Scientists for Global Responsibility

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**Funded by:** Marmot Charitable Trust

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Any errors remain, of course, the responsibility of the author.

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# Contents



## Acronyms

| | |
|---|---|
| CEOBS | Conflict and Environment Observatory |
| $CO_2$ | carbon dioxide |
| EEIOM | environmentally-extended input-output model |
| GDP | Gross Domestic Product |
| GHG | greenhouse gas |
| LCA | life-cycle assessment |
| NATO | North Atlantic Treaty Organisation |
| SIPRI | Stockholm International Peace Research Institute |
| SGR | Scientists for Global Responsibility |
| $tCO_2e$ | tonnes of carbon dioxide equivalent |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USD | US dollar |

# Executive summary

With military spending climbing rapidly around the world, this report assesses the results of eleven studies which have tried to estimate how such spending rises will impact greenhouse gas (GHG) emissions.

This review finds that a standardised spending rise of $100 billion will lead to an increase in the military carbon footprint of approximately 32 million tonnes of carbon dioxide equivalent ($tCO_2e$). However, the uncertainty in that figure is high.

Another finding is that the increase in NATO's military spending over the five years, 2019-24 has led to an increase in its military carbon footprint of about 64 million $tCO_2e$ – similar to the territorial emissions of Bahrain – and further planned increases are likely to lead to an additional rise of about 132 million $tCO_2e$ – more than the territorial emissions of Chile. Again, the uncertainty in these figures is high.

It should be noted that these are single-year totals and so, if spending is maintained at higher levels as currently planned, there will be a major cumulative impact of emissions on the climate system. These estimates also do not include emissions due to the impact of war-fighting.

The relationship between military spending and military GHG emissions is highly complex and not easy to predict, meaning that it will be difficult to reduce the uncertainty in these projections. It is therefore essential that measuring and reporting of direct and indirect military GHGs are greatly improved, so that these changes can be adequately monitored. For example, military spending increases can cause rises in numerous categories of emissions: military fuel or electricity consumption; supply-chains within the arms industry, in the home nation or abroad; production of raw materials and components for use in military goods and services, within the home nation or abroad; upper atmosphere heating effects due to aircraft use; or war-fighting emissions. The wider use of environmentally-extended input-output models is especially recommended to capture the impacts of indirect emissions.

Despite the uncertainties, the research to date indicates that much stronger efforts need to be directed towards measures to reduce the military carbon footprint. These efforts need to include both technological and non-technological measures, the latter including renewed efforts at peacebuilding, arms control, and disarmament. The research also indicates that reductions in military spending can result in GHG emissions falling at a more rapid rate then they grew.

The latest assessment by leading climate scientists is bleak. They say that the Paris 1.5°C target will be breached within a few years without "immediate, transformative action... to reduce emissions". It is extremely difficult to see how the current and planned military spending increases can be reconciled with the transformative action necessary to prevent dangerous climate change.

# 1. Introduction

Military activity is very energy intensive and, since most of this energy is derived from fossil fuels, it leads to large emissions of greenhouse gases (GHGs). But it is not just the direct emissions from fuel-hungry combat planes, warships and armoured vehicles that contribute to climate change, there are also numerous indirect emissions – due to the movement of equipment, huge and complex supply-chains including energy-intensive production of materials such as steel and aluminium, and the impacts of war-fighting itself. The global military carbon footprint – including supply-chains, but excluding war-fighting impacts – was estimated to be about 5.5% of global GHG emissions in 2019.[1] This was larger than the carbon footprint of the whole of Russia.

Since then, global military expenditure has surged, reaching $2,718 billion in 2024, the highest since at least the end of the Cold War.[2] The latest rises have been driven especially by Russia's 2022 invasion of Ukraine and the consequent growth in military spending among the member nations of the North Atlantic Treaty Organisation (NATO), as well as increases in armed conflict more widely, especially in the Middle East. With NATO recently agreeing a new military spending target of 3.5% of Gross Domestic Product (GDP) – as part of a wider security spending target of 5% GDP – there is a very real possibility that the global military carbon footprint could be rising rapidly.

However, data on military GHG emissions is often of poor quality or missing altogether.[3] The National Inventory Reports – required by the United Nations Framework Convention on Climate Change (UNFCCC) – have numerous loopholes which allow data on direct military emissions to be obscured. Data quality for indirect emissions is even worse. Some militaries in industrialised, democratic nations have begun independently publishing GHG data, but its quality is variable.

These data problems mean that current estimates of regional and global military emissions are subject to high uncertainty, with future projections even more so. Several studies have been published over the past two years estimating the potential increases in military GHG emissions due to the current and future spending surges. The level of agreement between these estimates is often difficult to determine, because of differing methodologies, geographical coverage, timescales, and other factors. The purpose of this report is to compare these studies and estimate the range of emissions increase for a standardised spending rise.

The report is laid out as follows. Section 2 discusses the numerous ways in which military spending levels can affect military GHG emissions. Section 3 summarises the findings of eleven studies published in the past two years that have examined the link between military expenditure and emissions. Section 4 compares all the findings and calculates estimates for GHG emissions rises for a standardised increase in military spending of $100 billion. Section 5 discusses data gaps which affect these figures and, in Section 6, all this analysis is brought together to estimate a range for the change in military carbon footprint for a $100 billion change in spending. This is also used to estimate the

1 Parkinson, S. and Cottrell, L. (2022). *Estimating the Military's Global Greenhouse Gas Emissions*. SGR. https://www.sgr.org.uk/publications/estimating-military-s-global-greenhouse-gas-emissions

2 Liang *et al.* (2025). *Trends in World Military Expenditure, 2024*. Stockholm International Peace Research Institute. https://www.sipri.org/publications/2025/sipri-fact-sheets/trends-world-military-expenditure-2024

3 See, for example: The Military Emissions Gap (2025). https://militaryemissions.org/

effect of NATO's new 3.5% GDP spending target on military emissions.

To aid in the discussion, Box 1 summarises the key terminology used in this report.

## BOX 1. SUMMARY OF MILITARY GHG EMISSIONS TERMINOLOGY

The terminology used to describe military GHG emissions is quite extensive, and there has often been inconsistency between different studies. Here is a summary of the main terms used in this report, based on methodologies recommended by the GHG Protocol[i] and the Conflict and Environmental Observatory (CEOBS).[ii]

**Scope 1/direct emissions.**
These are due to activities carried out using equipment, buildings etc owned by the specific organisation under study. These activities most commonly include fossil fuel combustion by aircraft, naval craft, and land vehicles, and for the heating of buildings.

