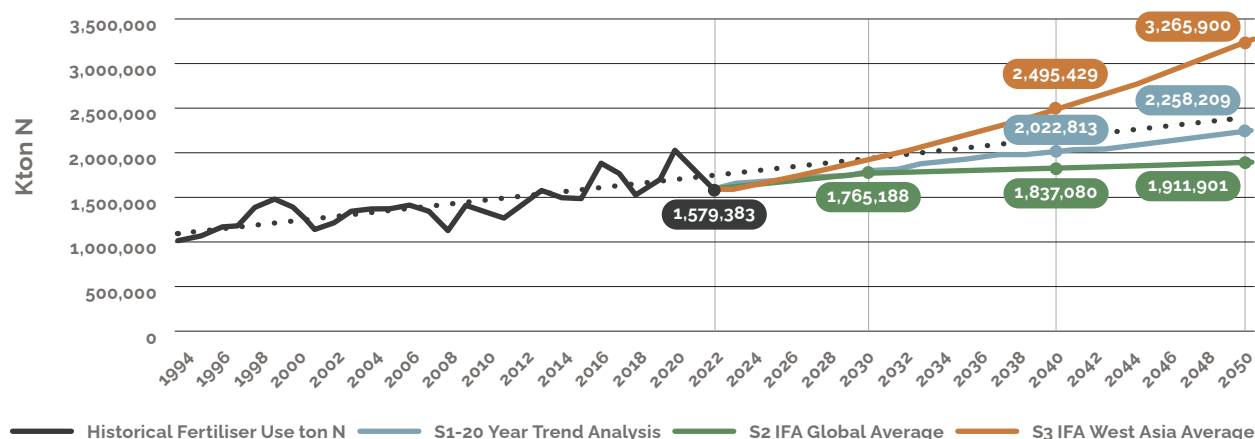


Figure 15. Comparison of Different Nitrogen Demand Projection Approaches

Total fertiliser production, along with the production volumes of each fertiliser type and their proportions in total production, are presented on a scenario basis in **Table 6** and **Figure 16**.

Organic and OM fertiliser types are increasingly influencing fertiliser usage efficiency in agriculture, leading to a reduction in total fertiliser demand in Türkiye. Consequently, in the LCP and FTS scenarios, the production amounts of organic and OM fertilisers were given emphasis. As a result of this support, the production volumes of chemical fertilisers have decreased.

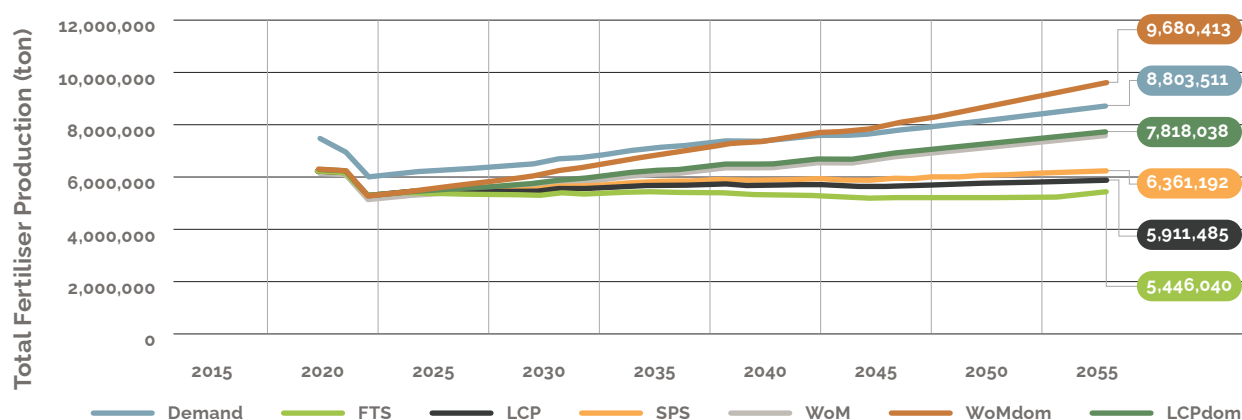


Figure 16. Demand and Production for Each Scenario in the 2020-2053 Projection

Table 6. Production of Each Fertiliser Type in 2053

Fertiliser Type	Scenario/Total Production (ton) by 2053					
	FTS	LCP	LCPdom	SPS	WoM	WoMdom
UREA	499,127	558,323	2,059,654	625,722	562,497	2,308,146
UAN	3,375	1,782	14,722	3,620	2,927	13,284
AN	78,949	109,880	109,880	120,190	180,484	180,484
AS	722,225	640,766	640,766	700,890	1,052,492	1,052,492
CAN	863,578	1,185,140	1,185,140	1,296,342	1,946,653	1,946,653
NPK	52,097	1,387,686	1,856,021	1,975,072	2,662,792	2,700,957
NP	11,784	419,810	335,820	743,313	613,170	712,881
NK	3,390	7,714	50,124	5,236	7,750	45,228
Organic/OM	3,211,514	1,600,384	1,565,910	890,806	729,564	720,289
Total Production Amount (ton)	5,446,040	5,911,485	7,818,038	6,361,192	7,758,329	9,680,413

In Figure 17, it is indicated that different types of fertilisers will require varying production levels across different scenarios in 2053. There are three main reasons behind this variation:

- Support for Organic/OM Fertiliser Production: In the LCP and FTS scenarios, there is a focus on supporting the production of organic and OM fertilisers.

