ART —— Analysis and Research Team

RESEARCH PAPER

Greening the armies

Is a sustainable approach to national defence possible?

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Introduction

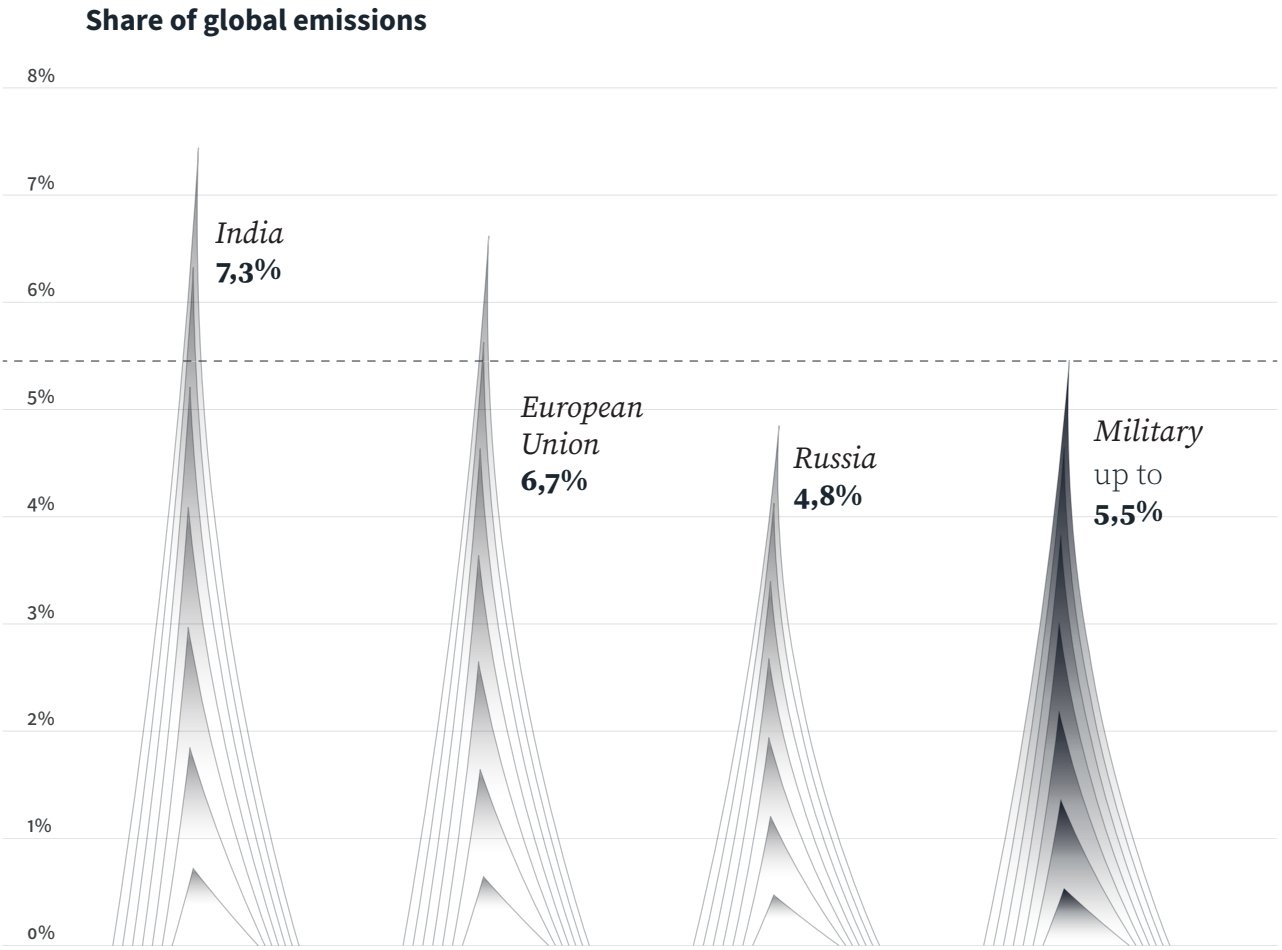
In an era marked by the pressing challenges of climate change and increasing competition over energy resources, every sector bears a responsibility for curbing emissions and reducing dependence on fossil fuels. But there is one sector which has managed to avoid attention in these discussions, having been excluded from any obligation to disclose emissions in both the Kyoto and Paris agreements[1]: **the military**.