**Scope 2 emissions.**
These are most commonly due to electricity use by a specific organisation, where the electricity is produced by a third-party energy utility burning fossil fuels. Emissions due to utility-owned district heating networks are also included in this category.

**Core emissions.**
The total of scopes 1 and 2 emissions. These are commonly reported by many major organisations.

**Scope 3/supply-chain emissions.**
These result from activities in the upstream or downstream supply-chain of an organisation, for example, in the production of goods and services. For a military, the overwhelming majority of scope 3 emissions are upstream.

**Indirect emissions.**
The total of scopes 2 and 3 emissions.

**Carbon footprint.**
The total of scopes 1, 2, and 3 emissions for a specific organisation.

**Scope 3+/ war-impact emissions.**
A recently defined category including additional emissions due to the impacts of armed conflict. Included within this category is: the destruction of carbon reservoirs such as fossil fuel storage facilities or forests; transport of refugees; and post-conflict reconstruction.

**Carbon bootprint.**
The total of scopes 1, 2, 3, and 3+ emissions for a specific military.

**Conflict emissions.**
An alternative, but overlapping, accounting system using a specific war/ armed conflict as the basis for assessment. It includes scope 1, 2, 3, and 3+ emissions specifically related to that conflict.

i GHG Protocol (2004). The GHG Protocol: A Corporate Accounting and Reporting Standard: Revised Edition. https://ghgprotocol.org/corporate-standard

ii CEOBS (2022). A framework for military greenhouse gas emissions reporting. https://ceobs.org/report-a-framework-for-military-greenhouse-gas-emissions-reporting/

## 2. Military spending and GHG emissions: an overview of the linkages

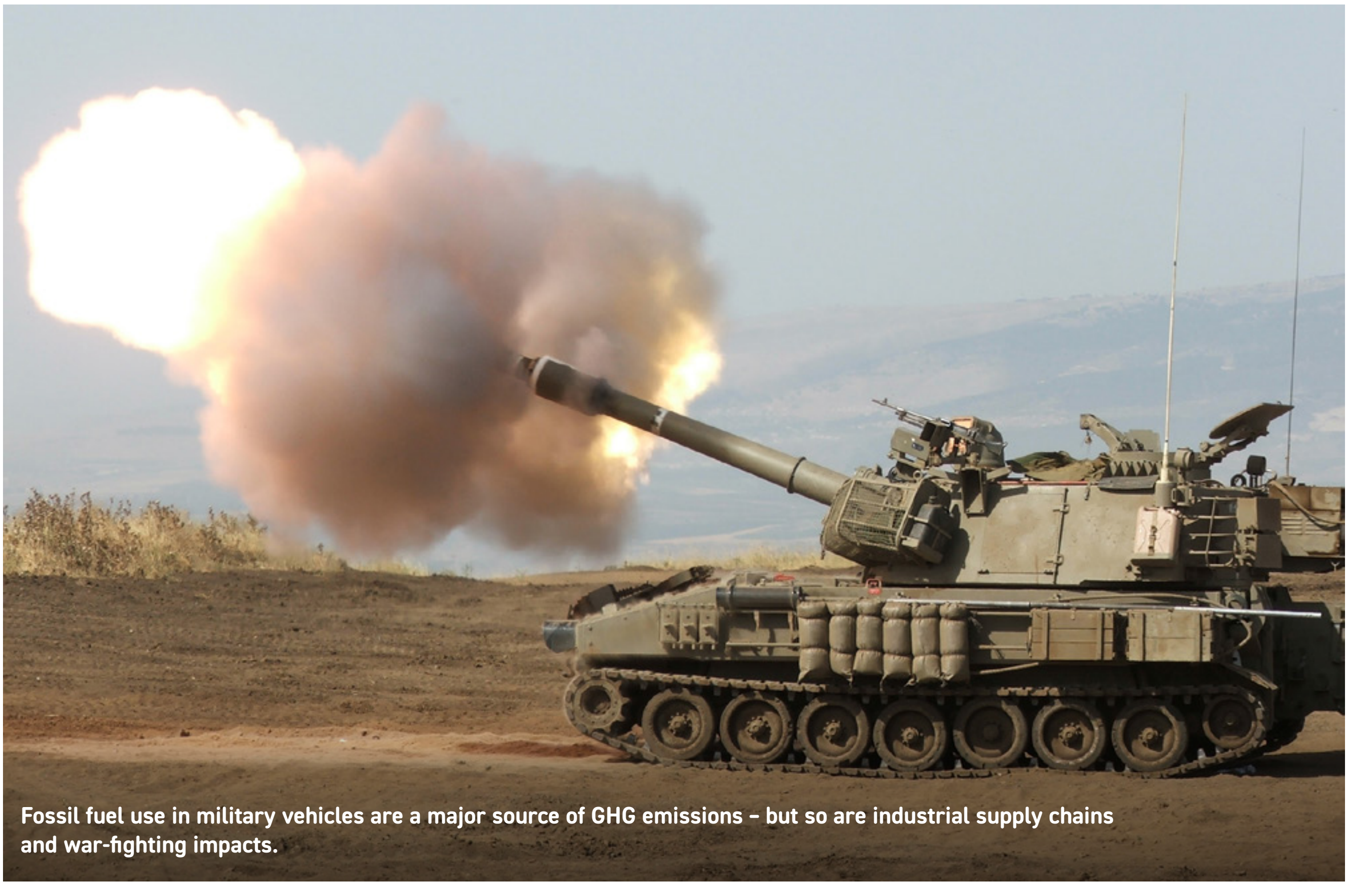
Changes in military spending can affect GHG emissions in many ways, the largest scale activities being:

1. Fossil fuel use in military-owned craft, on land, at sea and in the air, both for combat and non-combat roles;
2. Energy use at military bases, including fuel use for heating and electricity consumption, whether generated onsite or offsite;
3. Energy use in the industries that produce military equipment and other goods, as well as in their supply-chains, especially the production of carbon-intensive materials such as steel, aluminium, and 'rare earth' metals;
4. Energy use in sectors that provides services to the military, such as private military and security companies, logistics organisations, building contractors, and IT service providers;
5. Other civilian sectors impacted by military activity, including those damaged by weapons use;
6. Natural ecosystems impacted by military activity, including those damaged by weapons use;
7. Changes to civilian society due to technological diffusion or lock-in due related to military activity, including due to research and development.

In this list, items (1) and (2) lead to scope 1 emissions (see Box 1) and scope 2 emissions from energy use (mainly electricity). Activities (3) and (4) lead to scope 3 emissions. Activities (5) and (6) are included in the scope 3+ category, and are not assessed during standard GHG accounting. Likewise, activities within category (7) are not routinely compiled, as they are very difficult to measure. However, given that militaries are large and powerful organisations, it is important not to ignore these wider, potentially large, effects.

