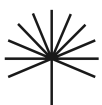


Food security in Europe is structurally exposed to energy markets through synthetic fertiliser

Joanne Bentley-McKune
June 2026

Key points

- European agriculture depends heavily on synthetic nitrogen fertiliser, which is made using natural gas. A substantial fraction of fertiliser is lost before it is taken up by a crop, meaning a significant share of the EU's fertiliser spend – and the gas embedded in it – generates no food.
- Farmers spent EUR 16.4 billion across the six years from 2019–2024 on synthetic nitrogen fertiliser that was never taken up by a crop. France, Spain, Poland and Germany spent the most, together accounting for more than half the value of all the states included in the analysis.
- Over the same period, EUR 6.1 billion was spent on gas – mostly imported – for fertiliser production that generated no food. Expenditure surged in the wake of Russia's invasion of Ukraine, jumping from EUR 0.4 billion in 2019 to EUR 2.9 billion in 2022; a stark illustration of the region's exposure to gas price volatility during geopolitical crises.
- Total environmental damage costs from synthetic nitrogen losses were EUR 233.7 billion across the six-year period, with water pollution accounting for 79% of total estimated costs and air pollution accounting for the remainder.
- Despite relatively high nitrogen use efficiency on EU farms, the scale of synthetic nitrogen application means absolute losses are large. Proven input-reduction measures could reduce usage by up to 43%, saving farmers up to EUR 5.08 billion a year in fertiliser bills, with proportional reductions in embedded gas costs and environmental damage.
- Depending on the gas price, the annual gas cost savings of reducing synthetic nitrogen range from EUR 1.1 billion – more than the annual CAP payment for Sweden – to EUR 3.9 billion – more than the combined CAP payments for the Netherlands, Denmark, Ireland and Latvia.



- Energy price shocks flow directly into food costs. Our model found that the post-Ukraine invasion energy crisis pushed wheat prices up by roughly 22%, and the link between gas, fertiliser and wheat prices remained much stronger than before the crisis, even as gas costs fell.
- Without a fundamental reduction in synthetic nitrogen dependency, Europe will remain vulnerable to volatile energy and food markets.

Recent years have exposed the fragility of global food systems. Climate shocks have disrupted harvests and strained supply chains, while volatile markets for fertiliser, gas and other inputs have driven production costs to record highs. At the same time, conventional farming practices are accelerating land degradation, undermining long-term productivity.

This is the second in a series of briefings we'll be publishing over the course of the year analysing the impact of extreme weather and geopolitical crises on food system resilience around the world.

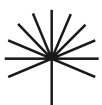
Europe's fertiliser industry is exposed to gas price shocks

European agriculture depends heavily on synthetic nitrogen fertiliser – the product of hydrogen from natural gas¹ reacting with atmospheric nitrogen in the Haber-Bosch process used to make ammonia, which is the building block for solid or liquid fertilisers such as urea and ammonium nitrate. Decades of fertiliser application has significantly improved crop yields in the region but has also led to [high nitrogen pollution](#) of the air and water, as well as [biodiversity loss](#).

Europe's ammonia industry runs almost entirely on natural gas, with hydrogen for the Haber-Bosch process produced through [steam methane reforming \(SMR\)](#). The SMR technology uses gas both as a feedstock (to create hydrogen) and an energy source (to fuel the reaction), making production costs acutely sensitive to gas price movements. Around [60–80% of fertiliser production costs in Europe are natural gas costs](#).²

¹ Also known as fossil gas.

² Despite operating some of the most [energy-efficient ammonia plants in the world](#), Europe has made limited progress in reducing this gas dependency: further efficiency gains from existing SMR technology are marginal, meaning the structural link between gas prices and fertiliser costs is unlikely to weaken without a fundamental shift in hydrogen feedstocks.



Europe's reliance on gas-based ammonia production was made economically viable by cheap Russian pipeline gas, which supplied [40% of EU natural gas demand](#) in 2020. Following the invasion of Ukraine in 2022, gas prices [surged by 180%](#) compared to pre-crisis levels, as [Russia suspended gas exports](#) to the EU. The EU also took a decision to phase out Russian gas imports – which [dropped to 14% of supply](#) by 2024 – to defund Russia's war.

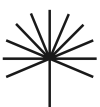
These events effectively removed the conditions keeping European fertiliser production competitive: soaring gas prices caused ammonia production plants in Europe to [operate at half capacity](#) during 2021–2023, forcing the region to increase imports to compensate. In the year to June 2023, the EU [imported twice as much urea from Russia compared with the previous year](#), meaning the country that started the invasion which triggered the gas price shock was supplying the fertiliser European plants could no longer profitably produce.

The cost of this dependency does not end at the farm gate. One analysis estimates that a [10% increase in gas prices raises euro area headline inflation by approximately 0.6 percentage points](#) after one year, with indirect effects related to production costs accounting for the majority of pass-through from gas price hikes to inflation. Of these, synthetic fertiliser is a critical indirect cost channel: research confirms that [energy price shocks propagate directly into food costs via fertiliser costs](#). In other words; gas price shocks become food price shocks.

Analysis shows Europe's reliance on gas-based fertiliser is a chronic drain on resources and an acute vulnerability during energy crises

Europe's dependency is aggravated by the fact that much of the natural gas embedded in European food production is never productively used. The EU's historically high-yield, high-synthetic-nitrogen model means the food system is structurally reliant on natural gas. With nitrogen use efficiency (NUE) in 17 EU member states ranging from 65.4% to 72.2% between 2019 and 2024,³ more than a quarter of applied synthetic nitrogen is lost to the environment before it can benefit a crop. Because the total volume of synthetic nitrogen fertiliser applied is so large – around [10 million tonnes per year](#) – even a moderate loss translates to billions of cubic metres of embodied natural gas.

³ Author's calculations from Eurostat [aei_pr_gnb](#) (2026). NUE was calculated as nitrogen output divided by total nitrogen input, expressed as a percentage.



This wastage represents a triple loss: farmers pay for inputs that never reach crops; natural gas – burned at great cost as a feedstock to synthesise fertiliser – is consumed for no productive purpose; and the synthetic nitrogen applied to croplands, whether it reaches a crop or not, causes environmental damage costing society billions of euros every year.

