Decarbonize the military - mandate emissions reporting

Armed forces have a massive carbon footprint, absent from global accounting

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Exactly how much carbon does your country's military emit, nobody really knows! Chances are that your country's military does not report carbon emissions, and that is a big problem. It is estimated that the worlds militaries emit between 1-5% of the world's greenhouse gases, which is a scale comparable to global aviation or shipping industries. Consider the emissions of the United States military, the world's largest in terms of expenditure. If it were a nation, the US military has the highest per capita emissions in the world, at 42 metric tonnes of CO_2eq per staff member (See Figure). The Air Force's signature F-35 fighter jet consumes 237 gallons of jet fuel per 100 nautical miles[1], emitting 2.27 metric tons of CO_2eq[i]. Astonishingly, annual emissions from jet fuel consumption within the US military is equivalent to driving 6 million passenger cars over a year [1ii]. Fuel efficiencies among other militaries are hardly better – and for many, much worse. Yet, militaries around the world are largely spared from having to report their emissions. This must change, or else mitigation measures risk becoming mere guesswork[2].

Why are IPCC reports (https://www.ipcc.ch) and climate summits (https://unfccc.int) silent on military emissions? The short answer is politics, and lack of expertise. During the 1997 Kyoto Protocol negotiations, US delegates lobbied on the grounds of national security to exclude the military from reporting requirements for greenhouse gases. That approach has stuck, even though this narrative no longer holds --- methods are now available for counting emissions along global supply chains without compromising intellectual property or disclosing sensitive information.

With no international agreement on accountability, requirement to report, leadership or the will to act, monitoring and cutting military emissions are low priorities. Only a handful of forces – including those of the UK (https://www.gov.uk/government/publications/ministry-of-defence-climate-change-and-sustainability-strategic-approach) and USA (https://www.denix.osd.mil/sustainability/dod-sspp/index.html) – have published strategy documents on climate actions. Across the 27 member states of the EU, for example, we found only ten militaries that had noted the need for greenhouse gas mitigation, of which just seven had set targets.

Also missing are accurate methodologies for calculating emissions from military activities. While those from permanent bases and routine deployments are straightforward to assess, as for any large business, recording is near impossible in hostile, fast changing or insecure locations. A lack of published data also makes it hard to estimate totals for military emissons[3].

Military emissions need to be put on the global agenda and they must be officially recognized and accurately reported in national inventories. Military operations also need to be decarbonized. Moreover, this cannot come merely from 'greening' military infrastructure or equipment, although that is important. Rather, a concerted effort is needed to reduce military spending on carbon-intensive program such as F-35 and other initiatives that lead to carbon-based path dependencies. Researchers need to develop transparent frameworks for reporting military emissions and identify data gaps. The 2022 UN Climate Change Conference of the Parties in Sharm el-Sheikh, Egypt (COP

27), and the 2023 Conference in Dubai, United Arab Emirates (COP 28), are opportunities to formalise this change.

Uncounted emissions

Reporting of military emissions under the UN Framework Convention on Climate Change (UNFCCC) is incomplete, unclear and inconsistent (see https://militaryemissions.org/). Some data have been shared on direct emissions from fuel consumption and operation of facilities and power consumed. However, indirect emissions along supply chains are absent and emissions calculations are often flawed. Some figures may not be flagged as military in origin, classified instead under broader categories such as public buildings and services or general aviation or shipping.

For example, the UK has one of the best track records in reporting its military carbon emissions. Since 2010, it has published data for direct emissions [iii] in the annexes of Ministry of Defence (MOD) reports. In 2018, for instance, British forces emitted around 2.7 million metric tonnes[iv] of CO_2eq https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831728/MOD_Annual_Report_and_Accounts_2018-19_WEB__ERRATUM_CORRECTED_.pdf), roughly equivalent to emissions to 1.5 million cars.

Yet, in the figures the UK reported to the UNFCCC in 2019, only 64% of the MOD's declared emissions were explicitly identified as military – those relating only to military aircraft and naval vessels. It is not clear how emissions from military bases and ground vehicles were reported. Further research might check, for example, whether such emissions were reported under civilian categories. Also unclear is whether all bunker fuels used for international military transport are included in the reported total.