Direct GHG emissions from an activity are obviously the easiest to measure. In our situation, a rise in military spending can cause a rise in military fuel use, as the military is able to undertake more activity, whether in training, patrols or armed conflict. Estimates of increases in GHG emissions can simply be calculated from data on rising fuel use, when that data is available. Likewise, increases in indirect GHG emissions from rises in electricity consumption at military bases are straightforward to measure. However, some of the extra military spending will be used to buy new equipment or expand military bases. The GHG emissions due to these activities are spread through numerous suppliers and contractors, many of whom could report little or no GHG emissions data. The wider the net is cast, the more reliance is needed on mathematical models which incorporate both economic and environmental data, and the uncertainties tend to be higher in these cases.

So, while research charting the relationship between military spending and direct GHG emissions is the easiest to carry out, it is likely that only through investigation of both direct and indirect emissions will the bigger picture be understood. Indeed, there is good reason to believe that indirect GHG emissions are the larger component of any analysis. Strong evidence for this view comes from regular international surveys of civilian companies which carry out comparable activities to militaries. For example, corporations in the civilian transport sectors – air, sea, and land – have some similarities with military operators of these technologies. In a 2024


Fossil fuel use in military vehicles are a major source of GHG emissions – but so are industrial supply chains and war-fighting impacts.

survey, these transport operators reported total emissions (scopes 1, 2, and 3) on average to be *9 times* the sum of their core (scope 1 and 2) emissions.[4] Meanwhile, civilian companies in the infrastructure sector have some similarities with military bases. These companies report their ratio of total emissions to core emissions as being *20 times*.[5] Care should be taken in simply extrapolating this data to militaries, especially due to the risk of double-counting. Nevertheless, these figures indicate that the changes in GHG emissions due to variations in military spending are likely to be found across many organisations.

4 CDP/BCG (2024). *Scope 3 Upstream: Big Challenges, Simple Remedies.* p.8. https://cdn.cdp.net/cdp-production/cms/reports/documents/000/007/834/original/Scope-3-Upstream-Report.pdf NB. The CDP/BCG report quotes the ratio between scope 3 only and scopes 1 plus 2. Hence its figures have been recalculated in this report so that they are directly comparable.

5 *Ibid.*

# 3. What do the studies say?

The eleven studies reviewed in this report are listed in Tables 1a & b. Two have been published in peer-reviewed academic journals, two are other academic works, five have been published by civil society organisations, and two by commercial consultancies. Three of the studies have been published by the same team of authors. All have been published in past two years.

**Table 1a. Main studies on the relationship between military spending and GHG emissions, 2023–25: author and institutional details (listed in date order)**

| Date published | Authors | Title | Lead publisher | Other information |
|---|---|---|---|---|
| Oct-2023 | Lin *et al.* | Climate crossfire: how NATO's 2% military spending targets contribute to climate breakdown | Transnational Institute | Civil society organisation |
| Jul-2024 | Lin *et al.*l | Climate in the crosshairs: the planetary impact of NATO's spending increases | Transnational Institute | Civil society organisation |
| Aug-2024 | Marko | The green peace dividend: the effects of militarization on emissions and the green transition | Research Gate | Self-published academic paper |
| May-2025 | Kinney *et al.* | How increasing global military expenditure threatens SDG 13 on climate action | Conflict and Environment Observatory | Civil society organisation |
| May-2025 | Dong *et al.* | Rising military spending jeopardizes climate targets | Nature Climate | Peer-reviewed academic journal |
| Jun-2025 | unknown | Rearming Europe: counting the carbon 'bootprint' | Greenly | Commercial consultancy |
| Jun-2025 | Subran *et al.* | Captain Europe: five ways to forge the region's defense shield | Allianz | Commercial consultancy |
| Jun-2025 | Lin *et al.* | NATO's 3.5% spending goal: unsustainable on every count | Transnational Institute | Civil society organisation |
| Jun-2025 | Huibregtsen | The military emissions gap: analysing the implications of militarization for the EU Green Deal | Leiden University | Academic thesis |
| Jul-2025 | Thombs *et al.* | Reducing U.S. military spending could lead to substantial decreases in energy consumption | PLOS Climate | Peer-reviewed academic journal |
| Jul-2025 | Bigger *et al.* | The $1 trillion Pentagon budget will make its emissions higher than the entire country of Ethiopia | Climate & Community Institute | Civil society organisation |

**Notes:**
URLs for the studies are as follows:
Lin *et al.* (2023): https://www.tni.org/en/publication/climate-collateral-COP28
Lin *et al.* (2024): https://www.tni.org/en/publication/climate-in-the-crosshairs
Marko (2024): https://www.researchgate.net/publication/383529958_The_Green_Peace_Dividend_the_Effects_of_Militarization_on_Emissions_and_the_Green_Transition
Kinney *et al.* (2025): https://ceobs.org/how-increasing-global-military-expenditure-threatens-sdg-13-on-climate-action/
Dong *et al.* (2025): https://www.nature.com/articles/s41467-025-59877-x
Greenly (2025): https://greenly.earth/en-gb/leaf-media/data-stories/rearming-europe-counting-the-carbon-bootprint
Subran *et al.* (2025): https://www.allianz.com/en/economic_research/insights/publications/specials_fmo/250602-defense-report.html – the analysis of military GHG emissions can be found on pp.38–39 of their report.
Lin *et al.* (2025): https://www.tni.org/en/publication/natos-35-spending-goal
Thombs *et al.* (2025): https://journals.plos.org/climate/article?id=10.1371/journal.pclm.0000569
Bigger *et al.* (2025). https://climatecommunityinstitute.substack.com/p/1-trillion-pentagon-budget
Huibregtsen (2025a): https://studenttheses.universiteitleiden.nl/handle/1887/4257781 – a summary of the main findings of this thesis can be found in: Huibregtsen H (2025b). *Military spending and military emissions: the hidden links.* Responsible Science blog, SGR. June. https://www.sgr.org.uk/resources/military-spending-and-military-emissions-hidden-links

