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Can Europe green its militaries?

How alternative fuels could lower military emissions while meeting performance requirements

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The 2022 invasion of Ukraine shocked Europe out of its security slumber. Suddenly, European Union member states became painfully aware of Europe's security risks and dependencies. As the United States security guarantees seem frail, the EU now seeks to reduce these strategic dependencies and secure supply chains in defence. Now, more than two years into this *war of warehouses*, military stockpiles have shrunk and defence spending continues to surge across the bloc, generating large orders for Europe's defence industry. Although these investments support the EU's goal of strategic autonomy, they conflict with other essential goals, such as reducing greenhouse gas emissions in an effort to combat climate change. In many cases, climate change itself poses additional security risks for the EU and its member states, for example, threats to military infrastructure or worsening conflicts.

This Alert assesses how emerging technologies could potentially reduce European defence emissions linked to this remilitarization while taking into account the need for operational effectiveness of defence operations. It focuses on sustainable aviation fuels and hydrogen, two alternatives for propulsion by fossil fuel combustion engines which are increasingly put to commercial use. This Alert identifies the (dis)advantages of their implementation for military use in order to encapsulate and critically assess conflicting perspectives around their use. It also identifies potential policy avenues for integrating these energies into wider EU plans for decarbonisation and defence reform.

The decarbonisation of Europe's armed forces

Currently, we are witnessing the largest investments in European defence since the Cold War. Such spending may conflict with the Union's climate ambitions, as formulated in the 2019 Green New Deal and the 2021 European Climate Law, which legally enshrines climate neutrality by 2050. Although armed forces contribute greatly to governments' emissions, the defence sector remains largely unbound by emissions targets or reporting requirements in international agreements. This is problematic considering Europe's goals to reduce its imports of fossil fuels and the costs that come along with buying and supplying them for military operations.

As part of its Strategic Compass for Security and Defence and proposed European Defence Industrial Strategy, the EU strives to invest in new innovative technologies through programmes such as the European Defence Fund (EDF). The combined upsurge in available funding and demand for defence production provides an opportunity to prioritise green technologies that are also suitable for the operational needs of modern militaries.

Modern warfare is increasingly defined by emerging technologies. Past technologies have often found their way to civilian use after having been developed for military purposes. When it comes to sustainable innovation, we may see these roles reversed. Indeed, the EU has already stated it wants to make better use of civilian advancements for its security purposes. Due to emissions targets, carbon offsets, consumer demand, and incentives such as the Net-Zero Industry Act and the Corporate Sustainability Reporting Directive (CSRD), Europe's commercial actors are increasingly innovating to limit their own emissions. Consequently, the market for sustainable innovation is flourishing, delivering promising technologies with dual-use applications.

This issue is especially prominent when considering the mobile and operational emissions of equipment such as aircraft, naval vessels and land vehicles. For European militaries these fuels are currently bought largely abroad and sometimes even indirectly from Russia. Aviation is of particular concern as it needs huge amounts of kerosene and often accounts for the bulk of a military's emissions. In the case of the French military, kerosene represents more than half of its energy demand. Aviation thus represents a major hurdle in achieving net-zero, for which electrification is currently not a solution. As such, alternative and more efficient fuels must be developed to achieve significant reductions. In addressing these needs, sustainable aviation fuels (SAF) and hydrogen are promising technologies.

Sustainable aviation fuels

An alternative to fossil fuels is the use of SAF derived from biomass. These fuels can be produced from a variety of converted feedstocks such as soy, wood, grass, oils and corn – some more efficient and cheaper than others. Currently the largest sources of feedstocks come from agricultural residue, followed by municipal and industrial waste. These fuels also have the potential to limit the share of energy that needs to be purchased from petrostates, thereby reducing undesirable energy dependencies.

For commercial flights, SAF technologies are receiving increasing attention. The EU aims to have SAF make up 63% of all aviation fuels by 2050. Since 2011, more than 450,000 commercial SAF flights have been completed. However, if the EU is to meet its ambitious SAF targets, some issues remain regarding scalability, namely the extensive pretreatments needed to make biofuels based on waste products commercially viable.

