REDUCING EMISSIONS FROM FERTILIZER USE

EXECUTIVE SUMMARY

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ifa
INTERNATIONAL FERTILIZER ASSOCIATION

Helping to feed the world sustainably

SYSTEMIQ

ABOUT THIS DOCUMENT

This document is a publication from Systemiq, commissioned by the International Fertilizer Association (IFA) and funded by ten IFA members.

Systemiq is a systems change company that partners with business, finance, policymakers and civil society to make economic systems truly sustainable.

IFA is the only global fertilizer association with 400+ members and a mission to promote the efficient and responsible production, distribution and use of plant nutrients. This mission plays a critical role in helping to feed the world sustainably.

The IFA members who sponsored this report are:

- Platinum sponsors – CF Industries, Nutrien, OCP, Qafco, Sabic Agri-Nutrients and Yara
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The report was prepared by the Systemiq team, Jeremy Oppenheim, Rupert Simons, Thomas Hegarty, and Paddy Ellen, in close consultation with and technical input from IFA and the sponsoring companies, as well as discussions with academia and civil society. The sponsoring companies and IFA endorse the general thrust of the arguments made in the publication but should not be taken as agreeing with every finding or recommendation.

Any questions may be sent to ifa@fertilizer.org.

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FOREWORD

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Founder and Senior Partner, Systemiq

Alzbeta Klein

CEO/Director General, International Fertilizer Association

The world is facing a food security crisis as a result of the war in Ukraine. This comes on top of the continued challenge of transforming how we grow food to meet climate, biodiversity and other environmental goals. These challenges are urgent, and the fertilizer sector has a core role in delivering solutions.

The world today is not on track to keep global warming to less than 1.5°C. Reports from the World Meteorological Organization indicate that there is a high chance that we will exceed 1.5°C of heating within the next five years. This is not a long-term problem. It is a problem whose impacts we will start to feel more and more in the near future. It is a problem that requires action now – and we can do something about it.

The food sector is responsible for 31% of greenhouse gas emissions, with mineral fertilizers contributing around 6% of these. At the same time, the fertilizer sector has the products, expertise and global reach to contribute solutions, working with farmers and policymakers, scientists and other partners across agriculture.

We welcome this report on reducing emissions from fertilizer use. It will act as an important resource for fertilizer companies and other stakeholders interested in working with the industry to help feed the world sustainably.

Many of the measures to reduce emissions from fertilizer use are known, well understood and affordable. Many of the same measures also improve farmers' resilience, reducing exposure to volatile input markets. Improving nitrogen use efficiency helps the climate and the wider environment; it also helps food security and can support farm profitability. Expanding the applicability of inhibitors can bring down emissions further. Fertilizer companies can also expand efforts to advise farmers on how to sequester carbon in soils – and support those farmers who are already doing so.

Efforts across the wider food system to address food loss and waste, and shift consumer demand towards more nitrogen-fixing crops would further lower emissions from fertilizer use and increase end-to-end resource productivity.

Delivering emissions reductions will require a step change in the sector's current outreach work with farmers, and in its research and development. Achieving the scale required will mean building and strengthening partnerships across the sector, up and down the distribution chain, and with food companies and retailers. It will mean changing the way crops' fertilizer needs are calculated and how farmers are advised on fertilizer use. And it will mean enhanced engagement with policymakers and standard setters to change the balance of incentives for farmers in favour of low-emission practices.

There has never been a better time for the fertilizer industry to contribute to solving both short- and longer-term crises.

ENDORSEMENTS

"I applaud the International Fertilizer Association for taking on this critical work. Farmers need support to reduce emissions from fertilizer use. For solutions to this important challenge to be durable and widely-adopted, they need to be flexible and farmer-centric, so we can help mitigate emissions, all while supporting food security. Increasing the use of enhanced efficiency fertilizers, in particular, can help reduce nitrous oxide emissions while matching crop nutrient requirements."

John Kerry
U.S. Special Presidential Envoy for Climate

"The World Resources Institute is focused on transitioning the food system to produce enough food for everyone while staying within a 1.5°C climate budget and protecting nature. This report highlights the critical role of the fertilizer industry. Two contributions stand out. First, the role of fertilizers in helping to produce more food on the same or less land. We need to close a roughly 50% food gap between what is produced today and what will be needed to feed everyone in 2050, while halting the conversion of forests by agricultural land expansion. Second, the role of fertilizer industry in increasing yields with less inputs and externalities. This requires a step-change in nitrogen use efficiency and wide-spread adoption of controlled-release fertilizers and nitrification inhibitors. To this end, I welcome the recommendation for more research on barriers and opportunities to scaling these approaches. I am delighted to see that the fertilizer industry is developing a science-based approach to decarbonize their sector, including scope 3 emissions. This is exactly the kind of leadership that is needed to help create a sustainable food future."