In this analysis, we quantify each of these losses across 17 EU member states for which nitrogen balance, fertiliser consumption, and farm expenditure data are available for the 2019–2024 study period.⁴ We also show that this wastage is not just a chronic drain on resources, but an acute vulnerability during energy crises. Analysing commodity price data, we show that gas price shocks triggered by Russia's invasion of Ukraine transmitted measurably through fertiliser markets to wheat prices, and that this structural link between energy and wheat prices has persisted beyond the initial phase of the crisis.

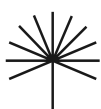
We used three official EU datasets, including the [Eurostat gross nutrient balance](#), [Eurostat synthetic fertiliser consumption](#) statistics, and [fertiliser expenditure data](#) from the Farm Accountancy Data Network (FADN), covering 17 EU member states for the years 2019 to 2024 (with 2024 projected). We then estimated:

- (a) the share of fertiliser expenditure attributable to nitrogen lost to the environment;⁵ and
- (b) the volume and cost of the natural gas consumed to produce this wasted nitrogen at prevailing prices.⁶

⁴ The 10 excluded member states (Belgium, Denmark, Estonia, Greece, Cyprus, Luxembourg, Malta, Romania, Slovenia and Sweden) were omitted due to gaps in Eurostat nitrogen balance data.

⁵ Total fertiliser expenditure for 2019–2023 was taken directly from the EU FADN (variable SE295, in EUR millions). For 2024, we estimated spending by holding 2023 expenditure constant and scaling it by the ratio of each country's synthetic nitrogen fertiliser consumption in 2024 versus 2023 (Eurostat dataset `aei_fm_usefert`). We then estimated nitrogen fertiliser expenditure by first calculating the market value of the synthetic nitrogen (N) and phosphorus (P) consumed in each country-year. Annual synthetic N and P consumption (tonnes) were taken from Eurostat (`aei_fm_usefert`). EU-average annual N and P prices (EUR/tonne of nutrient) come from the European Commission [fertiliser prices dashboard](#). P consumption is reported as elemental P; we multiplied it by 2.29 to convert to a phosphorus pentoxide (P_2O_5)-equivalent, reflecting the standard commercial basis for phosphate fertilisers. A potash (K_2O) factor of 1.21 was applied to the denominator to account for potassium's share of total nutrient spend, preventing over-attribution to N and P. The N share of total spend was then $N_value \div ((N_value + P_value) \times 1.21)$, and N fertiliser expenditure was obtained by multiplying total fertiliser spend by this share.

⁶ Nitrogen that is lost to the environment was defined using the Eurostat gross nutrient balance (dataset `aei_pr_gnb`). For each country and year, total N input and harvested N output (both in tonnes) give nitrogen use efficiency ($NUE = output \div input$) and N loss percentage ($1 - NUE$). Surplus N (input – output) is the N not taken up by crops. Wasted N fertiliser spend was estimated as N fertiliser



We also estimated the social and environmental damage costs associated with synthetic nitrogen fertiliser application, drawing on published unit-cost estimates.

Share of fertiliser spending attributable to nitrogen loss to the environment

Farm expenditure on synthetic nitrogen fertilisers in the assessed EU countries reached EUR 124 billion in the six years from 2019 to 2024.⁷ Over this period, we estimate that approximately EUR 16.4 billion in nitrogen fertiliser expenditure was effectively wasted: spent on inputs that were never taken up by a crop (Figure 1). On a per-hectare basis, the wasted nitrogen spend averages roughly EUR 27–33 per year across the EU.⁸ As an illustration, this equates to approximately one-fifth of the net margin for a typical Irish spring barley crop (EUR 174 ha⁻¹ in 2024) and close to one-tenth for winter wheat (EUR 364 ha⁻¹), according to the [Teagasc National Farm Survey](#).

In 2022 alone, at the peak of the energy crisis, EUR 3.7 billion in nitrogen fertiliser spending was wasted due to nitrogen loss to the environment. France, Spain, Poland and Germany spent the most, together accounting for more than half of the states included in the analysis.

expenditure × N loss %. We first isolated the synthetic share of the surplus by computing synthetic N consumed (Eurostat dataset `aei_fm_usefert`) divided by total N input (`aei_pr_gnb`), capped at 1.0. The synthetic surplus (tonnes N) was total surplus × synthetic share. The energy required to produce that synthetic N is based on the [International Fertilizer Association \(IFA\) global average benchmark of 36 gigajoules \(GJ\) per tonne of ammonia](#), converted to 43.71 GJ per tonne of N by dividing by the N fraction of NH₃ ($14 \div 17 = 0.8235$). We assumed 80% of EU ammonia production is gas-based ([Fertilizers Europe 2023](#)). The energy embedded in the wasted synthetic nitrogen (in GJ) was converted to a physical volume of natural gas using the [International Energy Agency's standard conversion factor](#): one gigajoule of natural gas occupies approximately 28.1 cubic metres ($1 \text{ GJ} = 1000 \text{ MJ} \div 35.6 \text{ MJ/m}^3 \approx 28.1 \text{ m}^3$). Multiplying the total energy (GJ) by 28.1 m³/GJ gives the equivalent volume in cubic metres; this figure is then divided by 10⁹ (one billion) to express it in billion cubic metres (bcm). Gas cost (EUR) was calculated by multiplying energy (GJ) by the annual TTF gas price (EUR/MWh) divided by 3.6 GJ/MWh (since 1 MWh is equivalent to 3.6 GJ), then dividing by 10⁶ to express in millions of euros. TTF prices are annual averages from the [World Bank Pink Sheets](#) (observed 2019–2023, estimated for 2024). Because the gas calculation is based on the surplus, the resulting cost represents the gas embedded in fertiliser that was lost. Applying the total N loss percentage to synthetic N alone may [overestimate synthetic N waste by approximately 17%](#), but the overall scale of potential savings remains robust even after this adjustment. Values should be treated as first-order approximations.

⁷ The FADN data covers ~90% of total EU agricultural production, with very small or subsistence farms excluded, meaning this value is probably an underestimate.

⁸ Calculated by dividing the wasted nitrogen spend by total EU-27 arable land. Because the wasted spend covers only the 17 EU countries included in the analysis, the true per-hectare figure is higher.

