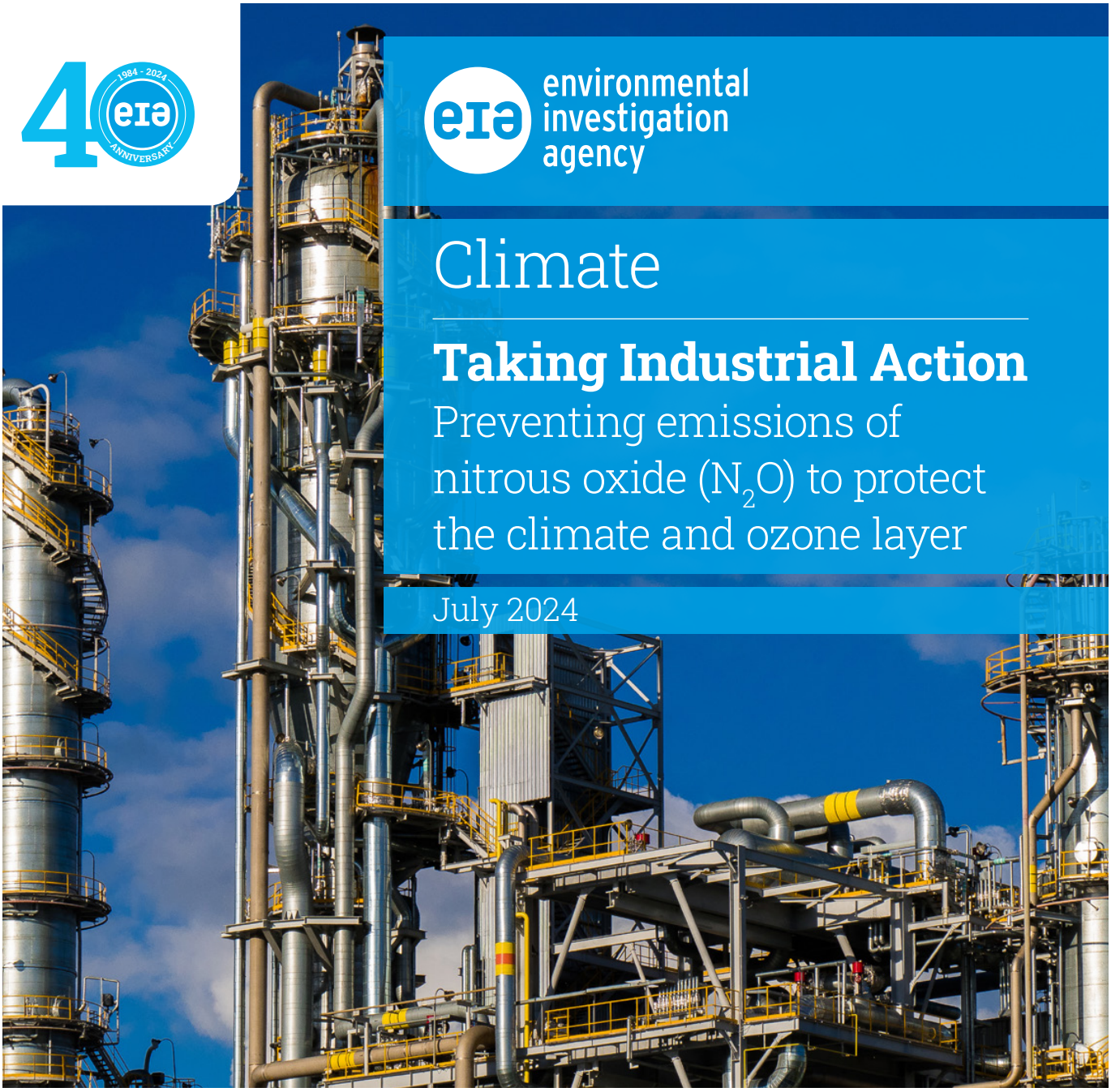
environmental investigation agency

Climate

Taking Industrial Action

Preventing emissions of nitrous oxide (N_2O) to protect the climate and ozone layer