Janet Ranganathan
Managing Director, Strategy, Learning & Results at the World Resources Institute (WRI)

"Fertilizer companies play a very important role in how we transition to a regenerative and equitable food system which produces healthy, safe and nutritious food for all. The actions highlighted in this report provide a map for how fertilizer companies help accelerate this transition. WBCSD looks forward to supporting IFA and companies along the value chain to deliver on the critical transformations needed."

Diane Holdorf
Executive Vice President Pathways at the World Business Council for Sustainable Development (WBCSD)

Mineral fertilizers are a critical input to the global food supply chain. Availability of these essential inputs has a direct impact on the quality and quantity of food that the world produces.

Mineral fertilizer has been a key factor in boosting agricultural yields, feeding a growing population and mitigating pressure for land use change. At the same time, mineral nitrogen fertilizer use is associated with annual greenhouse gas emissions of around 0.7 billion tonnes of carbon dioxide equivalent (Gt CO_2e), alongside other forms of nitrogen pollution.

The mineral fertilizer sector is looking to address these emissions, playing its part in keeping to the Paris Agreement's 1.5°C goal, while ensuring the continued supply of fertilizers required by farmers to ensure the world's ability to feed a growing global population. Proactive efforts will also help the sector meet increasing demands for decarbonization from investors, policymakers, scientists and civil society.

The fertilizer industry is pursuing the development of a Sectoral Decarbonization Approach to enable it to set Science Based Targets for its Scope 1 and 2 emissions. This will build on existing work to decarbonize ammonia production. The purpose of this report is to examine the opportunities to reduce the industry's downstream Scope 3 emissions from fertilizer use, and the scope to support carbon removals from the atmosphere through soil carbon sequestration.

Implementing the recommendations in this report, and meeting the decarbonization challenge head-on, will help secure the long-term economic and environmental sustainability of the entire food system and create a crop nutrition sector for the future. At a time when the availability and affordability of food and fertilizer are under great pressure, it is more essential than ever to put the industry on a sustainable footing.

Increased use of mineral fertilizer and developments in the wider food system have fed the world over the past century but have led to significant greenhouse gas emissions

1. Mineral fertilizer has played a critical role in improving food security over the past century, boosting crop yields and agricultural productivity. This has helped to reduce hunger even as the global population has grown rapidly, and to contain the need for cropland expansion and associated land conversion.[a] Fertilizers are critical to addressing the UN Sustainable Development Goal 2 of reaching zero hunger. At the same time, we have seen increasing gross deforestation and expanding cropland, because of market opportunities that exceed possible yield increases on existing land or because it easier to expand cultivated land than to close yield gaps.

2. At the same time, the food system "from farm to fork" is responsible for net 17 Gt CO_2e/year,[b] 31% of human-caused greenhouse gas emissions.[1] Within this, mineral nitrogen fertilizer use is associated with around 717 Mt CO_2e/year.[c] There is considerable uncertainty around this figure given data availability, but it is similar to the total emissions from the German economy each year.[2]

3. Limiting the global temperature rise to 1.5°C[d] and achieving the United Nations' Sustainable Development Goals will require the food system, and the fertilizer sector, to change. The fertilizer sector has commissioned this report to identify ways to address emissions on-farm as a step towards this change in the food system. These emissions form part of fertilizer companies' downstream Scope 3 emissions inventory, as defined by the Greenhouse Gas Protocol.

4. The recommendations in this report build on existing activity but also require new initiatives. Farmers cannot be expected to meet the costs and burdens of cutting emissions alone. This means that the fertilizer sector needs to scale up its work with farmers, as well as with stakeholders in other parts of the food system, policymakers and standard-setters to create the right environment for better fertilizer use. This needs to happen at the same time as continuing efforts to increase yields, grow more nutritious food, improve soil health and increase soil carbon stocks.

5. Failure to act faster carries significant risks. Climate change will destabilize food production systems, increasing volatility and the financial vulnerability of fertilizer companies' customers. And the fertilizer sector is experiencing growing pressure from investors, policymakers, scientists and civil society to put in place plans to address its greenhouse gas emissions and wider environmental impact.

6. Taking voluntary action now can address these risks to the sector and cut emissions. This will allow the sector to continue to deliver its mission of feeding the world as part of the broader agri-food system, supporting farmer livelihoods and mitigating pressure for land conversion.

Many of the mechanisms to cut emissions already exist

7. Increasing nitrogen use efficiency (NUE) through best management practices is key to addressing greenhouse gas emissions from mineral fertilizer use. Mineral nitrogen fertilizer applications should synchronize nutrient supply with crop requirements and so maximize the share of nutrients taken up by the plant, thereby reducing nutrient losses to the environment.

8. NUE varies significantly across the globe. In France and the United States it is above 70%, while in China and India it is below 50%.[3] %. A realistic ambition would be to improve average global NUE in crop production from around 50% currently to 70% by 2040. This could save 190–370 Mt CO_2e in nitrous oxide emissions and 30–50 Mt of carbon dioxide in 2050, relative to a business-as-usual scenario (see Box 1).

