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Decarbonizing defense: Imperative and opportunity

Defense organizations are a major source of carbon emissions. How can they operate more sustainably while preserving mission-critical capabilities?

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Climate change is high on the global agenda. In the run-up to the 26th United Nations Climate Change (COP26) conference in Glasgow, governments and companies worldwide are announcing ambitious new decarbonization targets to achieve net-zero emissions by 2050. While climate change as a national security matter is well understood, there is little consensus about how to align defense forces to address it.

For defense forces, climate change brings wide-ranging risks, from undermining military assets to destabilizing societies to triggering conflict over resources. Defense forces, which typically account for at least 50 percent of governments' carbon emissions, could help prevent these risks by taking dramatic action to decarbonize and reduce emissions.

Defense departments will encounter challenges when attempting to reduce the emissions for which they are directly responsible because of the primacy of having mission-critical capability (that is, the ability to achieve a desired effect in a specific operating environment), long equipment life cycles (which means fossil-fuel-powered equipment in use now, or coming into service shortly, will still be fielded in 2050), and an increased focus on niches with high emission intensity, such as space launch. In consequence, a complete elimination of all defense emissions is unlikely by 2050. A net-zero defense force will therefore need to find ways to compensate for these remaining emissions, such as by pursuing offsets in countries with high climate-change risk or by pushing for decarbonization beyond their own emissions.

For defense supply chains, the complexity of the full supplier landscape presents a challenge to quantifying and directly managing emissions. Defense forces have unique suppliers and unique products. This prevents the creation of an ecosystem to generate mutual benefits between defense forces and their suppliers, akin to the ones developing in the automotive sector that could help electric vehicles (EVs) displace vehicles with internal combustion engines. It may therefore be most effective to address supply-chain emissions by setting decarbonization requirements aligned to national targets for all suppliers, as opposed to quantifying emissions directly and actively trying to reduce them.

Where possible, defense forces should benefit from off-the-shelf, low-carbon civilian technology, such as sustainable aviation fuel, fuel cells, and EVs. They should also build on these technologies in specific areas to develop more sustainable capabilities, such as supersonic flight with electric engines. With these tasks accomplished, defense forces could leverage their assets, including their real estate, to decarbonize further in certain areas—for instance, by generating green power on bases or capturing carbon.

This article focuses on understanding the current emissions baseline and outlining how defense leaders could minimize emissions and deliver net-zero defense forces by 2050. It proposes a method for categorizing emissions to help defense leaders address trade-offs that are unique to defense organizations, such as the need to balance climate-change concerns against the inherent primacy of having mission-critical capabilities.

Defense forces and carbon emissions

Defense forces contribute a substantial amount to government CO_2 emissions. Estimates suggest that each year the US Department of Defense emits over 56 million metric tons of CO_2 equivalent (a metric ton of CO_2 equivalent measures emissions with the same global warming potential as one metric ton of CO_2). Of this amount, 60 percent is from vehicle, aircraft, ship and passenger-fleet emissions; 25 percent is purchased electricity; 10 percent is on-site fuel consumption at federal facilities; and 5 percent comes from other sources.[1] For perspective, consider that the entire country of Peru is responsible for emitting about 55 million metric tons of CO_2 annually.

[1] "Comprehensive annual energy data and sustainability performance," US Department of Energy, Federal Energy Management Program, 2020, ctsedwweb.ee.doe.gov; Hannah Ritchie and Max Roser, "CO_2 emissions," Our World in Data, ourworldindata.org.

For many countries, decarbonizing their defense forces may be an essential step toward achieving government targets without relying on expensive offsets.

Emissions from the US Department of Defense represent about 80 percent of emissions from the US federal government. In the United Kingdom, defense accounts for as much as 50 percent of government emissions[2]; in Canada, the Department of National Defence is responsible for roughly half of the government's fleet and facilities emissions.[3]

As governments elevate climate priorities and emphasize the need for net-zero emissions, they have begun to recognize the challenge posed by defense-related decarbonization. For many countries, decarbonizing their defense forces may be an essential step toward achieving government targets without relying on expensive offsets.