Reporting in other countries can be even more scattershot. In the US, records of direct military emissions are decentralised, located across different government departments, and often opaque due to so-called 'national security' concerns (https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/).Crawford estimated that activities of the US Department of Defense (DOD) – including all branches of the US armed forces and their civilian support staff – released 55.4 million metric tonnes of greenhouse gases (CO_2eq)[1] in 2018, roughly equals to that of 12 million cars[v]. The emissions from the US military exceed those of many countries, including Peru, Singapore, Switzerland, Ghana and New Zealand. Indeed, were the US DOD a nation, it would be the 54th highest emitter globally (see Table S1 and Figure S1).

Scant data are available from other nations with large armed forces. This includes Russia – currently, of course, engaged in a major war with Ukraine. It also includes China and India, which have more active military personnel than the USA. It also includes other leading military spenders such as Saudi Arabia -which has a very carbon intensive economy. Indeed rapid growth for the biggest military power, China with its 2 million personnel, can be expected as earlier this month Xi Jinping announced that they intend to be a "world Class Military" in 2049. Other countries, such as Peru, Indonesia and South Africa do not have to report their national emissions annually, as UNFCCC obligations vary according to levels of economic development. As emerging economies are often carbon-intensive, their military emissions might be even more significant than those we know about or can estimate.

All told, analyses of fossil fuel consumption suggest that the world's militaries could be responsible for 1% to 5%[vi] of global greenhouse emissions each year, or 0.4 to 2 billion metric tonnes of CO_2eq annually[4]. The true total could be even higher: factoring in other energy supplies, raw materials, supply

chains and equipment manufacturing could more than triple emissions estimates[5]. Emissions from warfare[vii] would add yet more[4] but are difficult to measure. For example, just accounting for the fuel consumption during the war in Iraq, it was estimated that some 254 million metric tons of CO_2eq were emitted between 2003 and 2011, more than the annual emissions of many countries around the world[4].

Tracking and reporting

No methodologies for tracking emissions on military bases or in conflict areas have been published. NATO is reportedly developing such a framework for its members (https://www.nato.int/cps/en/natohq/official_texts_185174.htm) ; little is known publicly about its methodology, robustness and applicability[6]. We anticipate that supply chain emissions or emissions from armed conflicts will go unaddressed.

A standardised methodology and comprehensive assessment framework for greenhouse gas emissions, including life-cycle embedded emissions, is needed. While much can be drawn from other industries, military-specific environments and circumstances must be considered.

There are two major gaps. First, the day-to-day footprint of militaries themselves must include the emissions associated with the management of bases and estates --- from providing infrastructure and cement to food to feed and house the troops. Second, a reckoning is needed of the impacts of infrastructure damage, land use changes, socioeconomic shifts, and post-war reconstruction and recovery[7]. Despite two decades of progress on documenting the environmental dimensions of armed conflicts, efforts to calculate these emissions are in their infancy.

Russia's war in Ukraine has drawn fresh attention to the role of fossil fuels in financing conflicts, as a target and as a tool for political coercion. The Ukrainian government is calculating the financial and environmental costs of the impact of the conflict on the climate – the first time that any conflict affected state has done so, which will be raised at COP27.

Research areas requiring investment include methods for independently verifying military emissions accounting by third parties, including academics and civil society groups, without compromising national security. Breaking down emissions by technology sectors will help prioritize actions and targets. Studies on the feasibility of adopting low-carbon technologies are key. 'Barcoding' software used in the private sector to track emissions throughout a supply chain, as in from farm to fork initiatives, may be helpful. Such data can be fed into a product passport or declarations of emissions for processes, products or services[8].

Decarbonizing operations

Once reporting mechanisms are in place, plans for decarbonizing the military must be assessed and improved. Militaries will need support from researchers to do this effectively. One major challenge is 'lock in' -- emissions from military equipment are fixed for decades owing to long procurement processes and lifespans. For example, F-16 fighter planes entered service with the US Air Force in 1980 and are not due to be retired until about 2040. Despite proposals to electrify land vehicles, and to promote synthetic fuels for aviation[9], fossil fuel use within global militaries will continue to rise for many years to come.