9. The changes in practice required to improve NUE depend on local circumstances. The fertilizer sector's 4R Nutrient Stewardship programme sets out how to improve NUE by applying the right nutrient source, at the right rate, at the right time and in the right place to best meet plant needs. Farmers and nutrition advisers can use the 4R toolbox to select those practices that are most suitable to their site- and crop-specific conditions.

10. Improving NUE does not only mean optimizing nitrogen management, but also other inputs. Plants need access to the right mix of other nutrients, including phosphorus, potassium, sulphur, calcium, magnesium and micronutrients, as well as sufficient water, healthy soil and appropriate labour inputs. For example, phosphorus can improve plants' nitrogen uptake and biological nitrogen fixation, thus increasing NUE.

11. Extending the use of inhibitors and controlled-release fertilizers can further reduce nitrous oxide emissions. Urease and nitrification inhibitors slow the conversion of nitrogen fertilizer to other nitrogen compounds in the soil. Controlled-release fertilizers help match nutrient release with crop requirements. Further research and product development is needed to make these technologies more affordable, to better understand the synergies between them, and to improve understanding of wider environmental impacts. If these technologies were implemented with half of all mineral nitrogen fertilizer applied, it could cut greenhouse gas emissions by a further 100–200 Mt CO_2e in 2050, relative to a business-as-usual scenario.

12. These measures will not eliminate emissions from fertilizer use. Further reductions will depend on a wider transformation of the food system. Changing crop rotations to allow more biological nitrogen fixation could further reduce nitrogen fertilizer use, though it also requires a rebalancing of human dietary preferences and industrial processes towards increased consumption of such crops. Together, these actions could save a further 65–75 Mt CO_2e in nitrous oxide and 10–15 Mt of carbon dioxide in 2050, relative to a business-as-usual scenario. Measures to improve yield and reduce food loss and waste would also reduce emissions from fertilizer in the future.

Box 1. High level scenario for cumulative emissions reductions

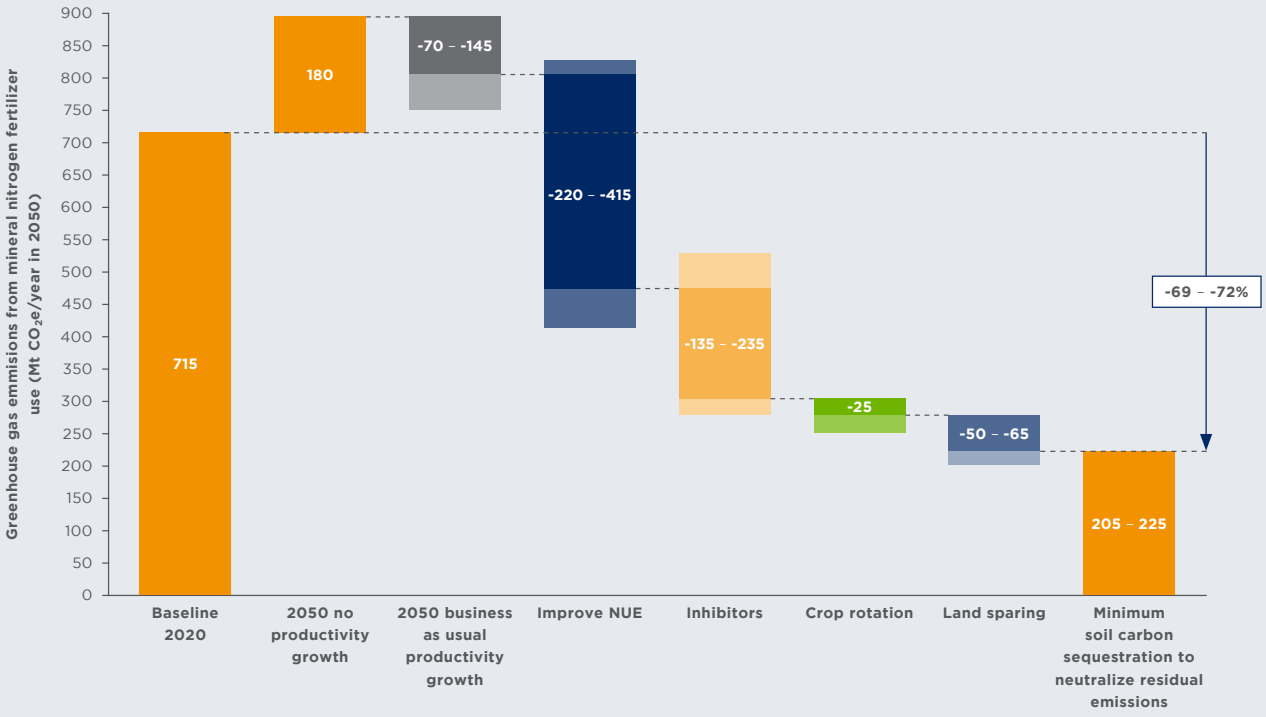
The report presents a top–down scenario for reducing greenhouse gas emissions. The aim of the scenario is to illustrate the potential of the various interventions when applied at scale over the next 30 years. It should not be taken as a forecast or statement of what should happen, nor an exhaustive list of all interventions.