Given new impetus, sustainability has become an important agenda item for defense forces. In June 2021, NATO leaders confirmed their shared political commitment to reduce defense emissions, labeling climate change, "a defining challenge of our times."[4] Similarly, Germany's Federal Defence Minister Annegret Kramp-Karrenbauer has said the consequences of climate change "represent a key challenge for global stability and security."[5] Recognizing the threat of climate change, Germany's defense forces achieved a 33 percent reduction in heating and electricity CO_2 emissions between 2008 and 2018.[6] In its 2020 *Sustainability Report & Implementation Plan*, the US Department of Defense offered details about how it will integrate sustainability into its mission and operations while noting that it had achieved a 23 percent reduction in emissions from 2008 to 2019 through, for example, a reduction in overall electricity use and greater use of renewable energy. More recently, US Defense Secretary Lloyd Austin called climate change an "existential threat" and noted the importance of increasing the energy efficiency of platforms and installations, deploying clean distributed-energy generation and storage, and electrifying vehicle fleets.[7]

Looking at levers similar to those under consideration in the United States, the UK Ministry of Defence is contributing to the government's commitment to reach net-zero greenhouse-gas emissions by 2050. France has committed its armed forces to a three-pillar strategy designed to achieve climate neutrality by 2050, and Germany has also launched defense sustainability goals. While targets are a good starting point, none of these governments yet has a fully comprehensive public plan that involves hard choices, costs money, and requires substantial innovation.

[2] *Climate change and sustainability strategic approach*, UK Ministry of Defence, March 30, 2021, assets.publishing.service.gov.uk.
[3] "Inventory of federal greenhouse gas emissions fiscal year 2019 to 2020," Government of Canada, last modified November 26, 2020, canada.ca.
[4] "NATO climate change and security action plan," NATO, June 14, 2021, nato.int.
[5] Jan Dörner, "Klimawandel fordert auch die Bundeswehr heraus" [Climate change is also a challenge for the Bundeswehr], *Stuttgarter Zeitung*, October 5, 2020, stuttgarter-zeitung.de.
[6] *Sustainability report 2020 of the Federal Ministry of Defense and the Bundeswehr*, Federal Ministry of Defense, 2018–2019, bmvg.de.
[7] David Vergun, "Defense secretary calls climate change an existential threat," US Department of Defense, April 22, 2021, defense.gov.

The need to reduce carbon levels without making unacceptable trade-offs

To set priorities for decarbonization, defense forces can benefit from categorizing their emissions as those for which they are directly responsible (categorized as Scopes 1 and 2) and those resulting from the full supply chain, including both direct suppliers and subsuppliers (Scope 3). For these categories, defense-related emissions can be further assessed based on whether they are linked to mission-critical capabilities. Using this classification system, three types of defense-related emissions emerge:

— *Emissions that can be reduced, as in any other industry, given that they are not linked to mission-critical capabilities.* For Scopes 1 and 2, examples include emissions arising from head-office operations and the electricity and heating of estate or civilian vehicles (the "white fleet"). Examples of Scope 3 emissions include those for nonessential personnel transport (such as commuting or travel for meetings where video-conference could be used). Most defense forces will find a set of feasible opportunities for emissions reduction here.

— *Emissions that are linked to mission-critical capabilities but can be addressed without any impact on the mission.* Examples of Scope 1 and 2 emissions include those from combat vehicles that could be electrified, those from naval vessels that could be made more fuel efficient, or those resulting from aircraft using fossil-based fuels on sorties where peak performance is not required. Scope 3 emissions in this category include those related to equipment maintenance or disposal. For this group, an assessment must conclude that there would be no detriment to capability, either through optimization, efficiency gains, or substitution, and there must be satisfaction with these findings across the defense community.