July 2024



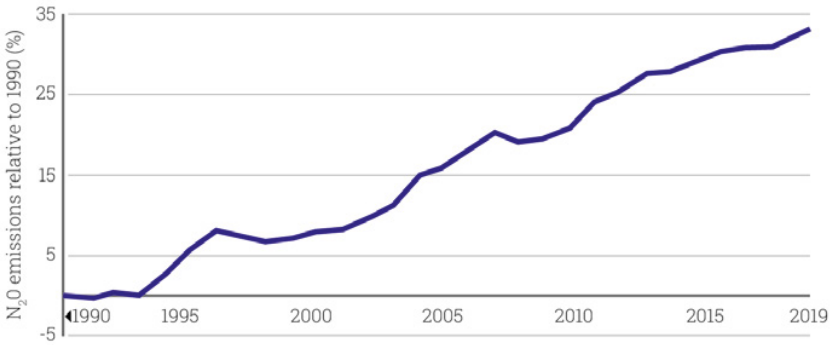
Introduction

Nitrous oxide (N_2O) is the most significant ozone-depleting substance (ODS) in the world today and is projected to remain so throughout the 21st century.[1] It is also the third most important greenhouse gas (GHG), being 273 times more potent than carbon dioxide (CO_2) on a tonne-for-tonne basis over a 100-year period.[2]

Although its ozone-depleting potential was first recognised more than 50 years ago, and despite being listed as one of six GHGs under the UN Framework Convention on Climate Change (UNFCCC), N_2O emissions have been largely ignored in environmental policy discussions to date.[3] N_2O is not subject to controls under the Montreal Protocol, although it is listed under the Vienna Convention for the Protection of the Ozone Layer, and it has received limited attention in countries' Nationally Determined Contributions (NDCs) under the UNFCCC.

According to the IPCC, anthropogenic N_2O emissions have increased by at least 33 per cent since 1990, exceeding some of the highest projected emission scenarios (see Figure 1, overleaf).[4] Largely unchecked, N_2O emissions simultaneously undermine global efforts to reverse depletion of the ozone layer under the Montreal Protocol and limit global warming to 1.5°C under the Paris Climate Agreement.

Figure 1: *Global anthropogenic N_2O emissions, relative to 1990 (IPCC Sixth Assessment Report)*



	N_2O
2019 Emissions	2.7+1.6 $GtCO_2$-eq
1990-2019 growth	0.65 $GtCO_2$-eq
Change in emissions, relative to 1990	+33%

Source: *Lamb, W. F., 2022, Data for Figure SPM.1 - Summary for Policymakers of the Working Group III Contribution to the IPCC Sixth Assessment Report, MetadataWorks, https://doi.org/10.48490/vfxm-tm28*

Industrial emissions of N_2O

The majority of human-caused N_2O emissions come from agriculture, largely through the overuse of synthetic fertilisers and manure, with wastewater, biomass burning, transport and industrial emissions also contributing significantly to the total anthropogenic output.[5]

Emissions of N_2O from industrial sources and the energy sector make up about 14 per cent of the anthropogenic total, equivalent to approximately 372 million CO_2-equivalent tonnes (372 $MtCO_2$-eq) annually (see Figure 2, overleaf).[6] These emissions are almost entirely avoidable. Using existing low-cost abatement technologies, already employed in many plants and facilities across the world and already required by regulation in some regions, industrial emissions of N_2O can be reduced to nearly zero.[7, i]

