Strengthening Sustainability *in the Fertilizer Industry*

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Growing global concerns over climate change are putting an increasing focus on sustainability. This report is part of an occasional series on sustainability in industry, which examines the opportunities and challenges facing various industrial sectors and the role that the International Finance Corporation can play to support their efforts and contribute to a greener planet.

The world depends on fertilizers to feed itself. Until the widespread adoption of synthetic nitrogen fertilizers in the second half of the 20th century, hunger, malnutrition, and food insecurity were far more common, particularly in developing countries.

Chemical fertilizers were an agricultural game changer. They helped to catalyze the green revolution, which dramatically increased global food production by leveraging new technologies and practices to increase yields and reduce prices.[1] Between 1960 and 2000, wheat yields for developing countries increased by 208%, while yields for rice doubled and those for maize rose 157%, according to the Proceedings of the National Academy of Sciences.[2]

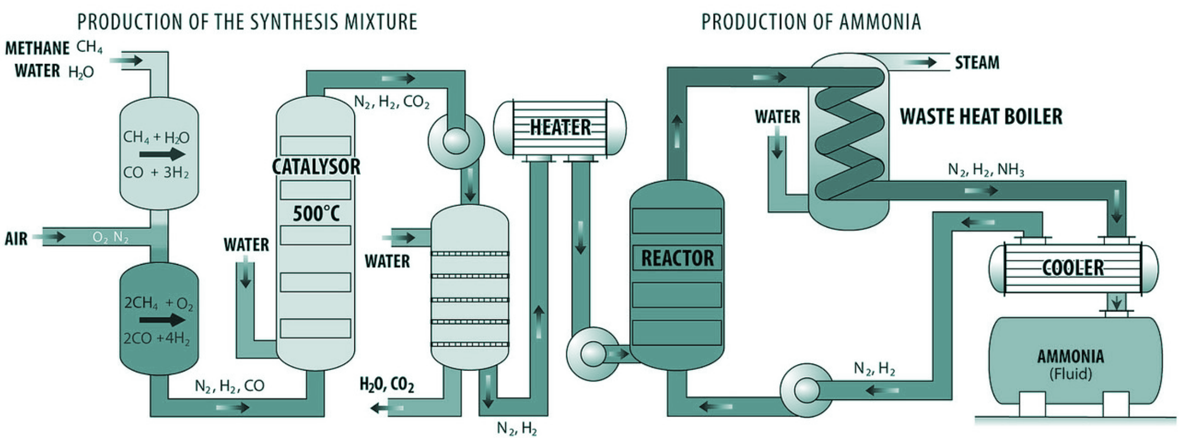
However, the increase in synthetic fertilizer use has come at an environmental price. Researchers have calculated that synthetic fertilizers are responsible for 5% of global greenhouse gases—with a third of emissions generated from the manufacture of the fertilizers and two-thirds from their breakdown by microbes in the soil after being applied on fields.[3] Nutrient runoff from synthetic fertilizers poses another environmental risk, contributing to excessive algae growth that depletes oxygen and kills aquatic life in rivers and oceans.

Greening and decarbonizing the synthetic fertilizer industry is imperative for combatting global warming, even as an expanding world population substantially increases the demand for food and more efficient food production. Shrinking the industry's environmental footprint in the face of these trends will require close collaboration among policy makers, multilateral lenders such as the International Finance Corporation (IFC), manufacturers of synthetic fertilizers, and the farmers and communities that use the fertilizers. The complex path to achieving net-zero fertilizer production underscores the challenges facing high-emissions industries as they transition to a more sustainable and circular future.

Sector Background

The use of fertilizer in agriculture dates back to ancient times when farmers spread manure on their fields to improve soil fertility. The first fertilizer produced by chemical processes was superphosphate in the early 19th century.[4] But it was the Haber-Bosch process, developed in 1909 by Fritz Haber, and scaled into an industrial process a few years later by another German chemist Carl Bosch — both of whom won Nobel Prizes—that revolutionized food production and enabled a global population boom.[5] The process made it economically feasible to convert nitrogen in the atmosphere—a form inaccessible to plants— into ammonia, the primary ingredient in modern fertilizers including urea, urea ammonium nitrate (UAN), and ammonium sulfate. Applied to soil, nitrogen fertilizers help accelerate plant growth. "Without the Haber-Bosch process it is estimated that 30–50% of the world's harvest would be lost," the Economist wrote in 2022.[6] Besides nitrogen, plants require two other macronutrients