— *Emissions that are related to mission-critical capabilities and where a decrease in emissions would affect those capabilities.* Examples of Scope 1 and 2 emissions include the use of fossil fuels during essential sorties where peak performance is required and those associated with space launches. Scope 3 emissions include those related to equipment transport from manufacturing sites to operating sites. These emissions will be the hardest to decarbonize. Solutions available for such emissions include offsets or increased attention to innovation (for instance, generating renewable electricity on the defense estate).

Defense forces have various options for reducing emissions, based on their source and their relation to mission-critical capabilities, as shown in the exhibit.

To set priorities for decarbonization, defense forces can benefit from categorizing their emissions as those for which they are directly responsible and those resulting from the full supply chain.

Daunting as the challenge of decarbonization may be, there is much that defense forces can do without compromising their effectiveness. Indeed, some of the changes to enable decarbonization may also bear other operational or capability improvements, such as a reduced reliance on fossil supply chains or a greater ability to leverage local renewables.

Understanding the emissions-reduction opportunity

A reduction of up to about 60 percent of present-day Scope 1 and 2 emissions is achievable by focusing on the first two types of defense emissions: those that are not linked to mission-critical capabilities and those that are linked to mission-

Exhibit

Defense-force emissions can be categorized based on emission type and ease of reducing emissions.

Emissions-reduction actions

	Scopes 1 & 2: Emissions for which defense forces are directly responsible	**Scope 3:** Emissions resulting from the full supply chain, including both direct suppliers and subsuppliers
Emissions not linked to mission-critical capabilities	Focus on quick-win opportunities under full control of the defense force, comparable with decarbonization in any other industry • Understand emissions baseline and targets • Consider how the organization can support change • Identify and prioritize initiatives • Implement reduction initiatives and conduct tests of low-carbon opportunities	Provide incentives for supply chain to decarbonize core functions in the short term and cease purchasing unnecessary, non-mission-critical goods or services • Build decarbonization into the supply chain (eg, by developing emissions-reduction targets and requirements for suppliers) • Consider how the organization can support change • Consider reduction initiatives and test capability of low-carbon opportunities
Emissions linked to mission-critical capabilities but can be addressed without any impact to mission	Reduce emissions intensity of mission-critical activities or replace with low-emissions alternatives where possible • Understand emissions baseline and targets • Create a framework so more complex initiatives can be successful • Identify and prioritize initiatives • Implement reduction initiatives and conduct tests of low-carbon opportunities	Provide incentives for supply chain to reduce emissions intensity of new and existing equipment in areas where solutions are available • Build decarbonization into the supply chain (eg, by developing emissions-reduction targets and requirements for suppliers) • Create a framework so more complex initiatives can be successful • Consider reduction initiatives and test capability of low-carbon opportunities
Emissions related to mission-critical capabilities; a decrease in emissions would affect those capabilities	Develop negative-emissions schemes to decarbonize currently irreducible emissions in the short term; focus R&D on developing long-term solutions • Understand emissions baseline and targets • Plan capabilities • Create a framework so more complex initiatives can be successful (eg, by funding research to develop low-carbon alternatives) • Identify and prioritize initiatives • Seek to become net negative in selected areas to offset the irreducible emissions in other areas	Work with supply chain to develop zero-emissions solutions to currently irreducible emissions over the long term and offset emissions over the short term • Build decarbonization into the supply chain (eg, by developing emissions-reduction targets and requirements for suppliers) • Create a framework so more complex initiatives can be successful • Seek to become net negative in selected areas to offset the irreducible emissions in other areas

critical capabilities but can be addressed without any impact on the mission. This opportunity is based on an evaluation of potential emissions reductions from electricity and facilities, vehicles, aircraft, and vessels, which now account for about 95 percent of total emissions from the US Department of Defense. While it is unlikely that emissions will be eliminated entirely, any remaining emissions could be offset.