Industrial byproduct emissions of N_2O are produced during the manufacture of nitric acid, adipic acid and caprolactam. Among other uses, nitric acid is a key component in the manufacture of nitrogen-based fertilisers and explosives. Adipic acid and caprolactam, meanwhile, are key components in the production of high-strength nylons, which are themselves used in the manufacture of tyres, carpets and other textiles.[8] The United States Environmental Protection Agency (US EPA) estimates that ~80 per cent of the total abatement potential for N_2O emissions from adipic and nitric acid production is achievable at break-even prices below $20 (USD). Many studies estimate this cost to be even lower, with some suggesting that abatement potentials of 98-99 per cent could be achievable during adipic acid production for between $1-$11 (USD) per tonne of CO_2-eq.[9]

Of the approximately 580 nitric acid plants operating worldwide, just over 100 have N_2O abatement technologies installed (about 17 per cent). Without the installation of widespread abatement equipment, the US EPA estimates that N_2O emissions from nitric acid production will increase to almost 92 $MtCO_2$-eq per year by 2030, representing a 17 per cent increase from 2015.[10]

Abatement technologies are more widely used in adipic acid and caprolactam production, but the adoption of this equipment is not universal and installation alone is not a guarantee of effective use. In the case of adipic acid production, the US EPA estimates that without intervention to install abatement equipment globally, annual by-product emissions of N_2O will rise to more than 178 $MtCO_2$-eq by 2030, an 86 per cent increase from 2015.[11]

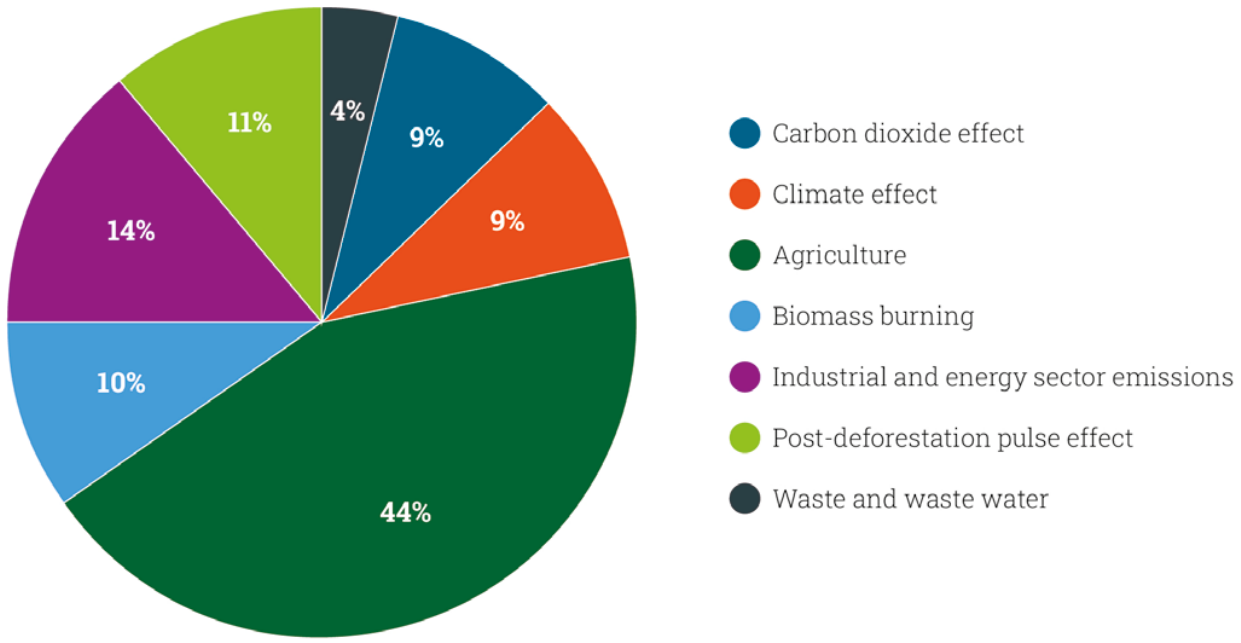
The uneven application of N_2O abatement practices across different regions is demonstrated by the variation in emission intensities associated with adipic acid production. For example, in the US – where N_2O abatement is not mandated for industrial processes at the federal level – an average 40kg N_2O (11 tCO_2-eq) are released per tonne of adipic acid produced.[12] In the EU and South Korea, where abatement requirements are in place, average N_2O emissions are between 2-4kg N_2O (0.5-1 tCO_2-eq) per tonne of adipic acid.[13]