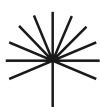
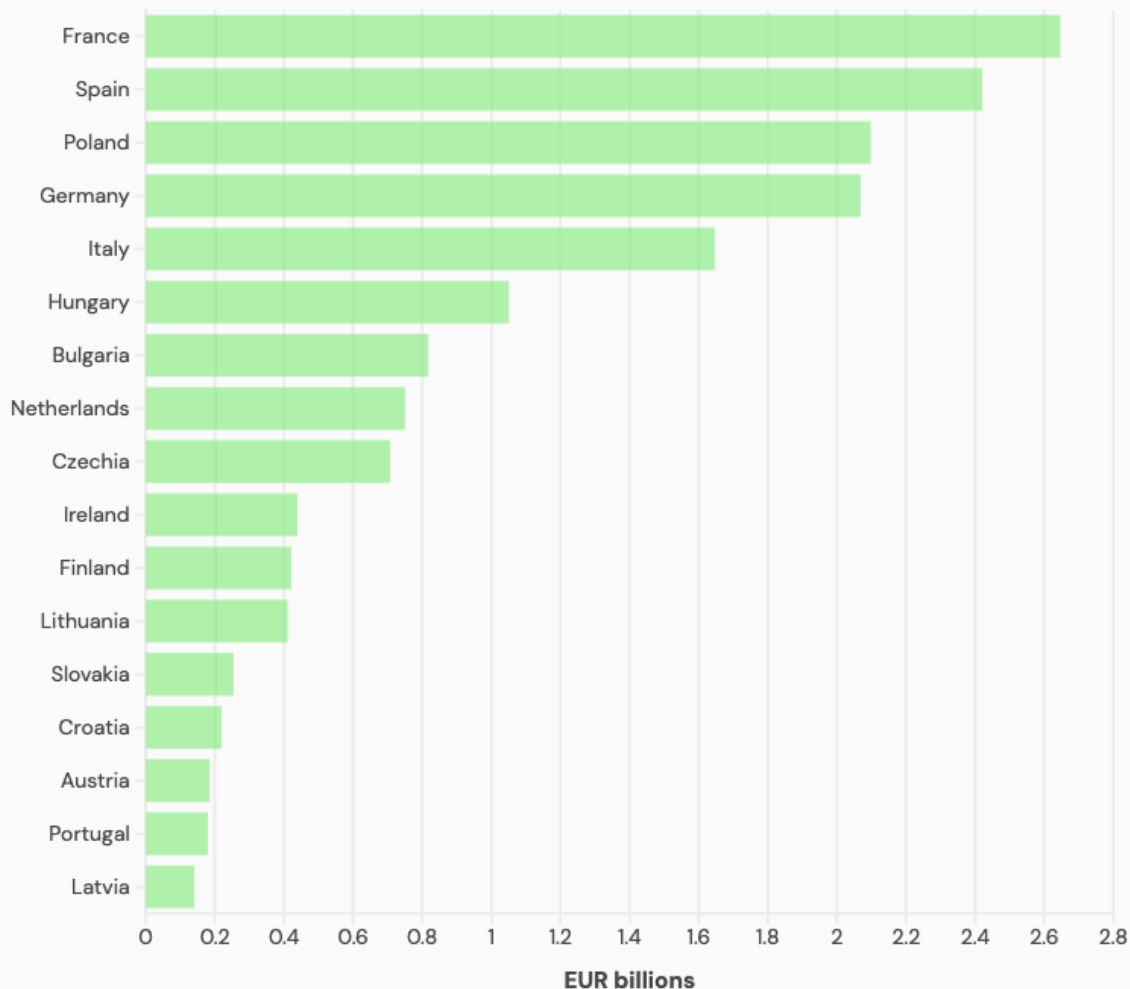


Figure 1

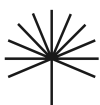


EU countries spent EUR 16.4 billion on synthetic nitrogen fertiliser that was never taken up by a crop (2019–2024)

EU member state



Source: ZCA analysis of Eurostat and FADN data. • Nitrogen wasted (EUR) refers to expenditure on synthetic nitrogen fertilisers that was applied but not taken up by crops (nitrogen surplus). It is calculated for each year and country by multiplying estimated nitrogen fertiliser spend by the proportion of applied nitrogen that is lost (1 – Nitrogen Use Efficiency). Nitrogen spend is extracted from total FADN fertiliser expenditure using year-specific EU average N and P_2O_5 prices and an adjustment for potassium's share of the fertiliser bill. The period shown is the cumulative total 2019–2024; 2024 values are based on projected fertiliser spending (2023 FADN scaled by N-consumption change). This assumes wasted expenditure is directly proportional to the physical surplus, which may over- or understate true financial losses per country.

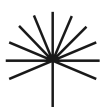


Cost of gas used to make fertiliser that generated no food

The energy consequences are equally striking. Over the same six-year period, 14.1 billion cubic metres (bcm) of natural gas were consumed to produce nitrogen that was subsequently lost. This is equal to the volume of liquified natural gas ([LNG](#)) imported by the EU from Russia in 2021. Over the period, EUR 6.1 billion was spent on gas for fertiliser inputs that generated no food.