Electricity and facilities

Electricity and facilities now account for about 35 percent of the US Department of Defense's Scope 1 and 2 emissions.[8] McKinsey research, which looked at emissions in Europe across industries, suggests that renewable power could satisfy more than 80 percent of primary energy demand by 2050.[9] Example levers available to defense leaders include the following:

— *Improving efficiency of the defense estate and bases.* This could be achieved with thermal insulation, systems that minimize water use, and improved waste-management systems.

— *Transitioning to renewable heating.* This includes use of biofuels or heat pumps powered by renewable electricity.

— *Using renewable power sources.* This includes solar systems that can take advantage of the large surfaces available (for example, rooftops or land on bases) to enable decarbonization. Green energy can also be sold back into the grid. A typical base could generate its annual electricity demand with 40 to 50 acres of solar panels, equivalent to the roof area of a midsize site.

— *Installing carbon-capture technology as it becomes more efficient and affordable.* Bases may be a logical site to install such technologies, particularly as defense forces build, operate, and occupy most of their estate, so the benefit of any upfront costs that lead to future cost reduction will be fully captured.

Vehicles, aircraft, and vessels

Combat vehicles, aircraft, naval vessels, and the civilian fleet now account for about 60 percent of current US Department of Defense Scope 1 and 2 emissions, but this could be reduced by up to about 50 percent by 2050. Some initiatives to capture this opportunity include the following:

— *Using drop-in biofuels for ships and some aircraft for selected missions* as some countries are already beginning to evaluate in trials. The Netherlands, Sweden, and the United States have all tested biofuels in selected air platforms, such as the F-16 and the JAS 39, while Italy has launched a project to promote widespread use of biofuels and nonfossil marine fuels. Trials by the Swedish Air Force have tested a fuel mix containing up to 50 percent sustainable aviation fuel, which has the potential to provide a life-cycle carbon reduction of up to 80 percent compared with traditional jet fuel.[10]

— *Using more efficient engines, lightweight materials and more aero- or hydrodynamic designs.* Aircraft efficiency is expected to increase by 36 percent between 2020 and 2050, assuming minimal electrification.[11]

— *Transitioning to alternative fuels for heavy-duty vehicles and naval vessels.* If this involves a nascent technology, such as hydrogen or e-methanol, for which the infrastructure does not currently exist, defense forces may need to begin investing to develop it, noting that this may also affect where private-sector funding flows. This could provide a 100 percent reduction in emissions if alternative fuels are generated sustainably.

[8] "Comprehensive annual energy data and sustainability performance," 2020.
[9] Paolo d'Aprile, Hauke Engel, Godart van Gendt, Stefan Helmcke, Solveigh Hieronimus, Tomas Nauclér, Dickon Pinner, Daan Walter, and Maaike Witteveen, "How the European Union could achieve net-zero emissions at net-zero cost," December 3, 2020, McKinsey.com.
[10] "Sweden continues to test fossil-free fuel using JAS 39 Gripen aircraft," Airforce Technology, December 4, 2020, airforce-technology.com; "What is sustainable aviation fuel (SAF)?" Air BP, August 2020, bp.com.
[11] *Aircraft technology roadmap to 2050*, International Aircraft Transport Association, December 2019, iata.org.

— *Using EVs for the "white fleet" of noncombat vehicles.* This could be implemented today and lead to a 100 percent reduction in these emissions (if combined with use of renewable power sources).

— *Introducing electric unmanned aerial vehicles (UAVs),* which, for missions where electric power is appropriate, could lead to a near-complete elimination of Scope 1 and 2 emissions. In this case, the switch to a low-carbon technology may even upgrade mission-critical capabilities, as it can increase stealth compared with fossil-powered alternatives. The financial cost is high, however. Any additional costs can be balanced against the capability and sustainability benefits.

