Technical Report

How are the military handling energy?

An overview of international status and suggestions for the Brazilian Armed Forces

Luiz Pereira da Silva Neto ▪ Marcio José Sorgato

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Stricto Sensu Postgraduate Program in Energy Efficiency and Sustainability

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NOTICE

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Abstract

Energy is and will continue to be essential for military activities, especially in the 21st-century warfare context. Currently, there is a growing interest in the energy resilience concept applied to the military. The North Atlantic Treaty Organization (NATO), the United Nations, and the European Union have shown themselves attentive to the theme and many policies and actions have been implemented for reducing energy consumption, enhancing energy efficiency and sustainability, and increasing renewable sources in the global energy matrix. Countries as the United States, the United Kingdom, Spain, and Canada – all NATO allies – and Australia – a major non-NATO ally – have developed important ways to grow in energy resilience in its Armed Forces. In July 2019 Brazil was accepted by the US as a major non-NATO ally and this brings good opportunities for changes and new challenges for the Brazilian military also in the energy context. This report analyzed the energy-related policies and actions that are being carried out by the aforementioned international organizations and countries through research on official websites and papers. Presenting a brief background of how is the Brazilian Ministry of Defense status on this subject, it was proposed four insights for Brazilian Armed Forces keeping up with the military world trend in energy-related issues, especially approaches about resilience and security: structure the organization for energy approach, appreciate the human role, diversify the energy sources using renewables, and have a facilities-focused approach with emphasis in energy efficiency.

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List of Acronyms and Abbreviations

ANEEL	Brazilian National Agency of Electric Energy
ASDS	Assistant Secretary of Defense for Sustainment
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
Btu	British Thermal Unit
CAF	The Canadian Armed Forces
CICE	Internal Commission for Energy Conservation
CO2	Carbon dioxide
CONSERVE	Brazilian Energy Conservation Program in the Industrial Sector
DEES	Defense Energy and Environment Strategy
DND	The Canadian Department of National Defense
EB	Brazilian Army
EC	European Commission
EDA	European Defense Agency
EEAS	European External Action Service
EEGO	Australian Energy Efficiency in Government Operations Policy
EISA	Energy Independence and Security Act
ENSEC COE	Energy Security Centers of Excellence
EPAct	Energy Policy Act
EPE	Brazilian Company of Electric Energy
eqCO2	Carbon dioxide equivalent
ES2	The United States Army Energy Security & Sustainability Strategy
ETID	Spanish Defense Technology and Innovation Strategy
EU	European Union
FAB	Brazilian Air Force
GDP	Gross Domestic Product
GHG	Greenhouse gas

IEA	International Energy Agency
IESMA	Innovative Energy Solutions for Military Application Conference
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
MD	Brazilian Ministry of Defense
MPOG	Brazilian Ministry of Planning, Budget, and Management
NATO	North Atlantic Treaty Organization
OPUS	Brazilian Army Unified Works Process System
PBE	Brazilian Building Labeling Program
PROCEL	Brazilian National Electricity Conservation Program
RDT&E	Research, Development, Test, and Evaluation
SD	Sustainable Development
SENT	Smart Energy Team
SPS	Science for Peace and Security
SPS Program	Science for Peace and Security Program
UFC	Unified Facilities Criteria
UK	The United Kingdom
UK MOD	The UK Ministry of Defense
UN	United Nations
UNEP	United Nations Environmental Program
US	The United States of America
US DoD	US Department of Defense
Wh	Watt-hour (energy unit)
ZEB	Zero Energy Buildings

List of Figures

List of Tables

Table of contents

1. Introduction

Far from being a secondary concern, energy has always been and will continue to be essential for the military world. How energy is supplied, used, stored, or wasted in military facilities and operations is a key factor and results in vantages or disadvantages on the battlefield, defining the success or failure of the military in fulfilling their defense goals (Samaras, Nuttall & Bazilian, 2019). Military activity demands energy for its fixed installations – lighting, heating and cooling equipment, and devices – and operations – training, provision, and transportation of the military, their weapons, and platforms (Danezis, 2017).

