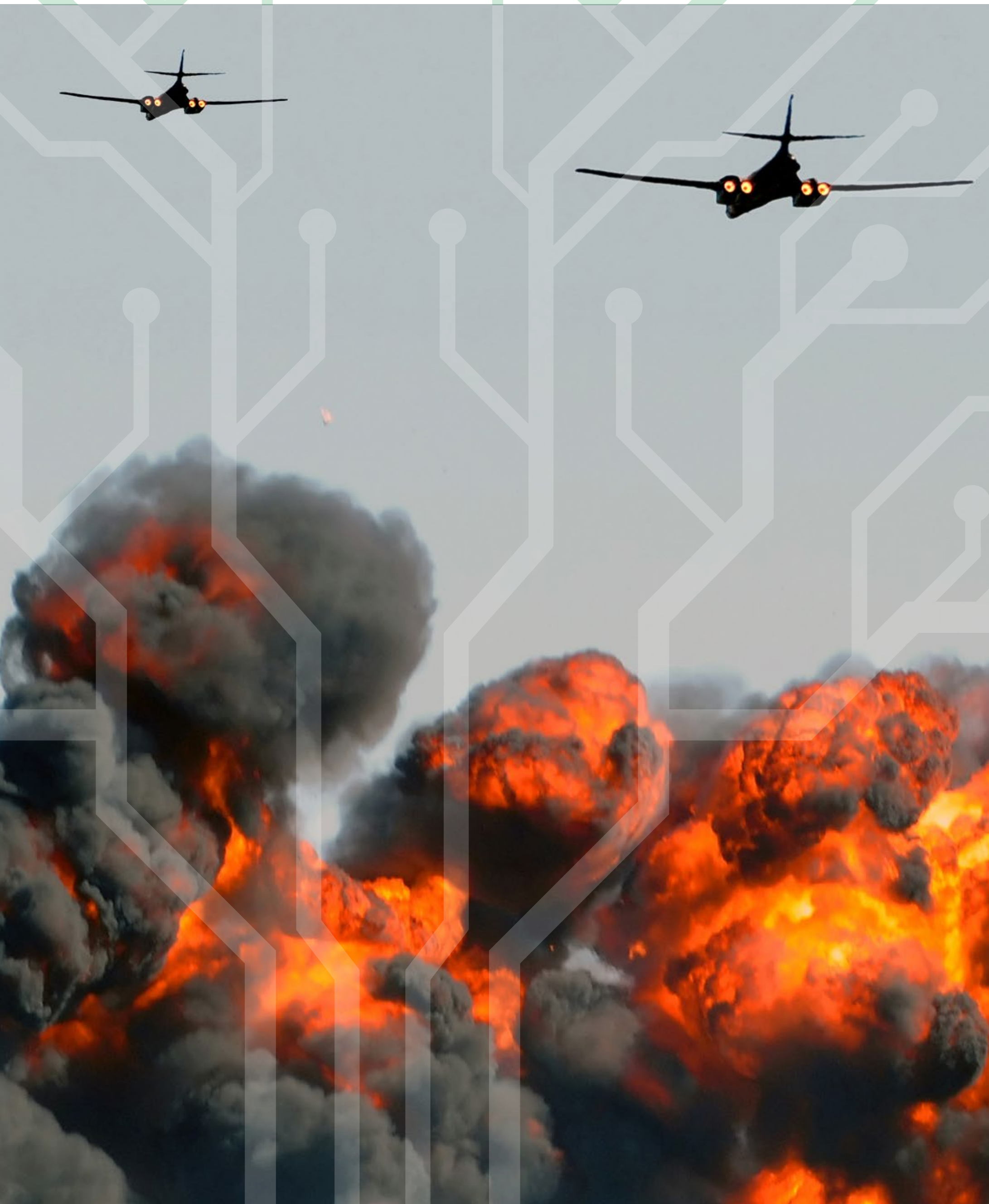
Scientists for Global Responsibility

Conflict and Environment Observatory

Estimating the Military's Global Greenhouse Gas Emissions



Estimating the Military's Global Greenhouse Gas Emissions

Authors: Stuart Parkinson, Scientists for Global Responsibility (SGR) with Linsey Cottrell, Conflict and Environment Observatory (CEOBS)

ABOUT THE AUTHORS

Dr Stuart Parkinson is Executive Director of SGR, a post he has held for 20 years, where he has co-ordinated research, education and campaigning on ethical issues across science and technology. He holds a PhD in climate change science and a Bachelors in physics and engineering from Lancaster University. He was a post-doctoral research fellow at the Centre for Environmental Strategy, University of Surrey, for five years, and has also worked in industry – including on military projects – and for other NGOs. He has also been an expert reviewer for the Intergovernmental Panel on Climate Change. He has authored/co-authored numerous reports, academic papers and popular science articles.

