



Confronting military greenhouse gas emissions

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Interactive content

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We cannot cut what we do not know

Dr Benjamin Neimark, Senior Lecturer, School of Business and Management, Queen Mary University of London

Global militaries are some of the largest carbon polluters on the planet. Yet we still know very little about their overall contribution to climate change. Militaries generally do not report their emissions to international climate bodies. If they do, their reporting is often inadequate, leaving **significant gaps** in accounting.

We cannot cut what we do not know. This collection of high-quality research seeks to fill the gap and open the 'black box' on military emissions.

This interactive policy brief is set up into three general themes for climate policy:



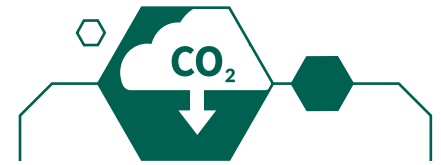
Big picture emission outputs of the world's largest militaries

Laying out some of the broader foundational empirical and conceptual work coalescing military greenhouse gas (GHG) emissions.



Carbon emissions and war

Including recent case studies from Ukraine, Israel-Gaza and Iraq, presenting some of the challenges in conducting real-time emissions during war and best practices to apply to overcome difficulties in data collection and analysis.



Military attempts at decarbonisation, opportunities and challenges moving forward

Addressing monetary and social costs of military GHG emissions.

These research contributions give policymakers, academics, activists and the public tools to hold governments accountable to fill the military emissions gap.

This is only a start. Much more research is needed. But these briefs already point to the urgent need for mandatory military emissions reporting for both war and peacetime through the UN Framework Convention on Climate Change (UNFCCC) and beyond.

Known unknowns

Big questions around military and military industrial emissions

Professor Neta C. Crawford, Montague Burton Professor of International Relations, University of Oxford

There is a lot we **don't know about military emissions**, mainly because military emissions reporting was exempted from the 1997 Kyoto Protocol. Here are some of the big military emissions questions we need to confront if there are to be any meaningful cuts:

1

What are the total greenhouse gas (GHG) emissions (CO₂e) of every country's military? How, in what level of specificity, and to whom is my nation reporting its military emissions annually?

2

What are the emissions of these overseas installations?

For example, the US has approx. 800 bases in 80 countries.

3

What are the radiative forcing (RF) effects of water vapour (contrails), black carbon and sulfates due to military aerial operations?

Such high altitude operations produce GHG emissions **and** can have RF effects that are **1.9 to 3 times greater** than the effects of the GHGs emitted.

4

What are the emissions of local military industries?

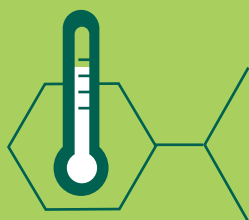
Military industry tends to be more GHG intensive, on average, than civilian manufacturing.

5

How much fuel is used to defend sea lanes so that fossil fuels can be transported from the Persian Gulf?

6

To what extent have 'drop-in' biofuel blends, or 100 percent biofuels, replaced petroleum-based fuels for naval, ground and air operations?



There is a political and scientific understanding of the need to limit the global temperature increase below 1.5°C (34.7°F), but without adequate baselines that include military emissions, we are in the dark on the amount of GHGs we need to cut.

Read more: Lee, D. S., et al. (2021) The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment*, 244. [Link](#)

