Green Defence: the defence and military implications of climate change for Europe

Ben Barry, with contributions from Shiloh Fetzek and Lieutenant Colonel Caroline Emmett

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Introduction

Climate change is an accelerator and multiplier of disasters, instability and conflict, requiring European forces to adapt to operations in a changing climate. The increasing risks from climate change mean that it is shifting from being solely a human security threat to a national security threat, both to Europe and to its strategic interests. But it also raises the question of how armed forces and defence organisations can help to mitigate climate change by reducing their greenhouse-gas (GHG) emissions and contribute to national and international decarbonisation targets.[2]

GHG emissions from Europe over the last 300 years have made a major contribution to climate change so there is an ethical imperative for Europe to assist other countries in countering the impacts of increasingly frequent extreme weather events and to reduce European emissions. Moreover, European militaries are themselves directly threatened by the proliferation of extreme weather events, both within Europe and around the globe.

This paper aims to examine the implications of climate change for European defence and armed forces. The paper distinguishes between: climate change adaptation – the adjustment in natural or human systems in anticipation of or response to a changing environment in a way that makes effective use of positive opportunities or reduces negative efforts; and climate change mitigation – measures to reduce the amount and speed of future climate change by reducing emissions of heat-trapping gases or removing carbon dioxide (CO_2) from the atmosphere.[3]

Bundeswehr soldiers assist with disaster-relief operations, following heavy floods at Altenar, Germany July 2021

(Torsten Silz/Contributor via Getty Images)

Implications of Climate Change for European Security and European Armed Forces

Climate change is now an immediate global threat. It is already having an impact on human security across the globe and on political stability in some of the world's most vulnerable regions. Climate security, therefore, is a vital national security interest for all European nations, the EU and NATO.

More frequent extreme weather events are predicted worldwide, and the imminent physical impact of climate change includes increasing numbers of storms, floods, heatwaves, and droughts. Secondary consequences include the degradation of water supplies, reduced agricultural productivity and impacts on energy infrastructure and generation, with all these having negative repercussions on the economy and employment. Such changes would result in forced migration and displacement, which pose additional challenges to already stressed governance systems. These can, in turn, increase popular grievances, weaken the social compact and contribute to political instability.

These dynamics can, under some circumstances, increase the risk of armed conflict. For example, intensified resource competition and increased friction between social groups may well lead to violent conflict both within states and potentially between them. The wider impacts of climate change can also make peace much harder to sustain, particularly in countries with a narrow natural-resource base or where competition over resources influences conflict dynamics. As renewable-energy technology matures, there may be greater inter-state competition over the minerals and commodities required. Whilst still contested amongst climate security academia, inter-state conflict, including major wars, could be triggered by climate change exacerbating existing disputes. Certainly, America's looming decision on solar-energy tariffs that pits its goal of combating climate change against its ambition to wrestle high-tech manufacturing supply chains from China illustrates the likely political-economic dilemmas states currently face.[4] Meanwhile, other potential conflagrations, such as war between the US and China over Taiwan, could so greatly damage international governance as to set back international efforts on climate change.

Climate change is likely to promote insecurity in regions important to the security of Europe, including many parts of Africa, Central Asia, the Middle East and the Indo-Pacific, increasing the potential for intra- and inter-state conflict.[5] Mass migration has already become an inter-state flashpoint. Extreme climate change could produce greatly increased migration 'spikes', due, for instance, to the island nations in the Indo-Pacific becoming uninhabitable. Conflict over scarce water supplies may become more likely. Indeed, cross-border water management is another potential flashpoint, particularly where tensions are already high, such as along the Euphrates, Indus, Mekong, Nile and Tigris rivers.

The Arctic typifies the way climate factors can interact to produce political and economic tensions. Diminishing Arctic Sea ice, whilst raising global sea levels and disrupting regional weather patterns, provides opportunities for an ice-free Northern Sea Route to allow faster and cheaper shipping between China and Europe, as well as increasing access to oil, gas and minerals in the High North. But increasing temperatures will see fish migrating north, exacerbating friction over fishing rights. These factors will probably lead to an increased military presence in the region by China and other non-Arctic states, with greater inter-state competition in the High North, and the attendant risk of miscalculation and escalation, an important consideration for the European Arctic states.

While climate activists currently adhere to non-violence, it is conceivable that climate activism could become violent, resulting in sabotage and attacks on targets that extremists see as 'climate enemies'. Such threats could occur both outside and within Europe, with violent climate activists assuming mandates at national, regional, and international scope. As the adverse effects of climate change multiply, there is an increasing probability of such actions. European citizens and businesses, including airlines, energy, An RAF A400M *Atlas* transport aircraft delivers emergency humanitarian aid to Caribbean islands stricken by Hurricane Irma in September 2017

(Sqn Ldr Andy Wasley/Crown/MoD)

aerospace and shipping companies, and even armed forces, could become potential targets. At the same time, countries with economies that depend on exporting hydrocarbons will be vulnerable to the consequences of global decarbonisation.

Damage to the environment, or irresponsible emissions, could become a justification for some form of military intervention in the future, although the response is more likely to be through sanctions than direct use of military force. Even so, increasingly extreme climate events could change public and political attitudes to this in the future. Even if the 2015 Paris Agreement and declarations made at the 2021 COP26 conference in Glasgow were fully implemented tomorrow, given the level of warming that has already occurred to the Earth's system, risks from climate change would continue to rise. The scope, scale and intensity of climate effects are projected to increase as climate change accelerates, increasing considerably after 2040, as assessed by the July 2021 Intergovernmental Panel on Climate Change report.[6] Recent extreme weather in North America has pointed in this direction. For example, between 1990 and 2010, Canadian forces conducted six domestic Humanitarian Assistance and Disaster Relief operations; between 2010 and 2019, it conducted 20 such operations. In 2021 alone there were four HADR operations combatting heatwaves, forest fires and floods in the province of British Colombia.[7] Public perception of an acceleration in climate change may influence national attitudes to armed forces, both as a last-resort national emergency service, but also as major emitters of GHGs. Defence policymakers and armed forces should be alert to the possibility of a 'tipping point' event rapidly creating a widespread sense that climate change has become a clear and present danger.

Since climate change functions as a conflict accelerant which exacerbates existing international security challenges, there is likely to be an increased demand for overseas military presence and activity by European forces. Indeed, European forces are already operating in countries and regions where climate change is aggravating insecurity, such as the Sahel. Furthermore, increased climate instability would increase the demand

Damage from Hurricane Michael at Tyndall Air Force Base, US

(Brendan Smialowski/AFP via Getty Images)

for European forces to conduct humanitarian assistance and disaster-relief operations, both at home and abroad, and thus might lead to calls to increase the emphasis on HADR in armed forces' missions.

As such, there is a greater probability of European operations across the spectrum of operations – HADR, peacekeeping, stabilisation and war fighting. There could also be an expansion in military efforts to counter poaching, illegal fishing and piracy. More migration and human trafficking will also increase the probability of the military having to support the border security of European states. Climate change is likely to exacerbate existing international disputes and increase the risk of flashpoints sparking inter-state conflict – including a great-power conflict. Defence forces would need to retain combat capabilities and ethos to deal with any such challenges in the future. However, increasingly extreme weather in Europe might result in governments shifting funds from war-fighting capabilities to other components of national climate resilience. It is plausible that most European citizens would regard domestic HADR as a non-negotiable military task, with the overall effect being a possible reduction of armed forces' combat readiness.

A larger proportion of military operations are likely to be in environments made increasingly fragile by climate change, including where fighting itself results in environmental degradation. Environmental damage by European forces, including damage to livelihoods, could inspire the same public opprobrium as civilian casualties and collateral damage. At the same time, armed forces and defence establishments will also need to better understand environmental changes that impact on military operations. For example, the changing salinity of seawater will influence submarine and anti-submarine operations. Changes in weather will affect air operations, the launching of satellites and radio communications. Rising temperatures will impact upon the effectiveness of military personnel and equipment, increasing requirements for cooling systems. An 'inconvenient truth' is that, with current equipment, these factors are likely to increase military carbon emissions. Environmental protection should therefore be a factor in operational planning. It will be increasingly

Dry winds whipped up California's record-breaking wildfires, 2020

(Dimitar Dilkoff/AFP via Getty Images)

important that deployed European forces should not exacerbate environmental problems and operational direction and rules of engagement should reflect this priority. Deployed forces will need to better understand how climate change is impacting their areas of operation and the local populations.

Many military installations will be threatened by climate change. Rising sea levels and storm surges will threaten ports and bases situated in low-lying coastal areas. Increasing aridity makes fires on ranges and training areas more likely and all installations are threatened by extreme weather events. In the US, recent storms have caused billions of dollars' worth of damage. For example, Tyndall Air Force Base was badly damaged by a hurricane in 2018. The US Air Force estimated the cost at US$4.7 billion and the damage significantly reduced the readiness of the F22 *Raptor* fighter, reducing the readiness of the whole aircraft fleet.