Linsey Cottrell is the Environmental Policy Officer at the Conflict and Environment Observatory (CEOBS), focusing on the environmental impacts of conflicts and the military. She is a Chartered Environmentalist and worked in the environmental consultancy sector for 25 years, before joining CEOBS in 2019. She holds a BSc in Chemical Sciences and MSc in Environmental Pollution Control from Leeds University. She was also a trustee for the Institution of Environmental Sciences from 2016 to 2022.

ABOUT SGR

Scientists for Global Responsibility is a UK-based membership organisation which promotes responsible science and technology. Its membership includes hundreds of natural scientists, social scientists, engineers and professionals in related areas. It carries out research, education, and advocacy work centred around science and technology for peace, social justice and environmental sustainability. It is an active partner of ICAN, which was awarded the Nobel Peace Prize in 2017.

To join, see: **https://www.sgr.org.uk/join**

ABOUT CEOBS

The Conflict and Environment Observatory (CEOBS) is a UK charity that undertakes research and advocacy on the environmental dimensions of armed conflicts and military activities and their derived humanitarian consequences. CEOBS' overarching aim is to ensure that the environmental consequences of armed conflicts and military activities are properly documented and addressed, and that those affected are assisted.

http://www.ceobs.org

Published by © Scientists for Global Responsibility (SGR) and the Conflict and Environment Observatory (CEOBS) in November 2022 under a Creative Commons Licence.
Attribution-ShareAlike 4.0 International License.

We are grateful to the Minor Foundation for Major Challenges for funding the production of this report.

The Minor Foundation for Major Challenges

Design and typesetting by the Argument by Design.

ISBN: 978-1-8383986-1-3

Scientists for Global Responsibility, 2 West Road, Lancaster LA1 5PG, UK, Email: info@sgr.org.uk

Conflict and Environment Observatory, The Chapel, Scout Rd, Mytholmroyd, West Yorkshire, HX7 5HZ, UK
Email: contact@ceobs.org

Electronic copies of this report can be downloaded from: http://www.sgr.org.uk/
and from https://ceobs.org/projects/military-emissions/

© Scientists for Global Responsibility (SGR) and the Conflict and Environment Observatory (CEOBS), 2022.

Cover images: iStockphoto

Contents

Summary

A lack of reporting and significant data gaps means it is inherently difficult to estimate the total greenhouse gas (GHG) emissions of the world's militaries. Nevertheless, the available data indicates this contribution could be very large. In this study, we describe an innovative new methodology to provide updated estimates for global and regional military GHG emissions. In particular, we find that the total military carbon footprint is approximately 5.5% of global emissions. If the world's militaries were a country, this figure would mean they have the fourth largest national carbon footprint in the world – greater than that of Russia. This emphasises the urgent need for concerted action to be taken both to robustly measure military emissions and to reduce the related carbon footprint – especially as these emissions are very likely to be growing in the wake of the war in Ukraine.

1. Why is estimating global military emissions important?

Tackling the climate crisis requires action from all industrial and economic sectors to markedly reduce their impact on our planet. The global military sector – including its supply chain – is a major element of government expenditure and a huge consumer of fossil fuels. Hence it is essential that military greenhouse gas (GHG) emissions are both reported robustly and subject to emission reduction targets. However, neither is currently the case.

The data for military GHG emissions across the world are frequently of low quality – often incomplete, hidden within civilian categories, or not collected at all. The root cause of this problem was government concern about potential restrictions of military activities – which led to exemptions first under the 1997 Kyoto Protocol. Currently, under the United Nations Framework Convention on Climate Change (UNFCCC), countries are obliged to provide an inventory of their GHG emissions. Reporting obligations for countries vary, depending on their historic contribution to the climate crisis.[1] Guidelines from the Intergovernmental Panel on Climate Change (IPCC) state that inventories submitted to the UNFCCC should include emissions from some military activities. In 2015, however, the Paris Agreement[2] made military emissions reporting voluntary, meaning that there are significant gaps in the datasets submitted to the UNFCCC and no accurate data on the true scale of the problem. Without even a minimum reporting obligation to the UNFCCC, most countries – including those with large military expenditures and military personnel – do not require their militaries to provide any meaningful GHG emissions reporting. These problems have been largely overlooked by the climate science community. For example, the latest (sixth) assessment report of the IPCC[3] barely discusses this sector at all. This has, in turn, led to neglect of this area when governments negotiate emission reduction targets under the UNFCCC.