i: Some examples of regions where regulation is already in place include: the EU, where N_2O emissions from nitric acid and adipic acid production have been included under the EU Emissions Trading Scheme (ETS) since 2013; South Korea, where N_2O emissions from nitric acid, adipic acid and caprolactam production have been fully included under the Korea Emissions Trading Scheme (K-ETS) since 2021; and Israel, where nitric acid plants are subject to environmental permits that place limits on maximum permissible emissions of N_2O. (For sources, see Reference 29).

In China – which has at least 11 adipic acid plants and produces more than half of the world's supply – no requirements to abate N_2O emissions exist. Abatement in China is thought to have largely ceased in the early 2010s when funding under the Clean Development Mechanism (CDM) ended due to companies 'gaming the system' by increasing their byproduct output in order to sell more destruction credits.[14] Although a comprehensive national inventory does not exist, quantification studies have estimated that China's N_2O emissions from adipic acid production alone could already be as high as 128 $MtCO_2$-eq annually.[15]

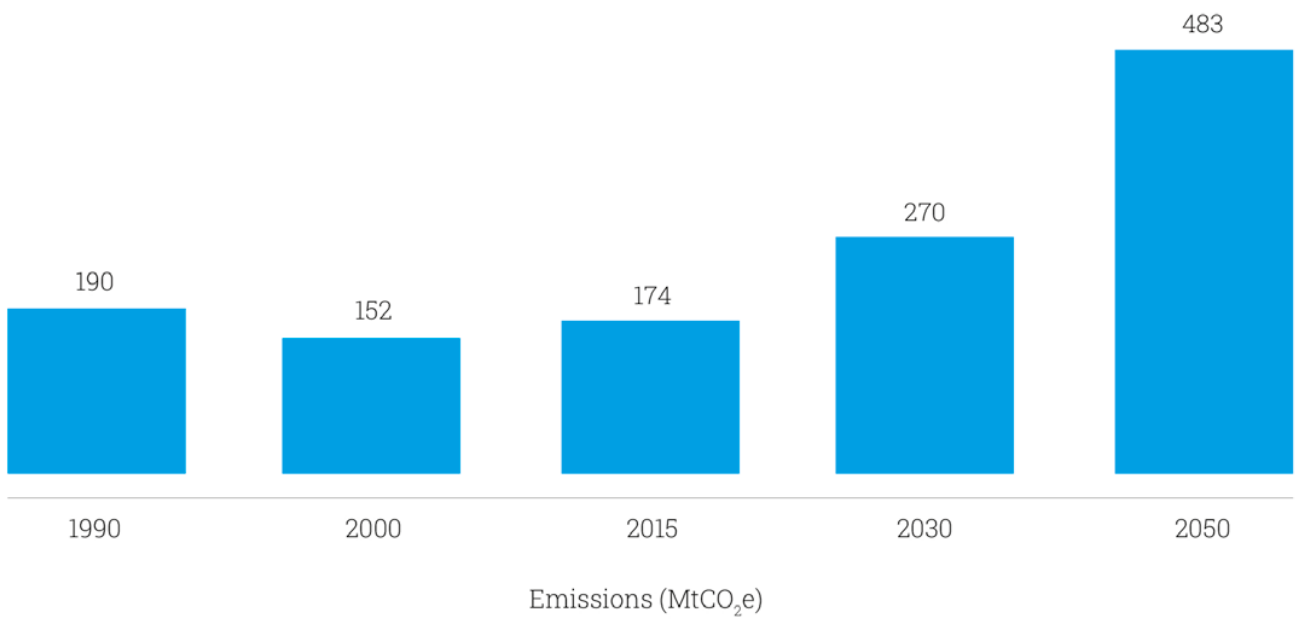
Without action, this issue will only compound as global demand for nitric and adipic acid continues to grow. In the absence of international efforts to ensure the universal application of abatement equipment, we face the prospect of combined N_2O emissions from these industrial sources reaching as high as 483 $MtCO_2$-eq annually by 2050 (see Figure 3).[16]