Climate change will change geopolitical landscapes and operational environments. To better conduct capability, operational and logistics planning, there is a need for greater understanding of climate risks in regions of interest to Europe. 'Climate risk horizon-scanning' is required to analyse climate-security challenges using a wide range of scenarios that might trigger intervention by European forces.

Climate Mandates for European Defence

Over the last three centuries Europe has produced a significant proportion of historic global emissions so there is a moral imperative for European nations to assist other countries with their adaptation to climate change and to mitigate its effects by reducing national emissions – including those by defence and armed forces.

Currently, reporting military carbon emissions is voluntary rather than compulsory in many nations. But this position may become increasingly difficult to sustain, particularly in light of a continued rise in extreme weather events. Indeed, while many international commitments to reduce greenhouse-gas (GHG) emissions may not be strictly legally enforceable, they still carry considerable moral weight.

The EU's European Climate Law sets a legally binding target of net-zero GHG emissions by 2050.[8] It includes the target of reducing net-GHG emissions by at least 55% by 2030, compared with levels in 1990. This requires member states to have plans to reduce national net-carbon emissions, including those made by defence ministries, defence industries and armed forces. Decarbonising armed forces without disarming them will be a considerable challenge. The EU has produced a Climate and Defence Roadmap that seeks to enhance climate resilience for current and future EU missions, and proposes measures to address the links between climate change and defence. This includes the European Defence Agency (EDA) Energy and Environment Programme, which has developed from the EDA's previous Military Green initiative.

At its 14 June 2021 Summit, NATO's leaders tasked the alliance 'to become the leading international organisation when it comes to understanding and adapting to the impact of climate change on security'.[9] Allies agreed to significantly reduce GHG emissions from military activities and installations without impairing personnel safety, operational effectiveness and their deterrence and defence posture. The NATO secretary-general was invited to formulate a realistic, ambitious and concrete target for the reduction of GHG emissions by the NATO political and military structures, as well as initiating a regular high-level climate and security dialogue to exchange views and coordinate further action.

Some NATO nations appear to be sceptical that NATO should devote so much energy and bandwidth to climate change. They see it as a distraction from NATO's core mission of territorial defence. NATO will need to resolve these contrasting perspectives through internal debate. It will be important to manage expectations; NATO will not solve climate change, but it can both adapt as an alliance and assist the adaptation of its members and partners. It also needs to understand that, whether or not climate change is treated as a free-standing issue, it will have an impact across the spectrum of NATO capabilities and activities.

Through its standardisation programme NATO promotes inter-operability between the forces of allies and partners. Particularly important is logistical standardisation, which makes it easier for national forces' to safely use other nations' ammunition and fuel. As new fuels and power sources are developed, it will be essential for NATO to assist with standardisation so that NATO units and formations can operate with each other whilst reducing emissions. Both NATO and the EU are seeking to better coordinate national efforts. There is much scope for international military cooperation in this area.

European and NATO Nations' Plans for Climate Mitigation

European militaries are increasingly responding to the way climate change is reshaping the domain, and their role in driving climate change through emissions. They are often the largest single emitter from government, a fact which is receiving more attention as governments commit to ambitious greenhouse-gas (GHG) mitigation targets. The IISS has conducted open-source research into how defence and security establishments in Europe and North America are approaching climate risk, and how this is reflected in policy and strategic documents. The focus of this analysis is on assessing how substantially climate change is integrated into defence planning, and, more specifically, how advanced the current plans for making the defence energy-transition are.

Defence establishments are increasingly integrating climate change into policy and planning. Militaries are beginning to pay more attention to mitigation, for strategic reasons as well as to contribute to national net-zero emission targets. There are many ways in which reducing emissions and making the energy transition can enhance operational effectiveness and confer strategic advantages.

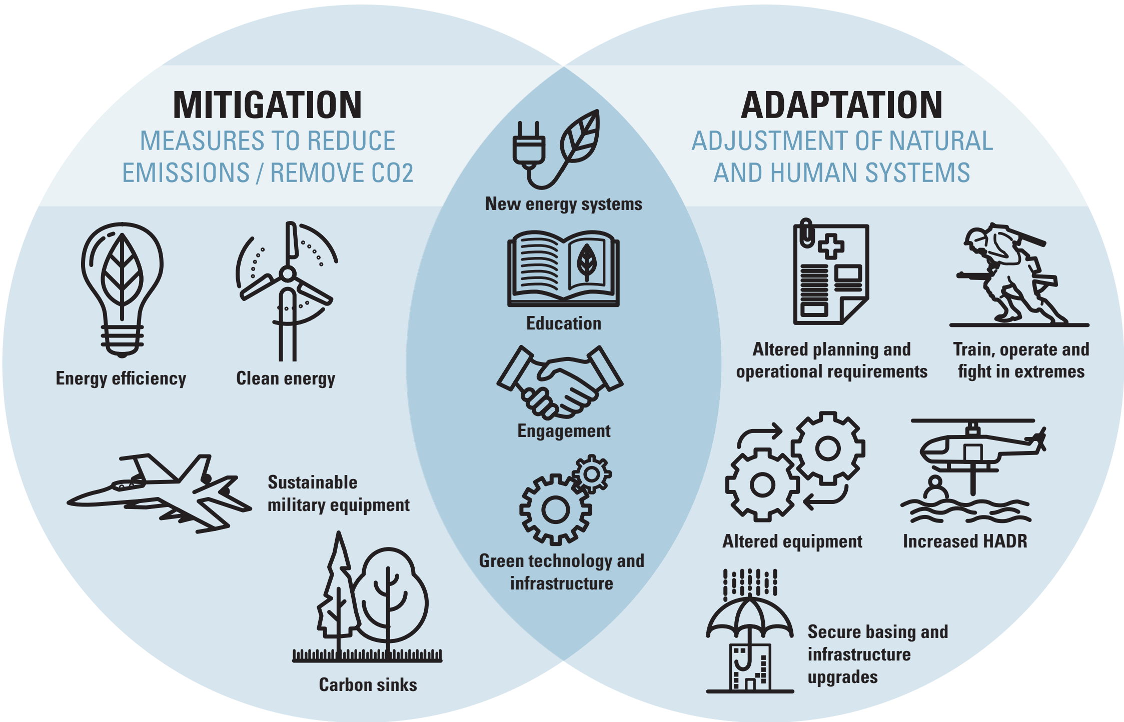
Many countries now acknowledge climate change in their defence strategies. There has been a range of responses to the issue, from comprehensive climate strategies like the UK's, to singular mentions of climate change, to not mentioning climate by name but nevertheless discussing climate-sensitive issues like water or energy security. Whether countries acknowledge climate change per se, or merely note its impacts, it is now commonly addressed in defence strategic planning. The degree of attention paid in defence strategies may also be a function of when they were developed, as awareness of this issue has increased in recent years. This has been reflected in some more recently updated strategies which address climate change more comprehensively.

The analysis presented here also seeks to assess the current momentum for addressing climate change in the defence arena and progress to date, as indicated in open-source information. These questions include how central climate change is as a national-security issue, whether countries have developed specific defence climate change strategies, or undertaken assessments for individual branches/services. It also assesses the degree to which defence establishments are focusing on mitigation compared with adaptation – including, energy transition, adopting lower-carbon technologies and seeking to cut GHG emissions. Further assessments

Table 1: **Areas of opportunity for climate-change adaptation and mitigation in Defence**

Category	Examples
Sustainable mobility	• Alternative fuels – synthetic fuels • Alternative propulsion systems – electric, hybrid, hydrogen • Improving fuel efficiency and reducing emissions
Energy storage	• Portable batteries
Platforms	• Uncrewed systems
Training	• Simulation systems • Training on lower-emissions vehicles
Energy systems at installations	• Installing renewables – photovoltaic (PV), solar thermal, wind power systems • Microgrids, distributed energy generation
Building offsets on the defence estate	• Siting renewables on the estate • Carbon sinks – reforestation, carbon sequestration in soils • Rewilding, ecosystem restoration
Improve emissions data collection	• Standardising measures • Addressing emissions involved in defence supply chains
Other sustainability initiatives	• Circular economy • Promoting awareness and behavioural change

Figure 1: **Implications of climate change: responses**



Source: IISS

of 'greening' defence could look into how this integration is supported, resourced and staffed, and the nature and function of any new institutional infrastructure for addressing climate change within defence.

There are several categories under which defence agencies are taking action on emissions reduction, energy transition and environmental sustainability, across both installation energy – including installations and non-tactical vehicles – and operational energy.

