Long-term transformations in national pathways to net zero

SOURCES OF NON-CO_2 EMISSIONS

Measures designed to address CO_2 emissions are not sufficient to reduce non-CO_2 emissions from agriculture in national pathways to net zero. Targeted actions on non-CO_2 gases require a country-driven approach to the transformation of the agriculture sector

In national pathways to net zero, non-CO_2 emissions from the energy sector will significantly decrease in almost all countries (**Figure 12**). These reductions result from actions that drive the energy transition away from fossil fuels, primarily to reduce CO_2 emissions. Non-CO_2 emissions in the energy sector largely originate from coal mining and oil and gas extraction. Therefore, as fossil fuel production decreases, methane (CH_4) and nitrous oxide (N_2O) emissions from the energy sector will also decrease. In addition, some countries have implemented specific measures to further reduce non-CO_2 emissions from coal mining and oil and gas extraction. For example, in China, the implementation of enhanced methane recovery technologies, stricter regulations, and policies that prioritize the early closure of gas-rich coal mines are important measures to reduce non-CO_2 emissions from the energy sector (see the following case study on the reduction of non-CO_2 emissions from energy and agriculture).

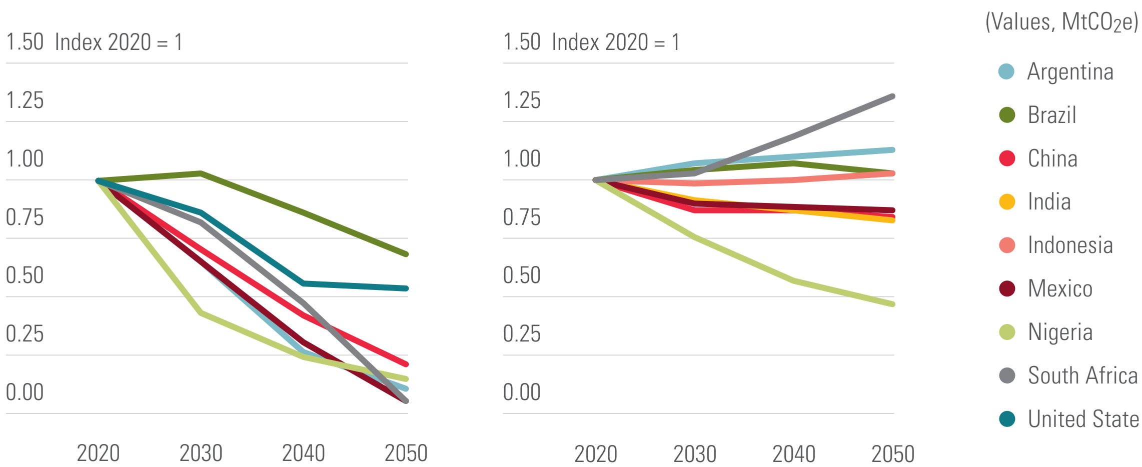
In contrast, CH_4 and N_2O emissions from agriculture, which accounted for between 7% and 30% of total GHG emissions in 2020 in the countries studied, show a very different pattern by 2050. Although trends vary by country, it is noteworthy that no country significantly reduces non-CO_2 emissions from agriculture: in some countries these emissions increase, while in others they decrease only marginally (**Figure 12**). This trend can be attributed to the fact that the sources of these emissions differ from CO_2 sources and are therefore not addressed by measures targeting CO_2 emissions, which constitute the core of the analysis presented in this study. The main sources of methane include enteric fermentation from ruminant digestion and manure management from livestock, as well as rice cultivation, while the main sources of nitrous oxide include livestock manure and fertilizer use.

CASE STUDY – CHINA

The transition away from fossil fuels is expected to significantly reduce methane and nitrous oxide emissions from the energy sector, but non-CO_2 emissions from agriculture require targeted mitigation action

The coal sector is responsible for approximately 85% of China's energy-related methane emissions and 45% of its anthropogenic methane emissions. Achieving carbon neutrality will require a peak in coal consumption and production followed by a rapid decline, which is expected to reduce energy methane emissions by about 90% by 2060. However, phasing out coal will result in the closure of more than 3,000 coal mines, and abandoned coal mines represent a methane emission source that is not fully accounted for in current inventories. To address this, implementing enhanced methane recovery technologies, stricter regula-

Figure 12. Indexed Non-CO_2 emissions from energy and agriculture



tions, and policies that prioritize the early closure of gas-rich coal mines will be critical for effectively controlling and mitigating methane emissions from these abandoned mines. China's case highlights the dual impact of energy transition policies: while they offer substantial benefits in reducing methane emissions, they also cause unintended consequences—such as increased methane emissions from abandoned coal mines—and so must be carefully managed. Thus, both carbon dioxide and other GHG emissions must be addressed holistically to maintain the environmental integrity of national policies.

The agricultural sector remains one of the most challenging sectors to decarbonize due to a lack of advanced mitigation technologies, limited capacity, and the difficulty of accurately measuring emission reductions cost effectively—especially in a sector dominated by small-scale farmers. Even in GHG neutrality scenarios, over 80% of residual emissions are expected to originate from agriculture, primarily as methane and nitrous oxide. While improving water management in rice cultivation and optimizing nutrient management in animal husbandry theoretically offer significant mitigation potential, realizing these reductions is challenging due to the need to modify entrenched practices among millions of small-scale farmers. As a result, effective policy incentives and innovative solutions are essential for turning these theoretical mitigation potentials into reality.

