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SCIENCE AND TECHNOLOGY COMMITTEE (STC)

SPECIAL REPORT

CLIMATE CHANGE MITIGATION AND ADAPTATION: THE ROLE OF TECHNOLOGY

Special Report
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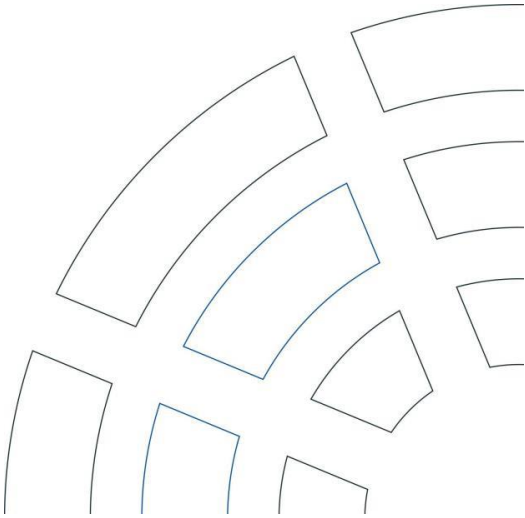
Founded in 1955, the NATO Parliamentary Assembly acts as a consultative interparliamentary organisation which is institutionally separate from NATO. This report was adopted by the Committee at the 68th Annual Session of the NATO Parliamentary Assembly. It is based on information from publicly available sources or NATO PA meetings, which are all unclassified.



EXECUTIVE SUMMARY

Russia's unprovoked invasion of Ukraine has completely overshadowed the sixth assessment report (AR 6) of the Intergovernmental Panel on Climate Change (IPCC), published shortly after the beginning of the war. However, the IPCC's message is clear: climate change is at least partially irreversible and threatens to overwhelm human and natural systems beyond their ability to adapt. The 2022 Global Risks Perception Survey (GRPS) of the World Economic Forum (WEF) identified climate change as the most menacing long-term threat. Extreme weather events and biodiversity loss associated with climate change have already inflicted heavy costs and led to mass displacement. Societal and economic repercussions of climate change-related disasters are potentially catastrophic.

Climate change also presents a real and growing international security challenge. The 2022 Security Report of the Munich Security Conference named climate change as a key security risk. NATO Heads of State and Government stated at their 2021 Brussels Summit that climate change is "one of the defining challenges of our times" (NATO, 2021). At the 2022 Madrid Summit they also decided to include climate change considerations in the Alliance's three core tasks (NATO, 2022a).

In combination with resource scarcity and demographic growth, climatic changes are likely to create instability throughout the world, with fragile nations impacted most profoundly. In the worst case, this could lead to state failure, violent conflicts, and uncontrolled migration movements. Currently, NATO has only a summary overview of fragile governance in impacted nations. To better understand and prepare for such worst-case scenarios NATO should increase its study and early warning capacities with regards to fragile governance, for example through the creation of a Democratic Resilience Centre at NATO Headquarters as proposed by the NATO Parliamentary Assembly. Moreover, climate change is already affecting the planning and conduct of military operations, damages military bases and infrastructure and strains military forces' resources when providing support for dealing with climate change-related disasters.

This report first draws attention to the security implications of climate change and lays out NATO's evolving approach to climate change. A brief overview of NATO efforts to better understand, adapt to, and mitigate climate change follows. This includes research efforts conducted by the Science and Technology Organisation (STO) supporting innovative climate change mitigating technology. The report calls upon NATO Allies to continue and strengthen efforts to adapt to the impact of climate change. Efforts in this regard should focus on including climate change considerations in future strategic documents, adapting military capabilities to climate change challenges, outlining a robust energy transition plan without weakening our collective defence capabilities, and providing funding for the integration of energy saving and renewable technologies for military operations.

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I- INTRODUCTION

1. The Intergovernmental Panel on Climate Change (IPCC), the international body for assessing the science related to climate change, released the second report of its sixth assessment (AR 6) in February 2022[1]. It concluded that the dangers of climate change are mounting so rapidly that they could soon overwhelm the ability of both nature and humanity to adapt (IPCC, 2022). According to the IPCC, because of human-induced greenhouse gases the average global temperature between 2010 and 2019 was around 1.1 degrees higher than in the 1850-1900 period. Since the IPCC's fifth Assessment Report in 2014, it has risen by a further 0.2 degrees. The most visible effects of climate change today are more frequent and more pronounced heat waves, rising sea levels, sea ice retreat (which appears most dramatically in the Arctic as the region is warming at a rate of almost four times the global average) and changing precipitation patterns which cause devastating floods and droughts (Fountain, 2022). Extreme weather phenomena caused by human-induced climate change are already having a profound impact on our environment, our economies, infrastructure, and social systems.

2. Climate change also has important implications for security. Extreme weather phenomena can trigger migration flows, and disputes over habitable land or agricultural land could erupt into military conflict. The negative effects of climate change affect military forces in several ways. First, extreme weather events are impacting NATO's military forces' ability to operate.