Climate-change mitigation in Defence – strategies and actions

Most European and North American countries recognise and are prioritising the defence energy transition, and are committing to addressing a problem that they acknowledge they contribute to. National plans are at varying stages of development and implementation. Most strategies set achievable interim targets for emissions reductions, while noting that reliable fuels and technologies are not yet implementable for defence at a scale that would allow cuts deep enough to achieve net zero in the near to medium term.

The 'lower-hanging fruit' prioritised across these strategies include increasing energy efficiency on the estate and in the built environment, electrifying the non-tactical vehicle fleet, installing renewable energy systems, and training in simulated environments. A number of countries are also running pilot projects trialling the integration of new technologies, such as hydrogen or synthetic fuels. Fostering a culture of conservation and behavioural change was another common thread across defence climate initiatives.

Notable strategies and actions

A number of countries have well-developed defence mitigation and adaptation strategies.

The UK Ministry of Defence (MoD) has made the most thorough examination to date of how defence can make the energy transition and contribute to national net-zero goals. It has committed to building significant carbon offsets on the defence estate, rather than buying offsets.[10] The UK has a 'Defence Climate Change and Sustainability Strategy', and has appointed a non-executive director for the topic to its Defence Board.[11] The UK MoD has set itself a hard target of achieving net zero by 2050. The RAF has set itself even more ambitious targets, aiming to become carbon-neutral by 2040. The MoD has declared that it will be a 'fast follower' of relevant civilian technology and has an active programme for R&D that includes an experimental electric aircraft, synthetic aviation fuels and fitting electric drives to several in-service army vehicles.

Other European countries are also developing more comprehensive strategies and implementing defence energy, sustainability and GHG mitigation measures.

The Netherlands' 'Defence Energy and Environment Strategy 2019–2022' and 'Defence Energy Transition Plan of Action' set fossil fuel-reduction targets (dependence decreased by 20% by 2030 and 70% by 2050 compared to 2010 levels, camps generating 50% of energy from renewables by 2030 and energy self-sufficient by 2050). The plan details the incorporation of biofuels, exploring the use of hydrogen for long-range drones in maritime surveillance, researching energy-independent camps and increasing energy efficiency in the defence estate.[12]

France's 'Defence Energy Strategy 2020' addresses some aspects of climate risk and the energy transition, and sets out the goal of carbon neutrality for the aviation sector by 2050, relying on biofuels in the medium term. The strategy includes a range of other objectives around reducing fossil-fuel dependence and integrating new fuels and technologies – such as storage, renewables, biofuels and hydrogen. Energy efficiency requirements will be added to armaments programmes. It prioritises the hybridisation of powertrains for vehicles in ground operations, biofuels for aviation and energy optimisation on board in the naval sector.[13] The army is seeking to build a hybrid Griffon (multi-role armoured vehicle) demonstrator by 2025 and pursuing an energy and water self-sufficient external operations (OPEX) camp with the 'Eco Camp 2025' project. Pilot training also includes virtual simulations of energy-efficient operations (with a simulation centre in Mont-de Marsan).[14] Substantial analytical work on the climate-security nexus is also carried out by L'Observatoire géopolitique des enjeux des changements climatiques en termes de sécurité et de défense (Geopolitical observatory of the challenges of climate change in terms of security and defence).[15]

The Spanish MOD's 'Programme to Combat Climate Change' has, since 2012, developed and implemented a 'methodology for the estimation of GHG emissions derived from military activities', which aims to set institutional standards and focuses on providing tools and training for participation in GHG measurement and reduction, and on verification and independent certification of its findings. Although no timeline is set, the programme aims to reduce defence emissions to 'as close as possible to "zero carbon" in line with the government's commitments' through efficiency, transitioning to renewable, alternative and complementary energies, adaptation of fuels, improving carbon sinks and incentivising lower emissions in the supply chain.[16]

Slovenia convenes an 'Energy and Environmental Partnership in Defence' to promote international R&D and technological cooperation in defence programmes with EU and NATO member states.[17] One outcome is its Defence RESilience HUB Network in Europe project, supported by the EDA, which is establishing a network of self-sufficient energy hubs aimed at distributing energy generation and storage for defence (bases and barracks) and civil (disaster relief and other crises) use. The aim is to expand these hubs beyond the barracks of the Slovenian Armed Forces and establish a 'hydrogen motorway' across the EU.[18] The Slovenian MoD is also co-financing projects between industry and research institutes at the Hydrogen Technology Development Centre.[19]

The German MoD addressed energy efficiency in operational infrastructure in its 2017 policy document 'Increasing the Security of Supply by Optimising the Energy and Utility Supply in Static Field Accommodations'.[20] It has also identified synthetic fuels as the best way to achieve sustainable mobility, without having to compromise on operational capabilities or make major adjustments to current propulsion systems.[21] In addition, it is working on the electrification of its non-military vehicle fleet, and sustainable construction and energy consumption at installations.[22]

Similarly, the Austrian MoD is purchasing electric vehicles for non-military purposes, increasing energy self-sufficiency on installations, installing photovoltaic systems, and promoting environmental and energy consciousness among personnel.[23]

Italy's 'Defence Energy Strategy' aims to improve energy efficiency, independence and infrastructure resilience, and foster an 'energy-oriented mentality' across operations, logistics and infrastructure.[24] In addition to developing ‘green basing’ and ‘smart’ military districts, the strategy establishes a basis for planning to identify the most appropriate weapon systems and force structure of the future. The Italian Navy previously had a Flotta Verde ('green fleet') project to develop and trial green diesel biofuels, in partnership with the US Navy.[25] As with many other defence energy or environmental strategies, the Italian programme sets out ways it will contribute to and comply with national, EU and NATO regulations or objectives on decarbonisation, without setting a fixed target or timeline for defence emissions reductions.

Numerous other defence energy and environment strategies work towards similar aims, including those from Denmark, Finland and Greece, which focus on: emissions reductions across buildings, the estate and procurement; more efficient fossil fuel use; and installing renewables, with the aim of reducing other defence emissions when possible.[26,27,28]

Sweden, for instance, has a ‘Fossil-free Armed Forces 2045’ project, aiming to reduce its dependence on fossil fuels and meet national net-zero targets.[29] Among other efforts, it has conducted tests with a 50/50 mix of biofuels in JAS 39 *Gripen* aircraft engines, showing unchanged function and performance.[30]

The Swiss MoD has an emissions reduction target of 40% by the end of 2030 (compared to 2001) for installations, to be achieved through installing renewables, expanding electric charging infrastructure and energy efficient construction and renovation.[31] It is also reducing emissions by altering training programmes. Pilots now start on the PC-21 (instead of the old F-5 *Tiger*) and only later move on to the F/A-18 *Hornet*; this configuration is cheaper and reduces fuel consumption by a factor of nine and overall emissions by a factor of ten.[32]

In North America, Canada’s ‘Defence Energy and Environment Strategy 2020–2023’ sets out sectoral GHG reduction targets (40% cut from defence department infrastructure and commercial light-duty vehicle fleets by 2030, net zero in these sectors by 2050). It focuses on improving the energy efficiency of bases and command wings, clean energy procurement, modernising the vehicle fleet and increasing the energy independence of remote installations such as Canadian Forces Station Alert on Ellesmere Island in the Arctic. It aims to use cleaner fuels for military activities and operations when they are available, affordable and meet both military technical requirements and the NATO standards that enable inter-operability. The strategy also focuses on designing more efficient troop equipment and kits, and providing more efficient power solutions for operations, including for camp infrastructure and utilities.[33]

There is significant momentum in the US Department of Defense (DoD) (as well as in the intelligence community and across the national security apparatus) to address climate change and the energy transition. At the time of writing, the DoD had released its ‘Defence Climate Risk Analysis and Climate Adaptation Plan’, which outlines the problem and part of the solution; its ‘Sustainability Report and Implementation Plan’, which will outline mitigation strategies, is forthcoming.[34]

Many initiatives are underway to increase efficiency at installations; diversify energy generation; electrify the non-tactical vehicle fleet; expand hybrid technologies for tactical vehicles; explore tactical and combat vehicle electrification; investigate the requirements for supporting electric-vehicle fleets and capabilities; and improve supply chain security for energy storage, among other mitigation-delivering activities. These are driven in part by federal regulations on energy efficiency that apply to installation energy, but not operational energy.[35] While not creating mandatory GHG mitigation targets, the United States’ ‘Operational Energy Strategy’ addresses issues around efficiency and improving capabilities.[36]

At the multilateral level, a number of EU policies and structures will drive action on defence energy transition, including the European External Action Service’s ‘Climate Change and Defence Roadmap’, and ‘EU Concept for Environmental Protection and Energy Optimisation for EU-led Military Operations and Missions’.[37,38]