The 21st century brought new challenges for the military worldwide. Following the civilian emphasis in seeking ways to conjugate sustainability and development, the military is engaged to meet the United Nations (UN) Sustainable Development Goals aiming to mitigate the effects of the probable extinction of natural resources due to unruly and prodigal use. The European Union (EU) Security Strategy states clearly the close connection between defense and sustainable development: there is "no sustainable development without peace and security, nor is there sustainable peace without development", showing that sustainable development and military actions must be pursued together (EEAS, 2012).

The energy consumption of military operations has increased because both camps and soldiers are using equipment with greater energy demand, there's inefficiency in using fuel generators in the fields, the tents have poor thermal insulation, and lacks awareness on energy consumption control (NATO, 2014c). With the great connectivity of all the components of military facilities, nowadays military bases are no longer understood as secure as they were before, and because of it, they became points of vulnerability (USA, 2019m). Not only the electronics used by the soldiers to enhance their safety and comfort but all components inside the military base are also massively energy-dependent – from the lighting systems, going through the military vehicles and food facilities until the communication and internet-based systems. The concerns about the electric power systems are crucial in the digital time, preventing also cyberattacks (Pires De Azevedo *et al.*, 2020). An interruption is not ruled outs and, as pointed by (Saritas & Burmaoglu, 2016), an energy outage would stagnate the military base, influencing tightly in its operational capacity.

Most military installations around the world have many buildings and different interactions among them and the users, which impacts the performance of the military in their missions. There is a growing interest in military bases become energy independents – zero or nearly zero-energy (Zhivov *et al.*, 2014; Zhivov & Case, 2017b; Case *et al.*, 2015; Zhivov *et al.*, 2010) – considering the specific energy needs for operational missions, the energy impacts on mission and security, the cost of energy, the availability of local resources, and the fulfillment of federal energy laws (Anderson *et al.*, 2011). However, applying the concept of zero energy to military installations in a way physically and economically viable requires

unconventional approaches to organization, implementation, financing, and technical decisions (Zhivov & Case, 2017a).

The need to continuously maintain the operational capacity of military installations even in face of problems related to interruptions and power failures has been known as energy resilience (USA, 2019m). Energy resilience is correlated with energy security. Therefore, for the military, there is a more important energy concern at a strategic level for strictly military-related activities comparing to the civilian world. It is very essential to provide an improvement in the energy resilience of the troops even on deployed or homeland bases because doing so military activity will absorb greater energy security, contributing also to sustainable development. (Baublys *et al.*, 2015) pointed out that by taking advantage of opportunities to reduce demand, using energy efficiently, implementing smart technologies, improving energy management, and encouraging the use of renewable energy sources, energy security will grow.

As State organizations, the Armed Forces have a fundamental role regarding the energetic development of society, as presented in the historical overview developed by (Macdonald, 2012). One of its conclusions made explicit that the state's dedication to implementing renewable sources in the military would influence the development of such sources across society. (Anderson, 2015) agrees with this conclusion, which shows how the military, in dealing properly with the problems of security and energy resilience in defense matters, will also influence how civil society deals with energy. The related technological development and energy policies and actions will be solutions applicable in the civil environment.

In this direction, several initiatives have been taken by international military coalitions, such as North Atlantic Treaty Organization (NATO), and both the European Union (EU) and the United Nations (UN) have been concerned with the energy resilience of military activities in their contexts. The objectives pursued are, for example, to maintain operational capacity on the battlefield, to mitigate post-conflict problems, to comply with international recommendations regarding the care of the environment, or even to increase the environmental awareness of preservation in the troops and civil society where the military has access to with their actions (EEAS, 2012). Organizations' decisions reflect in specific actions in the countries' Armed Forces, which have also individually considered energy as a crucial factor in the theater of military operations in both peace and wartime.