With most military planes still running on fossil fuels, Europe's air forces have yet to fully embrace SAF. However, some efforts are underway. SAF technologies are being developed by leading defence manufacturers, and successful tests have been conducted on both jets and helicopters, providing room for optimism in these decarbonisation endeavours. For instance, in November 2022 the British Royal Air Force completed test flights with the RAF Voyager, a military transport plane, using 100% SAF. Moreover, the engine of the Lockheed-Martin F-35 fighter jet has already run on 100% SAF.

In addition to its large potential for emissions reduction, an important advantage of SAF is that it allows for the completion of existing military materiel life cycles. SAF works with existing aircraft engines and does not require their replacement for a more sustainable alternative. Life-cycle considerations are crucial as the development of sustainable tech gains momentum. Long-lasting defence production timelines tend to prioritise cost-effective and long-lasting equipment. If these life cycles are respected, it takes years before new (sustainable) technologies are operationalised. Constantly replacing in-stock materiel with more sustainable versions comes with its own emissions costs and logistical challenges. It would increase demand for defence production and subsequently risk pressuring industries beyond their productive capacities.

Proponents of SAF will benefit from the introduction of the REFuelEU Aviation Initiative as it seeks to ensure a steady supply of SAF to civilian aviation operators. In addition, companies interested in the military applications of SAF could engage further with transatlantic initiatives such as DIANA and the NATO Innovation Fund, whose goal is to assist in the application of civilian technologies for military purposes by supporting start-ups and other private ventures. This would be relevant in assessing ways to integrate SAF production in a manner relevant for military operations, although the separate nature of these funds risks the replication of efforts due to institutional siloing. They could also consider supporting the introduction of modular designs, which allow for the modernisation of in-use materiel in accordance with new technologies rather than replacing the entire product.

Although SAF will inevitably play a key role in the decarbonisation of aviation, significant costs and barriers remain. The fuels are currently not commercially viable in comparison to traditional fossil fuels, with sustainable aviation fuels costing between 1.5 and 6 times more. However, continued investment in fossil-fuel reliant technologies comes with a price. By integrating the costs of offsetting fossil fuel emissions into price calculations, SAF could become competitive. This notion is relevant beyond SAF and holds for price calculations for a wide array of green tech alternatives.

The growth of the still small SAF market should help to offset many of these costs and we may eventually expect prices to drop due to subsidies and economies of scale. Integration of SAF produced in the EU also has the potential to promote strategic autonomy by reducing the vulnerability of the Union to energy crises and fluctuations in supply chains.

If SAF is to be approached as viable and truly sustainable, its land use remains an important consideration. Some of the feedstocks from which these biofuels are produced originate in agricultural produce. In order to produce the amount of biomass required for certain SAF, significant tracts of land area will have to be dedicated to the task. This raises concerns of increased deforestation and biodiversity loss, as natural areas may be cleared to keep up with demand. As a consequence, SAF risks becoming a GHG net emitter in the long run. Though next generation biofuels are less dependent on large inputs of feedstocks and food oils, they still require expensive pretreatments which acts as a barrier to their wider adoption. An overview of the potential opportunities and obstacles to SAF integration can been seen in Figure 1.

Figure 1 Opportunities for SAF to contribute to the green transition of armed forces in Europe and existing obstacles inhibiting this potential

Opportunities of SAF	Obstacles to SAF
• Ability to gradually integrate SAF through mixing with traditional fossil fuels	• Currently not commercially viable for militaries and aviation companies
• Production is being upscaled and significant investments are already available	• Land-use changes associated with sourcing biomass for first generation biofuels may degrade ecosystems
• Limits strategic energy dependencies for the EU	• Scalability issues for second generation biofuels based on waste products due to extensive pre-treatments
• Integrates well with existing procurement policies and timeframes of armed forces	