The institutional infrastructure to deliver on these objectives includes the European Defence Agency’s (EDA) Consultation Forum for Sustainable Energy in the Defence and Security Sector (CF SEDSS), which supports individual nations in strengthening their defence energy transition processes, as well as fostering multinational collaborative projects, including around research and innovation. Its main areas of focus are energy efficiency, particularly in the built environment; using renewables in the defence sector; and the protection and resilience of defence-related critical energy infrastructure. The Consultation Forum is a platform for sharing best practice and knowledge within the European Defence Energy Network, which engages 30 European countries and over 150 members.[39]

The Consultation Forum for Sustainable Energy in the Defence and Security Sector's work is linked with the EDA's Energy and Environment Working Group (EnE WG), which looks at resilience and sustainability issues related to climate change as well as other energy and resource security issues. It looks at alternative energies, efficiency and sustainability, with a focus on alternative fuels and drive/propulsion systems; engine and power-distribution system-efficiency technologies; energy storage (electrical, electrochemical, mechanical, structural and thermal); innovative and efficient energy-management systems; renewables including wind and solar (thermal and electric); military applications of other green technologies (waste and water-related); as well as systems integration, sustainable procurement, and knowledge, culture and behaviour.[40] The EnE WG is also a hub for compiling defence-related energy data for participating member states, and is developing standard operating procedures for collecting and monitoring this information, as well as helping it to reach decision-makers.

Establishing a baseline for current energy use and emissions, to set reduction targets against, or use as a basis for prioritising mitigation projects, is recognised as a challenging task in many defence energy and climate strategies. Indeed, the mitigation pillar of NATO's 'Climate Security Action Plan' is focused on strengthening methodologies for this.[41] Increasing Allied awareness of the climate-security nexus; promoting climate adaptation across NATO activities; and outreach to other nations and international organisations working on climate security form the other pillars of the action plan. These efforts are supported by the Energy Security Centre of Excellence, among other NATO structures and processes.[42]

Defence emissions within national net-zero targets

Part of the context for defence energy policies is how mitigation in the sector fits into national emissions reduction targets, whether countries have made net-zero commitments, and whether these commitments have been made legally binding.

Calculating and reporting on military emissions were exempt under the 1997 Kyoto Protocol, and remain voluntary under the 2015 Paris Agreement. This leaves defence mitigation goals somewhat at the discretion of national governments, particularly over whether the defence sector also needs to achieve net-zero emissions. As more countries push to meet their emission-reduction targets, there may be an incentive to omit military emissions from government tallies, particularly as they often constitute a substantial share of government emissions.

However, there are a number of political considerations around defence emissions. The military's use of resources can be controversial, and while government budgets are not infinite, they are more flexible than the hard constraints of CO_2 levels in the atmosphere. Within a finite carbon budget, and with increasingly narrow margins for staying within the limits necessary to prevent runaway climate change, military use of fossil fuels could become even more politicised than its use of other resources at present.

Annex I shows those European and North American countries that have included references to climate change or mitigation in strategic documents (defence strategies, white papers), and whether the defence climate change or energy strategies emphasise mitigation in order to comply with national targets. It also indicates which countries have made net-zero commitments, the legal or policy status of these commitments (e.g., whether national legislatures have made them legally binding), and, for European countries, whether they are subject to the EU's legislation on net zero 2050. It also shows whether the countries have formally committed their armed forces to comply with national net zero or other emissions reduction targets. Overall, whilst many European nations have declared that they will seek to reduce emissions to net zero by 2050, only a minority have legislated to do so. Some have begun work on

Solar farm at UK military base, Lyneham, Wiltshire

(Heritage Images/Contributor via Getty Images)

military decarbonisation, but the majority of European nations are yet to publish a defence strategy for climate adaptation or mitigation, let alone set hard targets.

The EU and NATO could accelerate their work in this area. Once the Pentagon sets in motion its R&D programme and the considerable resources of the US defence industry, the US will likely become a global leader in relevant technologies. From a European point of view there is a danger (less so for the UK) that the European defence industry may fall behind that of the US in this area. There is much scope for international collaboration on this topic, including improving military understanding of climate change, collaborative R&D, simulation and modelling. Both the EDA and NATO can act as forums for sharing good practice and research, while NATO would be the best forum for European nations to engage with Canada and the US. Indeed, Canada has offered to host a NATO Centre of Excellence on Climate and Security.[43] Its purpose is to better understand, adapt to and mitigate the security implications of climate change. This includes facilitating the exchange of expertise among allies, developing capacity to address the security implications of climate change, and supporting efforts to reduce the climate impact of NATO military activities. There are opportunities for further EU–NATO cooperation, such as on NATO standardisation agreements that already enable inter-operability across the alliance and are used by many partner nations. It is important that these continue to evolve alongside developments in fuel and propulsion technology. This would help the alliance play its part in achieving more sustainable defence practices.

Green Technology Opportunities for Defence

Currently, most of Europe's military equipment is optimised for operational advantage, with little consideration paid to sustainability issues such as emissions. Whilst many of Europe's planned equipment acquisitions appear to continue in this mode, the defence industry has begun to explore emerging 'next generation' greener technologies. These technologies could reduce emissions and provide useful options for balancing military effectiveness with improving climate resilience and establish new, imaginative concepts for future warfare.

Reducing emissions presents a range of challenges, opportunities and trade-offs for European defence. For instance, some of Europe's potential military adversaries, including Russia, could choose to retain carbon-heavy conventional capabilities, such as tanks and fighter jets until resources run out. There will be some win–win options in a lighter/zero carbon approach to warfare – including the increased use of uninhabited, robotic and autonomous systems. During this decade, it will be challenging to maintain capability whilst reducing emissions, requiring the defence sector to grapple with some uncomfortable compromises.

The bulk of a military's carbon footprint is from vehicles and platform systems consuming fossil fuels. Land vehicles should be the easiest to convert, with the transition to renewables well underway in the civilian sector (albeit slower progress has been made with heavy vehicles). Maritime, air and space forces face more significant issues due to their inherently larger platforms. Options to significantly reduce emissions include sustainable mobility (the use of alternative fuels, alternative propulsion systems and improving fuel efficiency), uncrewed platforms and synthetic training.

In the short term, the easiest way to contribute to 'greener' European armed forces is by reducing the emissions of military installations. Energy microgrids could offer options for self-sufficiency and even contribute to national energy generation. Key to this will be finding solutions for safe energy storage and in modifying defence supply-chain processes to meet the adaptation and mitigation challenges.

Reducing fuel consumption will also increase the range and endurance of military platforms, thus expanding options for employment and reducing logistic dependency. Whilst there is unlikely to be a single 'silver bullet' technology in the immediate term to eradicate fuel emissions altogether, there is much that can still be done to reduce them. Potential energy-optimisation measures include adjusting flight-planning to reduce aircraft fuel consumption; aids to vehicle drivers, pilots and ship bridge crews to limit fuel waste; and fielding improved engine-management software to improve platform efficiency.

Alternatives to hydrocarbons will also need to meet the standards set by NATO's single fuel policy (SFP). Options include blended and non-blended biofuels and synthetics. In the maritime domain, biofuel options include straight vegetable oil (SVO), biodiesel (1st and 2nd generations), biogas, biohydrogen and lignocellulosic-based bio-oil. These are not new technologies and have been experimented with in both the military and commercial sectors. For example, a Fischer–Tropsch biofuel blend was tested on five US Navy vessels on the Rim of the Pacific Exercise as early as 2012. A commercial initiative in the Port of Rotterdam tested a 100% renewable marine biofuel, completing 2000 running hours on the *Alexander von Humboldt* dredger vessel, resulting in an 80–90% reduction in CO_2 emissions.[44] Nevertheless, large scale use of biofuel remains a challenge for maritime platforms due to the volume of biofuels required, limited knowledge on their handling and application within maritime fuel supply and its high production cost in comparison with fossil fuels in the short to medium term.

Biofuels are already playing an important role in civilian road transport with relatively good performance achieved by so-called 'non-drop-in' solutions, which are fuels that are not completely compatible and which require adaptation or special treatment to the

Table 2: **Alternative fuels: definitions**	
Drop-in Alternative Fuel	**Non-drop-in Alternative Fuel**
An alternative fuel that is completely interchangeable and compatible with a particular conventional (typically petroleum-derived) fuel. A perfect drop-in fuel does not require adaptation of the fuel distribution network or the vehicle or equipment engine fuel systems, and can be used 'as is' in vehicles and engines that currently operate on that particular fuel. Some alternative fuels may become 'drop-in' only after blending with conventional fuel to a certain prescribed proportion.	An alternative fuel that is not completely interchangeable and compatible with a particular conventional (typically petroleum-derived) fuel. A non-drop-in fuel requires adaptation of (or special treatment within) one or more components of the existing fuel distribution network or the current fleet of vehicle and equipment engine fuel systems. Some alternative fuels must be carefully segregated from conventional fuels, while others may be safely blended with conventional fuels. Some alternative fuels may remain 'non-drop-in' even after blending with conventional fuel.

engine fuel systems. However, it is unlikely that biofuels will continue to advance progressively on a global scale, given the disparity of available feedstocks and with development limited to a few countries such as Brazil and the US; although Australia, Canada, China, India and the EU have significant potential. The lack of a 'drop-in' solution without reduced performance, and access to appropriate biomass at scale, make such alternatives less useful in a military context.