To demonstrate how non-CO_2 in the energy sector are reduced by actions targeting CO_2 emissions, a scenario that assumes that no actions specifically target non- CO_2 emissions are pursued results in an 85% reduction in non-CO_2 emissions from energy between 2020 and 2070. In comparison, a scenario that aims to mitigate all GHGs leads to a 94% reduction in non-CO_2 emissions from energy. The same is not true for agriculture, however. The scenario targeting CO_2 emissions achieves only an 8% reduction of non-CO_2 emissions from agriculture by 2070, while the scenario targeting all GHGs achieves a 21% reduction in non-CO_2 emissions from this sector. The still limited reduction of non-CO_2 from agriculture in the latter scenario illustrates the challenges inherent in reducing emissions from agriculture.

Some countries, however, make assumptions about measures that specifically target the reduction of non-CO_2 emissions from agriculture, primarily by reducing the emission intensity of agricultural output. For instance, Brazil assumes that the carcass weight of cattle will increase by 30% by 2050, making beef production less emission-intensive, and that fertilizer application will decrease from the current average of 60 kg/ha. The case study on Nigeria illustrates how non-CO_2 emissions in agriculture are projected to fall from 75 $MtCO_2eq$/yr in 2020 to 36 $MtCO_2eq$/yr in 2050.

CASE STUDY – NIGERIA

Enabling Strategies to reduce non-CO_2 emissions from agriculture

The agriculture sector accounted for nearly 38% of total employment in Nigeria in 2022.[21]

Specific agricultural activities contributing to GHG emissions include enteric fermentation from domestic livestock, livestock manure management, rice cultivation, agricultural soil management, field burning of agricultural residues, as well as liming, urea fertilization, and on-farm energy use. Enteric fermentation accounts for nearly half of these emissions alone.

The DDS indicates that Nigeria is projected to reduce non-CO_2 emissions from 75 $MtCO_2eq$ in 2020 to 36 $MtCO_2eq$ in 2050.[22] This 52% reduction is achieved through a combination of strategies that simultaneously target the achievement of key Sustainable Development Goals (SDGs), including poverty eradication, zero hunger, improved health and well-being, and the promotion of decent work and economic growth. The key strategies are:

Precision Agriculture and Urban Farming

Prioritize the use of technology and data-driven approaches to optimize resource use, reduce waste, and improve the efficiency of agricultural practices in rural and urban environments.

21 https://www.statista.com/statistics/1288871/agriculture-sector-share-in-employment-in-nigeria

22 Nigeria's Deep Decarbonization Pathways Report (2024): https://cccd.funai.edu.ng/nigeria-deep-decarbonization-pathways-ddp-for-nigerias-low-emission-development-up-to-2060-report/

Improved Livestock Management
Implement targeted and stringent policies promoting rotational grazing and other sustainable livestock management practices to reduce emissions from enteric fermentation and manure.
Integrated Water Resource Management
Adopt practices that improve water use efficiency, reduce erosion, and protect water quality in agricultural and forestry activities.
Supportive Policies and Incentives
Establish policies that incentivize climate-smart practices, including financial incentives, subsidies, and regulations that promote sustainable land use.
Knowledge Transfer and Capacity Building
Provide training and capacity-building programmes to farmers, foresters, and other stakeholders to enhance their understanding and adoption of climate-smart practices.

Furthermore, the technical mitigation potential in agriculture from actions that improve the GHG efficiency of agricultural output is limited, indicating that there are upper limits to the emission reductions achievable while ensuring global food security. For instance, emissions from enteric fermentation from livestock can be reduced by approximately 30% if cattle diets are modified but significantly deeper reductions of emissions from this source are not possible with today's knowledge..[23] A systemic transformation of agriculture, including shifts in demand, production methods, and increased diversity of crops and livestock provides a possible solution for achieving deeper reductions of non-CO_2 emissions from agriculture. However, there are no options that exist to reduce agricultural non-CO_2 emissions to near zero. This suggests that negative emissions from LULUCF are needed to compensate for hard-to-abate emissions in agriculture. Furthermore, many countries are hesitant to pursue transformative actions in agriculture due to concerns of negatively impacting rural livelihoods, food security, or export revenues from the agri-business sector. There is a need for further guidance on how to align reductions in non-CO_2 emissions from agriculture with positive outcomes for rural livelihoods and food security (Case study on China for an example).

Indeed, agriculture, and particularly primary agricultural production, is the predominant employer in many low-income countries, providing employment to 1.23 billion people, and further contributes to the livelihoods of 3.83 billion people worldwide.[24] Furthermore, the sector plays a vital role in ensuring global food security and developing food value chains that are resilient to climate change. A comprehensive strategy for transforming the sector that clearly defines these objectives is essential to fully integrate the agricultural sector into national pathways to net zero. The recent UAE Declaration on Sustainable Agriculture, Resilient Food Systems and Climate Action demonstrates the commitment of 160 states to move in this direction. This intent must now be translated into long-term strategies and sectoral policies to achieve tangible results.

23 Searchinger, T. (2019). Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. World Resource Institute, Washington DC. Available online: https://research.wri.org/wrr-food

24 Davis, B., Mane, E., Gurbuzer, L.Y., Caivano, G., Piedrahita, N., Schneider, K., Azhar, N., Benali, M., Chaudhary, N., Rivera, R., Ambikapathi, R. and Winters, P. 2023. Estimating global and country-level employment in agrifood systems. FAO Statistics Working Paper Series, No. 23-34. Rome, FAO. https://doi.org/10.4060/cc4337en