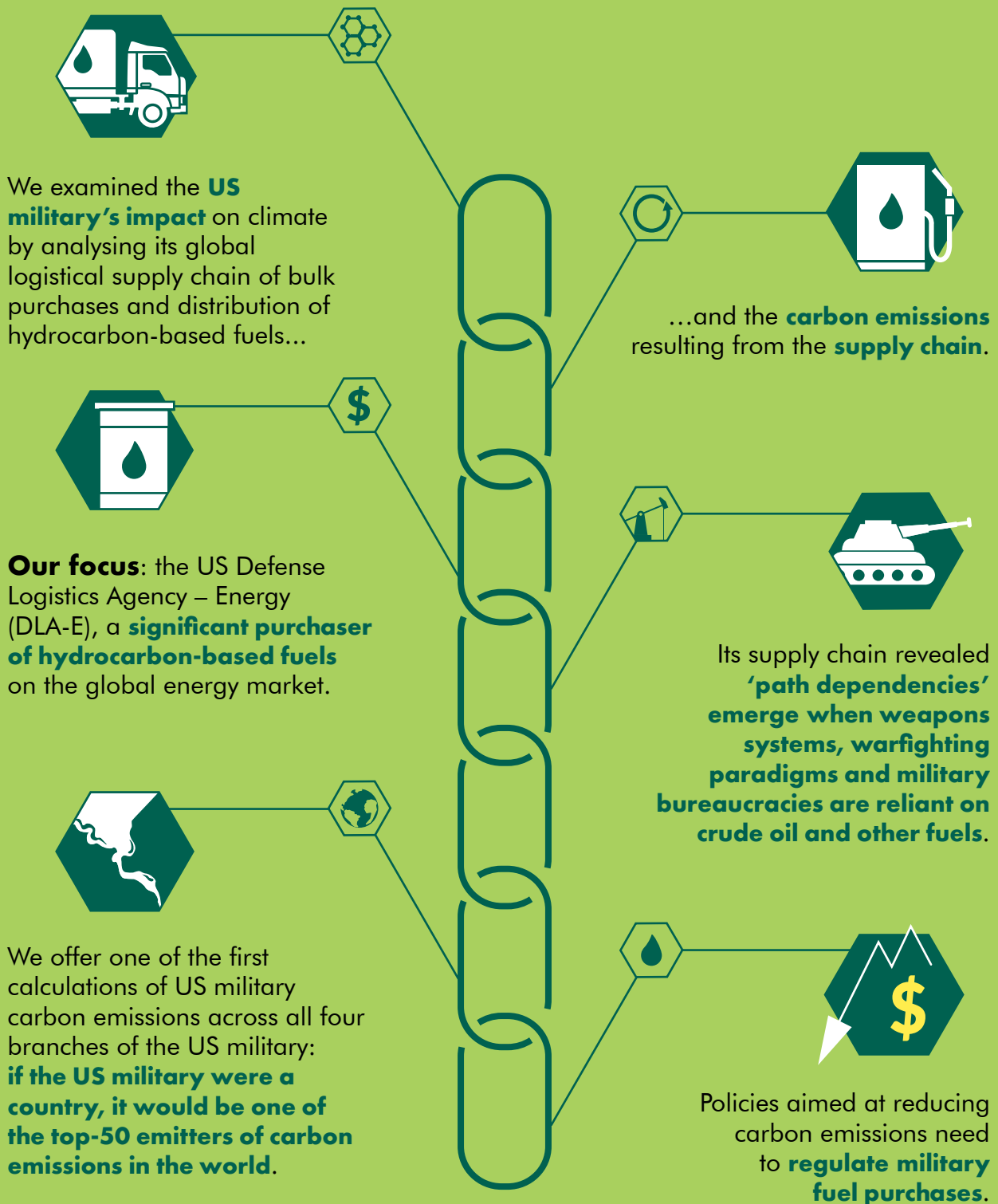
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Read more from our collaborative research contributors

Explore other contributions

Insights from military supply chain analysis

Dr Oliver Belcher, Associate Professor, School of Government and International Affairs, Durham University