Planning and behaviors

Other opportunities to decarbonize involve changes in planning and behaviors. For instance, defense authorities could shift the live or synthetic balance in training or improve planning by enhancing air-traffic flow or making logistics more efficient. They could also think about training staff on sustainability issues or promote greener modes of operations, such as by implementing policies that minimize travel whenever possible.

Seeking to compensate for emissions in selected areas. It may become clear that some emissions cannot be reduced without affecting mission-critical capabilities. In such cases, defense authorities could strive to compensate for remaining emissions. They could also think about capturing CO_2 at the source through carbon capture and storage or attempt to draw CO_2 out of the atmosphere through offsetting schemes.[12] Funds could be found to support such initiatives, either directly from defense-force budgets or from other government sources. As defense authorities think about their options, it will be helpful to remember that their future offsetting costs will be higher if they decide not to pursue low-carbon options today, and that could affect their future mission-critical capabilities.

Steps to a sustainable defense transition

Making defense sustainable will involve a long journey. It can start with a few simple steps that involve planning strategically and taking actions that directly reduce environmental impact. In practice, these two activities will run in parallel, with early progress in implementing initiatives used to inform the ongoing sustainability strategy. Below we suggest eight steps (divided into four categories) to consider.

Understand the start and end points

Understanding emissions baseline and targets. The first step involves establishing the starting point and the destination so that governments can set and track sustainability targets. The work required to understand the emissions baseline can begin immediately, and governments in some countries, such as Canada, are already making progress in this area. Setting intermediate short-term steps—for instance, those for 2025 or 2035—also helps to build clarity on the pathway to net-zero emissions. All organizations seeking to reduce emissions can take this step by building an integrated pathway cost curve, which breaks the pathway into the individual measures required to achieve net-zero emissions. Each measure is defined in terms of the magnitude of emissions abatement it achieves against the weighted-average cost per ton of delivering that abatement.

For defense departments, the baseline of Scope 1 and 2 emissions can be quantified with high accuracy. By comparison, it will be nearly impossible to develop a full understanding of the Scope 3 baseline given the large number of suppliers and

[12] Krysta Biniek, Kimberly Henderson, Matt Rogers, and Gregory Santoni, "Driving CO_2 emissions to zero (and beyond) with carbon capture, use, and storage," *McKinsey Quarterly*, June 30, 2020, McKinsey.com.

subsuppliers. As such, it may be necessary to impose decarbonization targets on suppliers, instead of directly quantifying their emissions and actively trying to reduce them.

Enable change

Planning capabilities. Given the longevity of defense equipment, achieving decarbonization targets for 2050 will require action today. As a first step, defense authorities could review all equipment that will be fielded in the coming 30 years, including those already in service.

Most defense departments follow regular planning cycles, such as those outlined in the US Department of Defenses' National Defense Strategy or the UK Ministry of Defence's Integrated Review. As always, the planning cycles could help them identify the need for capability upgrades that will assist their operations in tougher future environments. These cycles could also be used as an opportunity to identify opportunities to decarbonize (always considering the impact on mission-critical capabilities, as discussed previously) and could even be used to make a full carbon budget through 2050 to understand the residual carbon emissions.

The findings from such planning may help defense authorities identify the best areas to focus R&D on and could lead to breakthroughs that will enhance capabilities, such as the development of hydrogen-fueled tanks. Finally, defense authorities could adjust the approvals process for proposals—for example, by stipulating that they include a low-carbon option, as well as the associated costs. This approach may help stimulate innovation and the development of new solutions.

Considering how the organization can support change. Making defense forces more sustainable will inevitably bring change to complex organizations with established operating models. Given the size of this undertaking, defense authorities must establish the correct governance and provide incentives for the right behaviors to succeed.

Additionally, accountability for decarbonization is essential. This may be established by requiring the organizations responsible for emissions (typically the commands) to reduce Scope 1 and 2 emissions. By comparison, the acquisition agency may be best suited to address Scope 3 emissions. The separate organizations would then need to coordinate activities to ensure overall success.