**Table 1b. Main studies on the relationship between military spending and GHG emissions, 2023-25: key components and findings (listed according to emissions categories and date)**

| Study | GHG emissions categories | Geographical coverage | Original methodology or previous study | Key findings |
|---|---|---|---|---|
| Thombs *et al.* (2025) | scopes 1,2 only | USA | original | Rise of 51% in military spending would lead to 8% rise in energy consumption; fall of 19% in military spending would lead to 18% fall in energy consumption (2023–2032) |
| Lin *et al.* (2023) | scopes 1,2,3 | NATO (32 nations) | original | NATO military carbon footprint (2021): 196 million $tCO_2e$ |
| Lin *et al.* (2024) | scopes 1,2,3 | NATO (32 nations) | Lin *et al.* (2023) | NATO military carbon footprint: rise of 31 million $tCO_2e$ (2022–23) |
| Lin *et al.* (2025) | scopes 1,2,3 | NATO (32 nations) | Lin *et al.* (2023) | NATO military carbon footprint: rise of 77 million $tCO_2e$ (2021–24); further rise to hit 3.5% spending target: 115 million $tCO_2e$ |
| Huibregtsen (2025a) | scopes 1,2,3 | EU-NATO (23 nations) | Lin *et al.* (2023) | EU-NATO military carbon footprint: rise of 35 million $tCO_2e$ (2019–24); further rise to hit 3.5% spending target: 29 million $tCO_2e$ |
| Bigger *et al.* (2025) | scopes 1,2,3 | USA | Lin *et al.* (2023) | US military carbon footprint: rise of 26 million $tCO_2e$ (2023–26) |
| Greenly (2025) | scopes 1,2,3 | NATO (32 nations)/ EU-NATO (23 nations) | original | Military carbon footprints: NATO: rise of 23 million $tCO_2e$ (2023–24); EU-NATO: rise of 2 million $tCO_2e$ (2024–25); EU's 4y rearmament programme: 150 million $tCO_2e$ |
| Subran *et al.* (2025) | scopes 1,2,3 | NATO Europe (30 nations) | original | NATO Europe military carbon footprint: rise to hit 3.5% spending target: 462 million $tCO_2e$ |
| Marko (2024) | wider economy | NATO+ | original | Rise of 1% in military share of GDP leads to 0.9–2.0% rise in national emissions |
| Kinney *et al.* (2025) | wider economy | NATO ex-USA (31 nations) | Marko (2024) | Rise in NATO (ex-USA) annual military-related emissions to hit 3.5% spending target: 98 to 218 million $tCO_2e$ (over 2019) |
| Dong *et al.* (2025) | wider economy | Global | original | Rise of 1% in military share of global GDP leads to rise in global $CO_2$ emissions intensity of 0.04 kg/USD |

Six of the studies derive new mathematical relationships between military spending and GHG emissions, and then use these to deduce their findings. The other five studies use mathematical relationships derived from one of the others to deduce their findings. One study – Thombs *et al.* (2025) – focuses on scope 1 and 2 emissions only, while six others focus on scopes 1 to 3, and three examine changes across whole national or international economies.

We begin our summary of the findings with the study which examined the narrowest range of effects of military spending rises. Thombs *et al.* (2025) focused on the relationship between military expenditure and military energy consumption in the USA, using data from 1975–2022. Direct energy consumption from aircraft, ships, land vehicles, and bases (scope 1) and electricity use (scope 2) was included, but other indirect sources (scope 3), such as supply-chains, were not. Because 99%

of energy consumption during this period was derived from fossil fuels, this consumption is strongly related to GHG emissions. However, the paper does not include explicit figures for emissions. Among the findings of the study were that a 4.7% annual increase in military spending over 10 years – a total rise of 51% – would lead to a 8% rise in energy consumption, while a 2.3% annual decrease in military spending – a total fall of 19% – would lead to a fall of 18% in energy consumption.[6] They conclude that energy consumption – and therefore emissions – is much more sensitive to cuts in spending that it is to rises. One explanation they suggest is that spending cuts may lead to earlier retirement of inefficient craft, whereas newly purchased craft may be more energy efficient. With US military emissions (scopes 1 and 2) being 48 million $tCO_2e$ in 2022–23, and assuming that the carbon intensity of energy consumption remains unchanged, it is possible to carry out some approximate calculations of how such figures might convert into emissions. For example, it implies that a 10% rise in military spending would result in an increase of 0.7 million $tCO_2e$, while a 10% fall in military spending would result in a decrease of 4.6 million $tCO_2e$.

The next group of five studies used the methodology derived by Lin *et al.* (2023) covering scopes 1, 2 and 3.

The basic equation is:

*Carbon footprint of a national military, including associated military technology industry =*
*(military expenditure) x*
*(proportion spent on equipment) x*
*(spend–emission conversion factor) +*
*(number of military personnel) x*
*(average stationary emissions per military head)*

The spend-emission conversion factor was derived using data from two large military technology corporations, Thales and Airbus, for the years 2020–22.

Lin *et al.* (2023) estimated that increasing NATO's military spending from its level in 2021 to a level where all member nations reached a minimum of the (then) NATO target of 2% GDP would lead to annual military GHG emissions for the alliance increasing from 196 to 209 million $tCO_2e$, a rise of 13 million $tCO_2e$.

Lin *et al.* (2024) carried out a second analysis of NATO's military GHG emissions, this time for 2022 and 2023. The 2023 emissions were estimated at 233 million $tCO_2e$, a rise of 31 million $tCO_2e$ over the 2022 level.

Following the announcement of the EU's €800 billion ReArm Europe Plan and the prospect of NATO agreeing a military spending target of 3.5% GDP, Lin *et al.* (2025) carried out a third analysis. They estimated that, by 2024, NATO's military carbon footprint had reached 273 million $tCO_2e$, a rise of 77 million $tCO_2e$ in just three years. They further estimated that, to reach the 3.5% target, the military carbon footprint would hit 388 million $tCO_2e$, an increase of 115 million $tCO_2e$ over the 2024 level[7] and 192 million $tCO_2e$ over the 2021 level.

Huibregtsen (2025a) estimated the military carbon footprint of the 23 nations that are both members of the EU and NATO, using the Lin methodology. She estimated this footprint to be 31 million $tCO_2e$ in 2019, rising to 66 million $tCO_2e$ by 2024, based on historic data. She also made a future projection that, from 2025, annual emissions would rise to about 95 million $tCO_2e$ due to the ReArm Europe Plan. In calculating the figure for 2025 onwards, she made conservative assumptions on the proportion

6 Calculated from figures in Table 4 and others in the main text of Thombs *et al.* (2025).

7 Lin *et al.* (2025) gave a figure for GHG emissions of 2,330 million $tCO_2e$ for a six-year period (2025–2030 inclusive) assuming the 3.5% target was reached on average over this period. For consistency with other studies presented here, we have converted this to a single year total.

of spending directed to military equipment and on military personnel numbers.