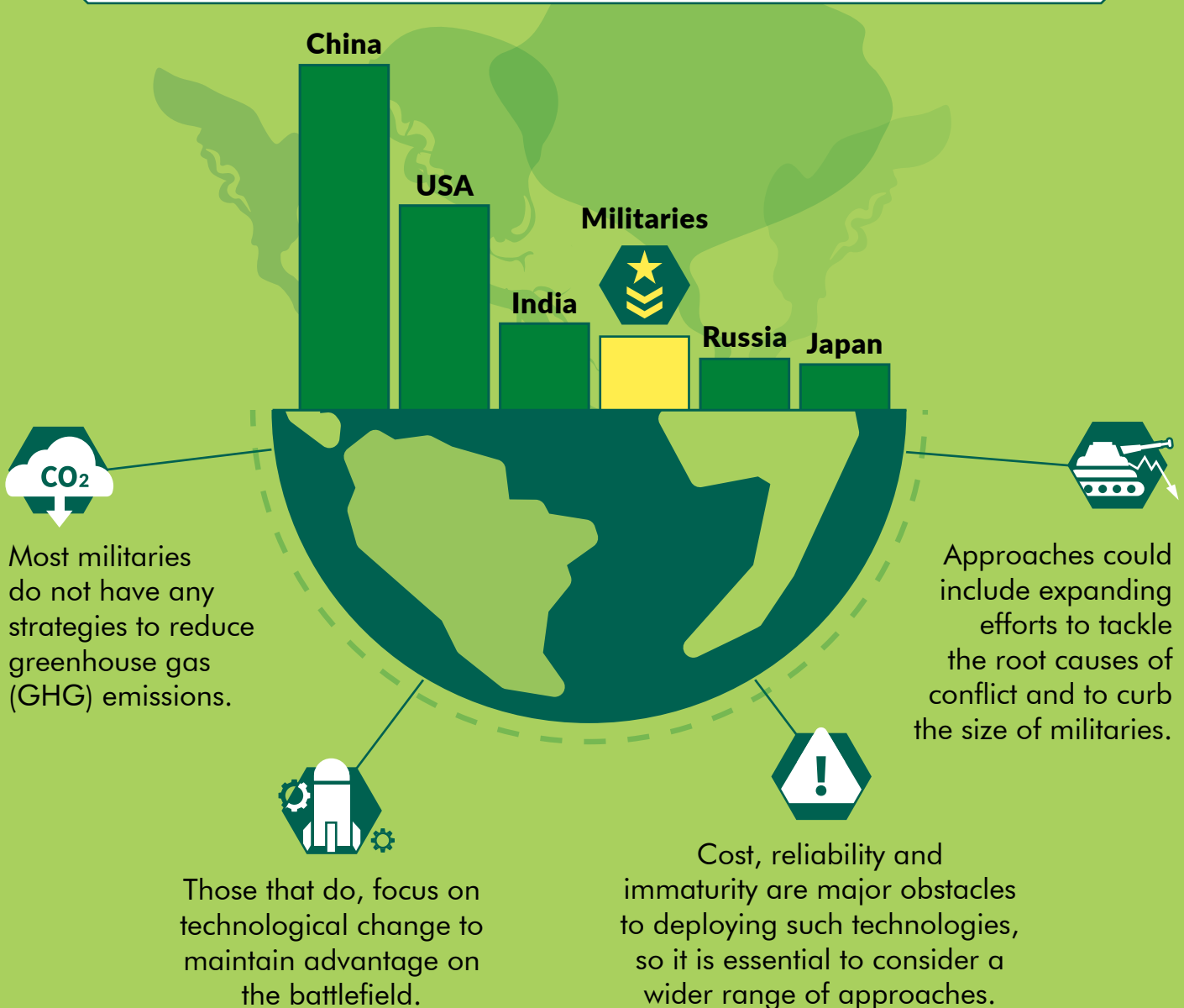
Read more: Belcher, O., Bigger, P., Neimark, B. and Kennelly, C. (2020) Hidden Carbon Costs of the "Everywhere War": Logistics, Geopolitical Ecology, and the Carbon Boot-Print of the US Military. *Transactions of the Institute of British Geographers*, 45(1), 65–80. [Link](#)

The global military carbon footprint

Dr Stuart Parkinson, Scientists for Global Responsibility (SGR)

We found that **5.5%^{1&2} of the world's emissions** can be attributed to global militaries. The largest fraction was supply chain emissions.

If the world's militaries were a single nation, they would have the **fourth highest** carbon footprint. Given the degree of control that governments have over the sizes of their militaries, there is a **huge and largely unrecognised opportunity** to reduce emissions.



¹Based on data related to: numbers of military personnel; energy use at military bases and from 'mobile' military activities; and embodied emissions in industrial supply chains. ²Our estimate does not take account of emissions due to the broader impacts of war, including infrastructure fires, forest fires, movement of refugees and post-conflict reconstruction. It also does not include climate heating due to the effects of military aviation emissions in the stratosphere ([page 4](#)).

Read more: Parkinson, S. and Cottrell, L. (2022) Estimating the military's global greenhouse gas emissions. Scientists for Global Responsibility and the Conflict and Environment Observatory. [Link](#)

Close the military emissions gap

Linsey Cottrell, Environmental Policy Officer, Conflict and Environment Observatory

Militaries are significant contributors to the climate crisis, but data on military emissions is often absent or incomplete – this is the **military emissions gap**.

Countries have different reporting responsibilities in the Framework Convention on Climate Change (UNFCCC), but none require mandatory reporting of military emissions.