Figure 1 shows the results of the analysis, constructed from three sub-scenarios with varying underlying assumptions. The first step is to create a business-as-usual scenario for 2050. In this scenario, the global population grows in line with UN projections, agricultural productivity grows 0.8%–1.1% per year, nitrogen uptake grows 0.4%–0.6% per year and the gap in mineral nitrogen application rates between Africa and the current global average closes by between one and two thirds.

Emissions-reduction measures are then applied sequentially: NUE is increased to 65%–75% through adoption of best practices; nitrification and urease inhibitors are applied to half the crop area and half the area fertilized with urea respectively, reducing direct nitrous oxide emissions on those areas by 30%–50% and the fraction of nitrogen from urea that is lost to volatilization by 30%–60%; the share of legumes in crop rotations is increased from c. 14% to 20% of global cropland; and dietary shifts allow the release of land from crop production to further reduce emissions.

Remaining emissions then need to be neutralised, potentially through supporting soil carbon sequestration.

Figure 1. High level scenario for cumulative emissions reductions



Darker bars show the core scenario, with the lighter shading showing some of the uncertainty around this result. Totals may not sum due to rounding and the way the sub-scenarios are aggregated.

Source: *Systemiq calculations*

13. Some emissions will never be eliminated. The proposed measures combined could reduce emissions to around 175–190 Mt CO_2e of nitrous oxide per year, less than 30% of current levels, and around 30 Mt of carbon dioxide, less than 40% of current levels. However, given the nature of mineral nitrogen fertilizer and microbial activity in the soil, some residual emissions will always occur. These will need to be neutralized through carbon dioxide removals from the atmosphere elsewhere for the sector to reach net zero.

14. Soil carbon sequestration is one source of carbon removals in the fertilizer sector's value chain. Estimates for the total potential carbon sequestration in soils range from 0.4–6.8 Gt CO_2/yr, with higher levels of confidence at the lower end of the scale. Maximizing this potential requires supporting farmers to adopt balanced nutrition, soil amelioration, and other best management and regenerative agricultural practices to improve soil structure and allow more biomass to be grown and incorporated into the soil. The stable carbon-to-nitrogen ratio in soil organic matter means that more nitrogen is needed to create the microbial conditions to decompose biomass to carbon. Phosphorus also plays a key role in increasing soil carbon under tropical phosphorus-fixing soils; these are widespread and have high biomass production and carbon sequestration potential.

15. The sequestration required to neutralize residual emissions from fertilizer use is equivalent to around a third of the Intergovernmental Panel on Climate Change's central estimate for cost-effective soil carbon sequestration on cropland.[4] Only removals projects that use a corporate accounting approach and are within the company's supply chain can count as insets. Inevitably, trade-offs between sequestering carbon in soils and nitrous oxide emissions need to be taken into account, as should the wider benefits from improved soil health.

There are significant emissions-saving opportunities across regions with benefits to farmers

16. Action is needed in all markets to reduce emissions and improve productivity. In China there remains excessive use of mineral nitrogen fertilizer, especially in smallholder farming systems and fruit and vegetable production. In India, fertilization is too weighted towards nitrogen with insufficient supply of other nutrients. In the United States and Europe there remains scope to push up efficiency through increased adoption of best fertilization practices, as well as additional opportunities from innovative products. In some parts of Africa and Latin America, additional mineral fertilizer will be required. Around the world there are opportunities from wider food system changes to reduce emissions further.

17. Many of these actions are cost-saving for farmers, but other barriers across the food system hold back implementation. Increasing NUE can reduce input costs and increase yields in many cases, improving farmers' financial positions. Farmers can also generate income from soil carbon sequestration through sale of credits, (including to their customers and suppliers who have set targets to reduce scope 3 emissions) strengthening financial returns from best practices, while also improving farming's wider environmental sustainability.[e]

18. However, farmers operate as part of a wider system and many face barriers to changing their business practices, often outside their control. Among the most prevalent hurdles are: lack of time, knowledge or resources to apply best practices; financial barriers to accessing required technology; constrained local labour markets; lack of agronomic advisers with appropriate credentials, professional agronomists, certified crop advisers, or other recognized agricultural credentials; lack of support among peer networks; insufficient sale price premiums associated with low emission practices or access to markets where there are; and the cost of measures such as application of inhibitors.