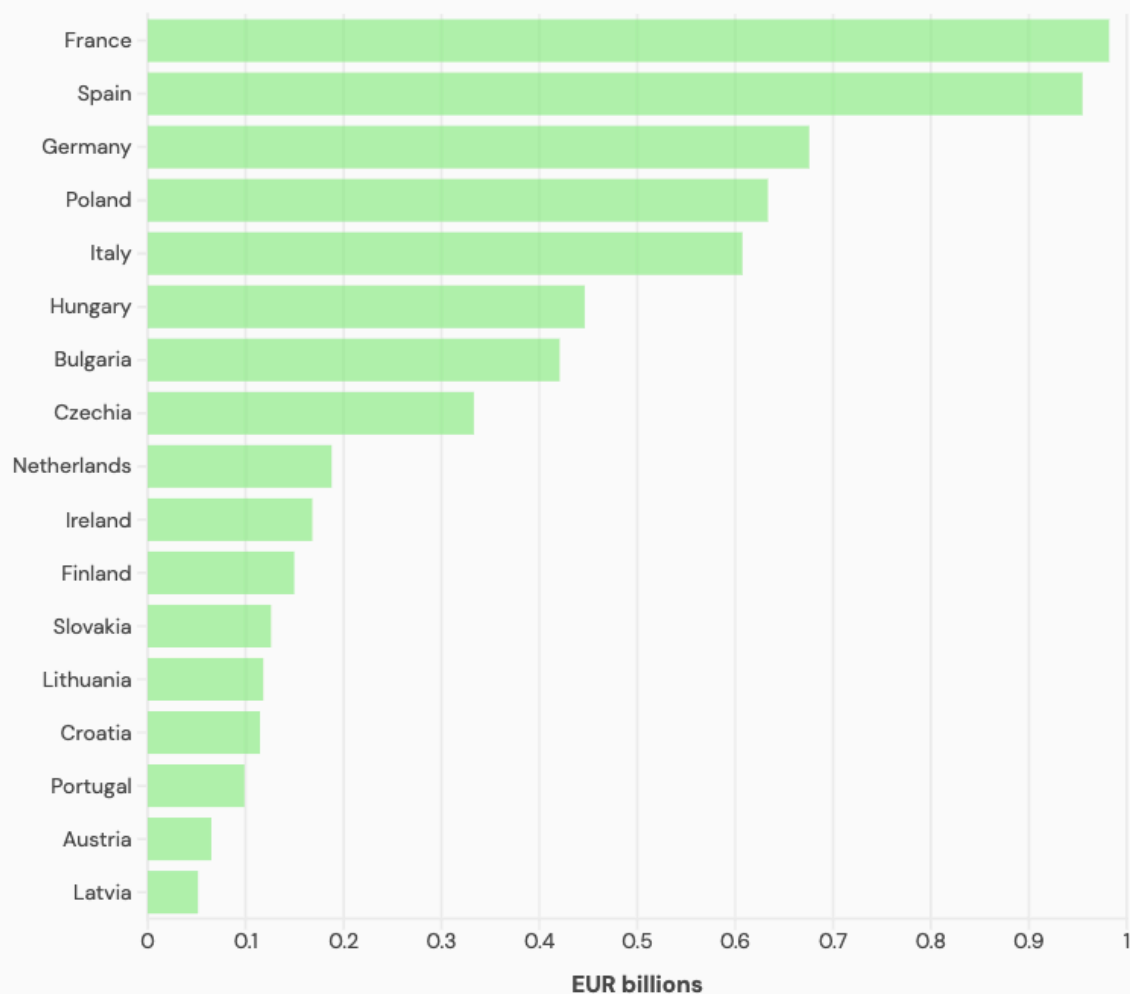
Expenditure surged in the wake of Russia's invasion of Ukraine, jumping from EUR 0.4 billion in 2019 to EUR 2.9 billion in 2022; a stark illustration of the region's exposure to gas price volatility during geopolitical crises. Had gas prices remained at their 2019 level, the same volume of wasted gas would have cost EUR 2.3 billion, meaning roughly EUR 3.8 billion of the total was attributable to the energy crisis alone.

Because NUE is a ratio, the waste figures above mainly reflect the sheer volume of synthetic nitrogen fertiliser applied – a function of the EU's longstanding reliance on high-yield, high-input farming. A system with the same NUE but half the input would produce half the waste. The costs are therefore a reflection of how much synthetic nitrogen the EU applies, rather than how well farmers use it.



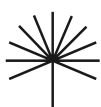
EU countries spent EUR 6.1 billion on gas for synthetic fertiliser inputs that generated no food (2019–2024)

EU member state



Source: ZCA analysis of Eurostat data. • The chart shows the estimated cost of the natural gas that was required to manufacture the portion of synthetic nitrogen (N) fertiliser that ended up as surplus. For each country, the synthetic N surplus is calculated from Eurostat N balances, then converted to gas energy using the IFA industry benchmark ($36 \text{ GJ t}^{-1} \text{NH}_3$, equivalent to $43.71 \text{ GJ t}^{-1} \text{N}$) and a gas-based production share of 80% (Fertilizers Europe 2023). The resulting gas volumes are priced at the 2024 TTF benchmark (EUR 35/MWh). The estimates cover only synthetic fertilisers and exclude manure and biological fixation.

Cumulative environmental damage costs exceed EUR 233 billion



The costs above – wasted fertiliser and gas – only capture the fraction of nitrogen that never reached a crop during the six-year period. Environmental damage costs are additional, and extend beyond farming: nitrogen causes harm across its entire lifecycle, whether it's taken up by a crop or lost directly to the environment.⁹ For this reason, we estimate the social costs that nitrogen applied to EU croplands imposes [on human health, ecosystems and the climate](#) by applying the unit social-cost rate (EUR 4.90 per kilogram of nitrogen) from the [European Nitrogen Assessment \(ETA\)](#) to the total quantity of synthetic nitrogen consumed in each country-year, giving an estimate of the total social damage attributable to synthetic nitrogen use across the EU.¹⁰

Cumulative environmental damage costs associated with synthetic nitrogen application totalled EUR 233.7 billion across 2019–2024, and EUR 37 billion in 2024 specifically (Figure 3). Nitrate groundwater contamination and nitrogen loading of surface waters together account for approximately 79% of total estimated costs (EUR 185 billion). These represent the ecosystem and health costs of nutrient enrichment in marine and coastal systems, and of nitrate contamination of drinking-water sources.

Among airborne pathways, ammonia emissions are the largest contributor (roughly 12.5%; EUR 29 billion), primarily via secondary particulate-matter formation (which causes health impacts when breathed in) and ecosystem nitrogen deposition (leading to eutrophication and biodiversity loss). Nitrous oxide (N₂O) and nitrogen oxides (NO_x) account for the remaining 5.5% (EUR 13 billion, mainly through climate damage) and 2.7% (EUR 6.5 billion), respectively.

Across all pathways, France, Germany, Poland and Spain bear the highest costs, together accounting for nearly two-thirds (EUR 147 billion) of the total damage over the 2019–2024 period.¹¹

⁹ This is the '[nitrogen cascade](#)' – once reactive nitrogen is introduced into the environment, its ecological and health impacts propagate through air, soil and water over time, so that the origin of any individual nitrogen atom quickly becomes irrelevant to the damage it causes.