Annex 1

economically developed countries, with the greatest historical emissions, asked to follow **voluntary reporting** guidelines

In 2022, 40 countries spent over **\$1,469 billion** on their militaries (including the US, UK and most of Europe).

In 2023, **only 4 recorded their emissions** in line with voluntary guidelines.

Non-Annex 1

less developed countries, with fewer reporting requirements and **no expectation** to separately report military emissions

In 2022, 25 countries spent over **\$335 billion on their militaries** (including India, Saudi Arabia, Brazil and Israel).

In 2023, **these countries reported no data** on their military emissions.

The Conflict and Environment Observatory (CEOBS) has developed a **framework for military greenhouse gas (GHG) emissions reporting**. Military emissions reporting **must be made mandatory** within UNFCCC and governments must commit to military emissions reduction targets in line with the Paris Climate Agreement.

Highlights of the framework

Applies the widely used Greenhouse Gas Protocol to militaries, using the industry standard of Scope 1, 2 and 3.

Identifies a further category, Scope 3+, vital for understanding the climatic consequences of armed conflicts.



Thorough military emissions reporting is essential to understand the impact that militarism has on global emissions. Crucially, it is also key to accountability.

Read more: CEOBS (2022) A framework for military greenhouse gas emissions reporting, Military Emissions Gap Report. [Link](#)

Climate change and the Gaza war

Dr Frederick Otu-Larbi, Research Associate, Lancaster University, UK,
and Lecturer, University of Energy and Natural Resources, Ghana

The greenhouse gas (GHG) emissions of the future **reconstruction** of Gaza alone are on par with the annual emissions of New Zealand. One aspect of this (and any) war that is less discussed is the **environmental impact of the conflict**, including the GHG emissions associated with the use of materials and resources by the warring factions.

Our work estimates the **carbon emissions** of the war in Gaza for three distinct periods:

1



Direct war activities – jets, bombs and rockets – in the first 60 days

More than the **annual emissions** of **20** individual countries and territories

281,315 tonnes of carbon dioxide equivalent (tCO₂e)

2



Construction of concrete infrastructure by both Israel and Hamas

More than the **annual emissions** of **33** individual countries and territories

Hamas – subterranean tunnel network:
176,000 tCO₂e

Israel – Iron wall:
274,000 tCO₂e

Total: **450,000 tCO₂e**

3



Future reconstruction of Gaza

More than the **annual emissions** of over **130** countries and on a par with New Zealand

30 million tCO₂e approx.

This analysis should be used as an entry point for a more comprehensive picture of the effects of war on the climate. Our figures highlight the significant climate footprint of armed conflicts.

Read more: Neimark, B., Bigger, P., Otu-Larbi, F. and Larbi, R. (2024) A multitemporal snapshot of greenhouse gas emissions from the Israel-Gaza conflict, SSRN. [Link](#)

Climate damage caused by Russia's war in Ukraine

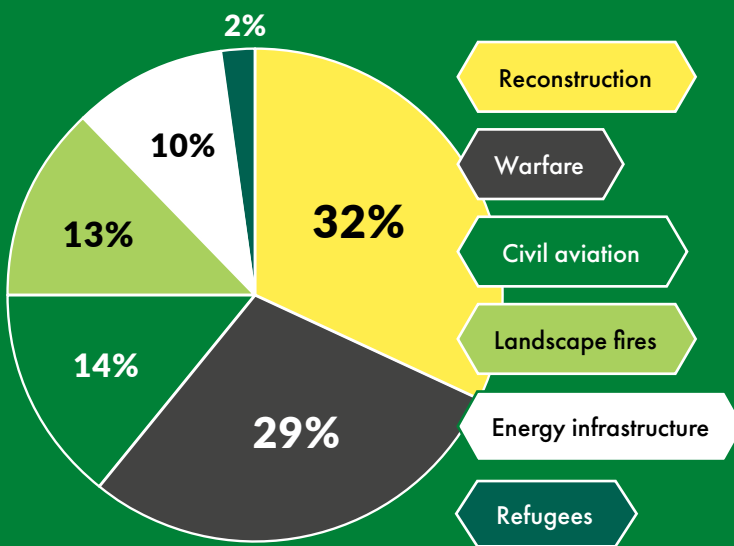
Lennard de Klerk, Lead Author, Initiative on GHG Emissions of War

The invasion of Ukraine by Russia led to unimaginable loss of lives, damage to buildings, schools, hospitals and infrastructure, the displacement of over six million Ukrainians, environmental damage and a trans-boundary impact on the climate.