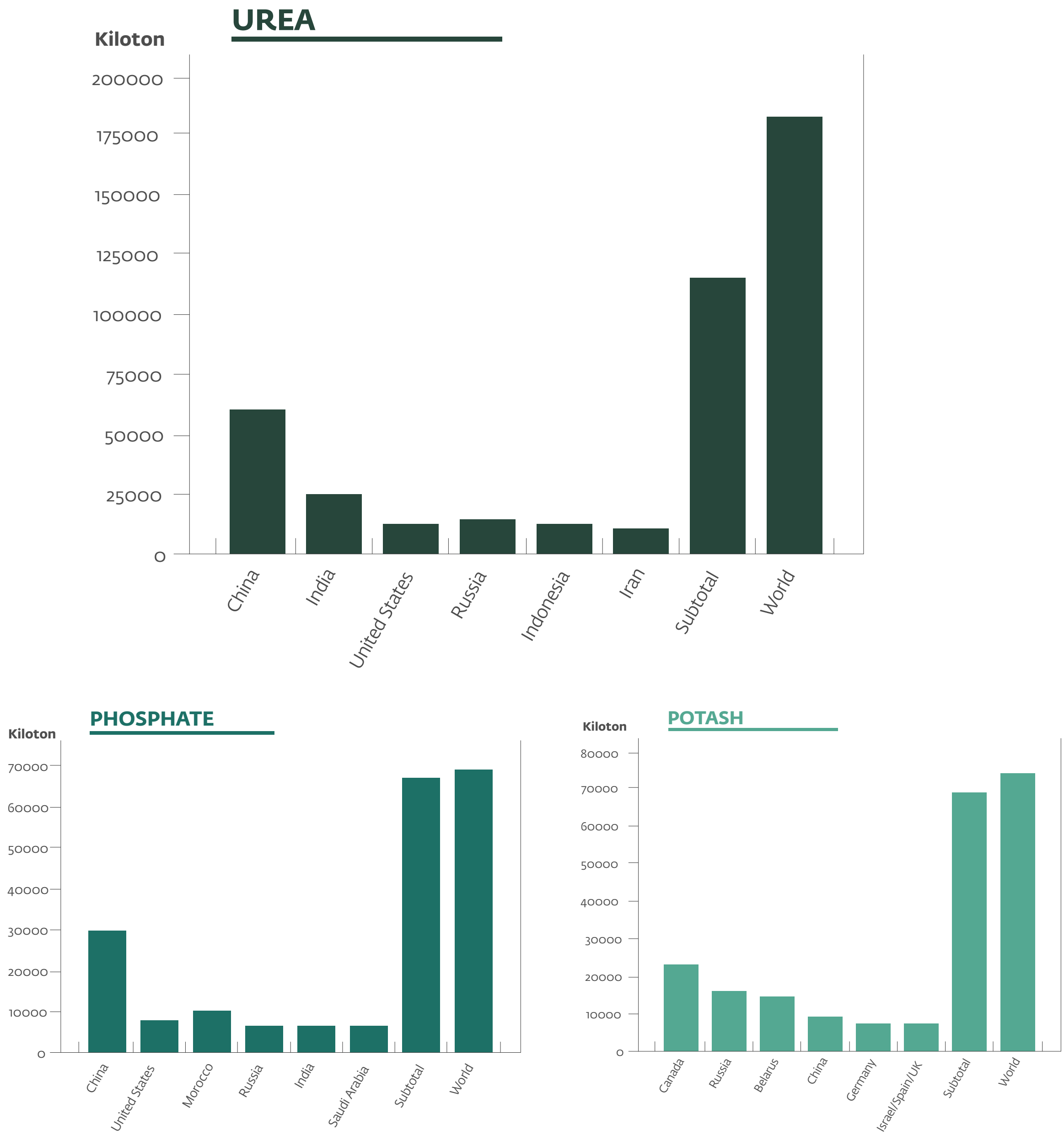
The Haber-Bosch Ammonia Process



Source: NEED-MEDIA SmugMug.