3. Second, military forces of NATO countries are also playing an active role in handling extreme weather events and in disaster relief operations. The first deployment of the NATO Response Force (NRF) was to Kashmir in 2006 to help Pakistan restore infrastructure and communications after a major earthquake (Shea, 2022). The military played an important role in the relief operations after hurricane Katrina struck the U.S. in 2005. More generally, national military forces support the civil authorities in handling extreme weather events like for example the floodings in Germany, Belgium and Luxembourg in 2021. Another example is the role of Allied soldiers support in relief efforts after hurricane Irma struck the Caribbean in 2017 (France24, 2017).

4. Moreover, military forces have a major carbon footprint. According to the International Military Council on Climate and Security (IMCCS), the defence sector remains the single largest consumer of hydrocarbons in the world (IMCCS, 2021). Military operations and exercises consume large amounts of resources and military forces are often exempt from reducing their greenhouse gases.

5. However, there is a recognition that military forces need to be better prepared to tackle the impact of climate change. As a result, a growing number of militaries now integrate climate change issues into their planning. And the Alliance has made climate change adaptation a key issue of the NATO 2030 project. NATO Heads of State and Government stated at their 2021 Brussels Summit that climate change is "one of the defining challenges of our times" (NATO, 2021). At the 2022 Madrid Summit they also decided to include climate change considerations in the Alliance's three core tasks (NATO, 2022a). In addition, the Strategic Concept lays down the Alliance's level of ambition to "become the leading international organisation when it comes to understanding and adapting to the impact of climate change on security" (NATO, 2022c). In doing so, the Allies will focus on awareness, adaptation, mitigation, and outreach.

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[1] The sixth assessment of the IPCC includes three special reports. The first, on the physical science basis, was published in August 2021. The second part, "Impacts, Adaptation, and Vulnerability", which deals with the consequences and necessary adjustments, was published on 28 February 2022. The third contribution, "Mitigation of Climate Change", identifies technical and economic possibilities to mitigate climate change and was released on 4 April 2022.

6. Russia's war against Ukraine has highlighted the current European Allies' dependency on fossil fuel and the security repercussions for NATO. This rekindled the interest in energy efficiency through innovation as new technological developments can create new methods for renewable energy. The NATO Parliamentary Assembly has been covering climate change as a security issue already since the 1980s. In addition to inviting experts and producing reports on the implications of climate change for the Alliance, your Rapporteur wants to stress Assembly Resolution 427 (NATO PA, 2015), which was presented by the Science and Technology Committee, which labelled climate change a threat multiplier already. More recently, the NATO PA made specific recommendations on climate change to NATO, among others in the Assembly's contribution to the NATO Secretary General's NATO 2030 project and particularly in our contribution to the update of NATO's 2022 Strategic Concept (NATO PA, 2022a).

7. This report gives a short overview of the implications of extreme weather for NATO and of how climate change is already influencing the planning and conduct of military operations. A few examples of how technology may help to mitigate the negative effects of climate change follow. The report also provides an overview of NATO's efforts regarding climate change, focusing on NATO's overall approach to environmental issues and the work of the Science and Technology Organisation (STO).

II- CLIMATE CHANGE – IMPLICATIONS FOR THE ALLIANCE

8. Human-induced global warming and the associated scale of recent changes in the entire climate system (climate change) affect NATO member states' economies and social stability and threaten the security and stability of the Alliance. Weather extremes such as extreme heat, heavy precipitations/floods, hurricanes, wildfires, and tornadoes have always existed. What is new is that their frequency and intensity will increase significantly. They pose a grave risk to NATO air, sea, and land operations as well as NATO and Allied bases, soldiers' health, military equipment, and critical infrastructure (Heise, 2021).

9. NATO and Allied military bases are an important pillar of the Alliance's collective security. Our security rests on the proper functioning and operational security of Allied bases at home and around the world. Military bases are put under extra stress due to climate change. For example, according to the US Congressional Research Service, over 1,700 US military installations worldwide are vulnerable to sea level rises associated with global warming (CRS, 2019). A 2019 Pentagon report suggested that at least half of US military bases worldwide face flooding, extreme heat, extreme wind, and drought. The material costs alone have been staggering: the damage caused by two hurricanes in 2018 and in 2020 amounted to USD 4 billion for Tyndall Air Force Base and Pensacola Naval Air Station in Florida. Hurricane Florence in 2018 caused another USD 3.5 billion in damages and repairs at Camp Lejeune, North Carolina (Liebermann, Kaufman, 2021). Flooding at Offutt Air Force Base in Nebraska caused about USD 500 million in damages in 2019.

10. The detrimental effects of climate change affect all Allies. France has a considerable military presence in the Indo-Pacific which faces a multitude of threats associated with climate change. Rising sea levels in the Pacific threaten to submerge critical infrastructure and islands hosting more than a million French citizens (Morcos, 2021).