The Royal Air Force is already using sustainable aviation fuel (SAF) which is a 50% blend and is developing a 100% SAF for flight in 2022. However, currently, SAF is relatively inaccessible and expensive. In terms of unblended biofuels, high-profile bio-jet-fuel tests on F-18 and *Gripen* fighters have already taken place. Sweden has conducted biofuel testing in the RM-12 engine. The Netherlands also has a pilot project underway to mix kerosene with biofuel for use in F-16 aircraft at Leeuwarden Air Base.[45]

Significant challenges remain in the use of biofuels for European armed forces at scale. Biofuels will need to guarantee environmental sustainability in the production chain, without competing with food production; be cost-competitive; achieve the necessary fuel quality and perform in engines comparably to fossil fuels; and meet NATO's SFP standards. For this reason, biofuels are likely only to be a partial answer.

The use of synthetic fuel is likely to be a better option. France, Germany and the UK all see tangible benefit in the use of synthetic aviation fuel due to the advantage of being able to 'drop in' to current platforms. Possessing similar physical and chemical properties as hydrocarbons, synthetics can be used without sacrificing the performance of proven combustion engines. There is no need to adopt alternative propulsion systems or re-design logistic chains. As a result, Germany plans to establish a new research centre for fossil-free fuels in Cottbus. The RAF's successful experimentation flight of an Ikarus C42 microlight in 2021 was the first to use 100% synthetic aviation fuel. Rolls Royce's EJ200 combat engine, which powers the Eurofighter *Typhoon*, and the MT30 gas turbine, in service with the US, UK and other militaries' naval ships, are already compatible with synthetic fuels.[46]

There are also several emerging propulsion and drive options to achieve reduced emissions. These include hybrid-electric, electric (battery), hydrogen (including air-independent propulsion), nuclear and renewable (solar, wind) solutions.

Maritime

There are already options for low-carbon ship propulsion. Hybrid-electric drive (HED) technology is in use in several of the US Navy's amphibious flat top ships. France's multi-mission frigate anti-submarine warfare version also uses an HED which has allowed it to optimise fuel consumption and reduce exhaust emissions.

Air-independent propulsion (AIP) is emission-free. Featuring hydrogen fuel-cells, it is in development mainly for sub-surface vehicles using a combination of an AIP hydrogen fuel-cell system and batteries. Current examples are South Korea's new KSS-III class submarines and ThyssenKrupp Marine Systems' large unmanned-vehicle demonstrator as part of the Underwater Mothership (MUM) project.

There are currently solar- and wind-powered maritime vehicles which could be operationally effective, particularly in the case of smaller unmanned vehicles. In December 2021, the US announced it had begun operationally testing a sailboat-style drone (wind-powered with solar sensors) which could provide the US Navy with a relatively inexpensive way to expand its sightline.[47] Boeing has developed a similar unmanned asset, which harvests its energy from wave and solar power, for intelligence, surveillance and reconnaissance (ISR) missions.[48]

Nuclear-powered surface and sub-surface vehicles remain an option for some – particularly for aircraft carriers and larger submarines. Nuclear submarines are operated by France and the UK, and the French aircraft carrier, the *Charles de Gaulle,* is nuclear-powered. During the Cold War, the US and the Soviet Union operated nuclear-powered cruisers and destroyers. Occasionally, the US also deployed entire carrier battle groups powered entirely by atomic energy. However, the nuclear option is limited for most navies; safety issues, high operating costs and investment in infrastructure and disposal options are prohibitive.

Land

In the land domain, electric motors, whether powered by battery or hydrogen fuel cells, have advantages over internal combustion due to their greater simplicity and reliability as well as a favourable power-to-size ratio. Electrification is likely to be critical to the integration of emerging war-fighting capabilities such as high-power communications, high-power jamming, vehicle-centric microgrids and directed-energy weapons.

Given the progress in the civilian sector over the last decade, it is not unrealistic to expect HED and electric technology to work for land applications; it is best suited to lighter vehicles. Hybridisation offers potential for tracked vehicles but seems more applicable to wheeled types; increasing range and functionality, as well as improving torque and therefore traction/off-road ability. In 2020, the UK's MAN SV *Foxhound* and *Jackal* vehicles were HED tested.[49] The US is also designing a HED GMV1.1 version of the Light Tactical All-Terrain vehicle (LTATV) and France is aiming to build an HED *Griffon* multi-role armoured vehicle demonstrator by 2025. There are clearly significant benefits for combat service support-logistic vehicles – including unmanned or autonomous versions – where a hybrid option will reduce operational costs and fossil fuel consumption.

Nevertheless, a full-electric driven land system is more challenging. Currently, batteries are heavy, slow to charge and offer limited range; removable, swappable batteries might solve issues with charging time, while ongoing improvements in lightweight and energy-dense materials will make batteries more competitive in terms of weight. In 2021, the Netherlands announced it was testing an electric truck to assess its operational feasibility. However, full-electric and HED options will both need extremely high-powered charging stations (likely greater than ten megawatts) for sustainability requirements during missions. In more contested environments, the protection of such stations will be a clear operational requirement.

Fuel-cell vehicles powered by hydrogen, by contrast, do not suffer from the same payload challenges as batteries and possess all the advantages of HED vehicles, but with the additional benefits of rapid fuelling and very low fuel consumption at idle. Examples already in development include General Motor's ZH2 hydrogen fuel cell-powered electric pick-up truck.[50] However, hydrogen vehicles are more complex and therefore more costly.

There are real challenges to overcome for armoured vehicles. The current tanks of the US, UK and many other NATO countries weigh 60–70 tonnes and the German MoD has currently assessed that propulsion systems based on batteries or fuel cells alone will not be able to achieve the special requirements of armoured vehicle fleets. Moreover, for heavier and some medium-weight combat support vehicles – such as missile launchers, bridge-layers and recovery vehicles – the cost of conversion is difficult to recoup over the vehicles' lifetime.

Air and Space

Despite the challenges, there have been notable developments in the air and space domains in alternative propulsion. For example, Elroy Air are working on Chaparral hybrid-electric autonomous vertical take-off and landing (VTOL) aircraft for cargo deliveries, and LIFT Aircraft on an optionally piloted amphibious all-electric version called Hexa.[51,52] Battery-powered small uninhabited aerial vehicles (UAVs) are already a reality and in military use globally by state and non-state actors. Due to current weight considerations, a scalable battery-driven aircraft for fast jet, bomber or transport operations is not possible in the near term even if offset against lighter construction materials.