A roadmap to realizing these opportunities for reducing emissions

19. This report from Systemiq, commissioned by the International Fertilizer Association (IFA) sets out a roadmap of actions for the fertilizer sector. The proposals can help to realize emissions-reduction opportunities, mitigate the growing risks, and address the greenhouse gas emissions associated with the use of mineral fertilizer in the field. It will be followed by detailed work to develop a sectoral decarbonization approach and Scope 3 guidance and target-setting under the Science-Based Targets initiative, and associated company commitments. Box 2 outlines how the fertilizer sector's emissions can be divided across the different emissions scopes.

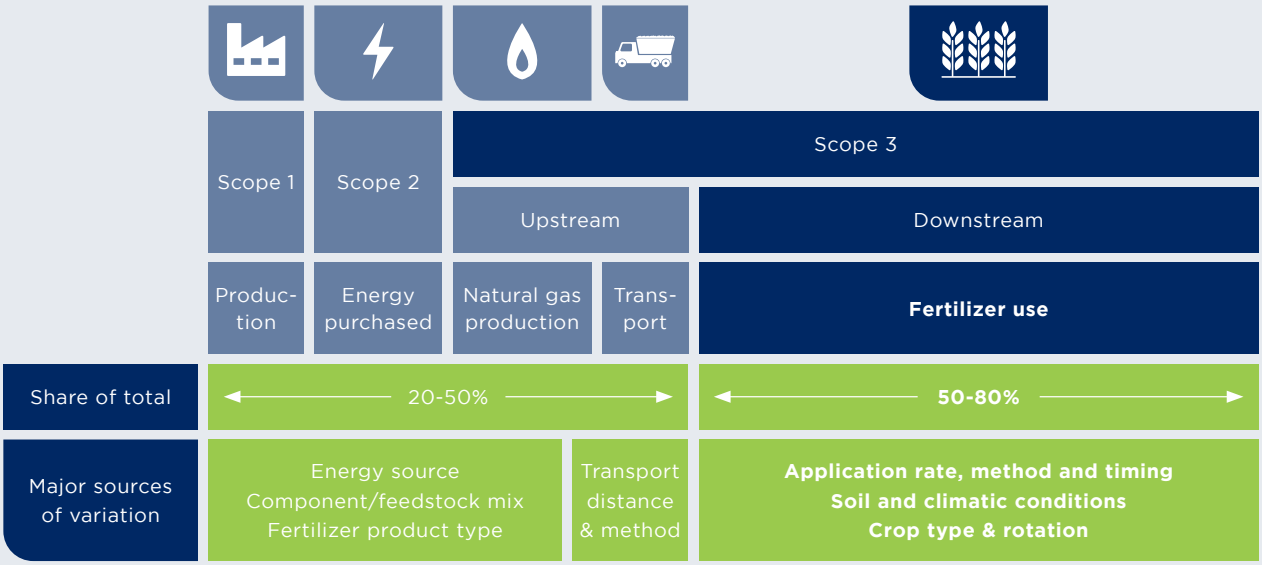
Box 2. Fertilizer sector emissions and the Greenhouse Gas Protocol

The Greenhouse Gas Protocol provides a standard against which companies can report their emissions. This provides a snapshot of performance for a given reporting period. The protocol divides corporate emissions into three "scopes":

- **Scope 1: Direct greenhouse gas emissions.** These are emissions that occur from sources that are owned or controlled by the company, such as the emissions from use of natural gas and other fossil fuels in the production of mineral nitrogen fertilizer or precursor products;
- **Scope 2: Electricity-related indirect greenhouse gas emissions.** These are the emissions associated with the production of electricity used by a company; and
- **Scope 3: Other indirect greenhouse gas emissions.** These are emissions that are consequences of the company's activities, but occur from sources not owned or controlled by the company, both upstream and downstream in the value chain, including use of the company's products.

Figure 2 shows the distribution of emissions across these different scopes for a fertilizer manufacturer. The focus of this report is downstream scope 3 emissions.

Figure 2. Fertilizer sector emissions



Source: *Nutrien, IFA, FAOSTAT, World Business Council for Sustainable Development and World Resources Institute (2004).*

20. Farmers will be key to realizing these opportunities, and solutions have to be farmer-centric. Farmers stand to benefit from many of the efficiency-improving measures through reduced input costs and improved yields. However, some enhanced products come with a price premium, and wider changes to the food system will also depend on changes to consumer preferences. The regional analysis in this report suggests that 25%–30% of the abatement measures would be cost saving for farmers.

21. Fertilizer companies acknowledge the shared responsibility to help farmers reduce emissions. This means working with farmers and distributors, policymakers, advisory bodies and other agri-food system actors to ensure that farmers have the incentives, resources, knowledge and products to implement the required measures.