¹⁰ This is an established rate that embeds pathway-specific loss fractions for ammonia, nitrous oxide, leaching and other pollutant routes, meaning the resulting figure represents the total social damage attributable to synthetic nitrogen fertiliser use (see Figure 3 for more). The rate is already expressed per kg N applied and is therefore designed to be multiplied by total consumption. A single central rate of EUR 4.90 kg N⁻¹ (2024 EUR) is applied. This is the sum of the pathway-specific midpoints from Brink et al. (2011) Table 22.14 (EUR 3.60 kg N⁻¹ in 2008 EUR), inflated to 2024 EUR using the IMF Euro-Area GDP deflator (×1.3624). As this value is applied to each country's synthetic nitrogen consumption, differences in total damage across countries reflect only differences in the volume of fertiliser applied. This uniform rate avoids attributing emissions from manure or biological fixation to synthetic fertiliser but it does not capture differences in local environmental sensitivity.

¹¹ These estimates are conservative: they cover only synthetic nitrogen fertiliser (excluding [manure, which accounts for ~38% of EU agricultural N input](#)), and the damage rates applied are based on

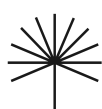
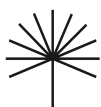


Figure 3

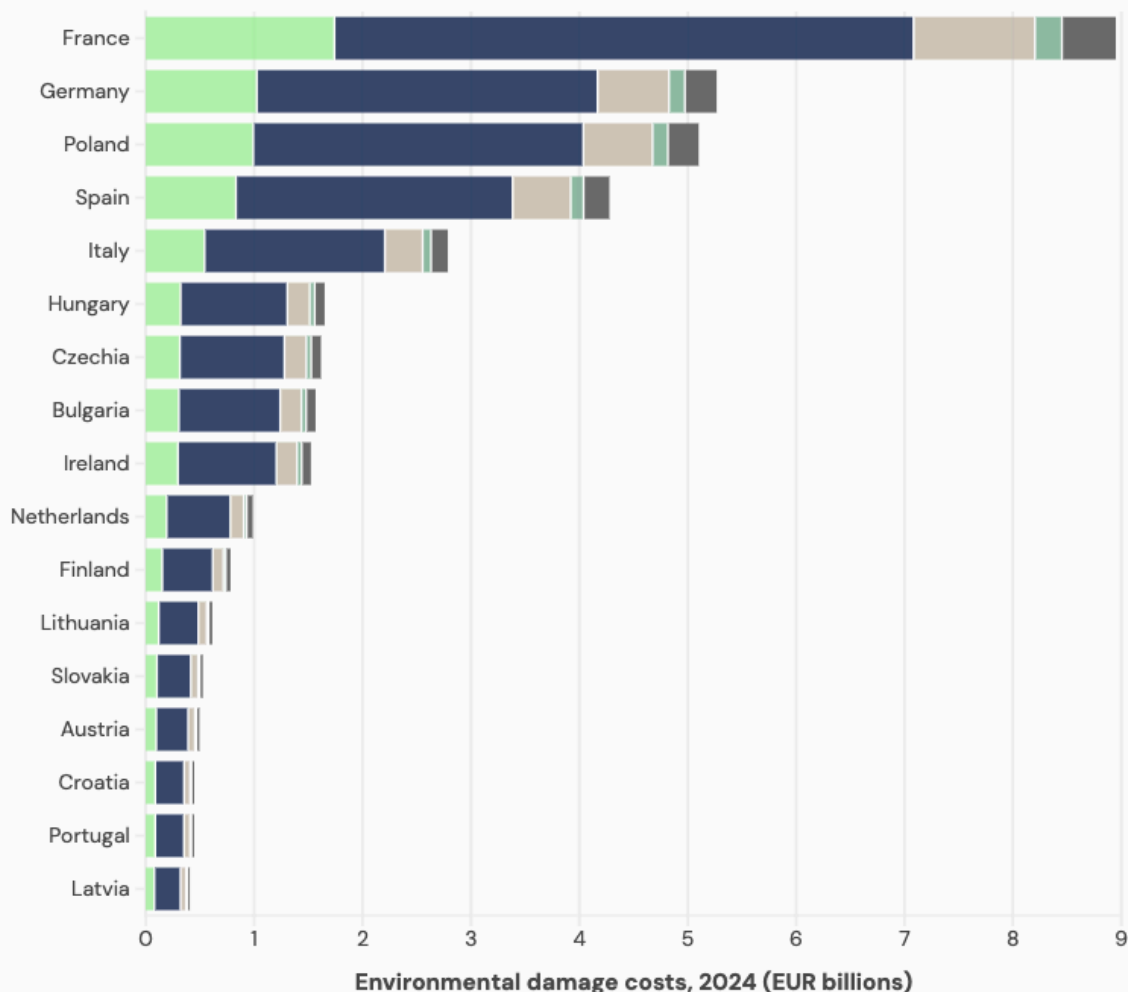
calcium ammonium nitrate (CAN), whereas the current EU fertiliser mix includes urea, which is more volatile. Emissions factors for airborne nitrogen compounds are low for CAN, which is why the damage costs for water pathways are highest. Total agricultural nitrogen damage could be higher – the European Nitrogen Assessment estimates [EU-27 total annual reactive nitrogen damage to be EUR 70–320 billion](#) when all nitrogen sources and pathways are included – outweighing the economic benefits of nitrogen application.



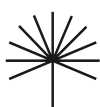
Environmental damage costs from synthetic nitrogen fertiliser exceeded EUR 37 billion in 2024

■ Nitrate groundwater
 ■ N-load surface water
 ■ NH_3 to air
 ■ NO_x to air
 ■ N_2O to air

EU member state



Source: ZCA analysis of data from FADN (2026), Eurostat (2026) and Brink et al. (2011) •
 Damage values represent the long-term social cost of synthetic nitrogen (N) fertiliser use in 2024, calculated by multiplying each country's synthetic N consumption by the central damage rate from Brink et al. (2011, Table 22.14). The rate of EUR 4.90 kg N⁻¹ (2024 EUR) is the sum of five pathway midpoints (nitrate groundwater, surface-water N loading, NH_3 , NO_x , and N_2O), inflated from 2008 EUR using the IMF Euro Area GDP deflator ($\times 1.362$). The method assumes all applied synthetic N eventually causes environmental damage; it does not include manure or biological N fixation.