In an effort to illustrate the scale of the problem both nationally and globally, in this study, we use the available data on military GHG emissions from a small number of nations to estimate totals for the world and its main geopolitical regions. We hope that this will stimulate more research – and especially action – focussed on reducing these emissions.

1 Annex I countries (industrialised and economies in transition) are required to submit annual National Inventory Reports (NIR) and non-Annex I countries are required to submit a national inventory of anthropogenic emissions, as part of their National Communications (NC) and biennial update reports.

2 UNFCCC (2015). https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

3 IPCC (2022). https://www.ipcc.ch/assessment-report/ar6/

2. High-level data on national GHG emissions and the military

Around 60% of all global GHG emissions come from just ten countries.[4] These are China, the USA, India, Indonesia, Russia, Brazil, Japan, Iran, Canada and Saudi Arabia. All of these – except Indonesia – are among the top 20 countries in terms of their military expenditure – see Appendix 1. Indeed, the next 10 highest GHG emitting nations also feature high within the ranks of nations with large military budgets and/or large numbers of active military personnel.

3. Outline of methodology

While data on military GHG emissions is generally very limited, some data has been compiled for the USA, UK and some EU nations. Sometimes the emissions data is reported directly by a military agency, and sometimes emissions have been calculated by independent researchers based on data for energy/fuel use published by military agencies. In this study, we extrapolate from these datasets to give global estimates, but this has its limitations since there are many variations between countries, including:

- differences in military structure, including the type and quantity of equipment and number of personnel;
- mobilisation rates, operational and training activities;
- the accuracy and disclosure around military expenditure; and
- the carbon intensity of national economies.[5]

We considered several starting points for estimating global military GHG emissions. The two which seemed most promising were emissions per unit currency – based on national military expenditures – and emissions per head of personnel – based on numbers of personnel in active service within national armed forces.

Due to significant fluctuations in financial data (e.g. currency exchange rates, inflation rates, and GDP growth rates) and limited data availability in certain key nations (e.g. China, Saudi Arabia, North Korea, and Vietnam), the currency-based option was rejected in favour of the personnel route.

The personnel route makes use of the following four key datasets:

- Operational GHG emissions (scopes 1 and 2[6]) per head of active personnel for military bases, also known as 'stationary emissions' (e_s);
- Number of active military personnel (p);
- Ratio of operational GHG emissions between mobile military activities (use of aircraft, marine vessels, land vehicles, and spacecraft) and stationary activities (r_{ms});
- Supply-chain multiplier, the ratio of the 'carbon footprint' (the sum of scopes 1, 2 and the upstream component of scope 3 emissions) to the sum of scope 1 and 2 emissions (s).

4 Climate Watch (2022). Data for 2019. https://www.climatewatchdata.org/ghg-emissions?chartType=percentage&end_year=2019&start_year=1990

5 For example, countries such as the UK and France have lower GHG emissions per unit of electricity (due to higher levels of renewables and nuclear) compared with the USA, China, India or Saudi Arabia, which have higher dependency on fossil fuels, especially coal and oil. See: Our World in Data (2022a). https://ourworldindata.org/grapher/carbon-intensity-electricity

6 For a definition of scopes 1, 2 and 3, see Chapter 4 of: GHG Protocol (2015). https://ghgprotocol.org/corporate-standard

The military carbon footprint for a given nation or region (F_n) is then estimated by multiplying these data together as follows:

$$F_n = e_s pr_{ms} s$$

And the global military carbon footprint (F_g) is sum of all the national (or regional) footprints:

$$F_g = \sum_{all\ n} F_n$$

3.1 Dataset 1 – Stationary emissions per head of personnel (e_s)

Credible annual data for stationary military emissions was found for the UK, USA and Germany. This was divided by the numbers of active military personnel in those nations to give figures for stationary emissions per head – see Table 1.

Table 1. Reported stationary GHG emissions per head of military personnel for three nations

Country	Averaged GHG emissions (tCO_2e) per military head
United Kingdom	5.0
Germany	5.1
USA	12.9

Notes

For UK, this is the mean of three years of data, 2017–2019[7]

For Germany, this is the mean of two years of data, 2018–2019[8]

For USA, this is one year of data, 2018[9]

The UK data was available for more than 10 years. It showed very consistent levels of energy consumption per head over the whole period, with a reduction in GHG emissions per head resulting almost entirely from a reduction in the carbon intensity of the national electricity supply. Since this had fallen markedly over the period, we only used the most recent years' data for the basis of our figure in Table 1.