Although determining the exact carbon 'boot print' of the armed forces is challenging, various estimates suggest the sector may be **responsible for up to 5.5% of the world's total CO2 emissions**[2]. To put this in perspective, if the world's militaries were a country, they would rank as the fourth-largest global emitter[3]. A particularly stark example of the impact of the military is the Pentagon, which constitutes the world's single largest consumer of petroleum products. Its total emissions are greater than those of entire countries such as Sweden, Denmark, or Portugal[4].

> *"We cannot choose between either green or strong armed forces, we need strong and green at the same time"*
>
> **Jens Stoltenberg**[5]

The **need to reconcile climate and defence priorities** is becoming increasingly pressing, especially at a time of significant increases in military activities and expenditure. This has received explicit support from the NATO Secretary General, who, in line with efforts undertaken so far by the EU, underlined the importance of having armed forces that are both robust and environmentally responsible[6]. This paper investigates this topic, although it does not address the broader issue of the impact of warfare itself on Co2 emissions and the environment. The first part highlights the potential win-win strategies of bringing together climate and defence objectives. The use of green resources already looks feasible for military installations and training activities, but could also offer very real operational advantages, something which is already being explored by several countries.

In contrast, the second part of the paper emphasises the many challenges associated with the decarbonisation of the armed forces. These revolve primarily around how to maintain the effectiveness of military assets and capabilities, particularly in combat operations, but are also connected to the lengthy timeframe required for the transition process as well as budgetary constraints. Given these considerations, the conclusions identify specific areas in the defence sector with the potential to transition to a more sustainable approach in the short term, as well as those areas where the transition may be conceivable in the longer term. The document concludes by raising issues that could benefit from further reflection at political level.



Potential win-win strategies

The transition towards environmentally sustainable armed forces represents a promising opportunity to bring **benefits for both the defence sector and the environment**. Embracing sustainable practices within the military could not only reduce reliance on costly fossil fuels, but also has the potential to enhance some aspects of operational effectiveness which are energy dependent. At the same time, a proactive shift towards renewable energy could significantly contribute to combating climate change, a threat that itself has a direct effect on military assets, capabilities, and operational readiness[7]. The **process of reducing carbon emissions** within the armed forces is not uniform, it **varies in complexity and degree of risk across different military assets and capabilities**.

Military installations: the low-hanging fruits in decarbonisation

Military installations and non-tactical fleets stand out as **obvious targets for rapid decarbonisation**. Installations, comparable to civilian infrastructures, account for a significant portion of defence emissions, whereas mobility represents a smaller share[8]. For instance, the US Department of Defence maintains more than 560,000 buildings in approximately 500 bases around the world[9]. In the EU, several Member States are prioritising these assets in their quest to reduce emissions. National authorities have started **renovation plans**, including the procurement of **electric vehicles**. However, given the substantial scale of these building stocks, progress will depend on **budgetary resources** and operational priorities.

By way of example, the Austrian Ministry of Defence is procuring electric vehicles for non-military purposes, increasing energy self-sufficiency, installing photovoltaic systems, and promoting environmental and energy awareness among personnel[10]. Similar **efforts aiming at encouraging a "sober energy culture"** are underway in other Member States such as France[11], Italy[12] and Spain[13]. Furthermore, the French army is exploring the development of external operations camps that are self-sufficient in energy and water as part of the ambitious 'Eco Camp 2025' project[14]. In a similar vein, Germany has developed a set of measures to limit energy and water requirements in operational infrastructure[15].