22. The steps each fertilizer company can take depend on their place in the supply and value chain, and on the markets they operate in. Some fertilizer manufacturers will be better placed to

improve the product mix available. Those with retail and distribution arms can work more directly with farmers and farm advisers. All can partner with food manufacturers and retailers to share best practices and ensure farmers see a financial return on reducing emissions; and all can participate in industry-wide initiatives to address emissions. Some actions listed may not contribute to a reduction in a company's Scope 3 emissions under the current accounting frameworks but will still support the emissions reductions demanded by policy actors and others. Key actions are summarized in Figure 3 and include:

i. **Supplying tailored products, nutrient blends and enhanced fertilizer products:** Fertilizer companies should develop and promote products optimized to minimize emissions and support soil carbon sequestration, according to different climate conditions, soil types and crops. They can offer tailored mixes of nutrients, work to improve the applicability, availability and take-up of enhanced fertilizers, and ensure distribution chains have the incentives and expertise to sell these products. Companies need to address price barriers to product adoption, for instance by promoting co-benefits beyond yield;

ii. **Educating and incentivizing farm advisers, input retailers and farmers themselves to make sustainable nutrient choices:** Fertilizer companies should work with their farm advisers and agri-input retailers, and farmers directly, to develop and promote the products, tools and software they need to address emissions and sequester carbon. New incentive structures are needed in commercial relationships with advisers, retailers and farmers to ensure that emissions reductions and removals are adequately incentivized. Additionally, tools and algorithms for determining fertilizer application need to take account of emissions and soil carbon impacts;

iii. **Pursuing in-house R&D, pre-competitive collaboration for innovation, and partnerships with research institutions:** Technical and cost barriers to reducing emissions from mineral fertilizer may be overcome through increased R&D addressing:

- local barriers to farmer uptake of best practices;
- continued improvements to the affordability, effectiveness and environmental sustainability of enhanced fertilizers;
- genetic improvements to enhance plant nutrient uptake; and
- temporally and spatially scalable nitrous oxide emissions and soil carbon measurement.

Innovation can take many forms, from in-house R&D, to collaboration with start-ups, ag-tech companies and public institutions. Industry-wide initiatives such as IFA's Smart & Green platform or competitions can also play an important role. The right form of innovation depends on the problem at hand, timespan, partnering institutions' expertise, and competition considerations;

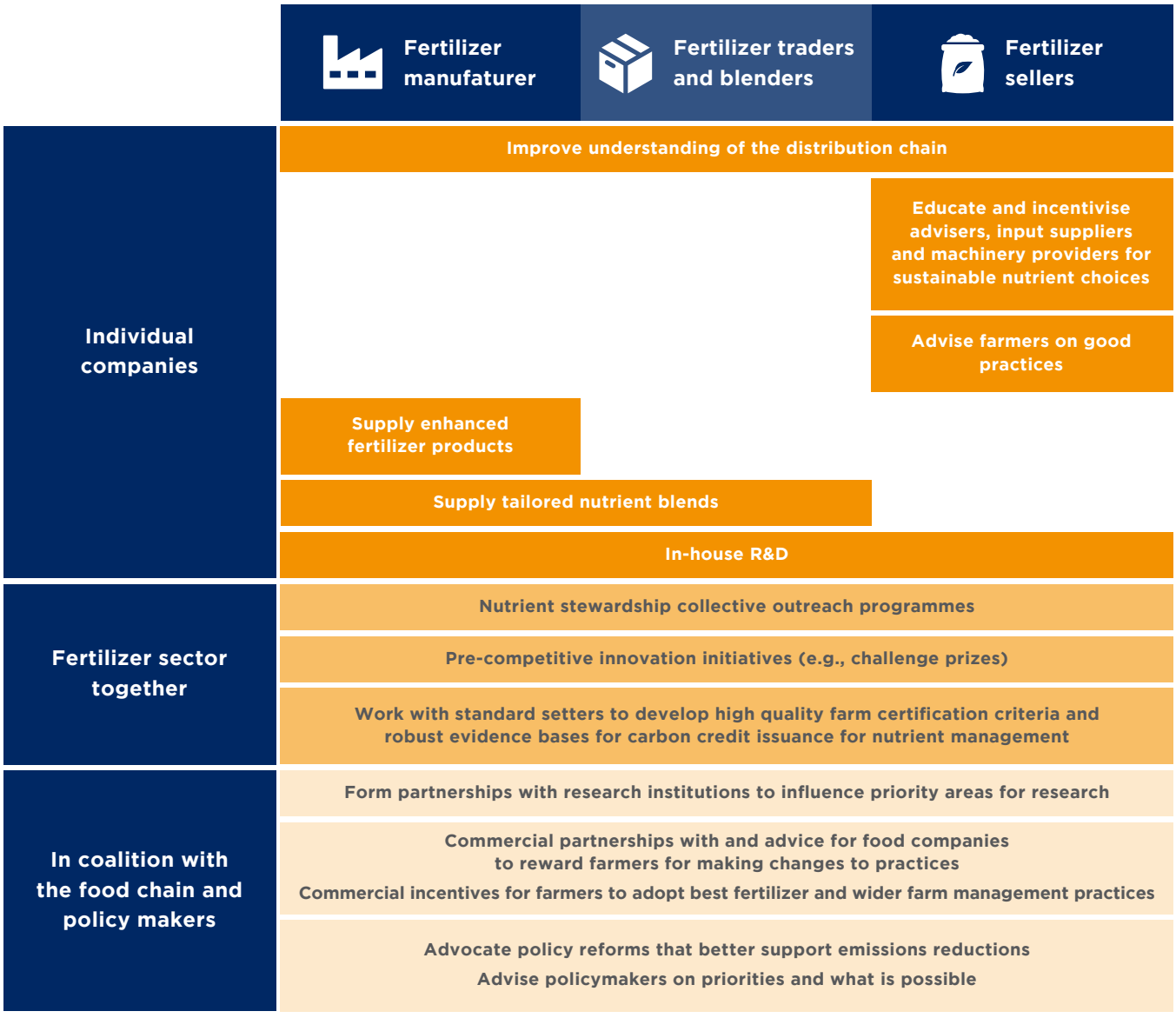
iv. **Participating in nutrient stewardship collective outreach programmes:** No single fertilizer company can reach all the farmers needed to achieve emissions targets. The sector could collectively fund outreach activities to promote emissions reduction practices and soil carbon sequestration. Activities would be tailored to each region, working in partnership with existing advisory infrastructures, and through innovative channels. This would build on the sector's existing initiatives such as 4R Nutrient Stewardship and the EU Nitrogen Expert Panel. Collaborations within the fertilizer industry could draw inspiration from advisory bodies such as the Grains Research and Development Corporation in Australia, and extended producer responsibility schemes to manage plastic and other waste;