Comparing the data between countries, we see that the UK and Germany have similar unit emission levels, while the figure for the USA is markedly higher. There are a number of potential reasons for similarities and differences. For example, higher population densities in European nations tend to lead to smaller living and working spaces, significantly reducing energy use per head. The GHG emissions intensity of electricity generation will also be a significant factor – with the UK's significantly lower than both Germany and the USA. The USA also has a large proportion of its military bases overseas, which is likely to lead to less strict energy efficiency and environmental standards being applied. The intensity of military activity is also likely to be a factor – with US levels tending to be higher than the UK's, which in turn are higher than Germany's. The level of industrial development of a nation and the extremes of climate that its bases operate within will also be significant.

Although these figures only cover three nations, collectively they represent 45% of global military expenditure, 14% of the world's GHG emissions, and 9% of all active military personnel. Hence, we consider them a reasonable starting point. In applying these figures to other nations, we assume that the US figures are typical for a military with an emissions-intensive stationary sector, and the UK and German figures typical for one at the lower end of the scale.

Table 2 shows our extrapolated figures for these unit emissions for the world's geopolitical regions.

Firstly, we assume that the USA is typical for North America and that the UK and Germany are typical for Europe. Russia and Eurasia, we consider to be comparable to North America – as their economies tend to be industrialised and carbon intensive, and a large proportion of military bases are in areas subject to climate extremes. For the region Asia and Oceania, we estimate that these unit emissions are halfway between

7 Ministry of Defence (2021). https://www.gov.uk/government/publications/ministry-of-defence-annual-report-and-accounts-2019-to-2020

8 SGR/CEOBS (2021). https://www.sgr.org.uk/publications/under-radar-carbon-footprint-europe-s-military-sectors

9 Crawford N (2019). https://watson.brown.edu/costsofwar/papers/ClimateChangeandCostofWar

Table 2. Estimated stationary GHG emissions per head of military personnel for world's geopolitical regions

Region	Leading military nations (ordered by personnel numbers)	Stationary GHG emissions per head (tCO_2e)
North America	USA, Canada	13
Russia and Eurasia	Russia, Ukraine	13
Asia and Oceania	China, India, North Korea, Pakistan, South Korea, Vietnam, Myanmar, Indonesia, Thailand, Sri Lanka, Japan, Australia	9
Middle East and North Africa	Iran, Egypt, Saudi Arabia	9
Europe	Türkiye, France, Germany, Italy, UK	5
Latin America	Brazil, Colombia, Mexico	5
Sub-Saharan Africa	Eritrea, Nigeria, South Africa	2.5

Figures rounded to nearest 0.5 tCO_2e/cap

Table 3. Number of active military personnel by geopolitical region, 2019

Region	Number of military personnel	Percentage of global total
Asia and Oceania	9,326,000	47%
Middle East and North Africa	2,533,000	13%
Europe	1,962,000	10%
Sub-Saharan Africa	1,594,000	8%
Latin America	1,523,000	8%
North America	1,447,200	7%
Russia and Eurasia	1,435,000	7%
TOTAL	**19,820,200**	

the North American and European figures. This seems reasonable as the main military nations in this region either have a medium-to-high level of economic development, or a carbon intensive economy, or both. We think that they are unlikely to be as high as the US, given the global network of US military bases, including many in extreme climates. We follow a similar line of reasoning for the Middle East and North Africa although the main military nations in this region tend to be at a lower level of economic development, but have a more carbon-intensive economy. We consider Latin America to be broadly comparable with Europe. For sub-Saharan Africa, we consider that their low levels of economic development point to low unit emissions, so we have assumed these are half of the European level.

3.2 Dataset 2 – Numbers of military personnel (*p*)

The estimated distribution of military personnel across the main geopolitical regions of the world is given in Table 3. This data is compiled annually by the International Institute for Strategic Studies (IISS) from national data.[10]

10 IISS (2020). The military balance 2020. https://www.iiss.org/publications/the-military-balance/archive

3.3 Dataset 3 – Ratio of mobile emissions to stationary emissions (r_{ms})

Operational GHG emissions from mobile military activities depend on a range of factors, principally the quantity, specification (especially fuel efficiency and range), age, and frequency of use of military vehicles. These factors are also affected by the 'domain' in which the military vehicles operate – land, sea, air, or space – and the force structures adopted by a given military. These complexities make it difficult to extrapolate from data on, for example, the number of vehicles in a given branch of the military to totals for mobile GHG emissions. From the available data, it is clear that militaries with, for example, a large air force or a 'blue water' navy tend to have higher GHG emissions, but beyond that extrapolations become difficult.