- Providing N:P:K Equivalents: The need for N:P:K equivalents in total production is determined by comparing the type of fertiliser and the ratio of nutrients consumed in Türkiye in 2020.
- Cost Differences and Model Optimization: The model takes into account differences in input costs and aims to optimize production based on these variations.

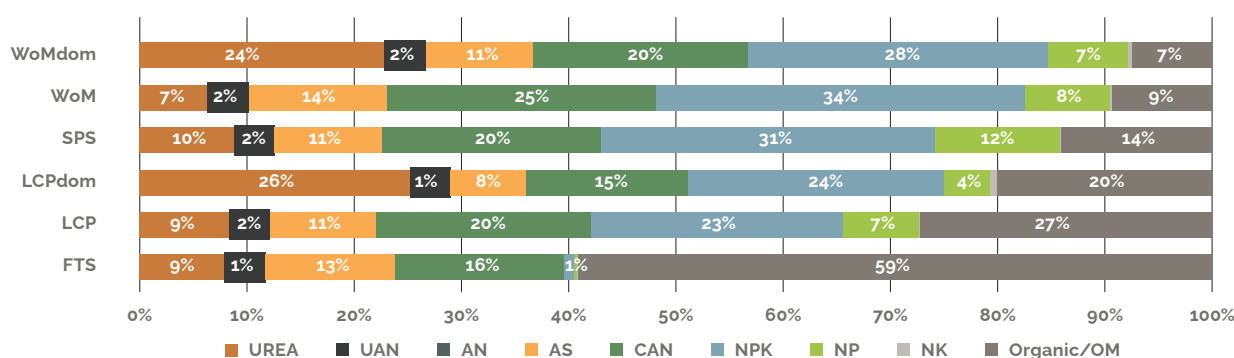


Figure 17. % Share of Each Fertiliser Type in Total Production by 2053

The model determines that the utilization of production capacity in the sector is directly related to the total amount of fertiliser production on a scenario basis, as illustrated in Figure 18.

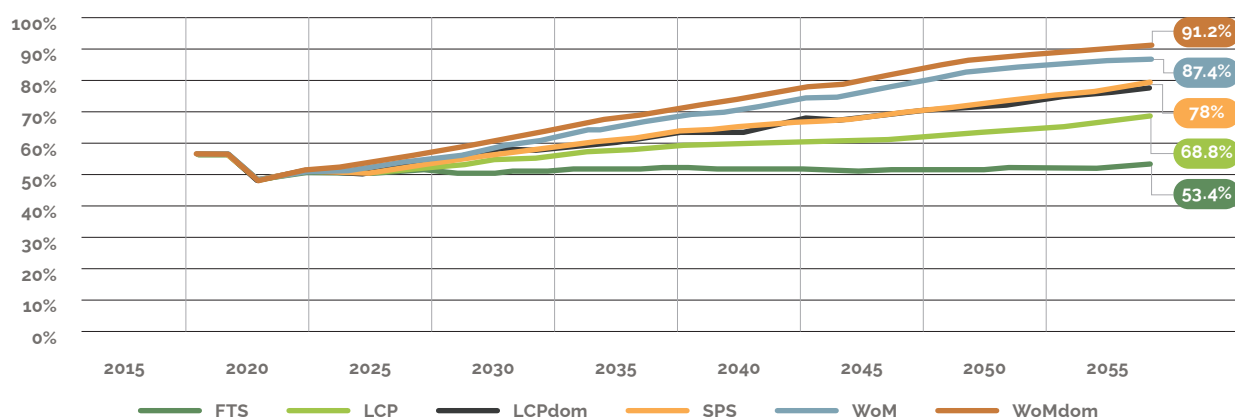


Figure 18. Production Capacity Usage by Each Scenario (%)

3.3 Low-Carbon Technologies

Table 7 presents the low carbon technologies utilized in the scenarios of the model study, along with brief descriptions of each.