Following agreement of the first $1 trillion budget for the US military, Bigger *et al.* (2025) used the Lin equation to estimate that the carbon footprint of the US military in 2026 will reach 178 million $tCO_2e$, a rise of 26 million $tCO_2e$ in three years.

Greenly (2025) used, as a starting point, the estimate from Lin *et al.* (2024) that NATO's 2023 military carbon footprint was 233 million $tCO_2e$. From this, they calculated the GHG emissions intensity per unit currency of military spending (in US dollars) for that year. They then used this to estimate that the military carbon footprint for all NATO countries in 2024 would be 256 million $tCO_2e$ – a rise of 23 million $tCO_2e$ over 2023 – and for EU-NATO nations in 2025 the footprint would be 81 million $tCO_2e$, and for the ReArm Europe Plan as a whole – over its planned four years – it would be 150 million $tCO_2e$.

Subran *et al.* (2025) estimated the rise in the military carbon footprint of NATO European countries if they increased military spending to reach the 3.5% GDP target. They concluded this rise would be 462 million $tCO_2e$ from the 2019 level – significantly higher than comparable studies. We will discuss this large difference below.

Marko (2024) derived a complex mathematical model examining how national (territorial) GHG emissions have varied with military spending levels, as measured as a percentage of GDP. He used data from 1970-2016 and a main sample of 20 NATO countries. His main conclusion was that a one percentage point rise in the military spending share of GDP leads to a 0.9–2.0% rise in national emissions.

Kinney *et al.* (2025) used the results of Marko's study to estimate the increase in national GHG emissions that would occur from an average rise in military spending from 1.5% to 3.5% GDP. This is approximately the situation planned for 31 NATO countries (i.e. without the USA which is already close to the 3.5% spending level) from the period 2019 to 2030–2035. The total rise across these countries in annual national GHG emissions would be in the range 98 to 218 million $tCO_2e$, with a mid-point of 158 million $tCO_2e$.

Dong *et al.* (2025) derived a complex model to look at how global military expenditure – again measured as a proportion of GDP – affected the world's carbon dioxide ($CO_2$) emissions intensity, i.e. emissions per unit currency. They used global data on spending and emissions from 1995–2023, including some derived using the Lin methodology. They concluded that a one percentage point rise in the military spending share of GDP leads to an increase in emissions intensity of 0.04 kilograms per US dollar (kg/USD).[8] With $CO_2$ emissions intensity of the global economy falling to approximately 0.26 kg/USD in 2023, such an increase in the global military spending share would represent a 15% increase in emissions intensity, a sizeable figure. Given that the 2024 size of the global economy was more than $173 trillion,[9] their calculations imply that a one percentage point increase in global military spending share would translate into about 70 million $tCO_2e$ of additional emissions each year – but only if there was no further economic growth. With the global economy currently growing at around 3% per year,[10] this would mean additional emissions of about 208 million $tCO_2e$ each year.

8 US dollars measured at a constant 2017 level of purchasing power parity.

9 World Bank Group (2025a). Data: GDP, PPP (constant 2021 international $). https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD

10 World Bank Group (2025b). Data: GDP growth (annual %). https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG

# 4. Do the studies agree with each other?

Given all this analysis, and the variation in technical approach, geographical spread, timescale, and the scope of GHG emissions included, a key question is to what extent do the studies agree with each other?

In trying to answer this, it is helpful to use a standard metric for comparison. This report uses an increase of $100 billion (US) in military spending – in constant 2023 prices – as a starting point. Military expenditure data from the Stockholm International Peace Research Institute (SIPRI)[11] and the World Bank's GDP deflator[12] have also been used in this analysis.

As discussed, Thombs *et al.* (2025) carried out some projections of energy consumption (scopes 1 and 2) based on military spending changes for the USA. With US military spending in 2023 being $916bn, a $100bn rise would be an 11% increase. Using the figures and assumptions quoted earlier, this would translate into an increase of 0.8 million tCO2e in the annual total. Furthermore, a decrease in military spending of $100bn would lead to a fall of 5.0 million $tCO_2e$. Obviously, this does not include supply-chain and other indirect emissions. Given that additional military spending could be focused on buying new technologies and other equipment – rather than buying extra fuel, which leads to rises in direct emissions – the figures of 0.8 million $tCO_2e$ and 5 million $tCO_2e$ may only represent a comparatively small fraction of the changes in the whole military carbon footprint.

The studies using the Lin methodology estimated increases in emissions for military spending rises in some or all NATO countries over various time periods or for specific spending targets. Starting with Huibregtsen (2025a), her figures can be recalculated – for the historic increase between 2019 and 2024 – based on the standard $100bn spending increase (in constant 2023 dollars). This yields a figure of approximately 31 million $tCO_2e$.[13] The difference between this figure and that of Thombs *et al.* is striking. We return to this issue in section 5.

Turning to another example, the key figures in Lin *et al.* (2025) are based on future projections of spending, so it is difficult to adequately adjust for inflation. They used future GDP projections from the International Monetary Fund in their calculations[14] but, of course, these are subject to significant uncertainty. This aspect is therefore likely to lead to overestimates in their emissions calculations. Similar problems also occur in the other studies that use the Lin methodology to project into the future. However, there is also an element of these studies which causes them to underestimate the emissions from a given spending rise. The data they have used for the spend-emissions conversion factor is based on industry data, some of which does not include upstream scope 3 emissions – i.e. those from

11 Tian *et al.* (2024). *Trends in World Military Expenditure, 2023.* April. SIPRI. https://www.sipri.org/publications/2024/sipri-fact-sheets/trends-world-military-expenditure-2023 ; SIPRI uses a standardised definition for military expenditure in all nations, whereas individual nations – and regional bodies such as NATO – use a variety of definitions. This is a further complication which affects this analysis.

12 World Bank (2025c). Data: Inflation, GDP deflator (annual %). https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG We note that other deflators are available, and calculations are complicated by a variety of economic factors such as exchange rates.

13 This is not far from her original figure of 35 million $tCO_2e$, since the spending rise for her period of analysis was €98bn, and she used constant 2015 figures The approximate currency exchange rate used for the calculation in this study was €1 = $1.1.

14 Lin, personal communication, 8 August, 2025.

the supply chains of the military technology corporations, including high carbon products such as steel and aluminium.[15] Including these emissions would likely increase their estimates. The overall effect of this combination of overestimates and underestimates is difficult to determine – and would require more detailed analysis, including the collection of additional industrial data. For the purposes of this report, we therefore settle for using the estimate based on Huibregtsen (2025a).