for healthy growth: phosphorous and potassium.[7] Both minerals are mined from ore deposits in the earth and can contribute to water contamination, air pollution, and environmental degradation.[8] Today, synthetic fertilizers are a necessity for modern societies. According to

World's Top Fertilizer Producers, by Country (2021)



Source: Based on IFA Market Intelligence 2022: Sulphuric Acid-Acuity Commodities 2023.

researchers at Cambridge University, roughly half of the global population is fed with crops grown with synthetic fertilizers.[9] The industry is valued at about $170 billion,[10] with China accounting for nearly 30% of global production. The country is the biggest manufacturer of ammonia, urea, and processed phosphates, as well as of synthetic fertilizer overall. Other major producers in 2021 included Russia, Canada, Morocco, and the United States.[11] Synthetic fertilizer is a major globally traded commodity. In 2021, synthetic fertilizer exports by all countries totaled $94.6 billion.[12] The leading exporting countries were Russia, China, Canada, Morocco, the U.S., and Saudi Arabia. Brazil was the biggest importer, followed by the U.S., India, Australia, and China. Sanctions and supply chain disruptions caused by the Russian invasion of Ukraine put upward pressure on fertilizer prices, which is among farmers' biggest expenses.[13] After jumping 80% in 2021, prices hit an all-time high in spring 2022, up nearly 30% since the beginning of that year. They have declined significantly since.

Some of the biggest commercial players in the synthetic fertilizer business include: CF Industries (U.S.), Haifa Group (Israel), Indian Farmers Fertiliser Cooperative Limited (India), ICL Group Ltd. (formerly Israel Chemicals Ltd.) (Israel), Nutrien Ltd (Canada), Sociedad Química y Minera (Chile), The Mosaic Co. (U.S.), Uralkali (Russia), Yara International (Norway), and Saudi Arabian Fertilizer Co. (Saudi Arabia).[14]

The synthetic fertilizer industry is forecast to expand rapidly over the next several decades, as the global population swells from 7.9 billion today to an estimated 8.5 billion by 2030 and 10.4 billion by 2100,[15] and demand for crops is predicted to double from 2005 to 2050.[16]
The industry is also expected to get a boost from growing consumption of fruits, vegetables, seeds, and nuts to support healthier eating, but this trend will also increasingly contribute to global pollution if left unchecked. The dilemma the industry faces is: How can it decarbonize without putting global food security in jeopardy?

Sustainability

As environmental concerns about synthetic fertilizers have grown in recent years, leading fertilizer companies have been adopting more sustainable manufacturing processes, from modernizing their facilities and transitioning to green ammonia to increasing investments in organically produced fertilizers.

Since 2004, member companies of the International Fertilizer Association (IFA) have decreased the carbon dioxide emissions rate per tonne of ammonia by 14.5% based on voluntary benchmarks.[17] New fertilizer plants typically use one-third less energy per tonne of ammonia produced compared to older plants, and manufacturers have taken further steps to reduce energy use and emissions. Innovations in advanced catalytic processes, which facilitate the chemical reactions needed to make fertilizer, for example, have allowed some producers to achieve an aggregate reduction in nitrous oxide (N2O) emissions in the manufacturing process totaling over 85%. N2O is a greenhouse gas which depletes the ozone layer and is 300 times stronger than CO2.[18]

Industry-developed roadmaps and standards programs envision further progress. The Ammonia Technology Roadmap, issued in 2021 by the International Energy Agency (IEA) with the European Bank for Reconstruction and Development (EBRD) and International Fertilizer Association, lays out several potential development paths for the industry, including a sustainable development scenario and one that would allow the industry to achieve zero emissions by 2050.[19] Both would rely on a combination of existing and emergent technologies.