Uncoupling high productivity from high synthetic fertiliser use

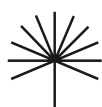
The wastage calculations above represent the total gas embedded in nitrogen that is lost to the environment under current practices. Not all of this can be recovered by improving efficiency alone – [some loss per kilogram is inevitable](#) and, more critically, the majority of the waste is a function of the sheer volume of synthetic nitrogen fertiliser applied.

In the EU, relatively high NUE (~70%) supports high crop yields, but it is achieved alongside large absolute nitrogen surpluses. This coupling of high productivity with high synthetic nitrogen input is not a necessary trade-off. South Africa, for instance, applies only one-third of the synthetic nitrogen fertiliser per hectare that France does, yet achieves 78% of France's cereal yields – producing more than twice as much grain per kilogram of synthetic nitrogen applied. Paraguay applies a similarly modest quantity of synthetic nitrogen, and produces 76% more grain per kilogram than France. Paraguay's performance is down to extensive biological nitrogen fixation from legume crops – a process driven by symbiotic bacteria rather than heavy fertiliser use and fossil fuels.¹²

Other systems obtain similar NUE to the EU with lower nitrogen inputs, but this can come with a yield penalty. The challenge therefore is not only to raise efficiency but to uncouple high productivity from high synthetic nitrogen use – reducing the input volume while keeping yield losses manageable.

¹² [FAOSTAT Cropland Nutrient Balance](#) (2023). Accessed 11 May 2026. France: synthetic N = 89.4 kg N ha⁻¹, manure = 38.7, biological N fixation = 4.6, total input = 132.7, crop removal = 87.2, surplus = 45.5, NUE = 65.7%.

South Africa: synthetic N = 42.5 kg N ha⁻¹, manure = 3.7, biological N fixation = 17.0, total input = 63.1, crop removal = 44.2, surplus = 19.0, NUE = 70%. Paraguay: synthetic N = 24.1 kg N ha⁻¹, manure = 8.3, biological N fixation = 146.9, total input = 179.3, crop removal = 153.8, surplus = 25.5, NUE = 85.8%. Crude protein estimated as crop N × 6.25. The difference is driven almost entirely by biological nitrogen fixation (146.9 kg N ha⁻¹ vs 4.6 kg N ha⁻¹). Cereal-specific N application rates and yields are from [Our World in Data](#) (2023), "Cereal yield vs. fertiliser use": France applied 87.04 kg N ha⁻¹ and yielded 7.27 t ha⁻¹ (84 kg grain/kg N); South Africa applied 30.50 kg N ha⁻¹ and yielded 5.70 t ha⁻¹ (187 kg grain/kg N); Paraguay applied 28.97 kg N ha⁻¹ and yielded 4.27 t ha⁻¹ (147 kg grain/kg N). South Africa's cereal yields were therefore 78% of France's, despite using 35% of the synthetic N per hectare. Paraguay's cereal productivity was 76% higher than France's. These comparisons do not imply that the EU should replicate any specific country's cropping patterns; they are illustrative and do not account for differences in climate, soil quality, crop mix or other agronomic factors that also influence yields and nitrogen dynamics.



In Box 1 below we quantify the potential savings that can be unlocked if the EU breaks that coupling, using realistic reduction scenarios that cut synthetic nitrogen volumes while protecting yields.

Box 1: Cutting synthetic nitrogen fertiliser use can reduce farmers' exposure to price spikes while maintaining yields

While EU commercial agriculture achieves relatively high NUE, its input base remains tethered to natural gas via the Haber–Bosch process used to produce synthetic fertiliser, which consumes around [1–2% of global energy and 5% of global natural gas output](#).¹³

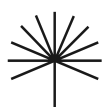
A narrow focus on NUE can mask the absolute scale of nitrogen application: high efficiency reduces the proportion of nitrogen wasted per unit of crop output, but does nothing to reduce the total volume of gas needed to sustain current input levels. [Other regions achieve comparable NUE](#) with a [fraction of the synthetic nitrogen fertiliser input](#) per hectare, though this can come with a yield penalty.¹⁴

However, there is evidence that [high yields need not rely on synthetic nitrogen](#). In one example from the US, a long-term field trial showed that maize, wheat and soybean yields in systems that entirely eliminated synthetic nitrogen in favour of legume fixation and composted manure [matched those of conventional systems, and outperformed conventional maize by 31% in drought years](#). A lower-input legume system, which also used no synthetic nitrogen, produced yields about 20% below conventional averages, but with lower production costs that maintained profitability.

Pathways to reduce the synthetic nitrogen input volume across EU farms include expanding **legume integration** – incorporating legumes such as beans, lentils

¹³ Decarbonising the fertiliser supply chain itself is not a near-term prospect. Green ammonia production – which uses electrolytic hydrogen from renewable energy – currently [costs around 2.5 times conventional production](#), with 2050 projections still substantially above today's fossil-based costs. Blue ammonia via carbon capture offers a transitional pathway but faces scalability and cost constraints. In the near term, reducing demand for synthetic nitrogen is a more immediately actionable route to cutting both gas dependency and emissions than waiting for supply-side decarbonisation.

¹⁴ EU-27 cropland receives roughly five times more nitrogen fertiliser per hectare than the African average (68.77 kg ha⁻¹ vs 14.37 kg ha⁻¹ in 2023), yet yields are only about three times higher, suggesting African systems produce roughly 64% more grain per kilogram of nitrogen fertiliser than the EU average. Values obtained from the chart 'Cereal yield vs fertiliser use', [Our World in Data](#).



and clover into farming systems – to replace synthetic nitrogen with biologically fixed nitrogen (BFN). Despite the well-documented potential for legume integration to reduce synthetic nitrogen demand, and therefore fossil fuel use, it [remains underexploited](#) globally: EU grain-legume cultivation only covers a marginal share of cultivated land – around 2.2%.¹⁵

One 50-year global analysis found that [countries drawing a higher proportion of nitrogen inputs from symbiotic fixation rather than synthetic fertiliser achieve better NUE](#), suggesting that the type of input, not just the application rate, influences efficiency.

Another pathway uses **precision nitrogen management** – where nitrogen supply is matched more closely to real-time crop demand through techniques such as split-dose timing (where fertiliser doses are customised according to growth periods) – which can [support optimal yields and reduce environmental impacts](#) while cutting nitrogen waste.