Behavioral change is essential to operating more sustainably. At a minimum, staff members will need to understand the cultural change required to promote decarbonization. To attract a defense force's top talent into decarbonization, sustainable actions must be incentivized and rewarded in the same way that actions to counter more traditional threats are.

Creating a framework so more complex initiatives can be successful. Some initiatives required to hit overall sustainability targets may be difficult to implement. In such cases, they may require additional support from defense departments to ensure their success. This support may involve providing funding or incentives to conduct R&D in a specific area, working with international partners to codevelop a solution (for example, similar to what was done at NATO for fuel standards), or seeking dedicated funding for a solution that would otherwise be unaffordable.

Reduce emissions arising from their own organizations

Identifying and prioritizing initiatives. Typically, this step will involve highlighting emission-reducing initiatives along three dimensions. While availability and financial feasibility are important in any industry, the consideration of capability trade-offs is unique to defense and makes prioritizing initiatives more complex. The dimensions include the following:

— *Availability of a solution.* Some problems may have available solutions because organizations within the private sector have already developed relevant decarbonization initiatives.

Some initiatives may put defense authorities at risk of reducing their mission-critical capabilities, making trade-offs an important consideration for senior officers and policy makers.

If so, the defense sector can adopt similar strategies. Other problems may not have a viable solution available, either currently or in the near future.

— *Financial feasibility.* Some sustainability initiatives will immediately produce positive financial results; others may cost money up front but could be financially beneficial over the long run. Yet more will have negative financial results but a positive impact on sustainability; this cost may be justified if the initiatives do not negatively affect capability.

— *Capability trade-offs.* Some initiatives will let defense authorities decarbonize without reducing their mission-critical capabilities, and some may even increase capabilities. In other instances, however, the initiatives may inevitably put defense authorities at risk of reducing their mission-critical capabilities. Trade-offs will be important considerations for senior officers and policy makers, as compromises in performance are only acceptable in certain cases.

If defense authorities consider scoring their initiatives against these three dimensions, it might help them to identify the appropriate levels of investment required for implementation. This scoring system could also help defense authorities prioritize their initiatives.

Consider how to reduce supply-chain emissions

Decarbonizing the supply chain is essential to achieving overarching sustainability goals. Defense authorities have several levers available to achieve this goal, including providing incentives for low-carbon products, funding investment programs, or requiring suppliers to meet specific decarbonization goals or environmental-performance requirements to qualify for a defense contract. For instance, the UK Cabinet Office recently announced new measures that will require businesses to commit to net-zero emissions by 2050.[13] The businesses must also publish clear and credible carbon-reduction plans before they can bid for major government contracts, including those in defense. Additionally, defense authorities

[13] UK Cabinet Office. "Firms must commit to net-zero to win major government contracts," June 7, 2021, gov.uk.

could measure embedded carbon in defense products and incorporate sustainable procurement standards into the acquisition and decision-making processes. These steps would directly provide incentives for industries to reduce the carbon footprint of their products and operations.

Defense authorities can also catalyze the creation of an ecosystem to encourage more sustainable production and manufacturing, for example, by changing regulation and subsidizing sustainable change in their supply chain. In this way, organizations could generate mutual benefits in the long term. Departments could consider using their position to promote sustainable R&D, such as that related to developing sustainable aviation fuels. They could also consider funding innovation programs that target improving the efficiency of next-generation equipment. These programs could be linked to future plans for upgrading or developing next-generation capabilities and may also be relevant for decarbonizing parts of the commercial sector.

The challenge of making defense forces sustainable without compromising capability will be formidable. Defense personnel are trained to overcome great challenges with the tools available at hand, however, and they are in the privileged position of being able to plan strategically. Now is the time for defense leaders to add sustainability to their agenda.

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