Brazil was accepted as a major non-NATO ally by the United States in 2019, which will intensify cooperation between the countries in the military field as well as with other NATO-allies (USA, 2019l). This new time brings great opportunities and big challenges for the Brazilian Armed Forces. They should follow the global trend of adapting the military activity to the demands of environmental care, sustainable development, and energy resilience and security. Some actions have already been taken within the scope of Defense, but there is still a long way to go. Accordingly, this report intends to answer the question: what policies and practices related to energy are being implemented in the military world that can be

applied to Brazilian military forces to keep them up-to-date for the 21st-century warfare demands?

For this, it will be presented an overview of how the military around the world deals with energy, pointing actions and policies carried out in reducing demand, increasing energy efficiency, and leveraging the use of renewable energy sources in the military environment. These will be presented to suggest the highlighted practices and policies that can be applied in the Brazilian military context, improving the energy resilience of the Brazilian Armed Forces.

There is a limited number of publications leading specifically to the military and their energy-related policies and actions. (Johnson & Boersma, 2015) compared to the United States and the European Union's approach according to energy security, not focusing specifically on military activity. (Closson, 2013) presented several policies and programs of the US Department of Defense (US DoD) pointing out the need for an important change in energy approach, seeking to reduce US DoD dependence on oil-based fuels. Also with the US DoD emphasis, (Strakos, Quintanilla & Huscroft, 2016) historically reviewed energy security facts, proposing a knowledge management framework to guide US DoD energy security research efforts. (Baublys *et al.*, 2015) analyzed the perspectives of energy consumption in Lithuania with a special focus on energy security. Briefly, the authors presented some NATO actions and studies running in that time, as well as European Union cooperation in this sense, and suggested actions to be implemented to overcome some shortcomings in this regard in the Lithuanian Armed Forces.