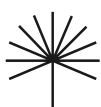
A recent EU-wide scenario analysis found that reducing synthetic nitrogen fertiliser by 43% and animal manure by 4%, together with improved technological and management practices – such as precision fertilisation and crops with higher NUE – can achieve [reductions of up to 30–45% in absolute nitrogen surplus while limiting yield losses to 1–15%](#).¹⁶

To illustrate the scale of potential savings, we have applied reduction percentages of 20% and 43% synthetic nitrogen from the above scenario analysis to our 2024 baseline (Table 1).¹⁷ This does not model improvements in NUE: it simply asks what the downstream savings would be if the volume of synthetic nitrogen applied across the 17 member states were reduced. The results show that in these scenarios, farmers could have saved EUR 2.36–5.08 billion in fertiliser costs annually (compared to a 2024 annual nitrogen fertiliser spend of EUR 11.5 billion). Additionally, 1.5–3.3 bcm of natural gas and EUR 0.52–1.12 billion in annual fertiliser-related gas costs could have been averted, along with up to EUR 16

¹⁵ Obtained by dividing 'dry pulses and protein crops' area from Eurostat dataset [apro_cpnh1](#) by [total EU arable area](#) from Eurostat.

¹⁶ The feasibility of such a shift has already been demonstrated in China, where a nationwide programme including 20.9 million [smallholder farmers increased maize, rice and wheat yields by 10.8–11.5% while simultaneously cutting nitrogen fertiliser use by 14.7–18.1%](#), saving 1.2 Mt of synthetic nitrogen fertilisers and averting USD 12.2 billion (EUR 11 billion) in net costs over a decade.

¹⁷ A 43% reduction in synthetic nitrogen is an ambitious scenario that would require substantial changes in farming practices.



billion in environmental damage.

Table 1:

Reducing synthetic nitrogen inputs could save farmers up to EUR 5.08 billion in fertiliser costs while reducing Europe's natural gas bills by EUR 1.12 billion

Scenario	Avoided synthetic nitrogen (Mt)	Gas saved (bcm)	Gas cost saved, 2024 TTF (EUR bn)	Gas premium avoided, 2024 TTF (EUR bn)	Gas premium avoided, 2022 peak (EUR bn)	Fertiliser costs saved (EUR bn, 2024)	Environment damage saved (EUR bn, 2024)
GD-F	1.53	1.5	0.52	0.31	1.79	2.36	7.48
FAO-FM	3.28	3.3	1.12	0.67	3.86	5.08	16.09

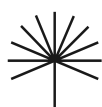
Source: Scenarios follow Batool et al. (2025), Nature Food: GD-F = -20% synthetic fertiliser use (EU Farm-to-Fork target); FAO-FM = -43% synthetic fertiliser and -4% manure (FAO TSS scenario, with balanced fertiliser-and-manure cuts). • Baseline 2024 synthetic nitrogen (N) consumption of 7.63 Mt covers the 17 EU member states included in this analysis. The gas savings shown are gross and assume that each kilogram of avoided N displaces domestic gas-based ammonia production. To the extent that reduced domestic production is replaced by fertiliser imports, the actual EU gas savings would be lower. The FAO-FM scenario also includes a 4% reduction in manure N inputs; the figures in the table capture only the synthetic N contribution to gas savings and damage reduction. The scenarios assume a uniform percentage reduction across all member states; in practice, the Batool et al. study shows that fertiliser-dependent regions (e.g. France, Germany) respond differently from manure-dominated regions (e.g. Netherlands, Ireland).



An annual saving of 3.3 bcm is a meaningful share of the gas currently embedded in EU synthetic fertiliser: at 2024 gas prices, this represents a saving of EUR 1.1 billion – [more than the annual Common Agricultural Policy \(CAP\) payment for Sweden in 2023](#) – while at crisis period gas costs, this represents a saving of almost EUR 3.9 billion – more than the annual CAP payments for the Netherlands, Denmark, Ireland and Latvia combined.

European farmers have already demonstrated that synthetic nitrogen use can be substantially reduced

A landmark benchmarking study of 78 regenerative farms – incorporating principles of agroecology, conservation agriculture and other holistic practices –



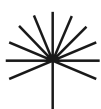
across 14 European countries found that between 2020 and 2023, participating farmers achieved on average [only 1% lower yields in terms of kilocalories and protein, while using 62% less synthetic nitrogen fertiliser and 76% fewer pesticides per hectare](#). The study covered Italy, Germany, Greece, Finland, Estonia, Sweden, Belgium, Spain, France, Hungary, Norway, Portugal, Slovenia and the Netherlands. These results reflect pioneering practitioners rather than average farms, and illustrate what is achievable rather than what is typical.¹⁸

A multi-country European study found that integrating legumes into crop rotations decreased nitrogen fertiliser use and nitrous oxide emissions in more than 90% of rotation comparisons, with [reductions ranging from 6–142 kg nitrogen per hectare](#). A review of 29 European field experiments found that [nitrogen fertilisation following grain legumes can be reduced by 23–31 kg nitrogen per hectare while maintaining yield potential](#), with cereal yields mostly 0.5–1.6 tonnes per hectare higher than after cereal pre-crops.

Large-scale cereal field trials co-designed with farmers in western France found that substantial nitrogen and pesticide reductions resulted in average yield gaps of only around 5%, while cost savings compensated for economic losses and even surpassed them in many conventional field experiments. Critically, during the 2022 energy crisis, [70% of farms reducing inputs showed improved gross margins](#) – demonstrating that input reduction is most economically attractive precisely when energy-driven price shocks make fertiliser expensive.

A trial on winter wheat in the Netherlands found that precision nitrogen management produced identical grain yield and protein content compared to traditional management, while [reducing nitrogen inputs by 15–27%](#). Another multi-year trial on arable farms in the nitrogen-intensive southeastern Netherlands found that [nitrogen fertilisation could be reduced by 25–50% compared to standard amounts without negatively affecting crop yields](#) or quality, while simultaneously halving groundwater nitrate concentrations. Key factors included careful matching of nitrogen demand and supply, and using catch crops (fast-growing plants sown between main agricultural crops).

¹⁸ The research was carried out by the European Alliance for Regenerative Agriculture (EARA), an independent, farmer-led coordination, advocacy and collective action organisation of the movement of regenerative agriculture at the European level. It was commissioned and stewarded by the Farmers of the European Alliance for Regenerative Agriculture with the aim to bring the voices of regeneration practitioners and pioneers into the economic, agronomic and political discourses on the transformation of agri-food ecosystems. [Farmer-led Research on Europe's Full Productivity](#) (2025).