Figure 2: *Breakdown of anthropogenic N_2O emission sources, based on H Tian's "Global N_2O Budget for 2010-2019"*



Source: *H Tian, et al., Global nitrous oxide budget (1980-2020), ESSD, 16, 2543–2604 (2024) https://doi.org/10.5194/essd-16-2543-2024*

Figure 3: *Historic and projected emissions of N_2O from nitric and adipic acid production globally, based on US EPA data*



Source: *US EPA, Global non-CO_2 greenhouse gas emission projections & mitigation 2015-2050 (EPA-430-R-19-010, 2019). Available at: https://epa.gov/global-mitigation-non-co2-greenhouse-gases*

N_2O emissions from the energy sector

The energy sector is also a significant source of N_2O as it is emitted whenever fossil fuels are burned. The extent to which N_2O is emitted depends on many factors, including the type of fuel and the level of nitrogen in it, the operating temperature for burning and the oxygen levels during combustion.[17] Fossil fuel-based energy production is estimated to emit about 824,000 tonnes of N_2O globally each year, equivalent to 225 $MtCO_2$-eq.[18] Despite the fact that abatement technologies exist in this sector (capable of removing up to 80 per cent of N_2O emissions from the combustion process), and despite the Glasgow Climate Pact commitment to accelerate the phase-down of unabated coal power (the largest source of N_2O emissions in the energy sector), these significant annual emissions also continue.[19]

Ammonia as an alternative fuel source

As the viability of 'green' ammonia (ammonia produced using a 100 per cent carbon-free process) is increasingly explored as a cleaner alternative to traditional fossil fuels, the implications for emissions of N_2O must be considered as a priority.[20] Numerous studies have shown that the potential for high N_2O emissions associated with the use of ammonia as a fuel would offset its "carbon-free advantages" without appropriate abatement practices in place.[21] Waiting until this technology is already deployed at scale before implementing clear regulations requiring the use of abatement equipment – much of which is still under development – will result in millions of CO_2-equivalent tonnes in unnecessary and avoidable emissions.[22]

Controlling industrial emissions under the Montreal Protocol

Strengthening the patchwork of national and regional regulations which currently govern industrial N_2O emissions – and plugging the gaps where no such regulations exist – will require a coordinated global effort guaranteed by a multilateral commitment.

With its successful track record in phasing out fluorinated ODS, including CFCs and HCFCs, and its legacy of increasing environmental and climate ambition, the Montreal Protocol is uniquely well-suited to address the challenge posed by industrial emissions of N_2O.

N_2O has been officially recognised as a substance that modifies the properties of the ozone layer since 1985 when it was listed under Annex I of the Vienna Convention alongside chlorine substances including CFCs and bromine substances such as methyl bromide.[23] It has an ozone-depletion potential (ODP) of 0.02, which is similar to that of many of the substances currently being phased out under the Montreal Protocol.[ii] Unlike these chlorine and bromine substances, however, Parties to the Montreal Protocol have not yet taken any action to control N_2O under the treaty, even though it is now recognised by the Protocol's Scientific Assessment Panel as "a serious threat" to stratospheric ozone.[24]

Historically, the Montreal Protocol's primary mechanism for controlling ODS has been to phase out their production and use, ultimately leading to a reduction in their emissions. In the case of industrial N_2O emissions, where the substance of concern is a byproduct and is not purposefully produced for "consumption", this approach would not be well suited. However, in its approach to tackling byproduct emissions of HFC-23 adopted under the Kigali Amendment, the Montreal Protocol has already set a precedent for how industrial emissions of N_2O could be addressed.

ii: ODP is measured relative to chlorofluorocarbon-11 (CFC-11), which has an ODP of 1.