11. On the operational front, climate change is already influencing the planning and conduct of military operations. The global rise in temperatures harms air operations because aircraft performance is directly impacted by air temperature and wind speed. Widespread droughts trigger sand and dust storms which jeopardise aerial and ground operations due to compromised vision and material attrition. Extreme heat puts additional stress on military equipment such as weapons systems, electronic systems, and vehicles. Troops also face an increased risk of "physiological heat

stress" under extreme temperatures. In the Sahel, French counterterrorism operations have been severely hampered by extreme heat (UN High Commissioner for Refugees, 2020; New York Times Magazine, 2020). The NATO training and advisory mission in Iraq is another case in point. Iraq is one of the most climate-vulnerable countries in the Middle East; drought and extreme temperatures have transformed wetlands into deserts. While the Alliance looks to expand its mission in Iraq beyond the greater Baghdad area, it will become harder to maintain a functioning mission in the country as the environmental situation deteriorates.

12. Weather extremes, such as flooding and snowstorms, can disrupt military supply lines which are critical to military bases and operations. As sea levels rise, operating bases will come at risk of being submerged, especially those located in low-lying coastal areas. For example, in March 2019, Offutt Air Force Base, the Headquarters of U.S. Strategic Command, was flooded following extreme storms. The storms and the floods damaged a third of the buildings on the base (Irfan 2019). Incidents such as this will be more commonplace as US military infrastructure will be put under risk as a result of rising sea levels (Congressional Research Service, 2019).

13. Beyond the immediate impact of climate change on NATO missions, military infrastructure, and troops, climate change is an accelerator of conflict and a threat multiplier. Pavel Kabat, Chief Scientist at the UN World Meteorological Organization, points out that "climate change has a multitude of security impacts - rolling back the gains in nutrition and access to food; (…) increasing the potential for water conflict; leading to more internal displacement and migration" (UN, 2019). Moreover, "the relationship between climate-related risks and conflict is complex and often intersects with political, social, economic and demographic factors", according to Rosemary DiCarlo, the Under-Secretary-General for Political and Peacebuilding Affairs (UN, 2019). The US National Intelligence Council foresees that climate change will bring with it new "geopolitical flashpoints" as states "take steps to secure their interests".

14. For example, new focal points for conflict may emerge as climate change triggers irreversible changes in the world's atmosphere. As the ice melts, the Arctic can become a theatre of conflict. For example, Russia has already claimed over 70% of the Arctic seabed, extending into the Canadian and Danish exclusive economic zones. The retreat of the Arctic ice could also open up new trade routes and spark new competition for resources.

15. Conflicts around the access to drinking water resources are likely to increase. Relatedly, violent conflict may emerge both within and between states over the competition to secure basic resources such as land and water. This is particularly relevant for countries suffering from "a narrow natural-resource base" (Barry et al, 2022). Disputes over the sovereignty of transboundary rivers are already occurring with examples from the Brahmaputra River in South Asia and the River Nile in Africa[2]. More generally, the negative effects of climate change can undermine the political stability of countries in NATO's periphery which will impact the security of the Alliance. Unfortunately, NATO does currently not dispose of an early warning system which would monitor the instability generated by climate change.

16. The increase in extreme weather events puts additional stress on armed forces as they have an important role as first responders in managing the fallout of extreme weather phenomena. The then Chief of the Canadian Defence Staff, General Jonathan Holbert Vance warned that Canada's armed forces are being pushed to the limit responding to an increasing number of

[2] The Brahmaputra River originates in Tibet and runs across China, India, and all the way down to Bangladesh. Known as the Yarlung Tsangpo River in China, the river has been a source of contention between upstream and downstream countries for decades due to the absence of a water sharing agreement. Recently, China announced the construction of a hydropower plant near the Indian-Chinese border, sparking a backlash from India.

climate-related events. As a result, the Canadian armed forces have to turn to reservists to tackle such events (Major, Shivji, 2019). In addition to dealing with environmental emergencies in their own countries, the militaries of NATO member states are likely to be called upon to provide assistance to other nations to address humanitarian disasters which follow extreme weather events, putting extra strain on the armed forces. Demand on military forces to assist in relief efforts will grow as the number and the intensity of extreme weather events due to climate change increase. Moreover, these developments also lead to a surge of instability in regions neighbouring the Alliance putting additional strain on the capacity of NATO forces to carry out their assigned missions.

III- NATO'S EVOLVING APPROACH TO CLIMATE CHANGE

17. NATO first addressed environmental challenges with the establishment of the Committee on the Challenges of Modern Society in 1969 which supported studies and fellowships focusing on air and noise pollution, as well as on hazardous waste management. The 2010 Strategic Concept briefly referred to the relationship between climate and security. Although it noted that it "will further shape the future security environment in areas of concern to NATO and have the potential to significantly affect NATO planning and operations" this did not have a major impact on NATO's policies because this mention was not the result of the usual drafting process among Allies but was largely drafted by the then Secretary General Anders Fogh Rasmussen. Due to this unusual procedure (no line-by-line drafting by Allies), the degree of ownership of the Nations was limited. (Rühle, Heise, 2021). Moreover, Allies felt little inclination to engage in an issue that could upset the delicate balance of geopolitical interests in certain regions (e.g., the High North).