Some companies are already adopting new technologies. Norway's Yara International is one of the many companies looking into incorporating the use of "green hydrogen"—produced by splitting water through electrolysis using renewable energy—to produce "green ammonia" on a commercial scale; the technology is expected to reduce carbon emissions by 80–90%.[20,21] Other companies working on new technologies include Denmark's Topsoe, Japan's Tsubame BHB, and U.S. startup ReMo Energy.[22]

Policy makers, meanwhile, are introducing regulations aimed at promoting further greening of the production process for synthetic fertilizers. The EU's Fertilising Products Regulation, which took effect in 2022, standardizes the use of organic and recovered waste-based fertilizers under a circular model.[23,24]
In 2019, the United Nations Environment Programme (UNEP) launched a global campaign to promote sustainable nitrogen management, with 30 member states endorsing the Colombo Declaration on Sustainable Nitrogen Management and its ambitious goal of halving nitrogen waste from all sources by 2030.[25]

Challenges & Opportunities

The synthetic fertilizer industry can achieve limited emissions reductions through such actions as adopting best available technologies and improving operations. But manufacturers will need to deploy near-zero-emission technologies on a commercial scale to approach net-zero production. Such technologies already exist. Fossil-based production of ammonia, for instance, could incorporate electrolysis, methane pyrolysis, and carbon capture and storage (CCS). However, today these and other evolving technologies are not economically feasible given challenges in scalability and high capital costs.

Ultimately, a combination of approaches will need to be used to improve the industry's sustainability and environmental performance. A major redirection of capital investment will also be necessary, along with funding and other support from governments, investors, and multilateral institutions such as IFC, to help pay for a sustainable energy transition, research and development, and the deployment of new technologies and supporting infrastructure.

Energy and Emissions

In synthetic-fertilizer manufacturing, one of the biggest challenges centers around the greenhouse gas footprint from producing ammonia for use in nitrogen-based fertilizers. Global ammonia production accounted for nearly 2% of total final energy consumption and 1.3% of CO_2 emissions from the energy system in 2020.[26] Energy, typically from natural gas or coal, is needed to fuel two key phases of the production process: to produce the hydrogen that combines with nitrogen to create ammonia and to generate high heat and pressure needed in the manufacturing process. Currently, about 40% of the fossil fuel consumed by the industry goes to feedstock.[27]

Using electrolysis to obtain the hydrogen needed in the production process could significantly reduce the industry's carbon emissions compared to traditional methods of producing hydrogen (natural gas steam reforming or coal gasification), especially if the electrolysis process is fueled by renewable energy such as solar, wind, or biogas. But challenges, including the sometimes-intermittent nature of renewable energy, will need to be addressed.

Another solution is to capture CO_2 emissions from the production process and store them underground to prevent them from entering the atmosphere. This strategy is expected to become increasingly common in natural gas-based production of fertilizer, but as with more widespread use of renewables, will require major investment in infrastructure.[28]