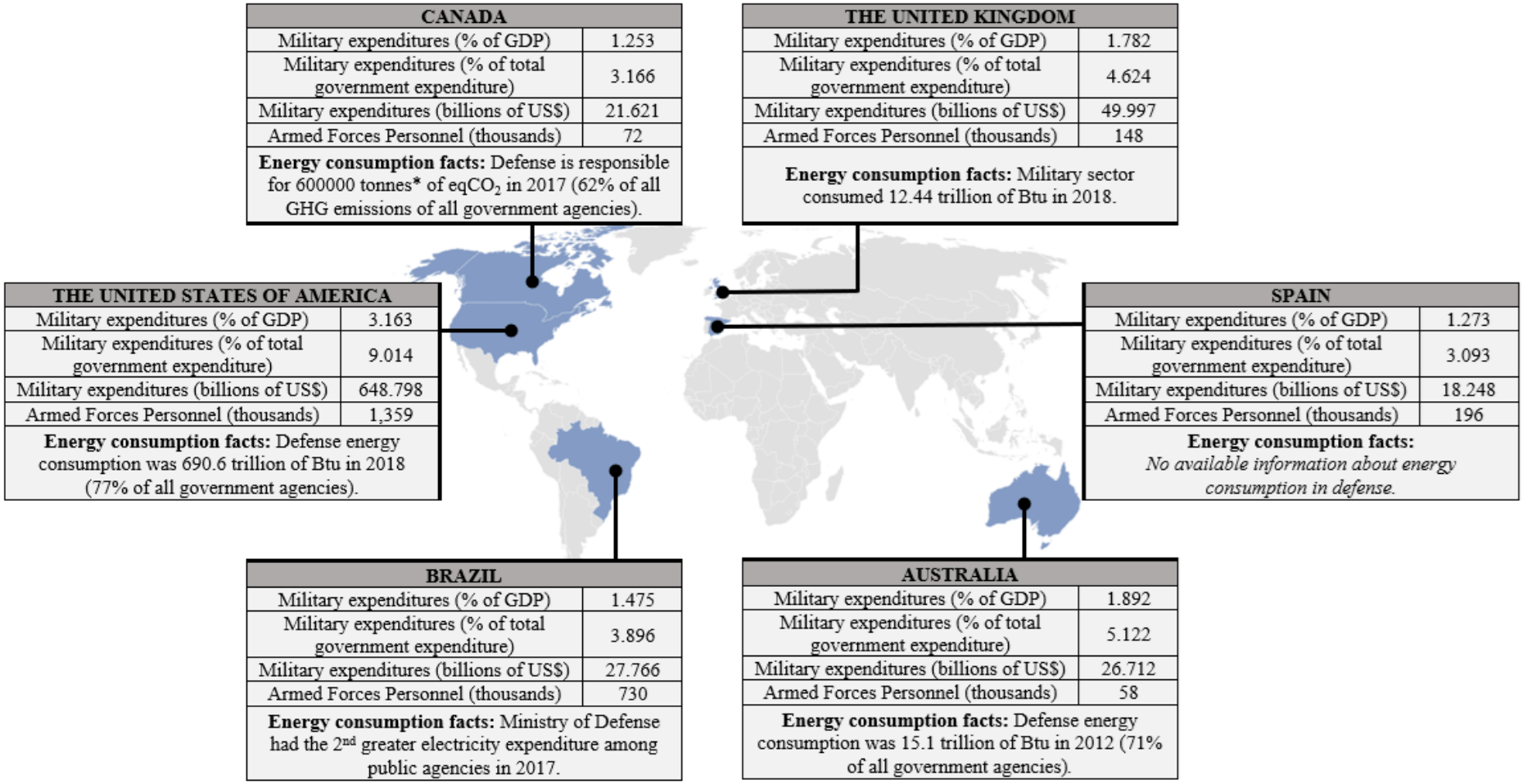
2. Methodology

Once Brazil was accepted as a major non-NATO ally, it is important to understand how NATO is conducting its actions related to energy as a military coalition. Not only this, looking for specific actions and policies of NATO allies is also adequate. Because of it, were chosen the United States of America, the United Kingdom, Spain, and Canada to be thoroughly investigated. Although the position of NATO allies according to this issue is relevant, it would be helpful to consider a major non-NATO too, for a more Brazilian-tailored analysis. For this, the Australia Defense Forces were chosen. Australia is a major non-NATO ally since 1989 and has strengthened relations with NATO allies, participating in many committees and programs, also supporting NATO operations and missions (NATO, 2020; Coffey, 2012).

Fig. 1 presents an overview of the Defense status in the countries analyzed. According to World Bank data, the US has the largest military expenditure among the countries analyzed, as well as the largest number of military personnel and high consumption of primary energy. The US military picture is very important for Brazil because, beyond the country having accepted Brazil as a major non-NATO ally, the American and Brazilian governments signed an Agreement for Defense Research, Development, Test, and Evaluation Projects (RDT&E) (Gielow, 2020). In the number of military personnel, Brazil is in second place among the countries analyzed; however, its military spending is comparable to Canada's and Australia's expenditure, which has more than 10 times fewer troops. Spain, despite having a larger force than the UK, has the lowest defense expenditure among the countries considered.

Once only a few numbers of publications are dedicated to analyzing the military and their energy approach, this report was based on extensive research of official documents and reports freely available on the internet. The first source used to investigate the energy-related actions and policies were the NATO documents freely available in the NATO LibGuides. This official multimedia library allows a broad view of what is happening in NATO and its allies in several issues. For the goal of this work, it was considered just the documents that are on the specific page on the topic of energy efficiency in the military (called in NATO of Smart Energy). In this way, for NATO and its allies, information was collected from reports, statements, articles in journals, etc. available there. Besides, country-specific actions were sought from what is on the referred portal for each country (in the case of NATO-allied countries) and/or from the respective Defense ministries or equivalent institution internet domains.

Fig. 1. Overview of military forces of the countries considered



Reference: (USA, 2020; WorldBank, 2020a, 2020c, 2020d, 2020b, 2020e; UK, 2018; Abertas, 2018; UK, 2019a; Australia, 2013; Sattar, 2018). *From buildings and commercial vehicles.

The European Union is an essential partner of NATO because many of the member states of these two international organizations are common and they are working in close cooperation, especially after the Joint Declaration of Warsaw in 2016. There is a great interest in energy concerns by the European Commission and the European Defense Agency (EDA), with efforts to reduce energy consumption and strength renewables. For example, the total energy consumption of the Armed Forces of the 22 EU Member States was 137.39 trillion Btu in 2017, 2.8% lower than 2016 consumption (EDA, 2019b). With this in mind, it will be also presented some actions and policies of the EU member states and their Armed Forces.