Training: transitioning towards greener practices

Training is an essential part of the military and constitutes a significant source of emissions. During non-operational periods, armed forces spend considerable time in preparing and carrying out training exercises. Although typically grouped within the broader scope of operational emissions, training possesses distinct characteristics that make it easier to reduce its environmental impact. **Increasing the proportion of virtual training activities** and simulations over live exercises could offer many advantages to armed forces with limited operational repercussions[16]. For instance, training aircrew in simulators can reduce the need for live flying by 90%[17]. This approach not

only **cuts costs and emissions but also enhances adaptability and the secrecy of training operations**. Simulations offer the strategic advantage of reducing the scope for enemy observation, whilst boosting operational flexibility by allowing repetitions of training segments to identify optimal strategies. Introducing lower emission vehicles into training modules provides an additional way of mitigating the carbon footprint without compromising operational effectiveness.

Operations: reducing reliance on convoys and logistics

Operations and combat assets, particularly Air, Space and Sea capabilities, along with heavy land forces, raise major challenges in terms of decarbonisation. However, they also stand to gain from the transition towards sustainability. The military's heavy **reliance on fossil fuels creates significant vulnerabilities**, not least by diverting combat power away from essential functions in order to safeguard convoys. Fuel convoys are an easy target for roadside bombs, which have accounted for nearly half of American deaths in Iraq and close to 40% in Afghanistan[18]. While **renewable energy** is not yet entirely suitable for combat, its higher efficiency and potential for on-site production could **reduce dependence on vulnerable convoys**.

Renewable technologies also offer solutions for energy scarcity and escalating costs. For instance, a UK army division can consume roughly 800,000 litres of diesel per day during high-intensity warfare, equivalent to the energy output of a medium-sized nuclear reactor. Green technologies offer further operational advantages, enabling self-sufficiency by recycling water, generating renewable energy, and cultivating food in vertical farms, thereby **reducing logistical supply lines**. Hybrid or **electric engine vehicles** offer a reduced impact in terms of noise, emissions, and heat, making them **less visible** on the battlefield.

Some EU Member States are testing biofuels on combat assets. Sweden, for instance, successfully tested a 50/50 mix of biofuels in JAS 39 Gripen aircraft engines, with no reduction in operational effectiveness or performance[19]. Similarly, in the US, GM Defense transformed the motor of an infantry Squad Vehicle into one powered by electricity using components of which 90% were off-the-shelf[20]. The UK military is developing an experimental electric aircraft, looking at synthetic aviation fuels and installing electric drives in several active army vehicles[21]. By 2025, the UK army will complete experiments with Hybrid Electric Drive prototypes that have shown promising results during initial trials[22].

Potential win-win strategies

More complex

Intermediate complexity

Quick wins

OPERATIONS

COMPLEXITY

Operations raise major challenges in terms of decarbonisation

- Using renewable sources of energy reduces dependence on vulnerable convoys
- EU Member States and Allies are experimenting new low carbon capabilities

TRAININGS

COMPLEXITY

Increasing simulations over live exercises could reduce the carbon footprint

- Training aircrew in simulators can reduce the need for live flying by 90%

MILITARY INSTALLATIONS

COMPLEXITY

Military installations and non-tactical fleets stand out as targets for rapid decarbonisation

- Renovation can move faster using civilian expertise and R&D
- Projects in several Member States on sober energy culture are underway

EU efforts to decarbonise the armies

The EU is actively engaging in initiatives to support Member States in mitigating the carbon emissions generated by their armed forces. As a result of the 2023 Joint Communication issued by the Commission and the European External Action Service, entitled "A new outlook on the climate and security nexus"[23], efforts are being directed at leveraging national increases in defence budgets. In line with the objectives of the European Green Deal and of the Strategic Compass, the Joint Communication:

- Establishes an EU Climate, Security and Defence Training Platform run by the European Security and Defence College;
- Sets-up a Climate and Defence Support Mechanism allowing Member States to identify collaboration opportunities and address gaps, particularly in developing eco-friendly standards;
- Considers a dedicated EU-led Competence Centre on Climate Change, Security and Defence.

These initiatives complement the actions envisaged as part of the November 2020 Climate Change and Defence Roadmap and the October 2021 EU Concept for Environmental Protection and Energy Optimisation for EU-led Military Operations and Missions. The roadmap sets out a plan for action on climate change mitigation. It calls for increased spending in research, technologies, and capabilities that will allow the armed forces to reduce their carbon footprint. The plan envisages actions such as developing a common methodology for measuring the carbon footprint of CSDP missions and operations, using the European Defence Fund for research and development activities on defence-oriented energy generation, storage, and efficiency, and inviting the European Defence Agency (EDA) to provide a collaborative platform for Member States willing to work together on energy and environment-related challenges in the defence sector.