Table 3: **Summary of sustainable mobility options**

Examples	Types	Maritime	Land	Air and Space
Improving Fuel Efficiency	• Improved engine-management software for platform efficiency. • Aids to vehicle drivers, pilots and ship bridge crew in reducing fuel consumption. • Adjust flight, ship and vehicle route planning.			
Fuels	**Biofuels**	**Biofuels:** SVO, biodiesel, biogas, biohydrogen and lignocellulose-based bio-oil testing and experimentation in the commercial and military sectors.	**Biofuels:** Civilian 'non drop-in' solutions being tested/used. Military tests: US TARDEC tests on caterpillar C7 engine successful.	**Biofuels:** SAF – 50% blended and 100% unblended. RAF tests underway and USAF F-18 and *Gripen* fighters; Sweden, RM-12 engine tests; Netherlands, kerosene mix used in F-16.
	Synthetics	**Synthetics:** MT30 gas turbine engine is compatible.		**Synthetics:** RAF test on microlight successful; Eurofighter *Typhoon* engine compatible.
Benefits	**Synthetics are 'drop-in' solutions to current platforms:** • Used on proven combustion-engine technology. • No need to adopt alternative propulsion systems or re-design logistic chains. • Does not sacrifice performance.			
Challenges	**Biofuels:** • Inaccessibility. Limited access to biomass at scale and disparity of feedstocks. • Expensive to produce, and 'non-drop-in' solutions are costly. • Environmental sustainability in production chain and could be in competition with food production. • Fuel quality and performance. Difficulties in meeting NATO SFP.			
Propulsion	**HED** **Electric** **Hydrogen** **Nuclear** **Renewables (solar, wind, thermal)**	**HED:** US Navy's amphibious flat top ships and French FREMM are using. **AIP hydrogen fuel cell power combined with battery:** Mainly sub-surface, e.g., KSS III class submarine; TKMS MUM project. **Nuclear:** Aircraft carriers and submarines. **Wind/Solar:** US sailboat-style drone with solar-powered sensors.	**HED:** Potential for tracks, most applicable for wheeled vehicles. e.g., UK *Foxhound & Jackal*; US GMV1.1 LTATV, French Griffon. **Electric:** Netherlands electric truck. **Hydrogen:** GM's ZH2 truck.	**HED:** Chaparral VTOL UAV. **Electric:** LIFT Hexa UAV. **Hydrogen:** *ScanEagle* 3 UAV; Boeing/Airbus single-aisle jets. **Wind:** Gliders. **Solar:** Space – power-beaming tech.
Benefits	• **HED:** Optimises fuel consumption (reduces operating costs); reduces emissions; greater reliability, range/functionality. On land, improved off-road capability due to improve torque. • **AIP and hydrogen:** Advantages of HED plus rapid refuelling and very low fuel consumption at idle. In air, unmanned aircraft systems are smaller and lower vibration/noise and more endurance. • **Solar/wind and nuclear:** Emissions free. In Space, power-beaming technology could be a game changer. • **Integration:** Electrification required for integration of critical future war fighting capabilities, including directed energy weapons.			
Challenges	• Heavy armoured, combat support vehicles, fast jets, bombers and transporters unable to be driven by all alternative propulsion in near future. • **Electric:** Battery weight; slow to charge; limited range. On land, high-powered charging stations required; protection of charging points. • **Nuclear:** Limited for most armed forces; safety; high operating costs and infrastructure investment; disposal options prohibitive. • **Hydrogen:** More complex and costly. Coolant and storage issues.			

Investment in and development of hydrogen cell propulsion for aircraft is well underway. At the lighter scale, hydrogen-powered UAVs are smaller and have greater endurance than existing battery-propelled options. They offer the benefit of low-noise and low-vibration, of particular importance for ISR missions. Major firms such as Boeing and Airbus are developing hydrogen-powered aircraft for small UAVs such as the *ScanEagle* 3, but also for the next generation of single-aisle jets from the mid-2030s.[53] However, currently, the size and range of aircraft that can be fuelled by hydrogen remains very limited. It is worth mentioning nuclear propulsion, if only to rule it out as a feasible option in aircraft. Whilst a technical possibility, as demonstrated by the US Air Force NB-36H in the 1950s, it is realistically very unlikely due to the excessive cost, safety issues and size.

In parallel with the maritime domain, solar and wind-powered energy options are readily available and offer niche/specific capabilities in certain areas of air power. In the past, gliders have been put to military use in transporting troops and heavy equipment but have had no proven operational utility since 1945. Solar power can be used for small UAVs, and for powering aerostats in forward operating bases. However, harnessing solar power for military effect may be most feasible in the space domain. For example, Chinese advances in space-based solar power, include a concept using power-beaming technology to transmit solar energy to receivers on earth – this would be extremely benign on the biosphere while also holding huge potential for military application.[54]

Energy-harvesting sources capture and store energy from external sources such as solar power, thermal energy, kinetic energy, salinity gradients and wind energy. Currently, this technology only allows for use in small autonomous devices and low-energy electronics or sensor networks. China is leading on developing technologies which use humans themselves as the principal energy source to provide portable and wearable self-powered systems. For example, triboelectricity and piezoelectricity, electromagnetic power, human motion, biochemicals and body temperature all are being developed for use as an energy source. These technologies could be developed for defence applications such as the self-powered generation of devices, communications, sensors and other human-machine technologies. This could reduce human payload significantly.

Military Installations

In the short term, military and defence supply chain installations are low-hanging fruit for energy transition. Changing the power source for facilities such as barracks, airbases, FOBs and headquarters is possible with existing technology and offers certain operational advantages. For example, a distributed array of solar panels might be more difficult to disable than a single, centralised generator or a single electricity grid access point.

Over the last decade, European governments have been considering ways to make their installations more carbon neutral. In 2018, Austria stated that it would strive for higher energy self-sufficiency on military properties by reducing energy consumption, increasing the use of renewables such as installing photovoltaic panels on buildings.[55] In Switzerland, the installation of photovoltaics at Othmarsingen provides enough energy to cover the demands of the army's logistics centre.

Many nations have set tangible goals to create 'net zero' camps. By 2025, France expects to create a sustainable camp on operations, whilst RAF Leeming will be the first net-zero air base in the UK and Rolls Royce's Bristol site will achieve net zero in 2022.[56] All RAF bases are set to be carbon neutral by 2030. Powered by solar, geothermal and hydrogen energies, future bases will include the use of ground-source heat pump technology for runway maintenance and solar-cell installation. Several other countries have similar plans, including Slovenia.

The introduction of microgrid systems that store electricity from renewable sources, as well as deployable hybrid microgrid systems to provide general-purpose power could offer self-sufficiency for defence. This would add resilience, improve efficiency (thus lowering costs in the longer term) and provide more autonomy to European armed forces. For example, Rheinmetall Group's Decentralised Energy System will provide a self-sufficient microgrid which uses solar cells, wind power and plasmolysis to produce hydrogen from waste water; a fuel-cell system which is scalable and adaptable for all applications; and a safety/security system to protect it.

In European countries which own large defence estates, there are also immediate opportunities to generate energy from erecting renewable energy farms – such as solar, wind and wave on sites. The Netherlands established solar fields at the Vliehors and Eindhoven air bases in 2018 and 2019 respectively. Renewables could be a key component of microgrids but also have the potential for income-generation by supplying surplus energy. Training areas could also offset military emissions elsewhere through the development of carbon 'sinks'. The UK, for example, has pledged to plant two million trees on training areas over the next decade.[57]

Challenges

Whilst the current infrastructure of European armed forces offers quick-win opportunities, there are significant infrastructure challenges which will need to be overcome, particularly in energy-storage facilities. In the maritime domain, even without the requirement to reduce emissions, current power systems will soon lack the capacity to withstand the increasing demands placed on them, including through the future integration of directed-energy weapons, advanced electronic-warfare systems, electromagnetic rail guns and radiated-energy systems such as radar. Ships will need to develop better energy-storage systems to support future sensors and weapons, as well as housing renewable energy sources themselves. If hydrogen is part of the solution, coolant systems may also be a key consideration. On land, there will need to be significant investment in storage systems and e-charging points. The Norwegian Armed Forces are already investing in electrical-energy storage (partnered with Energy Nest). The US is doing the same and looking for domestic sources for lithium (used in batteries) to ensure self-sufficiency. The protection of critical energy-storage facilities should be a key planning consideration for European armed forces – this will be particularly important in the cyber domain.

Key to all plans will be the ability to map the carbon emissions of armed forces. This will assist in measuring the effectiveness of decarbonisation options as they are introduced. It will also assist in promoting awareness and in making the behavioural changes required amongst military personnel. Addressing the emissions involved in defence supply chains will also be critical.

China's Military–Civilian Fusion model potentially gives it an R&D advantage in the development of emerging technology, and European models may be more vulnerable. For example, the UK model of being a 'fast follower of industry' may not work for more military-specific R&D with limited commercial use. A more robust partnership, with sufficient capital investment and commercial dual-use exploitation, will be necessary to achieve net zero. It should be of concern that European governments cannot currently track tech start-up businesses which are vulnerable to early investment from potential adversaries. The defence supply chain should also ensure that the primary defence organisations are optimising their business-to-business (B2B) engagement and partnerships, particularly with civilian-tech small- and medium-sized enterprises (SMEs) who are significantly more advanced in the development of net-zero products.

Alongside a decarbonisation agenda for European militaries during the 2020s, there will also be a need to reconceptualise the way armed forces fight. States should consider seeking alternative, less carbon-intensive ways of performing military missions in the future.

Considerations include the possibility that a combination of short-range drones, advanced sensors and distributed precision-guided munitions launchers could accomplish the same mission as a crewed combat aircraft. Many NATO members are investigating the Loyal Wingman concept (wherein UAVs accompany manned aircraft) for jet fighters. The increased use of robotic and autonomous systems would reduce emissions by taking people out of platforms, thereby reducing their size and weight. This could allow for protection to be traded out to provide more expendable systems.

IISS research suggests that there are potential alternatives to heavy armoured fighting vehicles (AFVs) in delivering armoured-warfare and anti-armour capabilities. These could entail the greater use of long-range surveillance systems, precision anti-armour weapons and uninhabited vehicles in a variety of combat and supporting roles. A battlegroup equipped in this way could have a similar effect to an existing heavy armoured battlegroup, although it would need to fight in a different way. How such a force might operate would need to be developed through conceptual work, experimentation and trials.