18. As the number of scientific studies and the understanding of the far-ranging implications of climate change increased, NATO's interest in the issue grew (Sikorsky and Goodman, 2021). Allies adopted the Green Defence Framework in February 2014. This document listed numerous proposals to reduce fuel consumption in the armed forces as well as to introduce "green" standards in NATO facilities (Rühle, Heise, 2021). However, although the Green Defence Framework aspired to reduce the environmental footprint of military operations and improve NATO's resilience by investing in green technologies to reduce fuel consumption, energy dependencies, mission footprints and long, vulnerable supply lines it contained no specific targets or commitments.

19. The Russian annexation of Crimea in March 2014 put the Green Defence Framework on the backburner, as NATO refocused on its core tasks of deterrence and collective defence. Prioritising the Green Defence Framework seemed like a distraction from the Alliance's purpose that could no longer be afforded. Restricting operational military capabilities through climate policy restrictions now seemed even more outmoded. Thus, the declaration of the 2014 NATO Summit merely stated that Alliance members would aim to "further develop NATO's competence in supporting the protection of critical energy infrastructure; and continue to work towards significantly improving the energy efficiency of our military forces" (Larsen, 2015; Jankowski, Wieczorkiewicz, 2020). Still, Allies continued exchanges on the security policy consequences of climate change, including on the basis of internal analyses of the political and military staffs and in informal debates of the NATO ambassadors (Rühle, Heise, 2021). A Smart Energy project, funded by the NATO Science Programme, attempts to reduce fuel consumption in remote bases or field camps by integrating wind and solar energy, thereby reducing greenhouse gas emissions at the same time. (Rühle, 2021). "Smart grid" technology uses renewable energy to reload batteries being used in military operations and is becoming widespread in exercises.

20. Following the annexation of Crimea and Russia's continuing aggressive rhetoric and actions, NATO members have been reluctant to set binding targets that could limit the capabilities of the armed forces and of the collective defence missions. NATO's key focus regarding climate change switched at the 2021 Brussels Summit. Allied Heads of State and Government decided that NATO

should become the “leading international organisation when it comes to understanding and adapting to the impact of climate change on security” (NATO, 2021). This change reflected the clear determination of Allies to include climate change considerations in NATO’s defence and deterrence calculus. Another consequential decision during this Summit was the agreement on the Climate Change and Security Action Plan, which identified multiple priorities to integrate climate into NATO’s agenda. More specifically, the Action Plan foresees cutting greenhouse gas emissions tied to military activities and installations, as well as the formulation of an annual Climate Change and Security Impact Assessment which will analyse the impact of climate change on the strategic environment and assets, installations, missions, and operations (NATO, 2021).

21. Some European NATO member states are heavily dependent on Russian gas and oil supplies. Reducing the demand for fossil fuels for the armed forces of NATO countries also has the effect of reducing dependence on Russian energy supplies. At the 2021 Brussels Summit, NATO leaders also agreed on producing a serious assessment on the feasibility of reaching net zero emissions by 2050. Leaders also pledged to initiate a regular high-level climate and security dialogue to exchange views and coordinate further action. As militaries are exempt from reporting greenhouse gas emissions, it is difficult to determine their environmental footprint correctly. Military operations and exercises are carbon intensive, a clear assessment of the environmental impact of militaries is thus crucial to mitigate climate change.

22. At the 2022 Madrid Summit, NATO presented its first annual Climate Change and Security Impact Assessment (CCSIA). The CCSIA will increase awareness of the impact of climate change on NATO’s strategic environment, Allied installations and assets, missions and multidomain operations, as well as resilience and civil preparedness (NATO, 2022b). The CCSIA also identifies eight measures that can help the Alliance in adapting to the effects of climate change:

- “**Develop** shared emergency response systems with civilian authorities
- **Prepare** for changes in mission profiles, military tasking, and standard operating procedures, to include Humanitarian Assistance and Disaster Relief HADR and climate change
- **Retrofit** infrastructure based on climate resilient/ eco-design principles
- **Alter** operational planning and training schedules
- **Incorporate** climate change into land management and the selection of training sites
- **Integrate** climate change into capability development and procurement processes
- **Build** supply chain resilience, e.g., through anticipatory logistics
- **Improve** resilience of utilities” (NATO, 2022d)

23. NATO’s activities regarding climate change highlight the need to increase awareness and to adapt NATO militaries to a changing environment. The annual CCSIAs will be based on six main considerations which Allies need to keep in mind regarding the adaptation of their armed forces. These are: 1) armed forces’ effectiveness in performing NATO’s core tasks; 2) the precarious Euro-Atlantic security due to Russia’s aggression increased NATO’s military activity (training, exercises, patrolling), creating thus a surge in the need and use of fuel; 3) procuring new equipment should take into account energy efficiency; 4) the transition to renewable energy sources should avoid forging new dependencies, especially on China; 5) interoperability is a priority in developing the technological edge; 6) the adaptation actions to new and cleaner technology should be dual-use, for military-civilian purposes (NATO, 2021b).