Table 7. Low-Carbon Technologies Used in Scenarios

Low-Carbon Technologies Used in Scenarios	Short Description
N₂O Catalytic Abatement System Installation/Renovation	The technology capable of capturing at least 95% of N ₂ O emissions during nitric acid production is currently available. If installed in all facilities, it will significantly reduce emissions in the sector.
Green Ammonia	Leveraging renewable energy-powered electrolysis can phase out natural gas consumption as a raw material, considerably decreasing the sector's total emissions.
Blue Ammonia	Ammonia production processes starting with natural gas, where the by-product CO ₂ is captured and stored.
Electrification	Transitioning to machinery and equipment powered by electricity (e.g., heat pumps) to decrease direct fossil fuel consumption. As the emission factor from electrical energy use decreases, so will the emissions from the sector's energy use in production.
Energy Efficiency	Substituting energy-inefficient machinery with up-to-date technology and more efficient use of waste heat in facilities will reduce the sector's total energy needs and production-related emissions.
Grid Electricity Emission Factor	A decrease in the national grid's electricity emission factor, alongside renewable energy investments in the coming years, will further reduce the sector's emissions from electrical energy use.
On site Renewable Energy Production/ Consumption by Producers	Investing in renewable energy for the consumption of produced energy in fertiliser production can lower the emission factor due to electricity consumption.
Fertiliser Use Efficiency	Reducing the total amount of fertiliser use in Türkiye will contribute to lowering production-related emissions by decreasing the total production required.
Organic/ OM Fertiliser Consumption	Reducing the total amount of chemical raw materials needed in fertiliser production will lower emissions from the production of these raw materials.
Hydrogen Injection to Pipeline	Implementing strategies to reduce emissions from heat energy production, such as injecting hydrogen into the natural gas distribution network.

3.4 Carbon Scenarios Through 2053

Table 8. Low-Carbon Scenarios Through 2053

Reference Scenarios	
WoM	
Definition	This scenario continues the Current Practices with no mitigation measures implemented
Applied mitigation actions/policies	Continuation of existing conditions without new measures or technologies, keeping current import/export rates of raw materials and fertiliser types constant from 2020-2053.
WoMdom	
Definition	This scenario continues the Current Practices with no mitigation measures implemented
Applied mitigation actions/policies	All required raw materials and fertiliser types are produced in Türkiye.
SPS (Stated Policy Scenario)	
Definition	Takes into account measures already in effect or being implemented to achieve announced energy and climate policy goals
Applied mitigation actions/policies	Grid EF reduction from 0.45 to 0.16 tCO ₂ /MWh.
	No change in industry energy intensity.
	Mixing 12% H ₂ into the natural gas network by 2053.
	0.2% annual improvement in nitrogen use efficiency.
Low Carbon Pathway Scenarios	
LCP	
Definition	An ambitious but feasible net-zero scenario representing the most favorable pathway, in parallel with Türkiye's NDC and 2053 Net Zero targets
Applied mitigation actions/policies	N ₂ O catalytic abatement system investments, with 95% removal efficiency, active in all Nitric Acid facilities between 2025-2028.
	Blue ammonia penetration starting in 2030, reaching 25% by 2040 and 6% by 2050.
	Green ammonia penetration starting after 2035, reaching 94% by 2053.
	Penetration of Middle Temperature Heat Pumps for electrification starting after 2030.
	10% improvement in energy intensity by 2030 and 20% by 2053 for energy efficiency.

	On-site renewable energy (electricity) generation and consumption meeting 50% of total needs in 2030 and 80% in 2053, with the residual amount supplied by the grid.
	Grid EF reduction in line with the National Energy Plan (0.45 to 0.16 tCO ₂ /MWh).
	0.2%/year improvement in fertiliser use efficiency to reach 50.8% by 2030 and 52.8% by 2053.
	Organic fertiliser production reaching 1.6 million tons in 2053.
	Hydrogen injection to the natural gas distribution system at 12% by volume in 2053.

LCPdom

Definition	An ambitious but feasible net-zero scenario representing the most favorable pathway, in parallel with Türkiye's NDC and 2053 Net Zero targets
Applied mitigation actions/policies	All required raw materials and fertiliser types produced in Türkiye, with mitigation actions/policies the same as in the LCP scenario.

Frontier Technologies Scenario

Definition	Most ambitious scenario aimed at achieving low emissions as quickly as possible by utilizing all policy and investment levers, focusing on new investments based on the lowest emissions technologies, resulting in an extremely rapid adoption of green ammonia and renewable energy systems (RES).
Applied mitigation actions/policies	N₂O catalytic abatement system investments (with 95% removal efficiency) to be active in all Nitric Acid facilities between 2025-2028. Blue ammonia penetration begins in 2030 at 5%, reaching 3% by 2050. Green ammonia penetration starts after 2030, reaching 97% by 2053. Electrification penetration starts after 2026 for Middle Temperature Heat Pumps. Energy efficiency improvement of 15% by 2030 and 30% by 2053. On-site renewable energy (electricity) generation and consumption to meet 100% of total needs by 2030. Fertiliser use efficiency improvement of 0.2%/year to reach 51.6% by 2030 and 57.8% by 2053. Organic fertiliser production to reach 3.2 million tons in 2053. Hydrogen injection into the natural gas distribution system at 12% by volume in 2053.