Brazilian Armed Forces operate in United Nations Peacekeeping Missions since the Emergency Force to address the Suez crisis in 1956 and currently serve in 10 UN missions globally (UN, 2020). The UN Peacekeepers have also under attention to its energy management once the inventory of UN greenhouse gas emissions showed a large contribution of diesel used in electric power generators or operational military vehicles and the fuel used in airplanes of such missions. Together, they totaled 56% of the total greenhouse gas emissions of the entire UN – 972,304 tons eqCO_2 in 2008 (Nyitrai, 2017). Because of it, a special topic related to the energy-concerns of the UN and its peacekeeping missions will also be presented. The information for the UN and the EU was obtained through surveys in reports and official documents from these international organizations freely available on the internet.

For Brazil, the information was obtained through research in specific military legislation regarding the issue, as well as other documents, news, and reports found in the Ministry of Defense and the Armed Forces' internet domains.

3. Military overview

3.1 NATO as a coalition

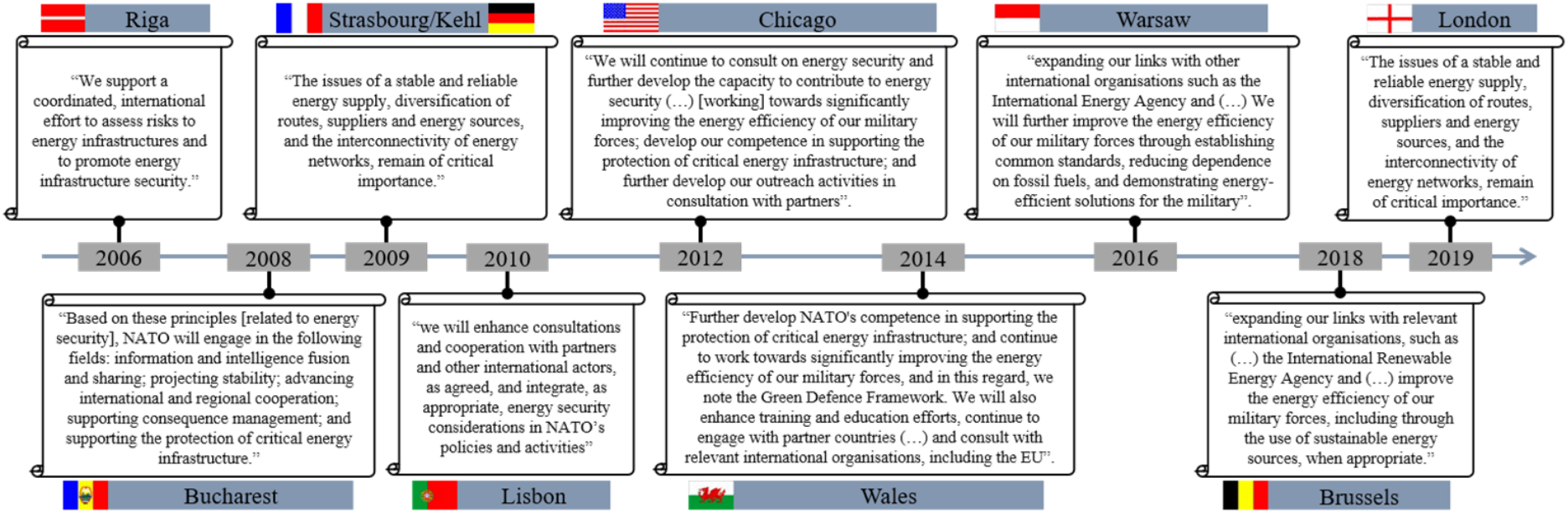
As a primarily military alliance, NATO-allied countries are concerned about energy supply. Always considering security implications, NATO's objectives are to enlarge troop resilience through stable and reliable sources of energy; to protect energy infrastructure in critical areas; to diversify power lines and energy sources and the interconnectivity between power networks; and to promote greater awareness among allies and partners as well as cooperation with the private sector, academy, and other international organizations in research for energetically safe and efficient solutions for military, reducing the vulnerabilities linked to political or economic manipulations (NATO, 2018a).