IV- SUPPORTING RESEARCH TO INCREASE AWARENESS AND BETTER UNDERSTANDING OF CLIMATE CHANGE

24. NATO's approach to mitigating climate change starts with a better understanding of it, and efforts in this regard are already underway. It is noteworthy that the Climate Change and Security Action Plan pledges to increase the Alliance's awareness on climate change by leveraging NATO science and technology programmes (NATO, 2021). NATO has also decided to establish a NATO Climate Change and Security Centre of Excellence. The centre will be hosted by Canada, as Allies agreed at the 2022 NATO Summit in Madrid (Canada, 2022).

25. NATO's main entity focused on science and technology is the Science and Technology Organization (STO). It is led by the NATO Science and Technology Board (STB) which is composed of national representatives and NATO stakeholders. The STB promotes coherence of the Alliance's science and technology research through objectives set out in the "NATO S&T Strategy" and serves as a focal point for all of NATO's science and technology work (Alleslev, 2018).

26. The STO is composed of three bodies: the Office of the Chief Scientist (OCS), the Collaboration Support Office (CSO), and the Centre for Maritime Research and Experimentation (CMRE). In 2021, after NATO Secretary General Stoltenberg's address on Earth Day, the three bodies of STO were directed to provide analyses of climate scenarios to the Chief Scientist so that he can inform the Secretary General, as well as member states, on how to best prepare for future security challenges (NATO CMRE, 2021).

27. Most of the STO's work on climate change thus far has been focused on maritime research, with the Centre for Maritime Research and Experimentation (CMRE) in La Spezia in the lead. CMRE pursues a rich programme of work worth about EUR 30 million; its activities are funded by NATO Allies and others and the centre also does work organised in consortia funded by the EU. CMRE has a strong Centre of Excellence with expertise both in antisubmarine warfare and naval mine countermeasures.

28. Through its collaborative programme of work (CPoW) and the Centre for Maritime Research and Experimentation (CMRE) the STO continues research into scientific and technological options to understand, mitigate, and adapt to climate change. The focus of this work has been on three areas: environmental characterisation and prediction; technological mitigation and sustainability; and analysis of strategic implications. Moreover, to support technological mitigation the NATO Science and Technology Board (STB) approved the following climate change-related NATO science and technology (S&T) priorities:

- Precision Engagement – weapons effects (environmental impact);
- Power & Energy – storage, alternative and renewable sources, enhanced efficiency and management
- Advanced Systems Concepts – efficient and effective logistics.

29. Other STO activities explore the strategic implications of climate in such areas as resilience, human security, and evolving threats. Moreover, the STO has also contributed to the development of a NATO Greenhouse Gas Emissions methodology and organisational assessment, as well as the CSS impact assessment. In addition, the STO has been working with Defence R&D Canada on emerging and disruptive technological (EDT) aspects of climate change and security issues.

30. CMRE activities include, for example, assessing the impact of new shipping lanes in the Arctic, changes in the underwater acoustic environment, development of new sensors and autonomous systems, monitoring ship movement, and, more generally, increasing NATO's environmental knowledge. Of value is the CMRE's work on maritime environmental monitoring which will be

instrumental in investigating, for example, a pan-Arctic ice-ocean prediction model to support NATO naval operations in the Arctic Ocean. The CMRE site at La Spezia has significant scientific facilities, including two world-class research vessels. The vessel Alliance is one of the quietest ships in the world; it is ice-capable and deployed every year to the High North, where it conducts environmental monitoring and research on antisubmarine warfare.

31. CMRE is also using a huge data set of the ocean provided by data retrieved from satellites (which measure ocean circulation and ice) and autonomous underwater gliders (which take temperature and salt measurements) to forecast the interior properties of the ocean. Measuring temperatures and salt content at certain depths is important for understanding climate change but also for antisubmarine warfare as these two properties affect the speed of sound travelling in water. Using high-performance computing CMRE combines these sources and creates a "digital twin" of the oceans. These data will allow to plan and conduct military operations and understand the implications of climate change. Moreover, CMRE also started to look at the impact of climate change on infrastructure such as possible risks to undersea internet cable networks arising from flooding.

32. CMRE had a very successful workshop to launch its Arctic S&T strategy in March 2021 which has generated significant interest in joint future Arctic research. STO's CMRE also partners with Alliance members to better understand and address climate change. For instance, the US National Oceanic and Atmospheric Administration (NOAA) and the CMRE renewed a Memorandum of Understanding in 2021 aimed at "improving understanding and forecasting in climate-critical areas, such as the north and north-eastern Atlantic Ocean" and "the sharing of assets and expertise to better accomplish common research programmes in detecting and monitoring long-term climate change." (NATO STO, 2021). CMRE is likely to be one of the test centres of NATO's Defence Innovation Accelerator for the North Atlantic (DIANA). Similar to the US Defense Advanced Research Projects Agency (DARPA), DIANA is designed to assist NATO to work more closely with private companies, academia and other non-governmental entities.