3.5 Assumptions Used in Model

The key assumptions used in the model study are provided below.

- The WoM scenario assumes constant current demand shares of fertilisers throughout the planning horizon.
- The LCP, LCPdom, and SPS scenarios incorporate an annual incremental 1% substitution in demand shares, while the FTS scenario assumes a 1.5% rate.
- Annual full utilization efficiency improvement is set at 0.2% for SPS, 0.5% for LCP scenarios, and 0.8% for the FTS scenario.
- The model enforces constraints on the supply-demand balance of total N, P, and K equivalents of fertilisers.
- Renewable power integrated into the fertiliser plants is assumed to be solar PVs, with the capacity factor estimated by historical hourly data.
- The COP value of heat pumps is assumed to be “2”.
- The model differentiates key raw materials, requiring dedicated equations and constraints due to their emission, production, and trade characteristics.
- Four main raw materials are identified: ammonia, phosphate rock, nitric acid, and sulfuric acid. In all scenarios, import rates of these materials are assumed constant from 2020 to 2053.
- The import shares of fertilisers are assumed constant except in WoMdom and LCPdom scenarios, where they are adjusted to ensure all demand is met by domestic production by 2053.
- CAPEX, OPEX, emission, and input-output parameters are compiled from three main sources: the MPP ammonia model, data from domestic companies, and official statistics.
- The penetration time and level of green/blue ammonia, N₂O catalytic abatement system installation/renovation, hydrogen injection to the pipeline, electrification, etc., are implemented as represented in **Figure 22** and **Figure 23**.

3.6 Investment Needs to Achieve Decarbonisation

Total investment needs have been calculated for all low carbon scenarios (**Table 9**). By 2053, the total investment requirement is estimated at 5.26 billion USD for the LCP scenario and 7.66 billion USD for the FTS scenario. The LCPdom scenario, which assumes that all demand is met through production in Türkiye, requires an investment of around 16.6 billion USD.

Table 9. Investment Needs for All Scenarios

CAPEX (Million USD)	LCP	LCPdom	FTS
N ₂ O Abatement	13	13	13
Green Ammonia	750	4,842	634
Blue Ammonia	105	357	20
Energy Efficiency	288	336	512
Heat Pump	1,322	3,370	1,369
Organic/OM	1,228	1,221	3,053
Renewable Energy	1,559	6,456	2,055
Total	5,265	16,595	7,655

In the LCP scenario, the major investment item will be renewable energy, followed by heat pump investments and Organic/OM fertiliser investments, with green ammonia ranking as the fourth major investment item. In comparison, the FTS scenario demands more investment in Organic/OM production capacity and higher renewable energy investments. The LCPdom scenario will necessitate significantly higher fertiliser production in Türkiye, leading to greater energy and electrification investment needs. The major differences in investment items across each scenario are illustrated in **Figure 19** below.

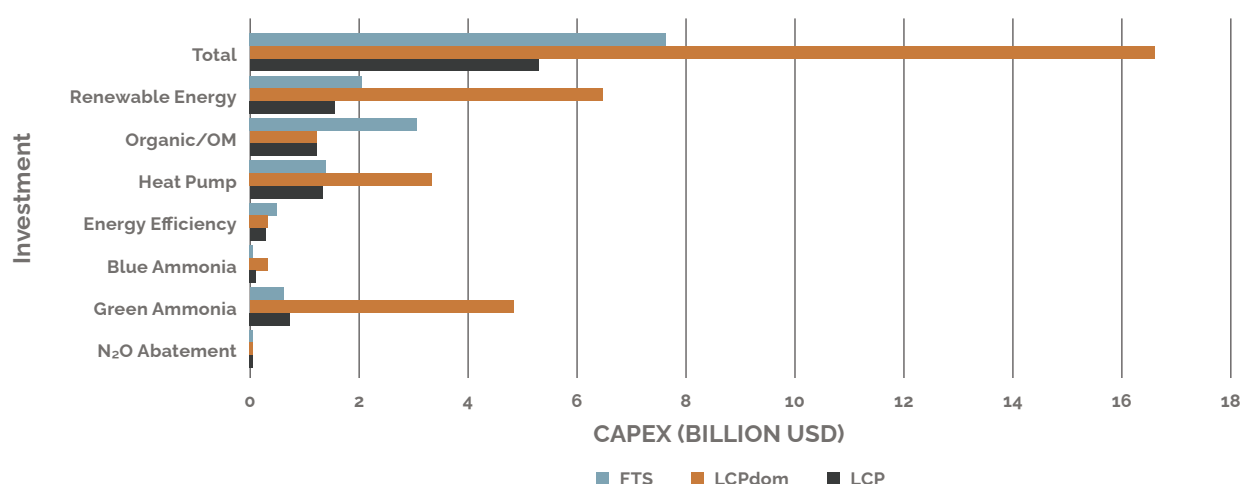


Figure 19. CAPEX (USD) Requirement for Each Mitigation Measure

Figure 20 and **Figure 21** display the CAPEX values per ton of CO₂ reduction for the LCP and FTS scenarios. In these figures, the cumulative emission reduction values that each investment/mitigation measure will provide from 2020 to 2053 are taken into consideration. Organic/OM fertiliser production and fertiliser use efficiency are grouped under the same investment item. Additionally, the investment values for green and blue ammonia and their collective contribution to total emission reduction are presented together.