\$32 billion

total climate damage caused by Russia in first 24 months of war

Total GHG emissions [Link](#)



Our research estimates the additional emissions of greenhouse gases (GHGs) that can be attributed to this act of aggression; this was the first time the climate impact of a large military conflict had been assessed.

Our third assessment concluded that the total GHG emissions that can be attributed to the war have increased to **175 million tonnes of carbon dioxide equivalent (tCO₂e) over an 24-month period**, more than the annual GHG emissions from a highly industrialised country like Belgium.



This report also investigated the possibility of holding Russia accountable for the damage done to the climate. We used the Social Cost of Carbon methodology to express the war emissions in monetary loss, resulting in climate damage of **\$32 billion** after 24 months of war.

The United Nations General Assembly has adopted a resolution that calls for Russia to pay war reparations to Ukraine.

A **Register of Damage** for Ukraine will be established to administer all damages and losses in which war emissions should be made part.



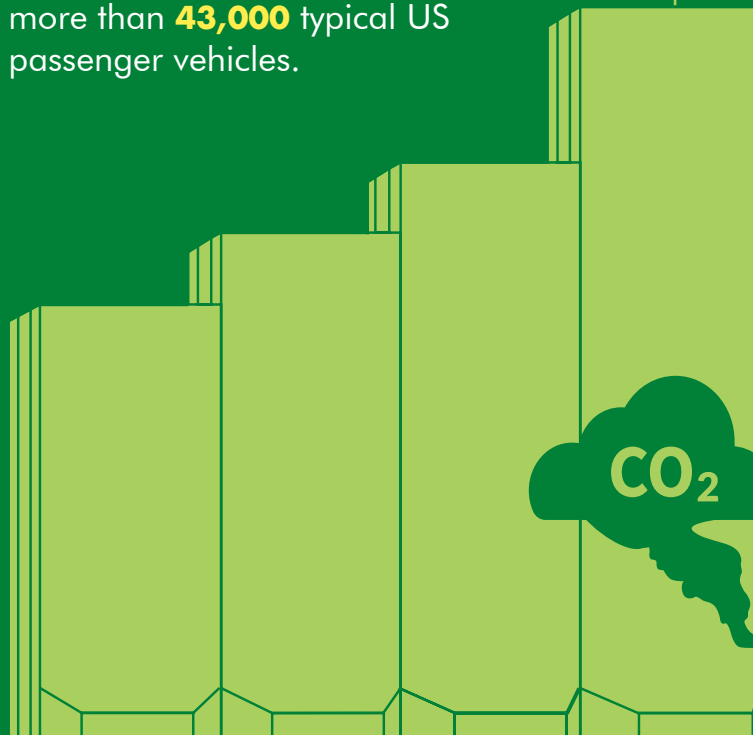
For updates on the environmental impact, head to: The Ukrainian Ministry of Environmental Protection and Natural Resources. [Link](#); Zoë Environmental Network. [Link](#); Ecoaction. [Link](#); Greenpeace. [Link](#)

Read more: De Klerk, L. et al. (2024) Climate damage caused by Russia's war in Ukraine, Initiative on GHG accounting of war. [Link](#); The Conflict and Environment Observatory (2024) The environmental consequences of the war against Ukraine: Preliminary 12-month assessment, summary and recommendations, CEOBS. [Link](#)

Concrete as a weapon of war: calculating emissions as a tool of resistance

Dr Reuben Larbi, Health Determinants Research Collaboration, Lancaster University |
Dr Kali Rubaii, Purdue University | Dr Benjamin Neimark, Queen Mary University of London

The total carbon embodied in the production of the concrete for blast walls in Baghdad 2003–2008 is equivalent to the annual tailpipe emissions from more than **43,000** typical US passenger vehicles.



1

The privatisation of war ('disaster-capitalism complex') where operations such as securing borders and rebuilding cities are performed by third party companies for profit complicates the collation and access to data.

2

Militaries' procurement processes can be complex and secretive, particularly during war time.

3

Researchers assessing military emissions face data deficits.



We use life cycle assessments (LCA) to present one of the first studies that **exposes direct and indirect military emissions** resulting from the **use of concrete** in combat.

Concerned citizens can use our framework for examining carbon emissions to overcome the secretive nature of military supply chains and calculate social and environmental impacts as a **mode of resistance to war and occupation**.