Hydrogen

Hydrogen is also receiving enormous attention from both the aviation and automobile industry, as it does not emit CO$_2$ in its propulsion. Hydrogen fuel cells could power both tracked and wheeled ground vehicles, ships and, in some cases, aircraft, all of which represent key components of military operations. However, not all hydrogen is created equally. While hydrogen propulsion is completely clean, with only water as a byproduct, its creation varies in its emission intensity. If hydrogen is produced with renewable energy sources it is labelled as green hydrogen (carbon neutral). Other production pathways are far less sustainable and are given different labels. Currently only a small share of total hydrogen production is labelled as green. The vast majority is still produced using natural gas and coal, resulting in significant emissions. For future hydrogen production, solar energy is considered a viable source in addition to off-shore wind energy and hydropower, although some technological advances and investment policies are still necessary.

Nonetheless, hydrogen technologies are potent and could, under the right circumstances, reduce defence emissions. However, to be considered for military use they will have to serve militaries' core objectives. In short, this means that the adaptation of hydrogen cannot compromise on operational effectiveness. Thus, for serious consideration, hydrogen must compete with the performance guarantees provided by fossil fuels.

Hydrogen does hold incredible potential as a military alternative to fossil fuels. A first convincing argument is the possibility of on-site production during military operations. Localised production could help reduce the significant resources and risks to personnel currently required for supplying armed forces. The technology may thus change the way we consider military logistics. Second, hydrogen-powered cars outrange both battery electric motors and internal combustion engines. And, as energy is still generated inside the vehicle, refills are also faster than battery electric vehicles. Other advantages are that hydrogen engines are quiet and low in temperature, making them more suitable for stealth operations. Some military artillery vehicles, such as the Howitzer, are difficult to hide from today's heat seeking drones due to their warm engines.

Though promising, the technology has several requirements which could limit its tactical suitability. Notably, it must be kept on board under high pressure and is, in that state, extremely flammable and explosive. In their development of a hydrogen military vehicle, the American General Motors included a bullet-proof storage tank. Whether that is sufficient to address these critical shortcomings remains to be seen. Maintaining the required low temperatures for hydrogen propulsion may also be challenging considering the hot climates of many recent Western military operations. Insulation helps to keep tanks cool but makes hydrogen systems heavier and bulkier, suggesting that further development may be necessary before these innovative technologies are deemed both reliable and functional. Additionally, hydrogen faces severe challenges related to the current cost of transportation in liquified form, and the large amount of space required to store it in tanks that often leak even when well-constructed.

Combining net-zero aspirations with hard security realities

Hard security is a necessity which often validates postponement of other political priorities. As Europe's defence industry struggles to keep up with demand, including emission considerations into the *zeitenwende* may seem unconvincing. However, an assessment of sustainable aviation fuels and hydrogen demonstrates that emission reductions and military operational effectiveness are not always mutually exclusive. Moreover, sustainable technologies may even solve some of the tactical challenges of modern warfare.

Hence, greater awareness is needed regarding the potential benefits of integrating sustainable technologies into defence production. With the EU investing in defence at unprecedented scale, now is the time to consider how to avoid greenhouse gas emissions and fossil fuel dependencies that might be locked in for decades to come. SAF and hydrogen are interesting alternatives and deserve consideration in military R&D, procurement standards, etc. Policy makers engaged in European defence could help effect change by drawing on the lessons learned from the wide array of energy policies already being implemented. In doing so they could help to mitigate the climate risks linked to greater carbon emissions, spur on new innovation, and lower fossil-fuel dependence and costs, particularly when alternative fuels are made in Europe.

About the Planetary Security Initiative
The Planetary Security Initiative sets out best practice, strategic entry points and new approaches to reducing climate-related risks to conflict and stability, thus promoting sustainable peace in a changing climate. The PSI is operated by the Clingendael Institute in partnership with Free Press Unlimited and The Hague Center for Strategic Studies.

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