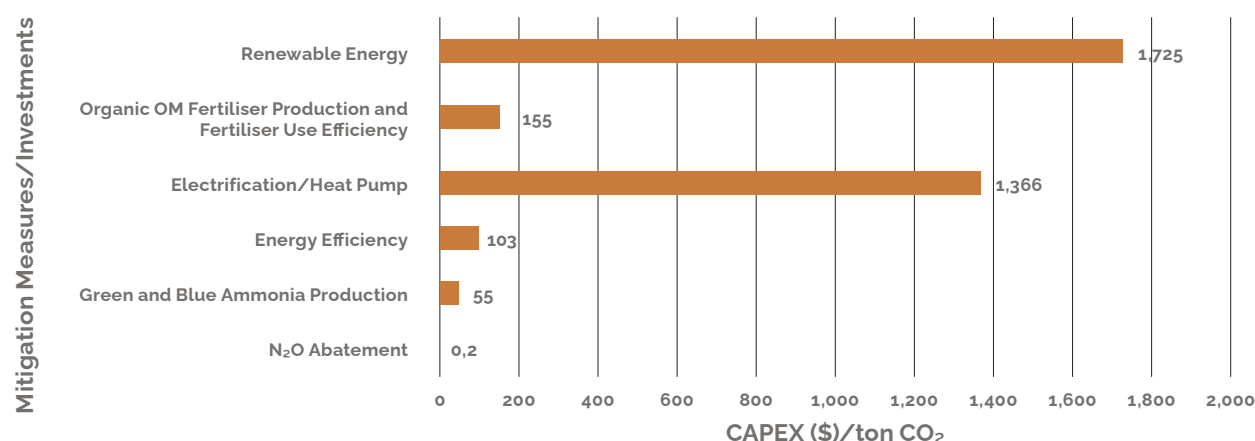


Figure 20. CAPEX (USD) per ton of CO₂ Reduction in the LCP Scenario

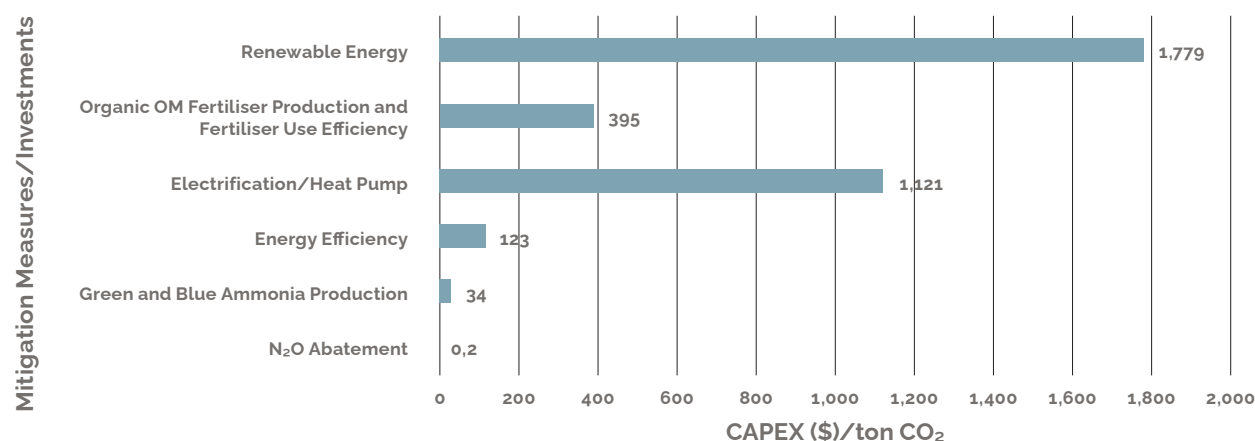


Figure 21. CAPEX (USD) per ton of CO₂ Reduction in the FTS Scenario



4. The Roadmap for Decarbonization of the Turkish Fertiliser Sector

Recommendations in the LCPs have been formulated considering national policies, sector trends, and technological advancements. Factors such as access to technology, market readiness, the current state and adaptive capacity of plants, and the time required for behaviour change in the value chain have been taken into account in the timing of these recommendations.