Paragraph 6 of Article 2J of the Protocol outlines that Parties manufacturing HCFCs or HFCs must ensure any emissions of HFC-23 generated during the process are "destroyed to the extent practicable using technology approved by the Parties".[25] A similar approach could be applied to address byproduct emissions of N_2O generated during industrial chemical production. These emissions can already be abated using proven, cost-effective technologies—which the Technology and Economic Assessment Panel (TEAP) could itself review and approve—and Parties would have the ability to clearly define in which processes they must be deployed.

In the case of the HFC-23, the Multilateral Fund for the Implementation of the Montreal Protocol (MLF) has provided funding to two Article 5 countries, Argentina and Mexico, to support the acquisition and operation of approved technologies necessary for compliance with the destruction requirement.[26] This model, and any lessons learnt from it, would be highly pertinent should a requirement to abate industrial N_2O emissions be implemented under the Protocol.

Also relevant is the work already being carried out bilaterally by GIZ's Nitric Acid Climate Action Group (NACAG).[27] NACAG has so far signed statements of understanding with 16 partner countries, providing them with financial and technical support to install N_2O abatement technologies in all their nitric acid production facilities at the national level, as well as policy advice on how to guarantee their ongoing use and maintenance.[28] Having already secured demonstrable action within its partner countries, the NACAG initiative offers a template that could be adapted to facilitate the implementation of an N_2O abatement requirement under the Montreal Protocol.

Below: Nitric acid is a highly corrosive substance, primarily used in the manufacture of nitrogen-based fertilisers and explosives.

Conclusions and recommendations

For far too long, N_2O emissions have been ignored in the climate debate, falling between the cracks of multiple multilateral treaties. With climate action more urgent than ever, we cannot continue to ignore this most low-hanging of mitigation fruits.

The Montreal Protocol's historic success relates directly to phasing out harmful ODS and GHGs associated with chemical manufacturing and the industrial sector. A precedent for increasing the Protocol's scope and ambition has also been firmly established throughout its history. With universal ratification, a mandate to act on ODS and an existing precedent to expand its scope to secure additional climate benefits, the Montreal Protocol is the best placed multilateral agreement to directly address industrial emissions of N_2O.

With this context in mind, EIA recommends the Parties to put in place the following steps for securing action on the universal abatement of industrial N_2O emissions under the Montreal Protocol:

- **request the Ozone Secretariat to engage with relevant stakeholders on the topic of controlling industrial N_2O emissions under the Montreal Protocol, including but not limited to: GIZ's Nitric Acid Climate Action Group (NACAG); the Climate & Clean Air Coalition (CCAC); the International Nitrogen Initiative (INI); the UNEP Nitrogen Working Group; and interested Parties**

- **request the TEAP, in coordination with the SAP, to produce a report on the technical feasibility, economic costs and ozone and climate benefits associated with the abatement of N_2O emissions from industrial sources (i.e., nitric acid, adipic acid and caprolactam production)**

- **request the SAP to produce a targeted report on the ozone and climate impacts of N_2O emissions from all sources and to outline the projected trends for such emissions.**

By agreeing a pathway to secure action on industrial emissions, the parties to the Montreal Protocol can take meaningful steps towards reducing annual global emissions of this powerful, long-lived and ozone-depleting greenhouse gas, further securing the Protocol's legacy as the world's most successful environmental treaty.

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environmental investigation agency

EIA US
PO Box 53343, Washington DC, 20009, USA
eia.org
+1 202 483 6621

EIA UK
62-63 Upper Street, London, N1 0NY, UK
eia-international.org
+44 (0)20 7354 7960