33. In the Collaborative Programme of Work (CPoW) conducted by CSO, researchers are looking at implications of the use of synthetic fuels on land and on sea, and also conduct an evaluation of hybrid electric propulsion technology. The STO also produced a publication on environmental regulation of energetic systems.

34. NATO's Science for Peace and Security (SPS) responds and adapts to the changing security environment to support strategic objectives and political priorities of the Alliance. This includes providing research on climate change and climate change action. More specifically, the SPS programme works also to develop policy and technical solutions to reduce the environmental footprint of NATO activities (NATO, 2021). One related project monitors military camps' energy consumption to find ways to improve energy efficiency (NATO, 2021).

35. Other than developing a better understanding of global warming and extreme weather conditions, the SPS programme also organises exercises involving military and civilian experts to increase understanding of the military's role in disaster relief (NATO, 2021). NATO military forces are increasingly being deployed as first responders to deal with the fallouts of the extreme weather events and natural disasters. NATO forces, particularly the rapid reaction units, have the capacity to provide immediate assistance, for instance in the distribution of relief supplies or the repair of telecommunications infrastructure (Shea, 2022).

36. As the Alliance looks to increase its efforts on climate change mitigation and adaptation, STO will shift more resources and research attention on climate issues (Rühle, 2021). The likely next step in this process is more research on the direct impact of climate change on Allied military mobility and provision of reinforcements. NATO is already looking for new ways to develop innovative technologies to improve energy efficiency in the military (NATO, 2021).

V- SUPPORTING CLIMATE CHANGE MITIGATION

37. Regarding climate change mitigation, some initial steps are already underway. To contribute to the Alliance's efforts to roll back CO_2 emissions to prevent the worst possible outcomes, NATO announced the development of a new methodology to measure greenhouse gas emissions from military activities and installations (NATO, 2021). This methodology will help determine voluntary goals for specific Allied countries.

38. Improving energy efficiency in military operations is also an important pillar of the Alliance's efforts to mitigate climate change. Since 2011, NATO is conducting the Smart Energy initiative which seeks to reduce the logistical burden of fossil fuels during operations. This initiative was notably tested during the Exercise Capable Logistician 2019, which consisted of various scenarios such as power cuts, diesel contamination and pollution of primary water sources. It required the Allied military to conduct smart energy responses using technologies, such as the water production unit that could save up fuel as well as purify water, and a "smart microgrid" which is an interoperable software that powers up diesel generators only when needed (NATO, 2019). All in all, these exercises not only make Allied militaries more energy efficient, but they also reduce their reliance on fossil fuels in the field and enhance interoperability between national armed forces. In fact, the research and development in new technologies by some of its member states will require more exercises to maintain and increase the interoperability between different armed forces and their equipment (NATO, 2019). Pressures from the NGO community to set the same targets for emissions reductions that Allied countries have agreed to in their Nationally Defined Contributions to the COP 26 also constrain action for certain member states, which will necessarily have to elevate action to the Alliance level (Shea, 2022).

39. There is renewed focus on energy efficiency through innovative technologies and diversification of energy sources. In fact, NATO is a natural venue for Allies and partners to organise trials and experimentation, exchange best practices and experience, and use NATO's system of certification and STANAGs (standardisation agreements) to set common standards and promote interoperability for green energy equipment (Shea, 2022).

40. As technology evolves, scientists will develop new ways to produce energy, which only underlines the importance of continued investment in R&D. However, while there is progress being made in reducing the dependency of the military on fossil fuels it is important to be realistic about what new, alternative energy sources can achieve in the short term. For example, biofuels produced via carbon transformation technology can only produce a fraction of the fuel that the armed forces need. Reduction of the military's carbon footprint may also occur as weapon platforms develop. For example, air forces are main users of fossil fuels; replacing manned fighter aircraft with drones, either partly or completely, could have a significant impact on the energy consumption. Moreover, as AI and computing power develop, training and exercises could increasingly be done digitally. It is clear, though, that we cannot compromise on national security. Deterrence and the prevention of war remain key. Russia's war of choice is a good example. Environmental costs, in addition to the suffering of the Ukrainian population, are enormous.

VI- OTHER MITIGATING TECHNOLOGIES

41. As the climate continues to change, military leaders are beginning to take these challenges into account for their long-term strategic planning of armed forces capacity and capability. They are also looking into which role existing and developing technologies can play to adapt armed forces and mitigate the negative impact of climate change.

42. Unlike in the past, technological developments are now driven primarily by the private sector. Technologies which are under consideration to dampen the impact of global warming include, among others:

43. **Carbon Capture and Sequestration** (CCS), which could be used to reduce the carbon footprint of military installations. CCS is the process of capturing carbon dioxide (CO_2) formed during power generation and industrial processes and storing it before it is emitted into the atmosphere. There are three modes of capture: post-combustion carbon capture, pre-combustion carbon capture, and oxy-fuel combustion systems. Only post-combustion has so far been demonstrated with success in existing power plants. For post-combustion, the CO_2 is first separated from the exhaust of a combustion process, then it is compressed and deeply chilled into a fluid, and finally transported into storage.