Warships, combat aircraft and ground vehicles must become more fuel efficient and benefit from renewable sources**.** For reconnaissance, more use should be made of lightweight craft such as drones and satellite data. Solar photovoltaic arrays and electric vehicles should become the norm on military bases. The UK's MOD and its Defence Innovation Fund ideas scheme, the ViTAL Living Lab

(from which O.H. receives funding), develops and harnesses solar, geothermal, hydrogen and electric energy for use on the Royal Air Force's Leeming base as a testbed.

Life cycle impacts and raw material requirements are another blackbox[8]. There may be unintended consequences when switching to alternative technologies. For example, high energy use and emissions may be embodied in supply chains of some technologies such as for manufacturing Lithium-ion batteries; or choosing a new technology may increase reliance on critical raw materials such as cobalt, antimony and others, due to the fact that some technologies are material dependant.

Materials required in wartimes may differ from those for everyday civilian environments. For instance, research investment is needed into low-carbon materials with high anti-blast properties in lieu of concrete. There may be some benefits to the civilian sector from military innovation. Innovation in the military could act as a catalyst for adoption in the public and private sector by considering for example new building materials, PV or other novel power sources – particularly for austere environments or use in disaster relief operations.

Military bases also need to cope with climate extremes such as storm surge flooding, wind, wildfire and drought**.** For example the US the Department of Defense oversees more than 1,700 international military facilities on coastlines that may be vulnerable to sea level rise, according to the Congressional Research Service. According to a departmental survey conducted in 2019 on 79 installations, nearly two-thirds of them are at risk from recurring flooding, and the other half face threats from drought or wildfires (https://www.defensenews.com/smr/energy-and-environment/2021/08/09/climate-change-is-going-to-cost-us-how-the-us-military-is-preparing-for-harsher-environments/).

All this needs to move beyond plans and high-level discussions that are part of diplomatic efforts, arms control treaties and other conflict prevention measures. Crucially, improving global security leads to reductions in international military expenditure, and its associated emissions. For example, after the end of the Cold War, military emissions across NATO and the Soviet bloc fell markedly between 1991 and 2000. Total US military emissions declined by 44%[1] and those of UK military aviation and shipping by 32%[10].

Next steps

We call for action in four areas.

First, militaries across the globe must be held accountable. While national net zero pledges have helped focus attention in some countries, common international standards and obligations must be agreed. The UNFCCC is the most appropriate forum and must strengthen and reform its reporting protocols to include militaries. COP27 and COP28 are key opportunities for those states that have already engaged on the military emissions agenda, such as the US and UK, to show leadership. Researchers must keep advocating for common standards for accounting, reporting and reducing military emissions. These must be transparent, time bounded and measurable.

Second, militaries must improve their capacity and personnel to calculate, manage and reduce emissions. Researchers should work with forces to: exchange knowledge and best practice from the civil sector; help develop new protocols for military-specific emissions; and use or procure low-carbon equipment.

Third, researchers need to document and understand how armed conflicts impact the climate and society. This dynamic is complex but vital for identifying low-carbon recovery pathways for countries coming into conflict, such as Ukraine**,** and for understanding of the long range costs of armed

conflict. Finally independent research is paramount to keep militaries accountable and to uphold obligations made under the UNFCCC. Clearly there is an urgent need to support researchers to conduct independent analysis and provide evidence-based solutions and militaries should work hand in hand with academia and industry to establish a commonly understood and verifiable means of accounting.