One pattern that we have noticed is the level of stationary emissions can be a helpful starting point for estimating mobile emissions, so we use that here. Table 4 provides some data on the ratios of mobile emissions to stationary emissions for Germany, the EU, the USA, and the UK. These figures were calculated using data from military agencies.

The lower ratio for Germany is due to its smaller air force and navy relative to its land-based activities, and its lower level of foreign military operations. The UK is at the higher end due its much larger air force and navy, and high level of foreign military operations, especially when compared to the relatively small number of its active military personnel. The EU – on average – is towards the lower German end of the scale, while the USA is towards the higher end, but not as high as the UK because of its high level of stationary emissions per head.

Table 4. Ratio of mobile GHG emissions to stationary emissions for the militaries of four nations/ regions

Country	Ratio (year 1)	Ratio (year 2)	Average ratio
Germany	0.7	0.8	0.7
EU	1.1	na	1.1
USA	1.6	2.1	1.9
UK	2.4	2.8	2.6

Notes

For EU, year 1 is 2017[11]

For USA, years 1 and 2 are 2017 and 2018[12]

For Germany and UK, years 1 and 2 are 2018 and 2019[13]

3.4 Dataset 4 – Supply-chain multiplier (*s*)

The final data relates to the GHG emissions of military supply-chains. This data allows lifecycle GHG emissions or the 'carbon footprint' of military activities to be estimated.

Militaries have extensive and complex supply-chains, comprising a large proportion of a military's carbon footprint. Emissions from supply-chains typically far exceed an organisation's own operational (scope 1 and 2) emissions, with estimates varying depending on sector. Data on the military sector is again sparse, although notably, some carbon footprint data has been published by the military technology corporations Thales[14] and Fincantieri.[15]

11 Data from: EDA (2019). https://eda.europa.eu/docs/default-source/eda-factsheets/2019-06-07-factsheet-energy-defence

12 Data from: Crawford (2019). *Op. cit.*

13 German data from: SGR/ CEOBS (2021) *Op.cit*. UK data from: MOD (2021). *Op. cit.*

14 Thales (2019). Universal Registration Document (including the Annual Financial Report) 2019. https://www.thalesgroup.com/en/investors

15 Fincantieri (2020). Environmental aspects: Greenhouse gas emissions, 2019. https://www.fincantieri.com/en/sustainability/environmental/environmental-aspects/

A 2020 analysis of the supply-chain for UK military spending estimated the ratio of the carbon footprint to the total operational emissions to be 3.6, using data from an environmental input-output economic model.[16] However, further investigation found that this carbon footprint estimate was based on only 62% of the operational emissions due to under-reporting of military emissions within the national GHG inventory.[17] Correcting for this error means this ratio is re-estimated to be 5.8.

A further way of estimating this ratio is to use business figures on the GHG emissions of global supply-chains. These statistics are gathered in regular surveys by the Carbon Disclosure Project (CDP), and some typical figures for sectors which have commonalties with the military are shown in Table 5.

Table 5. Ratio of carbon footprint to operational emissions for global business sectors[18]

Sector	Ratio of carbon footprint to operational emissions
All	12.4
Manufacturing	8.7
Infrastructure	5.0
Transport services	2.5
Military (this report)	5.8

As can be seen, our estimate of 5.8 seems credible when compared with these figures.

4. Estimates for global military GHG emissions

Using the preceding four datasets combined using our two equations, we are able to calculate estimates for the operational GHG emissions (scopes 1 and 2) of the military sector and the military carbon footprint.

Table 6 gives upper and lower estimates of these two types of military emissions for each of the seven geopolitical regions and the world as a whole. The upper estimate uses a mobile to stationary emissions ratio of 2.6 (the UK figure) and the lower estimate uses 0.7 (the German figure). We consider that this range encompasses the likely uncertainty across the four variables used to calculate the military emissions. The upper estimate is thus based on a situation where a given military emphasises the development and deployment of energy-intensive weapons systems, perhaps at the expense of troop numbers. The lower estimate is based on situations where a military is more focused on personnel levels, or has relatively low levels of long-distance deployment, or involvement in conflict zones.

The global range for operational military GHG emissions is approximately between 300 and 600 million tonnes (Mt) of CO_2e, which is between 0.6% and 1.2% of total global GHG emissions.[19] The estimate for the global military carbon footprint is approximately between 1,600 to 3,500 $MtCO_2e$, which is between 3.3% and 7.0% of total global GHG emissions. These are wide ranges of estimates, but they emphasise the paucity of data in this field.

16 P.16–17 of: SGR (2020). https://www.sgr.org.uk/publications/environmental-impacts-uk-military-sector NB This study was carried out by one of the authors of this paper, Stuart Parkinson.