- Short-term recommendations mainly involve policy changes and available technologies that do not require significant investment. These include shifting to organic/OM fertilisers, N₂O abatement systems, improving fertiliser use efficiency, and policy/legislation changes to be implemented by 2025.
- Medium-term recommendations consist of measures requiring investment, dependent on the realization of new policies/legislation or needing time for development. This includes RES, policies regarding ETS implementation, and incentives for grey ammonia.
- Long-term recommendations are recommended for implementation over a longer period due to the maturity and dissemination of technology and cost reduction factors. These measures include green/blue ammonia, electrification, and hydrogen blending into the existing natural gas grid.

The timeline for implementation is developed considering national plans/documents such as the National Energy Plan, 12th Development Plan, Hydrogen Strategy and Roadmap of Türkiye, Draft Climate Law, and Draft ETS legislation. International studies like the Ammonia Technology Roadmap of the International Energy Agency, Making Net-Zero Ammonia Possible study of MPP, and main studies published by IFA, JRC, and the International Renewable Energy Agency have also been referenced. **Table 10** below provides a prospective timeline for implementing the measures in the LCP scenario. Renewable energy, N₂O abatement, energy efficiency, fertiliser use efficiency and increasing use of organic material in fertiliser production are identified as measures which can be implemented in short term and can lead to quick and bulk emission reduction. Mitigation measures such as blue/green ammonia, electrification and hydrogen injection to the grid are expected to start in medium term and increase penetration rate in long term.

The implementation penetration rates of mitigation measures recommended for the LCP scenario and FTS from 2020 to 2053 are detailed in **Figure 22** and **Figure 23**. The most impactful measure for emission reduction is the N₂O abatement systems, proposed to be implemented at a 100% rate by 2028, with an annual penetration rate of 25% between 2025-2028 in both LCP and FTS scenarios. Renewable energy consumption, electrification, and green ammonia

production are expected to reach penetration rates of 80-90% in 2053. The penetration rate for each mitigation action is conservatively designed, considering the technological maturity level.