Greenly (2025) calculated a figure for GHG emissions intensity (in $tCO_2e$/USD) using 2023 data from Lin *et al.* (2024), and simply applied this to estimate the military carbon footprint of NATO in 2024, EU-NATO in 2025, and the whole four-year EU ReArm Europe Plan. Use of such a figure carries the implicit assumption that the relationship between emissions and spending is linear over the period of study. Their figure for GHG emissions intensity translates into 19 million $tCO_2e$ for a $100bn spending rise in constant 2023 prices.[16] This is significantly lower than studies using the Lin methodology, as the latter try to take into account the shift towards more emissions intensive military spending patterns – for example, on energy-intensive craft and fuel rather than personnel.

One study that has examined the emission rises across the wider economy due to military spending rises is Marko (2024). Kinney *et al.* (2024) used these findings to estimate the increase if NATO countries raise their spending to meet the new 3.5% spending target (except for the USA which has virtually reached the target already). Scaling this increase to the standard $100bn figure leads to an estimate of between 19 and 43 million $tCO_2e$ in annual emissions. The mid-point of this range is similar to the figure for Huibregtsen (2025a) and the lower end similar to Greenly (2025).

It is difficult to translate the results of Dong *et al.* (2025) into a standard figure comparable with the other studies. However, using a simplified calculation based on our earlier discussion,[17] this study seems to indicate that an increase of $100bn in military spending would cause a rise in annual GHG emissions of about 16 million $tCO_2e$. This is roughly midway between the highest and lowest estimates from the other studies above.

The study by Subran *et al.* (2025) gives an estimate of military emissions increase much higher than the other research. To reach the NATO 3.5% spending target, it calculates a rise of 462 million $tCO_2e$ for NATO European countries. This compares with, for example: 64 million $tCO_2e$ in Huibregtsen (2025) – which does not include the UK or Turkey; 98-218 million $tCO_2e$ in Kinney *et al.* (2025) – which also includes Canada; and 193 million $tCO_2e$ in Lin *et al.* (2025) – which also includes Canada and the USA. Subran *et al.*'s estimate is extrapolated from other data on military carbon emissions, but a lack of detail on methodology and sources in this paper means it is very difficult to understand why this figure is so much higher than other estimates. It is has therefore been decided not to include it further in this analysis.

In summary, these studies imply that a rise in military spending of $100bn (in constant 2023 prices) would lead to an increase of 0.8 to 43 million $tCO_2e$ in annual GHG emissions, whereas a corresponding fall would imply a reduction of 5 to 43 million $tCO_2e$. Critically, the lower end of these ranges exclude supply-chain emissions, and all figures exclude the impacts of any war-fighting. It is also important to note that this range for a standardised spend may change significantly over time if industrial, technological, or geopolitical conditions change significantly.

15 Lin *et al.* (2023) used emissions data from Thales and Airbus. The data they used from Airbus did *not* include upstream scope 3 emissions, whereas that from Thales *did* include these emissions.

16 This is slightly higher than their calculation of this figure due to the removal of the effects of inflation.

17 From section 3, a 0.1% GDP rise in global military spending would lead to additional emissions of (7+21)=28 million $tCO_2e$. Since 0.1% GDP is approximately $173bn, $100bn would lead to (100/173)=0.57 of this amount, i.e. 16 million $tCO_2e$.

# 5. What about the data gaps?

In assessing the findings of these studies, it is important to consider which emissions sources have not be included, or have only partially been included.

The first major group to consider are supply chain emissions. As we have discussed, Thombs *et al.* (2025) have not included any in their study, while those using the Lin methodology have, but these seem to be partial. Estimates of the military carbon footprint using the Lin methodology (once the effects of inflation has been removed) tend to about 2.8 times larger than core emissions (scopes 1 and 2) alone.[18] However, Parkinson and Cottrell (2022) have argued that this ratio should be more than 5.[19] This latter study is based on UK data derived using a type of economic model called an 'environmentally-extended input-output model' (EEIOM). EEIOMs are argued to provide a more complete assessment of sector-level carbon footprints – as required to assess the military sector – than studies using a more conventional life-cycle assessment (LCA).[20] The Norwegian military has recently used an EEIOM to estimate their own military carbon footprint,[21] and the ratio has again been found to be over 5. Applying this figure to the range of estimates in section 4 would multiply the figures from Thombs *et al.* (2025) by 5 times and those using the Lin methodology by 1.8 (i.e. 5/2.8). This implies that additional military spending of $100bn would lead to an increase of 4 to 56 million $tCO_2e$ in annual GHG emissions, and a corresponding fall would imply a reduction of 25 to 56 million $tCO_2e$.

A further issue related to supply-chains is especially relevant to the US situation, so will particularly affect the findings of Thombs *et al.* (2025) and Bigger *et al.* (2025). This is the high degree to which the US military has moved to using private contractors for activities that were once carried out using military personnel. For example, the end of the Cold War led a to major fall in the number of active military personnel – from 2.2 million in 1990 to 1.4 million in 2000.[22] While the Post-9/11 wars led to an increase of about 200,000 personnel by 2012, this was also accompanied by a very large rise in the number of private military contractors. For example, in the Iraq War of 2003–11 over 100,000 of these were employed, about ten times as many as in the Gulf War of 1990–91.[23] The GHG emissions associated with this rise is not counted within the US military's core (scope 1 and 2) emissions, and no additional data has been published either. Such an omission helps to explain why the increase in US core emissions seen during that period was not as high as might have been expected. This issue further strengthens the argument for using EEIOMs for assessing military carbon footprints.

A further important issue regarding indirect GHG emissions is the extra heating effect

18 SGR calculation based on figures from Lin *et al.* (2023) and data from defence ministry reports for the USA, UK, Germany, Canada, Norway, and Denmark.

19 Parkinson, S. and Cottrell, L. (2022). *Estimating the Military's Global Greenhouse Gas Emissions*. SGR/CEOBS. https://www.sgr.org.uk/publications/estimating-military-s-global-greenhouse-gas-emissions

20 See, for example pp. 215–219 of: Berners-Lee M (2020). *How bad are bananas? The carbon footprint of everything.* Profile books: London.