Read more: Neimark, B., Belcher, O., Ashworth, K. and Larbi, R. (2023) Concrete Impacts: Blast Walls, Wartime Emissions, and the US Occupation of Iraq. *Antipode*, 56(3), 983–1005. [Link](#); Larbi, R., Rubaii, K., Neimark, B. and Ashworth, K. (2024) Parting the Fog of War: Assessing Military Greenhouse Gas Emissions from Below. SSRN. [Link](#)

Cities' destruction and reconstruction are a massive source of emissions

Dr Ho-Chih Lin, Tipping Point North South, Lead Researcher, Transform Defence Project |

Dr Axel Michaelowa, Senior Founding Partner, Perspectives Climate Group and Senior Researcher, University of Zurich

There has **not been a single conflict-free year** since the end of World War II. Modern conflicts are mainly fought in and around cities which **suffer severe destruction, causing direct and indirect greenhouse gas (GHG) emissions.**

Direct emissions

Generated by fires triggered by bombing

Firebombing a city of several hundred thousand people generates direct emissions of **10–20 million tonnes of carbon dioxide equivalent (tCO₂e), comparable with annual emissions of a medium-sized country.**



Indirect emissions

From the need to clear rubble and produce building materials for reconstruction

In the wars of the last few decades, we have seen less firebombing, but massive destruction of buildings, as shown in Aleppo and Gaza.

Indirect emissions for reconstruction of 50,000 buildings reach **10 million tCO₂e.**

The cement alone required to rebuild the ten most-destroyed Syrian cities would release more than **20 million tCO₂e.**

To rebuild a megacity like Beijing from scratch would generate up to **500 million tCO₂e.**



These emissions are comparable with the annual emissions of large countries.



The climate impact of conflicts on cities should be recognised and addressed, starting with the Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Cities.



This requires a thorough assessment of direct and indirect emissions related to the destruction of cities in the 20th and 21st century, ideally in a peer-reviewed journal.

In World War II, the wooden cities of Japan and stone cities of Germany burned.

Now the Syrian, Ukrainian and Gaza wars have left huge piles of concrete rubble.

We must understand conflicts' GHG emissions alongside the human suffering they cause.



Read more: Michaelowa, A., Koch, T., Charro, D. and Gameros, C. (2022) Military and Conflict-Related Emissions: Kyoto to Glasgow and Beyond, Perspectives Climate Group and Tipping Point North South. [Link](#)

Addressing challenges in decarbonising militaries

Professor Oliver Heidrich, Professor of Civil and Environmental Engineering, Newcastle University | Dr Mohammad Rajaeifar, Senior Research Associate, Tyndall Centre for Climate Change, Newcastle University



While the defence sector is essential for national security it consumes vast amounts of fossil fuels. Despite efforts to reduce emissions, the **contribution of the defence sector** to global greenhouse gas (GHG) emissions is expected to rise due to increasing global military expenditure.

Challenges in decarbonising militaries

Accurately measuring and reporting emissions, with limited transparent data or consistent methodologies:

We know from other sectors (e.g., water) that there is an urgent need to align high-level policy and guidance.

Clarity and consistency across different initiatives are essential to mitigate climate change successfully without compromising national security and causing detrimental impacts along the value and supply chain.



Fossil fuel dependency:

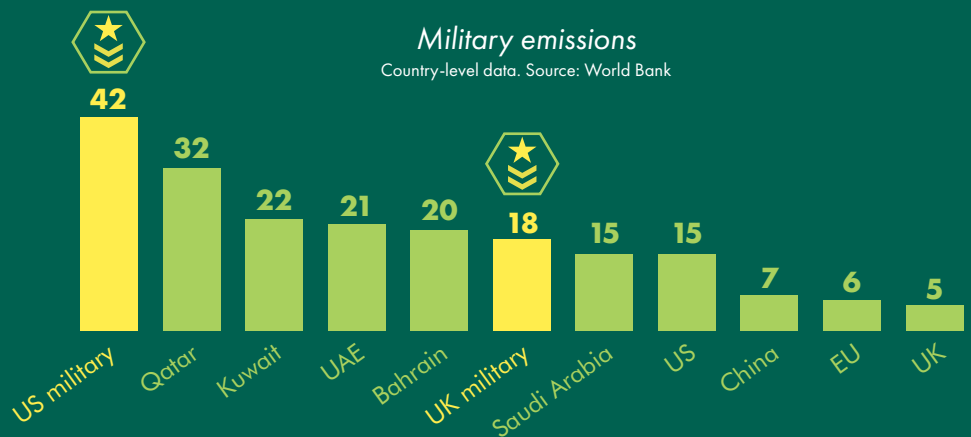
Requires energy efficiency improvements and technology-switching programmes.