v. **Working with standard-setters to develop high-quality farm certifications and metrics, and carbon credits for nutrient management:** Farm certification schemes are one way that farmers can unlock higher value for their products. In addition, measurement, reporting and verification bodies, and voluntary carbon market organizations set standards for soil carbon

sequestration credits. Fertilizer companies can help these standard-setters in developing robust criteria and metrics for nutrient management and fertilizer best practices. Such actions can support market transparency for the sector's emissions, develop carbon farming and ensure high-quality carbon credits;

vi. **Supporting policies consistent with emissions reductions and advising policymakers on how to incentivize and implement them:** Public policy has an important influence on farmers' business decisions. Some established policies, having achieved their initial objectives, now create perverse incentives for inefficient fertilizer use and should be reformed. In other areas, new regulations, payments or emissions pricing schemes may be needed. The appropriate levers will vary by geography and farm type, and those making reforms should carefully consider the impacts on farmers. The fertilizer sector should scale up work with policymakers to ensure they are aware of the opportunities from better fertilization and to advance policy reforms to support this goal;

Figure 3. Actions for fertilizer companies to address emissions alone and in coalition



vii. **Building relationships and coalitions for emissions reductions along the distribution chain:** The fertilizer distribution chain is complex, with mixing of products, and trading between fertilizer manufacturers, blenders and retailers. Companies need to understand how and where products are used to identify and report value-chain mitigation actions. The fertilizer sector should work to strengthen relationships and build coalitions along the distribution and value chain to improve understanding of how fertilizer is used, where there are gaps; and

viii. **Partnering with food companies and retailers to reward farmers for making changes to practices:** In-field emissions from mineral nitrogen fertilizer sit within food companies' and retailers' upstream Scope 3 inventories. Food companies can create a commercial motivation for farmers to address emissions by setting procurement standards or other incentives to foster positive climate action. Enforcing these can be challenging, but fertilizer companies can advise farmers on best fertilizer practices and supply tailored products. Fertilizer companies, food companies, retailers and farmers can work together to promote low-carbon food products to help meet growing market demand for such products.

23. The fertilizer sector should reflect on these proposals and use them to inform company and sector-wide targets. Next steps may include commitments by leading companies at the COP27 United Nations climate summit in Egypt in November 2022. Following this, the adoption of the forthcoming Sectoral Decarbonization Approach and Scope 3 emissions guidance and target setting being developed by the Science Based Targets initiative (SBTi) will be an even bigger step, covering Scope 1, 2 and 3 emissions. The fertilizer sector should press ahead with implementing changes and present the first emerging results at COP28 in the United Arab Emirates in November 2023. These initiatives should be complemented by government action to review and refocus food, farming and fertilizer subsidies and to support collaboration across the food and farming sectors to address emissions.

GLOSSARY OF TERMS

4R Nutrient Stewardship – Four areas of nutrient management (source, rate, time and place) that provide the basis of a science-based framework for the efficient and effective use of plant nutrients.

Agriculture, Forestry and Land Use (AFOLU) – Term used by the IPCC that describes the anthropogenic greenhouse gas emissions from Agriculture and LULUCF (Land Use, Land Use Change and Forestry).