NATO's climate action

The NATO 2022 Strategic Concept sets an objective for the Alliance "to contribute to combatting climate change by reducing greenhouse gas emissions, improving energy efficiency, investing in the transition to clean energy sources and leveraging green technologies, while ensuring military effectiveness and a credible deterrence and defence posture"[24]. NATO's 'Climate Security Action Plan' requires the Alliance to map greenhouse gas emissions from military activities and installations. This data will not only aid Allies in their own emission assessment programs but also support their voluntary emission reduction goals. Additionally, insights into military energy demand and consumption will guide Allies' investment decisions. NATO is actively exploring avenues to scale up innovative low-carbon technologies through its procurement practices. Canada has offered to host a NATO Centre of Excellence on Climate and Security to deepen understanding, adaptation, and mitigation efforts concerning the security implications of climate change[25].

The challenges of green armed forces

The shift towards sustainable armed forces could bring a range of benefits, but also entails significant risks. The key challenge is the need to **maintain the effectiveness and readiness of the military** in combat operations while undergoing the decarbonisation process. The **expected length of time needed for the transition process** is also likely to be challenging, not least in terms of maintaining and achieving **interoperability** both within the same army and in collaboration with allied forces. The need to allocate **additional financial resources** to the transition process is also likely to be an issue, particularly against a wider backdrop of budgetary rigour.

Maintaining the military edge while decarbonising

The main challenge in achieving a transition to establishing green armed forces lies in the need to maintain robust military effectiveness and combat readiness while pursuing decarbonisation initiatives, a challenge inherent in any innovation process. Warfare relies on the collective and coordinated use of force, where **immediate survival is at stake**. Consequently, green objectives will not be acceptable if they fail to meet the highest standards required for combat operations. A key issue arises over the use of renewable energy, which usually has lower energy density[26], for **military operations requiring high-energy density sources**, as well as how to store it in a way that works for combat purposes. Whilst some countries may commit to decarbonising their forces, there will be others who continue to rely on carbon-based conventional capabilities. This contrast raises a critical question as to whether a post-carbon army can hold its own in an **asymmetric confrontation with adversaries for whom fossil fuels will still be the norm**.

This question links the issue of decarbonisation of the armed forces with a broader discussion on **reimagining new approaches to warfare**. Future armed forces may well evolve into lighter, more agile units with reduced dependence on heavy armour, increasingly leveraging unmanned systems such as drones, and relying more on important cyber components[27]. These sorts of capabilities could benefit from energy-efficient systems and decreased logistical dependence. In Ukraine, some elements of this new approach to warfare, not least the extensive use of drones, has already proved to be effective[28]. Ensuring that these technologies meet rigorous standards and maintain superiority over adversaries, often in the context of life-and-death scenarios, will require **detailed assessment of their overall effectiveness** in comparison to more traditional methods of conducting warfare. Moreover, these emerging technologies will have to address the potential heightened **vulnerability to other threats**, such as electromagnetic pulse resulting from high-altitudes nuclear detonations[29], and possible disruptions caused by solar magnetic storms[30].

A long transition with interoperability problems

The transition to a decarbonised military is a **complex and prolonged process**. It poses challenges not only within the same armed force but also in ensuring interoperability with allied forces, such as in the EU and NATO. Despite promising advancements, **crucial technological breakthroughs are still required** before the opportunities presented by green technologies outweigh the associated risks. Moreover, the integration of new green technologies will have to take into account long development timelines and the **extended lifecycles of existing military assets**, including the procurement process. Compared to the civilian sector, the lifespan of military equipment is usually longer and its adaptation more challenging. Military equipment and platforms currently at the final design stage will only enter service in the 2030s and are likely to be in use up to the 2080s[31].