44. Depending on the nature and emission levels, captured CO_2 could also be used to produce manufactured goods in industrial and other processes rather than being stored underground. The International Energy Agency (IEA) estimates that CCS could reduce total CO_2 emissions from industrial and energy production facilities by as much as 20% (IEA, 2019).

45. According to the results of a project led by the American power company NRG and funded by the US Department of Energy, CCS technology can successfully store more than 90% of carbon emission in coal-fired power plants. In 2021, slightly more than 30 commercial CCS facilities were in operation or under construction. These facilities have the capacity to store more than 40 million metric tons of CO_2 per year.

46. Obstacles to a large-scale deployment of CCS technology are high costs, transportation and storage risks, and lacking public support. The lower energy efficiency of power plants using CCS technology and higher investment costs make investing in this technology riskier. In addition, there are also risks related to the transportation and storage of CO_2. Moreover, there is a significant amount of energy needed to compress and chill the carbon dioxide, and the CO_2 can only be stored in specific geologic conditions. Public acceptance of CCS technology is also limited because CCS technology would be seen as prolonging the use of fossil fuels.

47. **Carbon transformation technology** is another technology which could help mitigate the impact of climate change. The basic idea is to use the carbon dioxide in the air to extract carbon from it. This means that petrochemicals are no longer used to extract carbon. Initial research by the American company Twelve has shown that carbon transformation technology can turn carbon dioxide from the air into nearly any chemical or material (Poland, 2021; Roza, 2022). It is even possible to produce fuel, including fuel for aircraft with this method. Twelve was able to produce jet fuel from CO_2 in the air. According to initial tests by the company, the process is deployable and scalable which would allow to produce synthetic carbon-neutral fuel in larger quantities anywhere. If successful, the implications of this innovation could be profound. This would greatly facilitate access to fuel which is crucial for the conduct of military operations. Recent joint wargaming and operational exercises have underlined the significant risk that transporting, storing, and delivering fuel poses to troops – both at home and abroad.

48. **Batteries** operate through a chemical reaction that either recharges or discharges the battery and store energy in the form of chemical energy. Research into lithium-ion batteries, which have a higher energy and power density, continues to make them smaller, more powerful, and more effective. There is also research into other battery technologies, including aluminium or iron batteries. Batteries are also important for the storage of renewable energy, such as wind and solar power. Disadvantages of the current lithium-ion battery technology are that lithium requires large amounts of clean water to be extracted, which is diverted from communities and agriculture, and effective recycling infrastructure has not yet been developed for its disposal. Other disadvantages of current lithium-ion battery technology are the limited performance and charging problems of batteries in cold

weather and faster battery degradation and safety issues in hot weather. Additional disadvantages of batteries from a military perspective are long charging times and the necessary logistics for changing batteries in a contested environment.

49. **Hydrogen fuel cells** hold considerable promise for large-scale use in the military. Several nations have made research into hydrogen fuel cell technology a priority. However, they are currently an expensive and energy-intensive solution (hydrogen production) that has so far only been tested on a larger scale in submarines (Rühle, Heise, 2021; Roblin, 2021). In submarines, fuel cells provide operational advantages through quiet, long and deep dives. Fuel cells are also being tested in military vehicles, helicopters, aircraft, and tanks. Current disadvantages of hydrogen fuel cell technology include the inadequate infrastructure to ensure the production of green hydrogen and the related limited global availability of hydrogen as well as the relatively high production costs.

50. **Biofuels** such as bioethanol – which is made from corn and sugarcane – and biodiesel – made from vegetable oils and animal fats – have often been considered as the best medium-term solution to sustainable fuels[3]. However, biofuels are often used with conventional fuels. The most common form of the blend, called E10, is a mixture of 10% ethanol and 90% gasoline. Technological advancements seek to change the balance of this mixture, reaching up to 83% ethanol in new blends. However, biofuels, particularly biodiesel, are in fact carbon-negative as vegetables remove more carbon from the atmosphere than is released when they are harvested, processed, and burned for fuel. In addition, some fuel blends do not produce any significant reduction in greenhouse gases and could release more toxic and dangerous gases than CO_2 such as Nitric oxide (NO). In the United States and several other countries, government agencies are collaborating with research institutes and industry to develop next-generation biofuels made from wastes, cellulosic biomass, and algae-based resources (BETO, n.d.).