Consider **renewable energy integration**, including existing techniques (e.g., solar photovoltaic arrays, electric vehicles) and emerging technologies (e.g., carbon capture and hydrogen technologies).

Transitioning to emerging technologies must address national security concerns and **avoid technology lock-in** in raw material and supply chains dominated by hostile countries.

Fuel-use data show that US and UK armed forces emit as much CO₂ per capita as many carbon-intensive countries

Military emissions in metric tonnes CO₂eq per capita or per military personnel countries.



Read more: Rajaeifar, M.A., Belcher, O., Parkinson, S., Neimark, B., Weir, D., Ashworth, K., Larbi, R. and Heidrich, O. (2022) Decarbonize the military—mandate emissions reporting. *Nature*, 611(7934), 29–32. [Link](#)

How can militaries decarbonise?

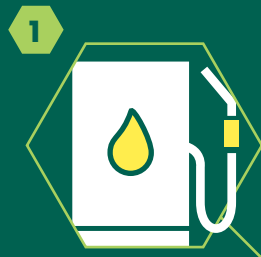
Dr Duncan Depledge, Senior Lecturer in Geopolitics and Security, Loughborough University |
Dr Tamiris Santos, Research Associate, Department of International Relations, Loughborough University

Many militaries acknowledge they are at risk of being 'left behind' by the unfolding energy transition; our work maps emerging socio-technical systems and imaginaries of 'low-carbon warfare'.

We have identified four pathways to military decarbonisation.

1 Refuel

Adopting alternative fuels (e.g., synthetic fuels, bio-fuels) to 'drop in' to existing military systems and platforms.



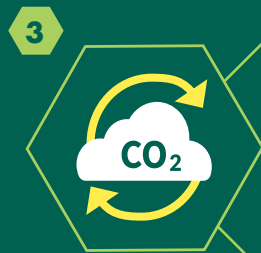
2 Repower

Developing alternative propulsion systems that could fundamental change how military systems and platforms are operated.



3 Redirect

Offsetting the carbon costs of military emissions through sequestration, outsourcing or by asking societies and/or nature to bear a higher share of the mitigation burden.



4 Review

Rethinking strategic posture and force structure, including the size of military forces, the need for specific capabilities, the geographic and temporal scope of operations, and the circumstances under which they should be deployed, especially in peace time.



Decarbonising military operations will require progress along **all four pathways**. Together with the defence sector, government, society and industry all have a part to play in reconfiguring the socio-technical systems and imaginaries that determine when, where, with what and for what ends militaries are deployed. Allies and partners must work together to ensure interoperability. The operational, political, legal, moral and financial risks of being the 'first mover' must be considered against the risks of 'lagging behind'.

Ultimately, we need more public debate about the carbon costs of defence and how these costs should be managed, shared and in the end reduced. **This is not a problem that militaries can solve alone.**

Read more: Depledge, D., Santos, T., Morisetti, N. and Nugee, R. (2023) Low carbon warfare, *Nature Climate Change*, 13, 881–882. [Link](#)

Decarbonising and diversifying defence: a workers' enquiry for a just transition

Dr Karen Bell, Senior Lecturer, Environmental Justice, University of Glasgow

We carried out interviews and focus groups with current and former defence sector workers in the US and UK.

Most defence workers had **never been consulted** on **decarbonisation, diversification or just transition**.



Many want to be involved in the **development of strategies and planning** on these issues.



Some **praised** their company's **efforts to decarbonise**. Others considered them **inadequate** to address the environmental harm caused by defence products and operations.



Some would prefer **'green jobs'** and non-military work. Others view military work as **essential** to protect fellow citizens.

Almost all supported **transitioning** the sector to **greater sustainability** as long as they would continue to have **equally secure and well-paid jobs**.

“ Do we really need any more weapons? I think we do need some kind of defence but, in the same token, are we producing too much?”

Female defence worker, UK

“ There's a lot more than just environmental benefits with decarbonisation. There is an increase in resilience of our supply chain if we can...wean ourselves off reliance on fossil fuels.”