17 Personal communication with Mike Berners-Lee, Lancaster University, 13/07/22. For further discussion of the under-reporting of military GHG emissions within official UK GHG statistics, see: SGR (2022). https://www.sgr.org.uk/publications/comparing-official-uk-statistics-military-greenhouse-gas-emissions

18 P.14 of: CDP (2021). Transparency to transformation: a chain reaction. CDP Global Supply Chain Report 2020. https://www.cdp.net/en/research/global-reports/transparency-to-transformation NB The figures in the CDP report are given in terms of the ratio of scope 3 (upstream) to scopes 1 and 2, and hence have been recalculated for Table 5.

19 This based on a global GHG emissions total for 2019 of 49.8 $GtCO_2e$ – see: Our World in Data (2022b). https://ourworldindata.org/greenhouse-gas-emissions

Table 6. Total operational GHG emissions and carbon footprint of the military sector for geopolitical regions and the world

	Operational GHG emissions		Carbon footprint	
Region	Upper estimate $MtCO_2e$	Lower estimate $MtCO_2e$	Upper estimate $MtCO_2e$	Lower estimate $MtCO_2e$
Asia and Oceania	305	144	1,766	833
Middle East and North Africa	83	39	480	226
North America	68	32	396	187
Russia and Eurasia	68	32	392	185
Europe	36	17	206	97
Latin America	28	13	160	76
Sub-Saharan Africa	15	7	84	40
Global total	602	284	3,484	1,644
% of total global GHG emissions[20]	**1.2%**	**0.6%**	**7.0%**	**3.3%**

Notes
Upper estimates use a mobile to stationary ratio of 2.6 (from dataset 3)
Lower estimates use a mobile to stationary ratio of 0.7 (from dataset 3)
Carbon footprint uses a supply chain multiplier of 5.8 (from dataset 4)

We consider that the lower end of these ranges – which assume that all the world's militaries are towards the more labour-intensive end of the scale – is not credible given the focus on energy-intensive military technology in much of the world. Hence, our best estimate for the military's operational GHG emissions is 500 $MtCO_2e$ – **1.0%** of global GHGs – and for the global carbon footprint, it is 2,750 $MtCO_2e$ – **5.5%** of the global total.

It should be understood that in producing these estimates, we have made a number of assumptions and also have not included some key GHG emission sources, meaning that our figures are conservative. These factors include the following.

- We assume that the data released by militaries for their operational GHG emissions and/or energy consumption are reliable and include all major sources.
- We have not included GHG emissions arising from the impacts of warfighting, such as fires, other damage to infrastructure and ecosystems, post-conflict reconstruction, and health-care for survivors. Partial estimates for some of these sources – which could potentially be very large – are given in a recent report by Perspectives Climate Group.[21]
- We have not included a radiative forcing factor for aviation GHG emissions to account for the additional heating effects which are caused by non-CO_2 exhaust gases in the stratosphere. Currently, a factor of 1.9 is applied to aviation GHG emissions to account for these effects.[22]
- We suspect that accounting for all these other effects – especially those directly relating to war-fighting – could increase the total figure significant beyond 5.5%. We call this overarching total level of GHG emissions, the 'global military carbon bootprint'.

20 Our World in Data (2022b). *Op.cit.*

21 Perspectives Climate Group (2022). https://transformdefence.org/publication/military-and-conflict-related-emissions-report/

22 See, for example, UK guidance for company reporting on GHG emissions: BEIS (2022). https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

However, these additional factors are even less well understood than the main emissions categories discussed in this paper. To try to improve the data in this area, 'A framework for military GHG emissions reporting' has recently been developed,[23] which militaries and researchers can apply in the field. Nevertheless, the practical difficulties in collating some of the data relating to warfighting, and the lack of agreed measurement tools, means significant gaps will likely remain for some time.

Finally, it should be remembered that the data used for all our estimates is dated before 2020, and therefore is not affected by changes induced by the COVID-19 pandemic, nor any increases in military spending, personnel or materiel due to the war in Ukraine.

5. Further analysis

Brief comparisons of our estimates for global military GHG emissions with other sectors, with national level data, and with military data officially reported to the UNFCCC, are all useful to better understand their scale and wider significance. Hence, we look at several examples in this section.