Energy price shocks directly transfer to food prices

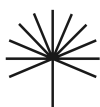
As synthetic nitrogen fertiliser is produced almost entirely from natural gas, energy price shocks can travel [directly into the cost of growing food](#). To test whether the energy crisis following Russia's invasion of Ukraine had a measurable and lasting impact on European wheat prices – the continent's most important cereal crop – we estimated the relationship between natural gas prices (Title Transfer Facility, TTF), urea prices and wheat prices from January 2010 to December 2025, controlling for US dollar movements and the disruption to Ukrainian grain exports. The model tests whether these three prices move together over time and, when they diverge, how quickly they correct – plus, crucially, how much of wheat's price variation can be traced back to energy and fertiliser markets.¹⁹

Our model shows that at the height of the energy crisis, rising gas and fertiliser costs drove wheat prices higher. Three years on, energy and fertiliser markets continued to explain a substantially larger share of wheat price movements than before the crisis.²⁰

At the height of the energy crisis in late 2022, our model estimates that gas and fertiliser price shocks together pushed wheat prices approximately 22% higher than

¹⁹ Monthly price data are from the [World Bank Pink Sheets](#). We used a Vector Error Correction Model (VECM), which is used for commodity price series that share long-run equilibria while fluctuating around them in the short run. This approach identifies how much of the unpredictable variation in wheat prices can be attributed to independent shocks originating in gas and fertiliser markets specifically, after accounting for the long-run equilibrium relationship between the three price series. Following [Janda & Kravec \(2022\)](#), sub-period analysis was used to test whether the transmission relationship is stable across time, rather than assuming a fixed long-run elasticity. We used the wheat series US Hard Red Winter (HRW) and the urea series East Europe, bagged, f.o.b. Black Sea (USD/tonne).

²⁰ Before 2020, urea price changes had no statistically significant positive pass-through to wheat prices: the coefficient was negative (-0.108). After 2020, this flipped: the urea-to-wheat coefficient became positive (+0.119) and the shift was statistically robust ($p=0.003$).



what market conditions alone would otherwise have implied.²¹ This occurred even after accounting for the loss of Ukrainian grain exports.²²

The model also shows that after the energy crisis peak, energy and fertiliser markets did not simply return to their pre-crisis relationship with wheat prices. In the three years after the crisis, gas and fertiliser prices together continued to explain a substantially larger share of wheat price movements than before 2020.²³

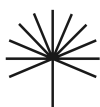
Europe's fertiliser dependency is a structural risk that supply chain policy cannot solve

Today, Europe's dependency dynamic is unfolding again: after years of import dependence on Russian fertiliser, the [EU imposed prohibitive tariffs in early 2025](#), redirecting its dependence toward North Africa and the Middle East rather than resolving it – effectively substituting one geopolitical exposure for another.

²¹ The 22% figure is derived from a historical shock decomposition (a standard technique that partitions each period's data into the cumulative contributions of different structural shocks, e.g. see [Whelan 2025](#)) of the VECM, using Cholesky identification with natural gas treated as the most upstream variable in the chain. Gas and urea contributions are expressed as approximate percentage deviations from the model baseline. To test whether this was a one-off or something more durable, we tracked the energy–food relationship across successive five-year windows throughout the sample (84 windows, December 2014 to August 2025). Over the whole period, gas and urea together explained around 13–14% of wheat price variation over a 12-month horizon. In post-crisis windows that share rose to 50–60%, and has not fallen back. By 2024, gas and urea contributed roughly equally – each around 28–33% – where before the crisis gas dominated and urea contributed relatively little.

²² Because there was disruption to Ukrainian and Russian wheat exports following the February 2022 invasion, we added a dummy variable for the Ukraine war period and its interaction with urea price changes to the model. The post-2020 amplification of the urea-to-wheat transmission remained statistically significant at the 5% level after this control ($p=0.021$), while the Ukraine-specific interaction term was not statistically significant ($p=0.76$). This confirms that the fertiliser channel amplification is not just an artefact of reduced wheat exports due to the invasion. This is also supported by [Vatsa et al. \(2023\)](#), which found that cereal prices can respond to energy and fertiliser price shocks independently of shifts in the underlying fundamentals of crop markets. Further, applying our same methodology finds no significant gas-to-coffee price transmission ($p=0.13$), supporting the interpretation that the channel operates specifically through nitrogen-dependent crops rather than reflecting general commodity co-movement.

²³ A literature search shows that prior to the crisis, the relationship between energy, fertiliser and food commodity prices was well-documented but modest. [Vatsa et al. \(2023\)](#) found that cereal price responses to gas and fertiliser shocks were small and short-lived under normal conditions, while Duan (2025) found that energy–fertiliser coupling strengthened after the Ukraine invasion in February 2022 (Price and volatility linkages between natural gas, fertilizer (urea), corn, and wheat markets using a VAR–DCC–GARCH model: uncertainties during the Ukraine war: thesis presented to the Faculty of the Graduate School of Cornell University).



Gulf countries account for at least 20% of all fertiliser exports, and [46% of globally traded urea originates from the region](#). The closure of the Strait of Hormuz as a result of the war in Iran has already choked urea shipments, [pushing urea prices up by 50% and European gas prices by 59%](#), squeezing margins and forcing some farmers to reduce nitrogen use. Fertiliser costs have [increased by 70% for UK farmers](#), with concerning impacts on global food prices in the coming year. The Bloomberg Agriculture Spot Index, which tracks 10 of the world's top crops, has [climbed to the highest levels since 2023](#), while a Nature comment warns that without structural change [‘the world will keep lurching from energy shock to harvest failure’](#).

Our analysis puts a number on what the EU's high synthetic nitrogen fertiliser use costs – and what reducing this dependency could save. Without structural reductions in nitrogen dependency, Europe's geopolitical exposure will persist, threatening farm livelihoods, food prices and environmental quality. Delivering the savings and resilience gains outlined above will require deliberate policy support, including for the transition to [low-input agricultural practices](#) such as legume crop rotations, reduced tillage, buffer zones such as vegetated strips, and precision agriculture aimed at nitrogen management.