Male defence worker, UK

Policy recommendations

Defence companies

- Make your environmental impact public
- Work with suppliers to estimate upstream emissions

Trade unions

- Expand education and dialogue around decarbonisation, diversification and just transition **with defence workers**
- Prioritise unionising the **green sector and improving pay and conditions** so these jobs are more attractive

Governments

- Enact legislation to include defence sector greenhouse gases (GHG) emissions in carbon accounting
- Substitute military force with 'human security' eco-social policies
- Set up national Just Transition Commissions to ensure that workers' voice is central to guiding net zero and other environmental policies

Read more: Bell, K., Price, V. McLoughlin, K. and Kojola, E. (2024) The necessity of a transformational approach to just transition: defence worker views on decarbonisation, diversification and sustainability, *Environmental Politics*, 33(2), 281–301. [Link](#)

Slash and pay: a reparative approach to military ecological damage

Dr Patrick Bigger, Research Director, Climate and Community Project |
Khem Rogaly, Senior Researcher, Common Wealth

Major militaries play an outsized role in perpetuating the fossil fuel economy.

The US military is the largest institutional consumer of fossil fuel in the world.

Applying a moderate social cost of carbon to these emissions nets at a total cost of **\$116 billion** between 2015 and 2021.

Fossil fuels

Developing carbon-intensive weapons systems threatens to **lock-in fossil fuel demand**.

The US and UK's overseas bases require fossil fuels to resupply. Overseas bases often have **detrimental social impacts** for host communities.

UK Ministry of Defence energy use accounts for **more than a fifth** of total public sector emissions.

US and UK militaries played **key roles** in the fossil economy's development and maintenance, and **vice versa**.

Militaries

The US and UK militaries have significant localised environmental impacts on **water, soil and human health**.

The direct **emissions** of the US and UK militaries are compounded by emissions from military industrial production.

The social costs of emissions by US/UK militaries **far exceed** their countries' contribution to international climate finance. The policy path points to:

A radical **reduction of military expenditures** – which constitute 55% of US government discretionary spending in 2023.



Repurposing military industrial manufacturing to more socially useful ends.

Savings should be **directed to vulnerable communities at home and abroad**, especially countries that suffered humanitarian, social and ecological harm as the result of US and UK military operations.

Read more: Bigger, P., Pearce, N., Rogaly, K. and Zodgekar, K. (2023) Less War, Less Warming: A reparative approach to US and UK military ecological damages, Common Wealth, Climate and Community Project. [Link](#)

Less military to address climate change?

Nico Edwards, School of Global Studies, University of Sussex*

In 2023, military spending and global temperatures soared to their highest ever levels. This is no coincidence. Militaries are a key driver of global carbon emissions, yet their complete role in climate change remains opaque. The 'known unknowns' hammer home the need to reveal this role.

This collection of robust research lays the groundwork for filling the military emissions knowledge gap. Mapping the carbon costs of militaries and conflict is a huge task. The contributors to this interactive policy brief help to show how to do it.

There are several key areas where we can track the emissions generated across the life cycle of military practice and armed conflict, for example:

- the **production** of weapons and military materials like concrete
- the **supply chains** of weapons and concrete
- the **carbon costs** of armed conflicts, such as the ongoing wars in Gaza and Ukraine
- **resource pressures** and **climate effects** of post-conflict reconstruction

This research proves that it is not only possible but of existential importance to open the military-climate black box and hold military sectors accountable for their ecological impact.

While providing actionable solutions to reduce militaries' planetary burden, the contributors foreground the vital importance of going beyond military decarbonisation to radically reduce our societies' reliance on military force and facilitate a just transition for arms workers.



These contributions can guide researchers, activists, practitioners, policymakers and journalists towards what kind of knowledge to look for, who to hold accountable and what actions to take.

Military expansion, however green, will not tackle **root causes** behind climate change or conflict. Military decarbonisation pathways will only be effective if they contribute to mitigating geopolitical tension, de-escalating arms races and preventing armed conflict.

Such system change is politically complicated and logistically and technologically challenging, but the path is clear. Learn from this research, share it and embark towards a more peaceful and just green transition. It is time to close the **military emissions gap**.

*Disclaimer: This is a personal reflection. The conclusions and recommendations do not reflect the opinions of all contributors.