Although State Parties to the Paris Agreement are required to prepare, communicate and maintain successive Nationally Determined Contributions (NDCs) to the UNFCCC, and set out the action to be taken to reduce their GHG emissions across key categories, emissions reporting is not straightforward or fully complete. Since GHG emissions reporting requirements differ for nations at different stages in their economic development,[24] the UNFCCC does not give an accurate estimate for total global emissions in any given year[25] – so complicating any comparisons that might want to be explored. GHG emissions reporting to the UNFCCC falls under five key categories: energy; industrial processes and product use; agriculture; land use, land use change and forestry; and waste. Due to some uncertainty and lack of transparency across international reporting of all GHG emissions, there are consequently limitations when comparing emissions across sectors and nations.

Nevertheless, a breakdown of global emissions by sector for 2016 has been produced by Climate Watch.[26] These figures can be compared with our data on operational emissions for the military, i.e. 1.0%. Sectors which are of a similar scale include aviation (1.9%), shipping (1.7%), and the food and tobacco industry (1.0%). However, it should be understood that, for example, some of the military emissions are currently classified under the aviation and shipping sectors, meaning that if classifications of *civil* aviation and *civil* shipping are used, then these sectors would be closer in size to the military.

Regarding comparisons of our estimate of the military carbon footprint – 2,750 $MtCO_2e$, or 5.5% of the global total – with other business sectors, this is more difficult to do. An alternative approach is simply to make comparisons with some other easily understood statistics. For example, in 2019, the world's passenger cars collectively emitted approximately 3,200

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

24 See note 1.

25 Such estimates are instead routinely compiled by other organisations - see: UNFCCC (2022). https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/frequently-asked-questions#-Do-you-have-estimates-for-global-GHG-emissions,-i

26 Climate Watch's data has been summarised in: Our World in Data (2022c). https://ourworldindata.org/ghg- emissions-by-sector

$MtCO_2$ during use[27] – so our figure for the military footprint is about 85% of that. Another comparison can be carried out with country level data. Using statistics on national carbon footprints from the Global Carbon Budget,[28] we see that if the global militaries were a country, they would have the world's fourth largest footprint, one larger than whole of Russia. Only the nations of China, the USA, and India would have larger carbon footprints.

These comparisons show just how significant military GHG emissions are. If we then look at this issue in terms of the emissions that can be *directly* affected by central government policy or spending decisions, then it becomes even clearer that this neglected area of potential emissions reduction deserves to become a priority focus.

Finally, it is important to compare our estimates to the data officially reported to the UNFCCC under military categories. This data has been compiled and presented in an accessible form on The Military Emissions Gap website.[29] However, the national reporting practices that have been followed are, in general, of such low quality – with numerous data gaps and, where data is reported, some of it being mixed with civilian sources – that it is very difficult to draw any useful conclusions, beyond the obvious one that reporting standards urgently need to improve.

6. Action needed

The new methodology presented in this paper has yielded updated estimates for the operational GHG emissions of the military sector – at approximately 500 $MtCO_2e$ each year or 1.0% of global GHG emissions – and the global military carbon footprint – at 2,750 $MtCO_2e$ or 5.5%. If the global military sector were a nation, it would have the fourth largest carbon footprint in world – greater than the whole of Russia. And it should be remembered that our estimates are conservative – they do not include GHG emissions due to the impacts of warfighting. These figures clearly indicate the very large scale of the military sector's contribution to total global GHG emissions.

The methodology is based on limited data and shows the urgent need for all militaries to report emissions using consistent, unambiguous, transparent, and robust data collection methodologies – and to take action to reduce them. It also shows the need for more detailed research by climate scientists and policy analysts to understand the scale of military emissions at national and international levels – and to scrutinise efforts to reduce them. This should include consideration of the emissions from warfighting itself, as well as the large and complex supply-chains of the military.

The recently published 'Framework for military GHG emission reporting' would be a useful starting point for such work.[30]

In the absence of robust data on the overwhelming majority of national military GHG emissions, the use of military personnel numbers and the other factors derived in this study would be a useful starting point for filling these data gaps. Even where military GHG emissions are reported – either in-country or through the UNFCCC's voluntary reporting obligations – the methodology applied here could be used

27 Statista (2022). https://www.statista.com/statistics/1107970/carbon-dioxide-emissions-passenger-transport/

28 Russia's national carbon footprint in 2019 (based on CO_2 emissions only) was 1,430 $MtCO_2$. As CO_2 represents 74% of global GHG emissions, this compares with 2,050 $MtCO_2$ for the equivalent global military footprint. Data from: Global Carbon Project (2021). https://www.icos-cp.eu/science-and-impact/global-carbon-budget/2021

29 The Military Emission Gap (2021). https://militaryemissions.org/

30 CEOBS (2022). *Op. cit.*

to give broad estimates, to help scrutinise the completeness and relevancy of this publicly available data. Such analysis will be the subject of a future research paper.