Meeting the Challenge of Change

With existing technologies, nations will find it difficult to make the necessary wide-ranging transformations of industry, transport and everyday life that are required to achieve net zero by 2050. Such a transformation is not impossible, but it will require a national strategy and plan, including government and industry investment in R&D. It will also require political leadership.

The UK has provided a foretaste of likely problems. In 2021, the British government launched a national strategy to achieve net zero. Whilst there was broad public support for the objective, there were many complaints from the public, media and politicians about the potential transformation of domestic boilers, which appeared to require significant additional costs to be borne by homeowners. This illustrated that any major decarbonisation initiatives will require strong political leadership, and over a sustained period of time. A credible national plan for energy transition that commands widespread support will greatly increase the probability of successful defence decarbonisation.

The defence sector needs to think hard about these challenging issues, identify the resilience and sustainability efforts it should be taking to adapt to a changing climate, and how these should be balanced with sustaining defence operations and capabilities. The full spectrum of defence activities, including travel and training, will need to adapt to reduce unnecessary emissions. Increasing the proportion of training in simulated environments would go some way towards this.

Barracks, docks, airfields and training areas offer considerable opportunities to reduce emissions, generate renewable energy and sequester carbon. This could help offset the emissions from elsewhere in the defence system, particularly in those areas where emissions are more difficult to reduce, such as from maritime and aviation fuels.

The Pipistrel Velis Electro electric aircraft being tested by the Royal Danish Air Force as a potential pilot-training aircraft, November 2021

(Henning Bagger/Contributor via Getty Images)

Such measures would have the operational advantage of making bases more energy independent, thus increasing resilience against external power-supply interruptions. This threat is not only more likely as a result of increasingly unstable European weather, but is also a potential outcome of cross-border cyber attacks, such as the Russian attack on Ukraine's electricity grid in December 2015. There might also be the added benefit of generating additional revenue by exporting power back to the national grid. A key factor would be the extent to which external energy providers reduce their own emissions and costs and increase sustainability and climate resilience. There could be opportunities for imaginative new partnerships between the defence estate, industry, and local communities.

The most difficult issue for European militaries will be whether operational capability should be reduced to meet emissions targets, or whether priority should be given to protecting capabilities at the expense of emissions reductions. Although there will be some win–win options, it will in general be challengingto maintain capability while reducing emissions – requiring the defence sector to grapple with uncomfortable trade-offs.

Climate adaptation would benefit from imaginative future concepts, to set benchmarks for the necessary changes. Emerging 'next-generation' capabilities could reduce emissions and might provide useful options for better balancing military effectiveness, operational capability and climate resilience. Identifying the best options would require an active programme of concept development, research and development, war games, experimentation and field trials.

Pursuing increased sustainability may not be antithetical to effectiveness. For example, increasing the use of renewable energy sources may reduce long-term operating costs as well as enabling deployed UK forces to be more self-sustaining – with a reduced demand for logistics support and the force protection needed to secure supply lines. Increased sustainability may also enhance Europe's freedom of action, for example by reducing reliance on suppliers from outside Europe.

There are almost three decades before 2050, when most net-zero targets are to be achieved. This ought to be sufficient time to take advantage of new propulsion technologies, such as using hydrogen. It might be possible to set intermediate goals, such as phasing out diesel engines from 2035. Some civilian technologies will be relevant, but many new green technologies are insufficiently mature for military use. Where there is insufficient relevant civilian research, defence R&D will be required to plug the gap.

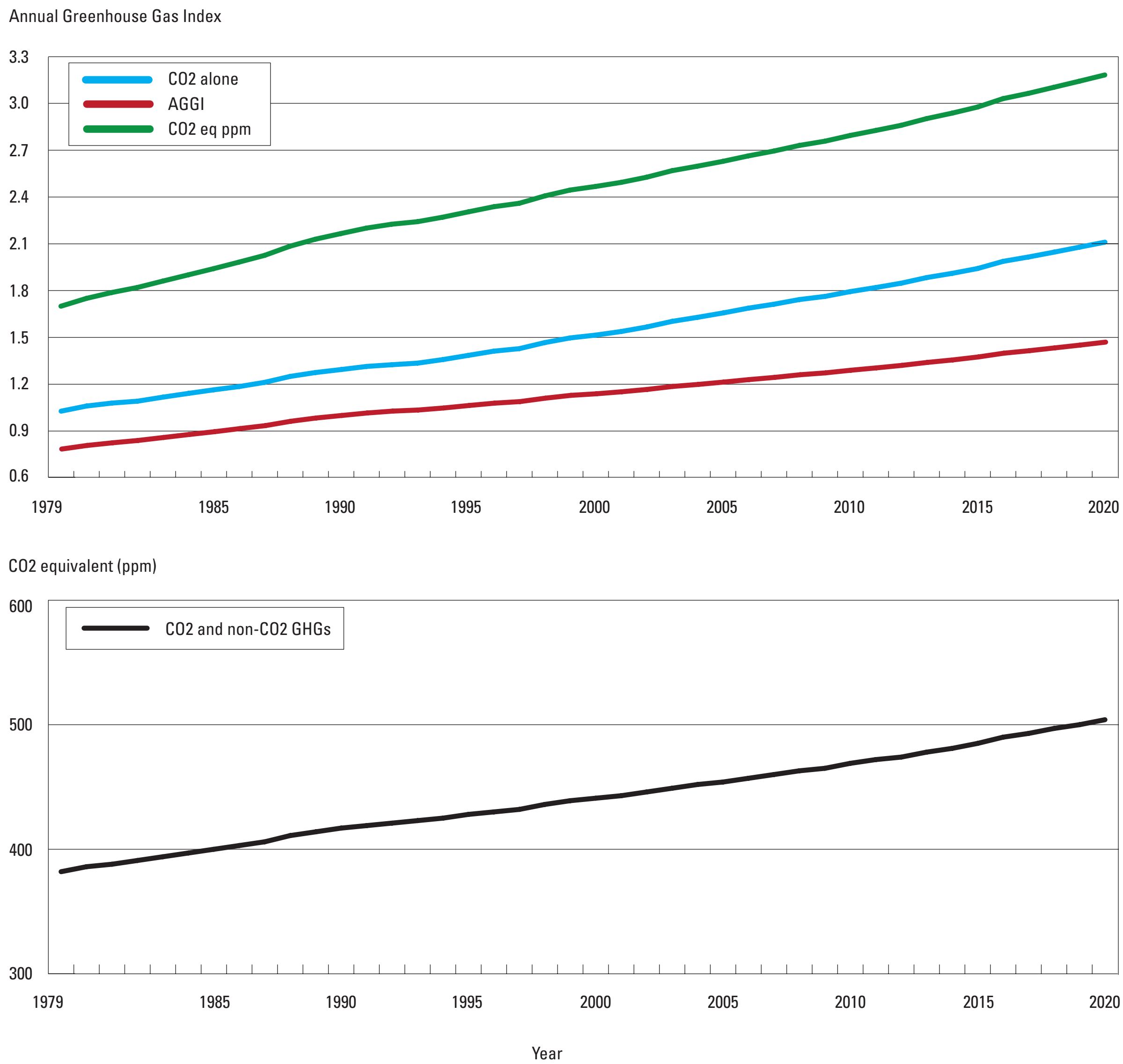
The defence sector needs to retain flexibility, avoiding irreversible procurement decisions that lock in investments in polluting equipment and close off opportunities to improve sustainability in future. This calls for approaches that would allow equipment to be adapted and improved mid-life, such as through spiral development, open-system architectures and modularity. However, there may continue to be capability programmes where deferring investment decisions or building in excessive flexibility would be too costly, meaning an upfront decision would still need to be made.

European defence organisations will need to consider the cost of trade-offs between flexibility and adaptability. Some technologies could both enhance sustainability and improve capability, such as by optimising fuel efficiency. Often though, a balance will be required to make best use of limited resources for those recapitalisation programmes which offer the best value for money for climate adaptation. The sector will need to develop a portfolio of targeted investments in sustainable technologies of the future, while mid-life updates of fighting equipment would provide opportunities to insert greener technology.

The defence industry should be challenged to play a role in tackling climate change. The industry should not expect quick fixes but should encourage both large companies and SMEs to experiment. The defence sector should be challenged to improve the sustainability of supply chains, including by encouraging industry to reduce greenhouse-gas (GHG) emissions throughout manufacturing cycles and transportation. Procurement policy could be leveraged to incentivise the overall reduction of emissions and greater adoption of renewable energy.