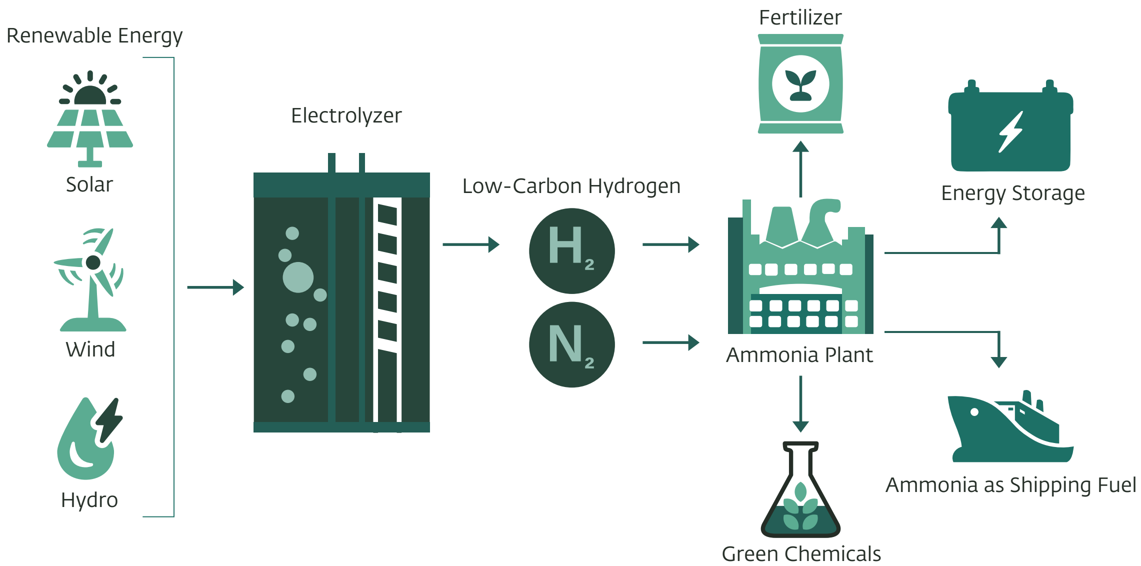
Beyond Haber-Bosch

Some experts believe the industry won't be able to achieve sustainable production unless it replaces the Haber-Bosch process altogether. A number of companies are exploring new approaches for making ammonia, such as manufacturing it directly using air, water, and electricity. Some scientists are working on a way to turn nitrogen into ammonia through the use of light while others are trying to commercialize a single-step ammonia production process that uses electrolysis at room temperature and doesn't require natural gas. However, most of these projects remain in the experimental stage.[29]

Excess Nitrogen

Over the last century, the amount of man-made nitrogen compounds in the water, soil, and air has doubled, due in large part to the use of

Green Ammonia Process



Source: Based on S&P Global Market Intelligence.

synthetic fertilizers.[30] Nitrogen runoff can poison water bodies and create dead zones, killing wildlife and plants. Nitrous oxide, which is emitted during the production process and from the soil during the use phase, contributes to smog and exacerbates climate change by causing stratospheric ozone depletion.[31] Some experts call the excess nitrogen from fertilizer use one of the most severe pollution threats today.[32]

Industry groups are working with farmers to help them use synthetic fertilizers more effectively and reduce runoff. The Fertilizer Institute in the U.S. has developed the "4R Nutrient Stewardship" to encourage farmers to decrease synthetic fertilizer use and improve efficiency through the four Rs, or four "rights": use of the right fertilizer source, at the right rate, at the right time, and in the right place.[33]

Some major companies also produce more environmentally friendly fertilizers such as time-released fertilizers, but these products account for a sliver of the market and are not widely used by farmers. Regulations aimed at reducing the climate impact of synthetic fertilizers could incentivize companies to produce more green fertilizers and to develop technologies tailored to specific crops and climates. Effective nitrogen management could boost demand for such products.[34]

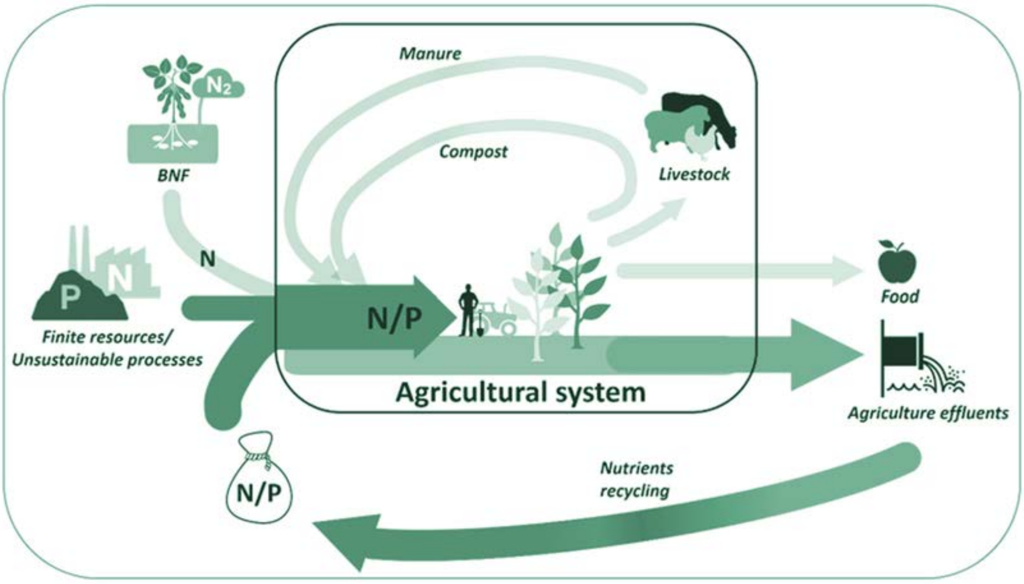
Phosphorous and Potassium

Plants tend to absorb less of these two macronutrients than of nitrogen, but their production also involves sustainability challenges. These center around the environmental impacts of mining, waste production and disposal—phosphorous production creates phosphogypsum as a byproduct, which has limited uses and must be stored as "waste mountains"—and soil degradation.[35] Proper fertilizer application and soil management, along with recapture efforts, could help address these problems. Researchers are also exploring alternative, organic sources of nutrients to substitute for these two elements.