External scrutiny should help to drive action by governments to reduce the GHG emissions of their military sectors. In 2021, a joint call was endorsed by 225 organisations and set out a list of commitments[31] needed by governments to address the GHG emissions of their military sectors. With the on-going escalation of military expenditure – especially in the wake of the war in Ukraine – commitments by governments to tackle this largely ignored contribution to global GHG emissions are urgently needed.

31 CEOBS (2021). https://ceobs.org/governments-must-commit-to-military-emissions-cuts-at-cop26/

Appendix 1:
Military expenditure, number of military personnel, and percentage of global GHG emissions for key countries

Table A1a. Top 20 countries in terms of military expenditure, 2019

State	Military expenditure (US$ billions)[1]	Number of active military personnel (world ranking)[2]	GHG emissions: national share of global total (world ranking)[3]
United States	800.7	1,379,800 (3rd)	12% (2nd)
China	[293.4]	2,035,000 (1st)	24% (1st)
India	76.6	1,442,900 (2nd)	6.8% (3rd)
United Kingdom	68.4	148,450	0.9%
Russia	65.9	900,000 (5th)	3.9% (5th)
France	56.6	203,750	0.7%
Germany	56.0	181,400	1.4% (11th)
Saudi Arabia	[55.6]	227,000 (20th)	1.5% (10th)
Japan	54.1	247,150 (18th)	2.3% (7th)
Korea, South	50.2	599,000 (8th)	1.3% (14th)
Italy	32.0	165,500	0.8%
Australia	31.8	57,200	1.2% (15th)
Canada	26.4	67,400	1.6% (9th)
Iran	24.6	610,000 (7th)	1.8% (8th)
Israel	24.3	170,000	0.2%
Spain	19.5	120,350	0.6%
Brazil	19.2	367,000 (13th)	2.9% (6th)
Türkiye	15.5	355,200 (15th)	0.9% (17th)
Netherlands	13.8	35,400	0.3%
Poland	13.7	123,700	0.6%

1 Figures in square brackets are conservative estimates based on incomplete data. Data for 2019 from: SIPRI (2021). https://milex.sipri.org/sipri

2 Top 20 rankings only. Data for 2019 from: IISS (2020). *Op. cit.*

3 Top 20 rankings only. Climate Watch (2022). *Op. cit.*

Table A1b. Other countries with large numbers of military personnel, 2019

State	Military expenditure (US$ billions)	Number of active military personnel (world ranking)	GHG emissions: national share of global total (world ranking)
Korea, North	No data	1,280,800 (4th)	0.2%
Pakistan	11.3	653,800 (6th)	0.9% (18th)
Vietnam	No data	482,000 (9th)	0.9% (19th)
Egypt	5.2	439,000 (10th)	0.7%
Myanmar	2.1	406,000 (11th)	0.5%
Indonesia	8.3	395,500 (12th)	3.9% (4th)
Thailand	6.6	360,850 (14th)	0.9% (20th)
Colombia	10.2	293,200 (16th)	0.5%
Sri Lanka	1.6	255,000 (17th)	0.1%
Mexico	8.7	236,250 (19th)	1.3% (13th)
Ukraine	[5.9]	209,000	0.4%

Estimating the Military's Global Greenhouse Gas Emissions

A lack of reporting and significant data gaps means it is inherently difficult to estimate the total greenhouse gas (GHG) emissions of the world's militaries. Nevertheless, the available data indicates this contribution could be very large. In this study, we describe an innovative new methodology to provide updated estimates for global and regional military GHG emissions. In particular, we find that the total military carbon footprint is approximately 5.5% of global emissions. If the world's militaries were a country, this figure would mean they have the fourth largest national carbon footprint in the world – greater than that of Russia. This emphasises the urgent need for concerted action to be taken both to robustly measure military emissions and to reduce the related carbon footprint – especially as these emissions are very likely to be growing in the wake of the war in Ukraine.

Scientists for Global Responsibility (SGR) is a UK-based membership organisation which promotes responsible science and technology. Its membership includes hundreds of natural scientists, social scientists, engineers and professionals in related areas. It carries out research, education, and advocacy work centred around science and technology for peace, social justice and environmental sustainability. It is an active partner of ICAN, which was awarded the Nobel Peace Prize in 2017.

To join, see: **https://www.sgr.org.uk/join**

The Conflict and Environment Observatory (CEOBS) is a UK charity that undertakes research and advocacy on the environmental dimensions of armed conflicts and military activities and their derived humanitarian consequences. CEOBS' overarching aim is to ensure that the environmental consequences of armed conflicts and military activities are properly documented and addressed, and that those affected are assisted.

http://www.ceobs.org