51. The move away from fossil fuels in the military will probably take place later than in the civilian sector, among others because the armed forces may for national security reasons be exempt from stricter civilian regulations. In addition, the lifetime of military equipment is often longer than in the private sector; this is particularly the case for aircraft. The private sector is therefore likely to introduce energy-saving equipment more quickly than the military. Fully transitioning from fossil fuels to renewable and sustainable energy sources is therefore not an easy fix and will not take place rapidly. For example, a US Air Force-supported project that aims to build a fuel plant that would use biomass instead of carbon monoxide would yield 16 million gallons of fuel per year (Roberts, 2016). This amount is only 1% of the total 2 billion gallons of jet fuel used by the US Air Force per year (De la Garza, 2022). In wartime, armed forces need vast quantities of fuel, which of course also requires the corresponding logistics for uninterrupted refuelling. Logistics supply chains are primary targets in any war, therefore reducing the need for fossil fuels will increase the resilience of military forces in operations. During the Afghanistan war, up to 30% of casualties were due to attacks on fuel and water convoys (Poland, 2021). Moreover, fossil fuels are also a finite resource, hence the Alliance must take serious measure of resource depletion before operations become unaffordable or unsustainable.

52. An important aspect to consider regarding investments into research on possible alternative energy sources is the energy density needed. The volumetric energy density of energy carriers (diesel, ammonia, hydrogen, lithium-ion batteries) varies significantly. Any investment in research into renewable energy sources to replace fossil fuels in the future needs to include realistic assessments of the technical operational challenges that military forces are likely to encounter. Moreover, as outlined above, most, if not all, new technologies necessary for the transition to renewable energy sources are based on rare earth elements and other critical raw materials. NATO

[3] Bioethanol and biodiesel are often referred to as “first-generation biofuels”.

and NATO Allies must avoid creating new dependencies on third countries, in their efforts to move away from fossil fuels.

53. As private companies and independent research institutes are leading efforts to develop climate change mitigation and adaptation technologies there is a clear opportunity for more collaboration between the private sector and NATO. NATO entities, particularly the STO and DIANA, can play crucial roles in deepening cooperation with the private and academic world.

VII- CONCLUSIONS

54. As a political-military Alliance, NATO's core tasks remain, as ever, collective defence, deterrence, and crisis management/cooperative security.

55. However, as extreme weather phenomena are increasing because of human-induced climate change, NATO and Allied member and partner nations need to prepare for these challenges. Available scientific data indicate that some of the climatic developments currently being observed are irreversible.

56. The effects of climate change need therefore to be higher on NATO's agenda. According to the IPCC, some of the effects of climate change are irreversible. Therefore, at the very least, NATO needs a process which allows a permanent adaptation of the risk assessment. Moreover, the Alliance needs to reflect the higher priority of climate change in its policies and strategic documents. The new Strategic Concept agreed upon by NATO Heads of State and Government at the Madrid Summit in 2022 gives this important issue higher priority. NATO and Allies also need to provide the necessary financial, personnel, and other resources to implement this decision.

57. Reducing the carbon footprint of Allied militaries will largely depend on technological progress. While private industry is a main driver of technological advances, NATO's STO plays an important part in advancing research on military and military-related technologies. The same is true of DIANA, the Defence Innovation Accelerator which is currently being set up by Allies. While the focus of their work differs insofar as they aim to promote S&T research at different Technology Readiness Levels (TRLs)[4] both need to develop close cooperation to ensure that future military capabilities will be adapted to climate change challenges.

58. Putting climate change higher on its agenda will also increase NATO's relevance for its citizens. However, the climate change policy of the Alliance must obviously not weaken member states' abilities to perform their core tasks of collective deterrence and defence. A realistic, gradual approach is therefore necessary. This highlights the need for a robust plan for the energy transition.

59. Cooperation among NATO member states on climate research needs to be improved and deepened. Similarly, collaboration with NATO partner countries is also important. The STO, which already has an extensive network of scientists, could consider a stronger emphasis on climate change research. Moreover, NATO should evaluate if and where the STO's resources can be strengthened and how an efficient cooperation between the STO's existing network of scientists and

[4] Technology Readiness Levels (TRL) is a measurement system first developed by the US National Air and Space Administration (NASA) to assess the maturity level of a particular technology. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the project's progress. There are nine technology readiness levels. TRL 1 is the lowest and TRL 9 is the highest.
https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level

DIANA's projects can be achieved. This is crucial if "NATO aims to become the leading international organisation when it comes to understanding and adapting to the impact of climate change on security" as stated in the 2021 NATO Summit Communiqué.

60. In addition to the Assembly's ongoing activities on climate change, NATO Parliamentarians can help their governments to provide sufficient funding for testing of energy-saving technologies for the military. The challenges posed by the negative effects of climate change are global. Moreover, NATO Parliamentarians should raise awareness among their fellow national parliamentarians about what the NATO S&T network can deliver and encourage their peers to make better use of this existing network. On the political level NATO should consider re-establishing a section at NATO HQ which focuses on "Strategic Foresight" to monitor the impact of climate change on the political, economic, and social stability of countries on the periphery of the Alliance. Such a unit could be attached to the Democratic Resilience Centre, which has been proposed by the NATO Parliamentary Assembly, and could provide advice to both NATO and partner countries upon their request.

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