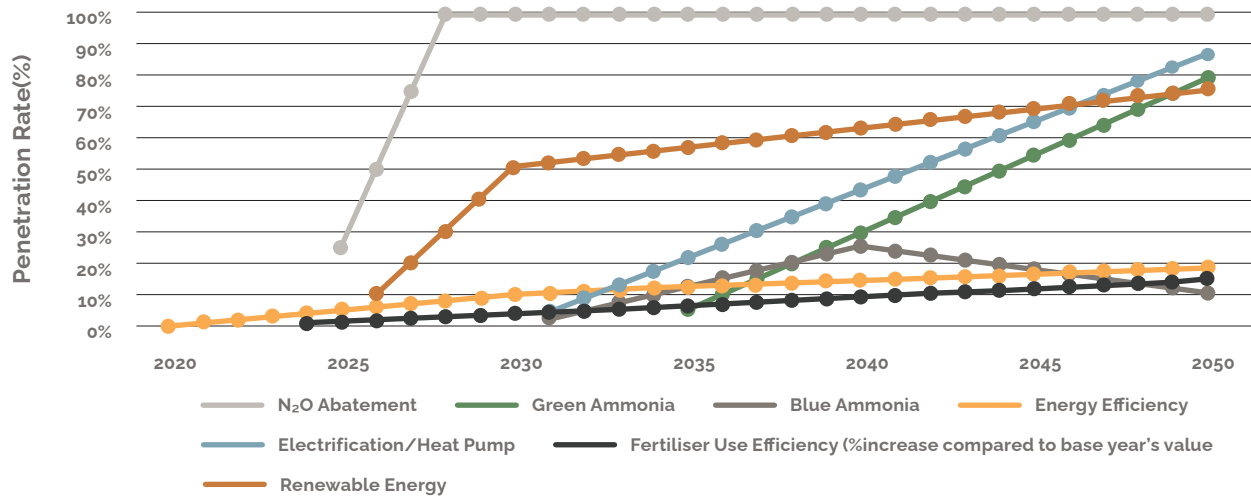


Figure 22. Penetration Rates of Mitigation Measures Under LCP Scenario

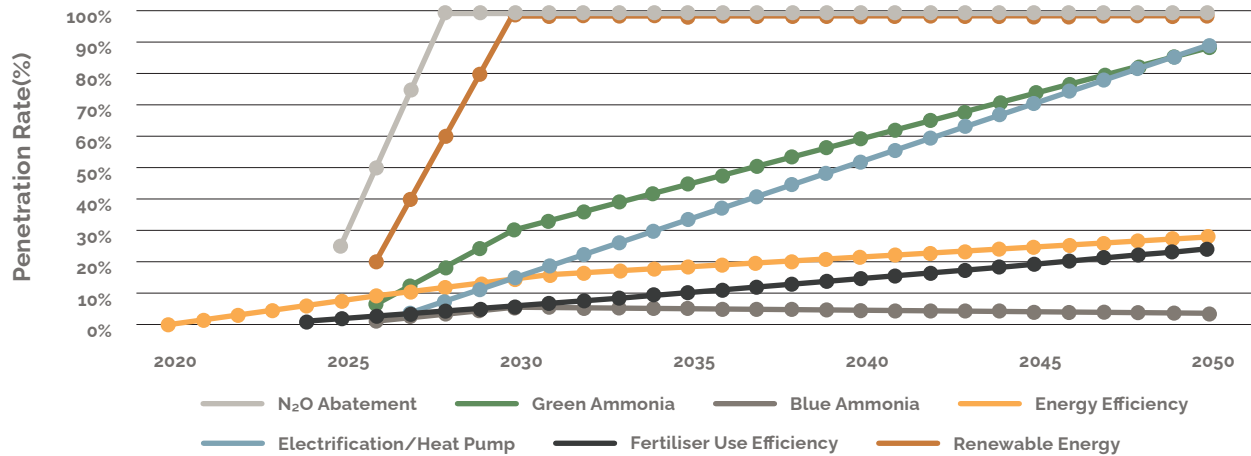


Figure 23. Penetration Rates of Mitigation Measures Under FTS

Table 10. Application Time Interval of Mitigation Measures/Technologies in LCP Scenario

Low-Carbon Technologies Used in Scenarios	Phase 1 (2024-2025)	Phase 2 (2026-2038)	Phase 3 (2039-2053)
N ₂ O Catalytic Abatement System Installation/Renovation	●	●	
Green Ammonia		●	●
Blue Ammonia		●	●
Electrification		●	●
Energy Efficiency	●	●	●
Grid Electricity Emission Factor	●	●	●
On site Renewable Energy Production/Consumption by Producers		●	●
Fertiliser Use Efficiency	●	●	●
Organic/OM Fertiliser Consumption	●	●	●
Hydrogen Injection to Pipeline		●	

Policy recommendations developed to support the low carbon pathway are summarised in tables below for four main policy axis and recommended implementation timeline. Policy type, relevant stakeholders, potential bottlenecks and coordinating institutions also included in full version of the report.

Policy and Legislation	Application Time/Interval		
	Phase 1 (2024 – 2025)	Phase 2 (2026 – 2038)	Phase 3 (2039 – 2053)
Conducting an integrated fertiliser-agriculture-food impact assessment by evaluating the impacts of the planned pilot ETS and CBAM in Türkiye on fertiliser prices, raw material imports, fertiliser production/consumption, exports, and agricultural activities.	●	●	
Taking into account sector-based assessments (current status of facilities, technology and products produced) when making free allocations under the ETS.	●	●	
Encouraging domestic production of catalysts used in the fertiliser sector		●	
Promoting the fertiliser sector through financial and banking instruments to accelerate the diffusion of low emission technologies.	●	●	●
Supporting the production/consumption of organic, slow-release, OM and microbial fertiliser, supporting biogas/landfill gas plants to establish fertiliser/compost plants.	●	●	
Developing incentives (within the scope of YEKDEM and Agricultural Subsidies) for the conversion of liquid and solid wastes of biogas plants into solid/liquid fertiliser in accordance with the legislation.	●		
Supporting cost-reducing R&D studies in fertiliser sector in order to accelerate the widespread use of medium and high temperature heat pumps in industry.	●	●	
Supporting R&D projects to reduce the costs of methane pyrolysis technologies, electrolyser costs and seawater desalination technologies in order to reduce the costs of Green Hydrogen and Green Ammonia production, which are the main inputs of the fertiliser sector.	●	●	
After 2030, providing incentives only for blue and green ammonia projects and not issuing investment incentive certificates for new grey ammonia plants.		●	

Policy and Legislation	Application Time/Interval		
	Phase 1 (2024 – 2025)	Phase 2 (2026 – 2038)	Phase 3 (2039 – 2053)
Including a strategy and action for fertiliser production and consumption under the agriculture sector within the scope of the preparation of the National Action Plan for Sustainable Consumption and Production (MoEUCC).	●	●	
Fertiliser sector inputs and outputs to be reflected in the Circular Economy Action Plan.	●	●	
Working with NACAG (The Nitric Acid Climate Action Group) on the reduction of emissions from nitric acid production, evaluation of technical and financial support possibilities.	●	●	
Supporting the establishment of NGOs representing all producers in the fertiliser sector.	●		
Fertiliser companies cooperate with relevant organisations to raise awareness of women, youth and disadvantaged groups on global climate change and food safety issues.	●		

Process Improvements and Technological Transformation	Application Time/Interval		
	Phase 1 (2024 – 2025)	Phase 2 (2026 – 2038)	Phase 3 (2039 – 2053)
Supporting the fertiliser sector's R&D studies and investments in CCUS technologies.	●	●	
Developing Green and Blue Hydrogen and Ammonia technologies in the fertiliser sector and encouraging their investments.	●	●	●
Increasing the effectiveness of incentives to improve the energy efficiency performance of existing fertiliser plants (waste heat utilisation, modernisation, etc.).	●	●	