There is considerable potential for 'dual use' civil–military technologies. But defence departments would have to accept that some equipment, such as heavy armoured vehicles, would for the foreseeable future be difficult to decarbonise. Retention of such

Figure 2: **Global rise in carbon dioxide and average surface temperature**



Source: Global Monitoring Laboratory

carbon-intensive capabilities could be balanced out by within the defence sector itself by generating the necessary carbon offsets elsewhere.

It is likely that the size of the military's carbon footprint will become a point of controversy in public debate across the political spectrum. Both the public and many people in the defence sector will want to improve sustainability but will be averse to reductions in military capability. They will not want decarbonisation to result in disarmament The necessary changes could well be difficult, drawn out and painful for some groups. It should also be recognised that adversarial influence operations seeking to promote a disarmament narrative within western societies may increase.

A cultural change will be required within the defence sector. It will be essential that new approaches are seen to benefit those working at the tactical level. Best practices drawn from successful programmes for major change would be relevant. For example, there would need to be a clear baseline showing the current state of environmental sustainability across national defence, both positive and negative, including audits of GHG emissions and current climate resilience. This should be transparent. Gaps in relevant defence knowledge and understanding should be mapped, and action taken to fill them.

This raises the importance of internal and external messaging. Both the public and those working in defence

British Army vehicles fitted with hybrid electric drives for a 2020 trial. From left to right: *Jackal* scout vehicle, MAN support vehicle and *Foxhound* armoured personnel carrier

(Sergeant Ben Beale, RLC/Crown/MoD)

must see climate change as a threat and understand why the sector is such an important climate actor, both in terms of its own emissions and in addressing the serious threats posed by climate change to peace and security.

Senior defence leaders should set clear, ambitious goals for change, prioritising where and how to reduce emissions. There would need to be a coherent strategy and road map for implementation. Meanwhile, such top-down direction needs to be integrated with identifying, encouraging and funding bottom-up initiatives. Pursuing a bold strategic vision, while also identifying technological opportunities and small efficiencies that could be achieved, would allow the defence sector to focus on cumulative marginal gains to deliver a big overall impact through incremental improvements in process and performance.

There will be both financial and opportunity costs in this process, and these should not be denied. Value for money must be a key factor in green decision-making.

The defence industry will not be able to bring about all the required changes on its own. It will depend on the actions of many other government departments. Indeed, if European nations are to become net zero by 2050 a whole-of-government approach will be vital. There will be ample opportunities to learn from other areas of government and the private and public sectors. All these factors point to the need for defence departments to collaborate widely across government to promote the shared interest of reducing emissions.

Achieving net zero will require a profound global shift in economics and technology. While it is of course difficult to anticipate disruptive 'Black Swan' events, there is a case for identifying and exploiting 'Green Swan' opportunities and initiatives to catalyse the energy transition and produce an exponential positive effect.[58] Reaching net zero is something that should contribute to economic and social regeneration, particularly in the aftermath of the coronavirus pandemic. As part of this regeneration, funding is less important than a shift in attitudes in government and defence. Many businesses are emphasising the importance of climate adaptation by designating 'Chief Climate Officers' at board level, and there is a strong case for defence companies to do so as well.

There is a risk that if senior defence leaders see climate change as a secondary priority, the issue will never attract the necessary attention, funding and integration, resulting in missed opportunities for synergies. There is a case for the defence sector to declare climate change to be the primary threat to domestic and international security and to the operational effectiveness of the services. The armed forces must reflect on whether they want to be seen in the future as organisations that failed to anticipate, adapt to or mitigate the approaching climate threats – ultimately undermining their mission and reducing their domestic legitimacy. The defence sector's internal and external communications should make clear the security threat that climate change poses, and to explain why it is such an important climate actor. Messaging should be clear and simple and should relate to the full spectrum of those who work in defence. The challenge of 'greening' the military without reducing capability will be an emotive issue and liable to be contested by misinformation. A defensive information operation might be required to counter this. Expectations should be managed; armed forces cannot 'solve' climate change, but they have a key role in mitigating its national and international consequences.

IISS has identified that for defence and military organisations to adapt successfully to a climate-changed world the following elements would be necessary:

- Developing a specific defence plan for climate mitigation and adaptation that harnesses both top-down and bottom-up initiatives;
- Nesting this defence plan within a whole-of-government plan to achieve net zero;
- Establishing a database for carbon emissions in the defence sector;
- Visible leadership and support from politicians and senior military and civilian officials to underline that climate change is a national-security issue;
- Changing attitudes and behaviours in defence to better take account of climate security;
- Using climate mitigation to improve military effectiveness (reducing logistic footprint, improving reach, endurance and security of supply lines);
- Actively researching more sustainable defence technologies through a programme of concept development, experimentation, and field trials;
- Investing in defence R&D where civil and commercial technologies are not applicable;
- Collaboration between defence and civilian industry, the public and private sectors, military allies and partners, and supporting cooperation between the EU and NATO;
- Having a well-developed internal and external communications plan.

Annex I: Survey of defence strategies that address climate change and mitigation

Country	Climate change mentioned in strategic documents	Mitigation mentioned in strategic documents	Defence CC/energy strategy emphasises mitigation	Net zero by	Legislation to achieve net zero?	Subject to EU net-zero 2050 legislation?	Formal mitigation targets for the armed forces?
Europe							
Albania				2050 (aligned with EU target)	No		No
Austria	✓			2040	No (despite declared intention, coalition has not yet agreed on a law)	✓	No
Belgium	✓			2050	No (proposed/in discussion)	✓	No
Bosnia and Herzegovina				?			No
Bulgaria	✓			2050	No (proposed/in discussion)	✓	No
Croatia	✓			2050	No (in policy document)	✓	No
Cyprus				-	No (proposed/in discussion)	✓	No
Czechia				2050	No (proposed/in discussion)	✓	No
Denmark	✓			2050	Yes (in law)	✓	No
Estonia	✓			2050	No (proposed/in discussion)	✓	No
Finland	✓			2035	No (in policy document)	✓	Yes
France	✓	✓	✓	2050	Yes (in law)	✓	Yes
Germany	✓	✓		2045	Yes (in law)	✓	No
Greece				2050	No (in policy document)	✓	No
Hungary				2050	Yes (in law)	✓	No
Iceland	✓			2040	No (in policy document)		No
Ireland	✓	✓		2050	Yes (in law)	✓	No
Italy	✓			2050	No (in policy document)	✓	No
Kosovo				-	-		No
Latvia				2050	No (in policy document)	✓	No
Liechtenstein				2050			No
Lithuania	✓			2050	No (in policy document)	✓	No
Luxembourg				2050	Yes (in law)	✓	No
Malta				2050	No (in policy document)	✓	No
Moldova				-	-		No
Montenegro				-	-		No
Netherlands	✓		✓	-	Legislation for other targets	✓	Yes
North Macedonia	✓			-	-		No
Norway	✓			2050	Legislation for other targets		No
Poland	✓			-	-	✓	No
Portugal	✓			2050	Yes	✓	No
Romania	✓			-	-	✓	No
Serbia	✓			-	-		No
Slovakia	✓	✓		-	No (proposed/in discussion)	✓	No
Slovenia	✓		✓	2050	No (in policy document)	✓	Yes
Spain	✓	✓	✓	2050	Yes	✓	No
Sweden	✓			2045	Yes	✓	Yes
Switzerland	✓			2050	No (in policy document)		Yes
Ukraine				2060	No (in policy document)		No
UK	✓	✓	✓	2050	Yes (in law)		Yes
North America							
US	✓	✓	✓	2050	No (in policy document)		No
Canada	✓	✓	✓	2050	Yes		Yes

Empty cells = No open-source information was available at time of writing

Notes

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The International Institute for Strategic Studies – UK
Arundel House | 6 Temple Place | London | WC2R 2PG | UK
t. +44 (0) 20 7379 7676 **f.** +44 (0) 20 7836 3108 **e.** iiss@iiss.org www.iiss.org

The International Institute for Strategic Studies – Americas
2121 K Street, NW | Suite 600 | Washington, DC 20037 | USA
t. +1 202 659 1490 **f.** +1 202 659 1499 **e.** iiss-americas@iiss.org

The International Institute for Strategic Studies – Asia
9 Raffles Place | #49-01 Republic Plaza | Singapore 048619
t. +65 6499 0055 **f.** +65 6499 0059 **e.** iiss-asia@iiss.org

The International Institute for Strategic Studies – Europe
Pariser Platz 6A | 10117 Berlin | Germany
t. +49 30 311 99 300 **e.** iiss-europe@iiss.org

The International Institute for Strategic Studies – Middle East
14th floor, GBCORP Tower | Bahrain Financial Harbour | Manama | Kingdom of Bahrain
t. +973 1718 1155 **f.** +973 1710 0155 **e.** iiss-middleeast@iiss.org