21 FFI (2024). Forsvarssektorens miljø- og klimaregnskap for 2023. (Norwegian Defence Research Establishment (2024). The defence sector's environmental and climate accounts for 2023.) https://www.forsvaret.no/om-forsvaret/miljo/Forsvarssektorens%20klimaregnskap%20for%202023.pdf/_/attachment/inline/c1183920-f674-4c03-bf75-b821a40492ec:b7ad2b1ae98e5290fbe88a59799e40b8be9c5778/Forsvarssektorens%20klimaregnskap%20for%202023.pdf

22 Our World in Data (2024). Military personnel. https://ourworldindata.org/grapher/military-personnel

23 p.11 of: Stiglitz, J. and Bilmes, L. (2008). *The Three Trillion Dollar War: The True Cost of the Iraq Conflict.* Penguin Books: London.

due to aircraft emissions in the stratosphere. Recent research indicates that, to take account of this, the direct GHG emissions of aviation need to be multiplied by a factor of 1.7.[24] However, it should also be noted that the heating effect is concentrated over a short timescale, hence the current increase in aviation emissions will accelerate global temperature rise in the near term, meaning a greater risk of breaching climate system 'tipping points', beyond which change becomes irreversible.[25] This factor has not been used in the GHG emission figures discussed earlier so it will be introduced here. With aviation emissions typically making up about one-third of core (scopes 1 and 2) emissions,[26] this results in the following expanded range. For a military spending rise of $100bn, annual GHG emissions would increase by 4 to 59 million $tCO_2e$, while a corresponding fall would imply a reduction of 26 to 59 million $tCO_2e$.

A further limitation of the studies discussed in this paper is that virtually all the data has come from industrialised, democratic nations. Only Marko (2024) has incorporated any data from, for example, China and Russia, the world's second and third highest military spenders. This is a significant shortcoming that also needs to be addressed.

Finally, there is the matter of war-fighting or 'scope 3+' emissions. It is very difficult to estimate what effect military spending changes would have on these emissions. While conventional military thought argues that increasing spending to expand the size of a military helps to deter external aggression and therefore reduces war-fighting, there is also corresponding evidence that increased military spending fuels arms races which can make wars more likely.[27] This is a major debate and beyond the scope of this paper.

24 The factor of 1.7 applies when considering a 100 year time-frame, which is standard practice. For a 20 year timeframe, the factor is 4.0. See: Lee *et al.* (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, vol. 244, pp.117834. https://doi.org/10.1016/j.atmosenv.2020.117834 Table 5; DESNZ. (2024). Greenhouse gas reporting: conversion factors 2024. UK Department for Energy Security and Net Zero. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2024

25 McGuire, B. (2023). The point of no return: how close is the world to irreversible climate change? *Responsible Science*, no.6. SGR. https://www.sgr.org.uk/resources/point-no-return-how-close-world-irreversible-climate-change

26 SGR estimate based on emissions data from US, UK, and German militaries, as stated in defence ministry reports.

27 Mitchell, D. and Pickering, J. (2017). *Arms Buildups and the Use of Military Force.* Kansas State University. https://doi.org/10.1093/acrefore/9780190228637.013.390

# 6. Main findings and conclusions

The relationship between military spending and GHG emissions is complex. If additional spending is used to directly increase military activity, then most money will be spent on fuel, and direct military GHG emissions (scope 1) will rise markedly. However, if the extra spending is mainly used to expand the number of military personnel, then there would be a rise in the emissions at military bases (scopes 1 and 2) and perhaps an expansion of those bases (scope 3). If, however, the additional spending is used to buy more military equipment, then most of the emissions rise will be in supply-chain emissions (scope 3). If the resulting military equipment is more energy-efficient, then increases in direct emissions may be at a lower rate than historically. However, a serious problem with energy-efficiency improvements is that they often lead to 'rebound', where a more efficient technology is cheaper to use, so it is simply used more, with little benefit in terms of reduced GHG emissions. Then there is the case where an extra military spending rise is used to increase the wages of military personnel – so no rise in military GHG emissions will be observed. Another possibility, especially when the spending rise is large and occurs over a short period of time – as currently – is that the dynamics of supply and demand economics kick in and the price of military equipment can shoot up. Under these conditions, profiteering can become commonplace – especially for equipment that only has a small number of manufacturers, such as warships, submarines, or combat aircraft. Hence, any increase in emissions could be subdued. Another possibility is that increased production can lead to economies of scale, so industrial emissions per unit of equipment can fall for some mass-produced items, e.g. ammunition. If extra spending is diverted away from cheap and effective low carbon technologies and practices, then the transition to a net zero economy will be slowed. Marko (2024) explicitly examined this possibility. He found that climate change mitigation and adaptation patents fell by 10-25% following a jump in military expenditure, probably due to climate innovation being 'crowded out'. As global emissions are already shooting past the level needed meet the Paris climate target of 1.5°C, such an indirect effect is likely to be a very serious problem.

The complexity of these effects explains why the range of estimates for the GHG emission increase due to a specific rise in military spending – as summarised in Table 2a – is so high. These effects can also lead to rises in military emissions being delayed in time, as found by both Thombs *et al.* (2025) and Marko (2024). Without much more solid data – which, as we have discussed, is still widely lacking – it will be difficult to reduce this uncertainty. However, the discussion in section 5 highlights several factors which point towards the changes in emissions being at the higher end of the range.

**Table 2a. Changes in military carbon footprint based on changes in military spending of $100bn (constant 2023 prices)**

| | Military carbon footprint change (million $tCO_2e$) | | |
|---|---|---|---|
| | Central estimate | Lower estimate | Upper estimate |
| Rise in military spending | 32 | 4 | 59 |
| Fall in military spending | -43 | -26 | -59 |

**Table 2b. GHG emission changes for meeting NATO's 3.5% spending target, using 2024 as a base year (constant 2023 prices)**

| | Military carbon footprint change (million $tCO_2e$) | | |
|---|---|---|---|
| | Central estimate | Lower estimate | Upper estimate |
| Rise in military spending | 132 | 17 | 247 |

Using military spending data from NATO,[28] we can estimate the range of the increase in GHG emissions necessary to meet the 3.5% military spending target – see Table 2b. The central estimate of 132 million $tCO_2e$ is higher than the territorial emissions of whole nations such as Chile or Oman, or one-third of the UK.[29]

It should be noted that this increase comes on top of the rise before 2024. Between 2019 and 2024, NATO military spending rose by about $200bn.[30] This translates into a central estimate of about 64 million $tCO_2e$ for the increase in the military carbon footprint during this five-year period – similar to territorial emissions of Bahrain.[31]

These spending increases are very likely to undermine national and international GHG emission targets. For example, under the European Green Deal, between 2023 and 2030, emissions need to decline by an average of 134 million $tCO_2e$ per year.[32] Although a significant fraction of the emissions increases related to EU military spending could happen in areas outside of this target (for example, within the US economy due to EU purchases from American arms companies), there would still be a major impact on this target.

It should also be remembered that the heating effects on the climate of GHG emissions are cumulative. So, for example, if the military expenditure of NATO members averaged 3.5% of GDP for a 10-year period, this would amount to extra emissions over the 2024 spending level of about 1,320 million $tCO_2e$ – higher than the annual territorial emissions of Brazil, the world's fifth highest emitting nation.[33]

One more hopeful conclusion arising from this data is that, if military spending is cut, emissions are likely to fall at a faster rate than they grew.