In the UK, for instance, in the absence of any immediate electrification options, much of its future Equipment Plan will rely heavily on conventional combustion engines until at least 2050. Full electrification of large platforms before 2035 seems unlikely without considerable advancements in battery technology[32]. The F-16 fighter planes, introduced into service by the U.S. Air Force in 1979, are not due to be retired until about 2040[33]. **Replacing** such assets **prematurely would lead to additional costs** and give rise to complex logistical challenges in managing a hybrid force based on both carbon-based and green technologies. The **coexistence of older and newer technologies** also impacts interoperability among allied countries and could subsequently result in additional financial burdens.

Financial issues amidst budget constraints

Among the key challenges faced in this transition is the **limited availability of financial resources**, particularly at a time of **significant budgetary constraint** within the European Union. The return of war to the European continent and escalating global instability have highlighted the need to increase defence spending in order to strengthen armed forces. Following Russia's full-scale invasion of Ukraine in February 2022, most NATO Allies committed to investing more, and more quickly, in defence. At the July 2023 Vilnius Summit, NATO leaders made a long-term commitment to invest at least 2% of GDP annually on defence[34]. While this commitment theoretically offers an opportunity to integrate eco-friendly projects within military frameworks, its main aim is to offset a legacy of years of low defence expenditure and the **urgent need to restock ammunition** and capabilities. With high intensity warfare re-emerging in Europe and at its borders, **speed and reliability take precedence**, with an understandable preference for tried-and-tested technology. An assumption therefore that the latest increase in defence spending might be used to facilitate a shift to green technology looks like wishful thinking. Additional funding must be found elsewhere, in a context of growing competition across the policy spectrum for limited financial resources.

The challenges of green armed forces

MAINTAINING THE MILITARY EDGE

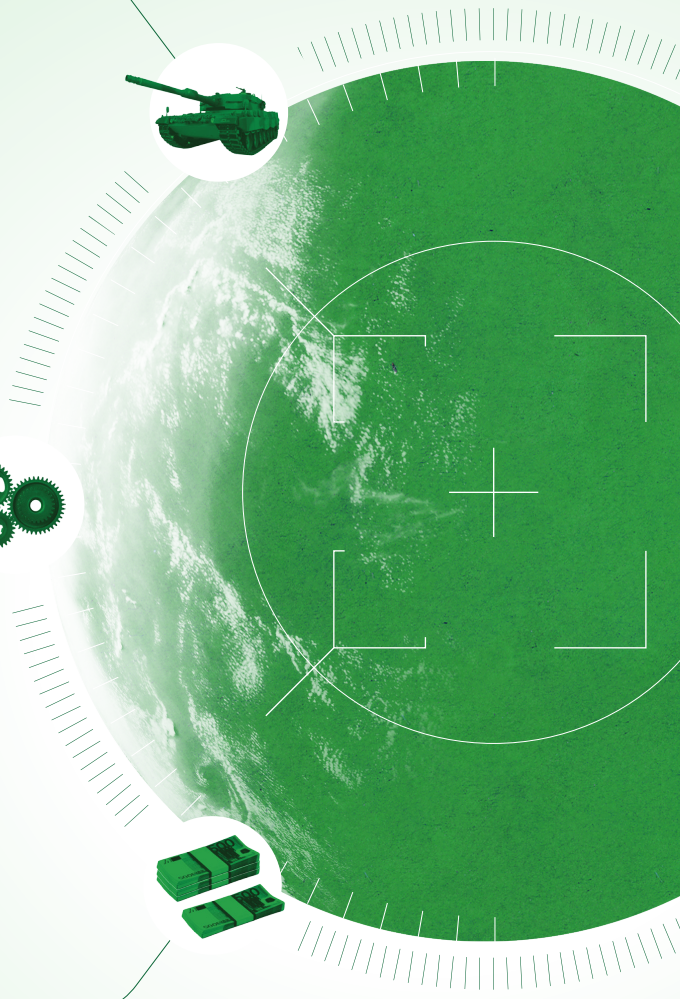
Green objectives will not be acceptable if they fail to meet the highest standards required for combat operations

INTEROPERABILITY

Technological breakthroughs are needed to allow replacing current capabilities with decarbonised ones.
The mix of old and new assets will pose interoperability problems