Process Improvements and Technological Transformation	Application Time/Interval		
	Phase 1 (2024 – 2025)	Phase 2 (2026 – 2038)	Phase 3 (2039 – 2053)
Prioritisation of the fertiliser sector, which is one of the priority sectors within the scope of ETS/CBAM, in capacity allocation for energy self-consumption.	●	●	
Facilitating access to Green Transformation in Industry financial incentive mechanisms for the fertiliser sector.	●	●	●

Sustainable and Circular Supply Chain Management	Application Time/Interval		
	Phase 1 (2024 – 2025)	Phase 2 (2026 – 2038)	Phase 3 (2039 – 2053)
Taking into account the cross-compliance rules (conditionality) and eco schemes in the EU Common Agricultural Policy, increasing support for good agricultural practices and organic agriculture, implementing support for carbon harvesting and emission-reducing practices in agricultural production.	●	●	
Expanding supports for increasing the use of organic wastes in fertiliser production (domestic organic wastes, animal wastes, natural resources, etc.) in order to reduce the use of synthetic raw materials.	●	●	
Inventory and mapping of domestic, animal, etc. wastes, biogas facilities and other natural resources that can be used in organic/OM fertiliser production.	●	●	

Employment and Capacity Building	Application Time/Interval		
	Phase 1 (2024 – 2025)	Phase 2 (2026 – 2038)	Phase 3 (2039 – 2053)
Ensuring transition processes for employment in the fertiliser sector, especially for women, youth and disadvantaged groups within the scope of Fair Transition Activities.			
Coordination of efforts to determine the new qualification and skill requirements that the green transformation process in the fertiliser sector will bring to the workforce demand and to train a workforce with new qualifications.			



5. CONCLUSION

Türkiye's fertiliser sector is heavily reliant on imports, with around 90% dependency for primary raw materials and intermediary inputs. While emissions from fertiliser production may seem low compared to other emission-intensive sectors, it's important to recognize that a significant portion of the value chain emissions is attributable to embedded emissions in imported raw materials upstream and during the use of fertilisers in agricultural production.

The sector's high dependency on natural gas and imported ammonia, combined with the advanced age of existing fertiliser plants (over 45 years old) in Türkiye, heightens the vulnerability of both the manufacturing and agricultural sectors.

As a net consumer with limited fertiliser exports to the EU, Türkiye's fertiliser sector's overall risk to the CBAM appears relatively low compared to other sectors. However, some manufacturers with significant exports to EU countries are more vulnerable to CBAM impacts. A greater risk may emerge from the planned ETS in Türkiye, given the emission-intensive production of nitric acid and the high energy intensity of inefficient local plants.

Achieving Türkiye's 2053 net-zero goals and decarbonizing the sector will not only reduce GHG emissions but also help diminish dependency on imported natural gas and secondary products. Thus, decarbonizing Türkiye's fertiliser sector will enhance the resilience of the fertiliser manufacturers, as well as the agricultural and food sectors. Implementation of measures will also bring other benefits, such as better valuation of liquid/solid wastes, biogas/organic wastes, improved nutrient use efficiency, and utilization of carbon from other sectors.

Realization of the decarbonization roadmap requires coordinated co-implementation of policy, finance, technology, R&D, and market-based solutions, involving all stakeholders. It necessitates behavioural change and the development of skills to create and adopt low-carbon solutions. This roadmap study demonstrates that significant and rapid decarbonization of the sector can be achieved in the short to medium term. If supported by other measures, fertiliser production can transition to a net-negative emission sector. Otherwise, fertiliser production, along with agricultural and food production, will continue to depend on fossil fuels.

In the absence of any effort for reducing GHG emissions from fertiliser production, fertiliser production sector's cumulative emissions is estimated 124 million tons in WoM scenario and 188 tons in WoMdom scenario for 2020-2053 period. Modelling studies have shown that implementation of measures defined in LCP scenario can result in 91.4 million tons of GHG emissions compared to WoM scenario and LCPdom scenario can enable almost 150 million tons of GHG emissions compared to WoMdom scenario in the same period. In all emission reduction scenarios, most of the emission reduction will arise from N₂O abatement systems

followed by green/blue ammonia and fertiliser use efficiency. In terms of cost effectiveness of the emission reduction, N₂O abatement will have the lowest capital investment (USD/t CO₂ reduction) with around 0.2 USD/tCO₂ and green ammonia will have around 3,161 USD/CO₂ reduction. Investing in low carbon technologies will not only enable emission reduction but also secure supply of input for agricultural production and provide co benefits such as reduced soil and water pollution, circular use of organic resources and improved competitiveness of agri-food industry in Türkiye.