Taking a global climate perspective, current GHG emissions targets are inadequate to stay within the Paris 1.5°C target. The latest assessment by leading climate scientists concluded that "reaching 1.5°C global warming on a long-term basis is now inevitable in around five years if we don't take the immediate, transformative action needed to reduce emissions from fossil fuels and deforestation to net zero."[34] In this context, it is extremely difficult to see how the current and planned military spending increases can be reconciled with preventing dangerous climate change.

28 NATO (2024). Defence Expenditure of NATO Countries (2014–2024). https://www.nato.int/cps/en/natohq/news_226465.htm

29 European Commission, Joint Research Centre, International Energy Agency (2024). EDGAR (Emissions Database for Global Atmospheric Research) Community GHG Database. Version EDGAR_2024_GHG. https://edgar.jrc.ec.europa.eu/report_2024

30 In constant 2023 prices. Calculated using data from: Liang *et al.* (2025). *op. cit.; NATO (2024). op. cit.* The exact figure depends on whether the SIPRI or NATO definition of military spending is used.

31 European Commission *et al.* (2024). *op. cit.*

32 European Commission (2025). Climate Action and the European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/climate-action-and-green-deal_en

33 European Commission *et al.* (2024). *op. cit.*

34 Climate Change Tracker (2025). Indicators of Global Climate Change: Key Messages 2025. https://climatechangetracker.org/igcc#key-messages

# 7. Recommendations

This report makes several recommendations:

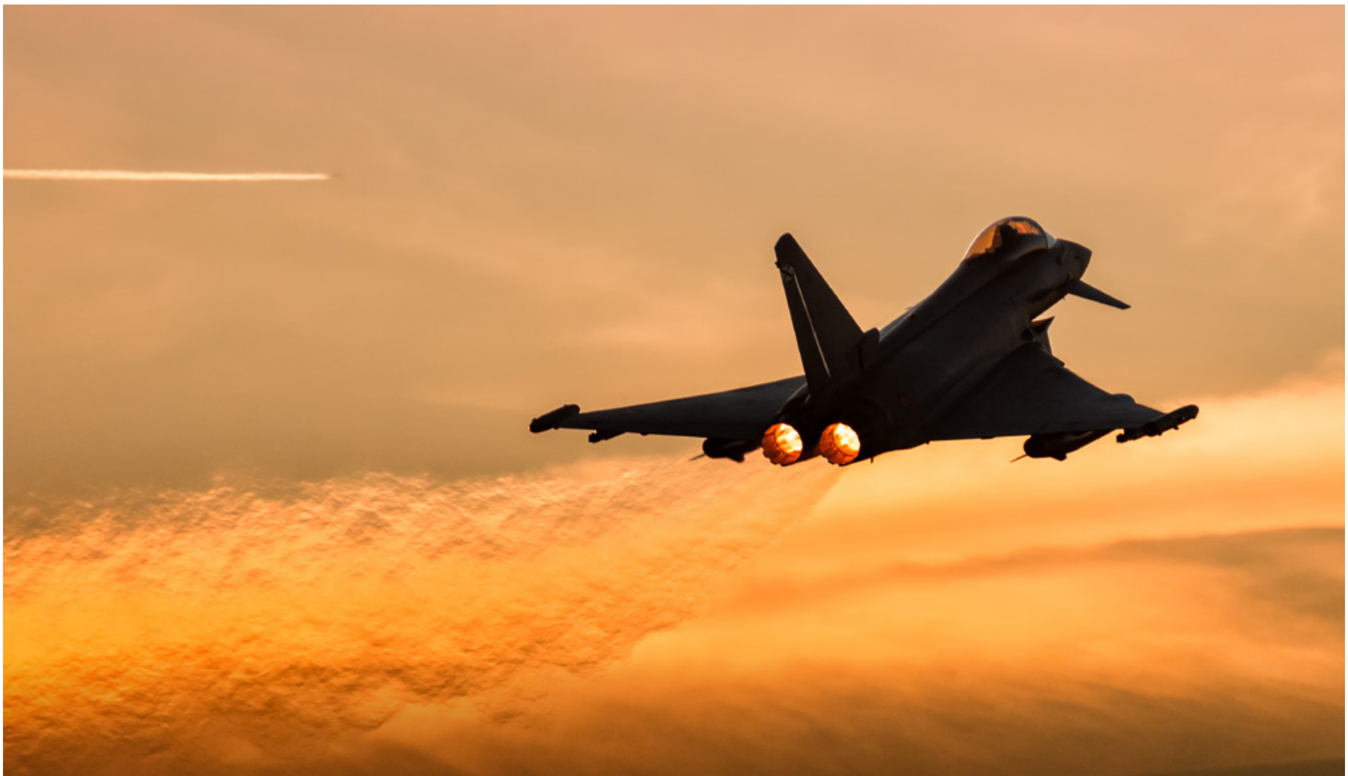
All nations with military spending above 0.5% GDP should:

- annually report robust data for core (scope 1 and 2) military GHG emissions, and provide estimates for emissions due to military supply-chains (scope 3), the latter ideally using environmentally-extended input-output models (EEIOMs);
- assist with estimates of emissions due to war-fighting;
- put in place robust plans to rapidly reduce military GHG emissions to net zero, including through both technological and non-technological measures, the latter including peace agreements, arms control, and disarmament initiatives.

Democratic nations should rapidly expand their leadership role in these areas.

More scientific research should be carried out to:

- reduce the existing data gaps in assessments of core GHG emissions and carbon footprints of militaries, especially using EEIOMs and especially where militaries and arms corporations resist the publishing of data;
- critically examine military initiatives to reduce GHG emissions, and explore the potential to reduce military emissions through neglected pathways, such as arms control and disarmament measures.



**Urgent steps are required to reduce both direct and indirect military GHG emissions – and improved reporting is a key element of this.**

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# Military spending rises and greenhouse gas emissions

## What does the research say?

With military spending climbing rapidly around the world, this report assesses and compares the results of eleven recent studies which have tried to estimate how such spending rises will impact greenhouse gas (GHG) emissions. It finds that major rises are very likely – around 32 million tonnes of carbon dioxide equivalent for every $100bn increase. However, the complexity of the relationship between spending and GHG emissions, together with poor quality data on emissions, means that the uncertainties are high. The report concludes that monitoring of military GHG emissions needs to be greatly improved – but there is already little doubt that military spending rises will greatly undermine climate action.

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