BUDGETARY CONSTRAINTS

Limited availability of financial resources, particularly at a time of significant budgetary constraints reduces opportunities to decarbonise the armies



China and Russia: limited interest in military decarbonisation

While EU Member States and NATO Allies are progressing at varying rates in efforts to decarbonise their armed forces, Russia and China display limited or no interest in such endeavours[35]. This raises concerns about potential asymmetry when comparing military capabilities, with forces on one side committed to the decarbonisation process, and those on the other side still relying on well-tested, albeit less advanced, fossil fuel-driven technologies. However, this divergence does not mean there is a complete disregard for climate change policies. China, for instance, approaches the issue from a different standpoint, focusing on the role of its armed forces in managing the risks posed by climate-induced national security issues rather than actively pursuinwg a green defence policy. Climate security is fully integrated into China's official concept of non-traditional security. In contrast, Russia has made no obvious effort to transition its armed forces to renewable energy sources, probably because of its easy access to affordable fossil fuels. And its focus on replenishing its arsenal, particularly in the context of the war in Ukraine, leaves few resources for greening its defence industry.

Conclusions: towards a convergence between climate and defence

The urgency of addressing climate change may not obviously resonate as a top priority within the military, particularly amid escalating geopolitical tensions and global conflicts. However, **achieving a greater convergence between environmental considerations and defence imperatives brings a number of benefits, and should be possible without compromising either**. This convergence requires that the transition not only maintains but ideally enhances the operational effectiveness of military assets and capabilities.

The shift towards green armed forces necessitates a gradual and phased approach, encompassing **short, medium, and long-term objectives**. Swift decarbonisation of civilian-oriented defence assets, including infrastructure and transportation vehicles, constitutes an area ready for immediate action. Similarly, training, a critical part of any military force, represents another area with the potential for transformation. The most challenging aspect of the transition concerns military operations and combat assets, which will certainly require a longer period to undergo substantial change. Developing and validating new technologies that are both effective and efficient will require considerable financial and temporal investment. Part of that will involve **establishing closer synergies** between the defence sector, research institutions, and industries as a way of **encouraging innovation** and implementing sustainable solutions.

Setting **clear long-term plans** with achievable milestones will be crucial for transitioning toward a more environmentally sustainable military. A key first step will be to **measure accurately military-related carbon emissions**, which are currently excluded from reporting due to concerns about potential risks to national security. But transparent reporting of emissions could be a significant first step in efforts to mitigate the military's environmental impact in that it would set a benchmark against which to measure progress. According to research published in November 2022 by Nature, only 10 of the armed forces across the 27 EU Member States see the need for greenhouse gas mitigation, with only 7 having set explicit targets[36].

In the long run, efforts to decarbonise the military could **lead to enhanced strategic autonomy**. The EU has been challenged in recent years over its reliance on fossil fuels, particularly cheap gas sourced predominantly from a single country, which has highlighted the costs of dependency. Shifting to renewable energy offers the EU a chance to secure greater independence, along with the potential advantage of shaping a self-sufficient army that minimises reliance on vulnerable convoys transporting fossil fuels. Yet, **this transition requires a proactive policy approach**, centred around developing clean extraction capacities within the EU, diversifying external sources, promoting recycling, and prioritising key technologies to reduce demand. Failure to adopt such an approach runs the risk of creating new dependencies, such as on metals and rare earths.

As societies move away from fossil fuels, **the military cannot remain the only sector still reliant on diesel and gas**. Continuing to run refineries and supporting fuel infrastructure for one sector alone could become prohibitively expensive, if not impossible, and would require disproportionately large resources[37].

Issues for further reflection at political level

- How might the EU further **encourage and coordinate efforts to gain a clearer overview** of the environmental impact of the military, including accurate information on their carbon footprint?
- What additional initiatives could the EU undertake to **facilitate information-sharing and leverage ongoing discussions** in some Member States and NATO over the adoption of less energy intensive models for their armed forces?
- How could the EU intensify its support for the transition towards environmentally sustainable armed forces, whilst **ensuring that this transformation enhances the EU's strategic autonomy**?
- To what extent could the current **increase in defence budgets be used to advance the transition** towards green armed forces?

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