For example, some technologies come with high embodied energy use and emissions in the upstream of their supply chains of, such as

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[Re graphic: as well as below, can you quickly cobble together another that puts military emissions in wider context, eg compares some key things to other sectors, or breaks down emissions into certain things? even if for one military with good records?]- WE WOULD NEED A BIT MORE TIME FOR THIS

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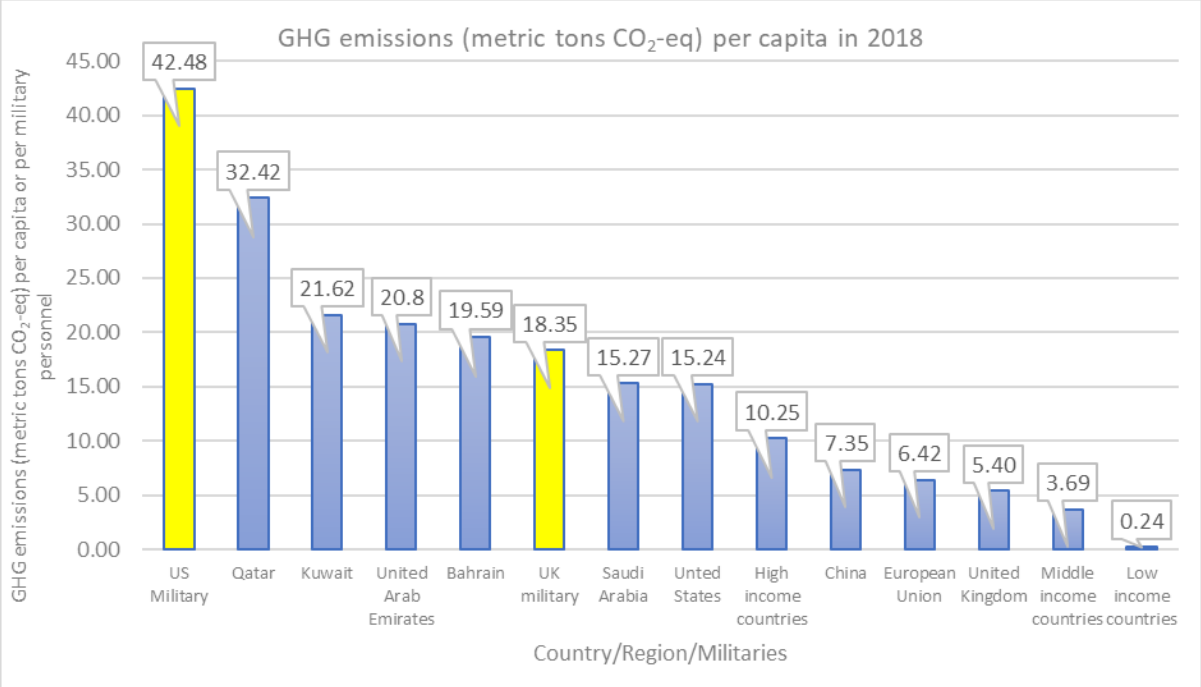

Figure. GHG emissions (in CO_2eq) per personnel of US and UK military compared to the total GHG emissions (in CO_2eq) of selected countries and regions per capita (based on the World Bank Data https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?end=2018&start=2000&view=chart)[viii]
(See SI Figure 1 and the underlaying data in the SI- excel spreadsheet)

[i] Considering 21.095 pounds of CO_2eq emissions per gallon of jet fuel.
[ii] According to 2017 data (see Reference No. 1)
[iii] Scope 3 has been recently considered in the MOD annual reports and accounts (from 2022). It should be mentioned that the considered scope 3 by MOD only includes Waste Generated, Employee commuting, Service Family Accommodation (SFA), Duty Travel (UK and overseas).

[iv] The official figure includes Scope 3 emissions as Waste Generated, Employee commuting, Service Family Accommodation (SFA), Duty Travel (UK and overseas).
[v] Considering 4.60 metric tonnes CO_2eq as the average GHG emission that each passenger vehicle produces in the US (EPA estimations see https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references#vehicles)
[vi] The estimated numbers only provide the minimum military GHG emissions as they only account for direct emissions from militaries' fossil-fuel consumption. There are some indirect emissions that including them would increase the emissions such as emissions from arms industry as well as emissions due to war.
[vii] including infrastructure or landscape fires, deforestation and other land-use change, displacement and humanitarian assistance and, significantly, post-conflict reconstruction
[viii] For the sake of consistency, all the data used in the figure were extracted for the year 2018.