Biowaste and Circular Economy

A circular approach could ease the strain on raw material reserves while decreasing energy use and greenhouse gas emissions in the production cycle. A European Union-funded project, NEWFERT, found that it was possible to transform livestock effluent into a new generation of fertilizers,[36] and the EU has set a 30% target for biowaste replacement of inorganic materials in synthetic fertilizer.[37] Under the circular model promoted by the EU and European Industrial Organization of Fertilizers, residual biomass, such as from harvest or livestock production, slaughter or food processing, or even human wastewater, could substitute for some raw materials used in fertilizer production. Investment in new technologies and infrastructure would be needed to address access, collection, processing, storage, and introduction of biowaste-based raw materials in safe and efficient ways—for example, by constructing small-scale fertilizer installations on waste generation sites.

Circular Economy in the Fertilizer Sector



Source: Perin et al. 2019.

Note: P = phosphorous, N = nitrogen, BNF = biological nitrogen fixation.

IFC Role

IFC emphasizes investments in businesses that seek to transition to renewable energy and to explore new technologies including carbon capture, carbon storage, green ammonia, and the production of slow-release synthetic fertilizers that can reduce the risk of nutrient runoff and minimize the volume of fertilizer needed. IFC is committed to a holistic factory-to-field approach for reducing greenhouse gas emissions and pollution, and supports efforts that encourage precision farming, which involves employing cutting-edge technologies that optimize fertilizer application and results in less waste. IFC aims to promote (i) increased

BOX I: ***IFC's Partnerships in the Fertilizer Industry***

IFC is working with fertilizer producers on an array of projects with the goal of reducing the industry's carbon footprint. It is engaged in pilot projects aimed at producing green hydrogen on a commercial scale for use as the primary input for manufacturing green ammonia. In Nigeria, IFC has supported an expansion of the fertilizer industry through financing for Indorama Eleme Fertilizer & Chemicals Ltd, helping to alleviate gas flaring, providing value generation, increasing supply, and reducing emissions. In Brazil, IFC has financed blending operations to improve farmer access to fertilizers. And in Latin America and the Caribbean, Africa, and Asia, it has provided enhanced credit lines to fertilizer-trading companies such as Nitron Group, so that they can better supply smaller farmers, lower inventories, and optimize working capital needs.

IFC also provided a €100 million Green Loan in 2023 to OCP Group, the world's largest phosphate-based fertilizer producer, to build four solar plants that will provide cost-effective energy for the production of low-carbon fertilizers. The plants, in the mining towns of Benguerir and Khouribga, home to Morocco's largest phosphate reserves, will have a capacity of 202-megawatt peak.

access to fertilizers, (ii) improved application and efficiency of use, and (iii) a sustainable approach.

Among other things, IFC works with private sector companies to provide early-stage engagement, advisory services, and financing to accomplish these goals. IFC also provides Green Loans and other financial instruments to finance projects that contribute to environmental objectives such as climate change mitigation or climate change adaptation.

Conclusion

The widespread use of synthetic fertilizers beginning in the second half of the 20th century helped to make food more plentiful, affordable, and nutritious. But the impact of these chemicals on the environment has been significant and there is an urgent need to help decarbonize the industry if the world is going to avert a climate crisis and safeguard the environment for future generations.

Ultimately, a combination of approaches and a great deal of investment will need to be used to improve the industry's environmental performance. Manufacturers will need to deploy new technologies, some of which are already in the works. Production lines will need to use less-polluting fuels. And farmers will need to adopt on a broad scale agricultural practices that use fertilizers more efficiently to grow high-yielding crops. IFC is committed to work with the industry by providing the financing and technical advice it needs to achieve these goals and become greener, more efficient, and more prosperous in its transition to a more sustainable future.

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