Carbon dioxide equivalent (CO_2e) – A carbon dioxide-equivalent, abbreviated as CO_2e, is a measure used to aggregate and compare emissions from various greenhouse gases on the basis of their different global-warming potentials (GWP). Quantities of each gas are converted to the equivalent amount of carbon dioxide based on the same global warming potential over a defined time period. For example, the GWP for methane is 25 and for nitrous oxide 298. This means that the global warming impact of emissions of 1 Mt of methane and nitrous oxide respectively are equivalent to emissions of 25 and 298 Mt of carbon dioxide over a 100-year time horizon.

Carbon dioxide removal (CDR) – Sometimes shortened to 'carbon removals' refers to actions such as soil carbon sequestration that can result in a net removal of CO_2 from the atmosphere.

Controlled-release fertilizer – A fertilizer product that releases nutrients at a controlled rate relative to a "reference soluble" product. The controlled rate of nutrient release is achieved by modifying readily available nutrient forms with recognized physical mechanisms such as coatings, occlusions or other similar means.

Farm-gate – Relating to processes and outputs that originate and conclude on the farm.

Greenhouse Gas Protocol – Establishes comprehensive global standardized frameworks to measure and manage greenhouse gas emissions from private and public sector operations, value chains and mitigation actions.

Inhibitors – Urease inhibitors are compounds that inhibit hydrolytic action on urea by the urease enzyme. This helps to slow ammonia volatilization, which is a potential source of air and water pollution and an indirect source of nitrous oxide.

Nitrification inhibitors are compounds that that inhibit the biological oxidation of ammoniacal-N to nitrate-N by the bacteria responsible for converting ammonium to nitrite (nitrosomonas) and nitrite to nitrate (nitrobacter). These compounds protect against both denitrification and nitrate leaching losses.

Urease and nitrification inhibitors break down over time. The rate of breakdown is influenced particularly by temperature, and these products generally remain effective longer at cooler soil temperatures, with efficacy ranging from two to several weeks.

Measurement, reporting, and verification (MRV) – The practice of "MRV," which integrates three independent, but related, processes of measurement or monitoring (data and information on emissions, mitigation actions, and support), reporting (compiling the information in inventories and other standardized formats), and verification (subjecting the reported information to some form of review or analysis or independent assessment).

Neutralization – Measures that companies take to remove carbon from the atmosphere and permanently store it to counterbalance the impact of emissions that remain unabated.

Nitrogen Use Efficiency (NUE) – NUE is defined here as the ratio of the quantity of nitrogen removed from a given area during harvest and the total amount of nitrogen that enters that area. Nitrogen inputs include mineral and organic fertilizer, biological nitrogen fixation and atmospheric deposition. An optimal level of NUE (e.g., about 70-80% in cereal systems) represents high crop productivity, minimum risk of nitrogen surpluses and the consequent environmental impacts and no depletion of soil nitrogen resources.

Scope 1, 2, 3 emissions – As defined by the Greenhouse Gas Protocol, Scope 1 emissions are from the direct emissions from a reporting company, Scope 2 are indirect emissions from purchased energy, and Scope 3 are indirect emissions in both the upstream and downstream activities and value chain of the reporting company.

Slow-and controlled-release fertilizer – A fertilizer product that releases (converts to a plant-available form) its nutrients at a slower rate relative to a "reference soluble" product. This may be accomplished by biological activity and/or by limited solubility and/or by hydrolysis or other recognized chemical or biochemical means.

Tiers 1, 2, 3 (in context of IPCC) – These tiers represent a level of methodological complexity. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 the most demanding in terms of complexity and data requirements.

NOTES

a. The number of calories available per person per day increased from 2,196 in 1961 to 2,884 in 2013, while the population grew from 3 to 7 billion.

FAO. (2013). Food Balances (-2013, old methodology and population). FAOSTAT. https://www.fao.org/faostat/en/#data/FBSH.

The impact of mineral fertilizer is difficult to quantify, but some estimates indicate that half the global population is now fed by mineral fertilizer, and that if global crop yields had stayed at their 1961 levels, an additional 1.3 billion ha would have needed to be converted to arable land by 2014 to match production increases. These estimates only consider tonnes of food production, not the food's nutritional content, which some evidence indicates could have declined over the period.

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b. These are net figures. Gross emissions are higher: the Food and Land Use Coalition estimates removals by land systems as 24.2 Gt CO_2e.

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c. Under the 2015 Paris Agreement, countries agreed to cut greenhouse gas emissions with a view to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels".

d. Part of a set of ambitions approved by IFA's Board of Directors on 25 May 2021.

e. Once a credit has been sold outside the supply chain, the fertilizer sector cannot count the sequestration towards Scope 3 emissions reductions.

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Reducing Emissions from Fertilizer Use examines the opportunities to reduce Scope 3 emissions from the use of fertilizers in agriculture and to support the removal of carbon from the atmosphere through soil carbon sequestration. The fertilizer industry is looking to address these emissions, playing its part in keeping to the Paris Agreement's 1.5°C goal, while ensuring the continued supply of fertilizers required by farmers to ensure the world's ability to feed a growing population.

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For more information about this report, please contact, ifa@fertilizer.org.

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