These concerns can be identified in the NATO Summit's Official Texts. Starting in Riga's 2006 and with a special focus after Chicago's 2012 (Fig. 2), the documents bring energy-related commitments. In 2011, NATO started to treat military energy efficiency as "Smart Energy" and, in 2012, Smart Energy Team (SENT) was established, having the goal of identifying and highlighting the best multinational energy efficiency practices with a focus on military ground operations (NATO, 2015). Resolution 407, published in 2013, recognized the urgency of allocating resources for research aimed at improving energy efficiency in military installations and operations, despite budgetary pressures. Among the established priorities is the effective accountability of energy consumption, the reduction of energy demand for fixed or operating installations, and the diversification of energy sources using renewables (NATO, 2013).

In 2014, NATO's Framework for Green Defense was launched, providing a basis for allied countries to cooperate on sustainable defense solutions (Fig. 3), and NATO Green Defense Concept was also presented, combining operational and security-related challenges in military exercises, such as budget, energy security and global climate change (Fig. 4) (Nyitrai, 2017; Larsen, 2015).

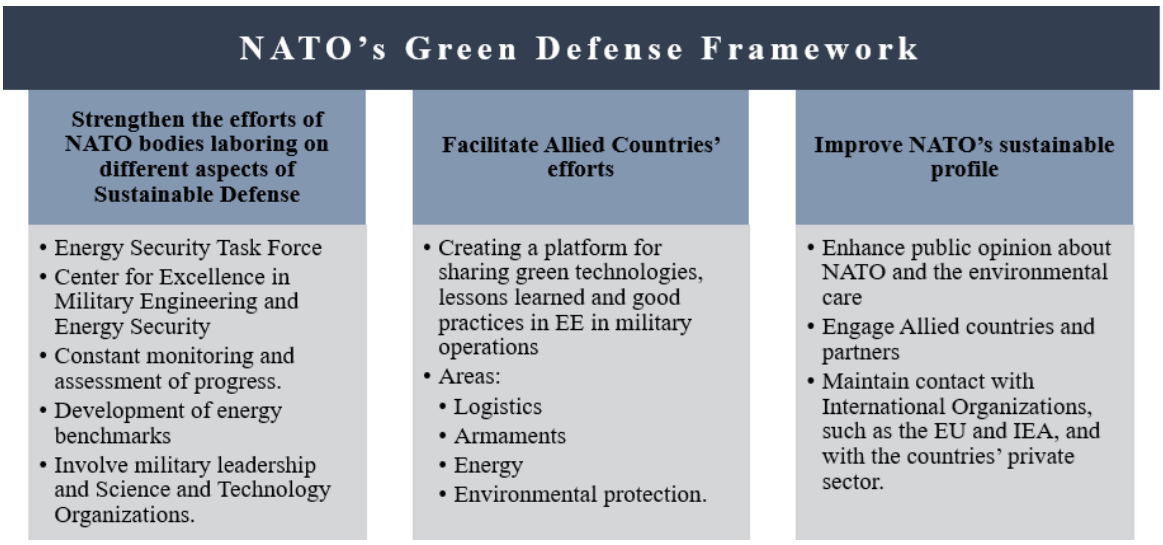
Within the NATO Science for Peace and Security (SPS) Program, military engineers developed the Sustainable Military Compounds Project aiming, among other things, to develop a conceptual model of military infrastructure considering more energy efficient generation (NATO, 2014c). The Policy on Power Generation for Deployed Force Infrastructure provided the principles of modularity, interoperability, and sustainability and the guidelines of energy planning and management, infrastructure project and management, and command and control training and awareness for increasing energy efficiency in military operations (Fig. 5).

Fig. 2. Highlights of NATO summit declarations related to energy



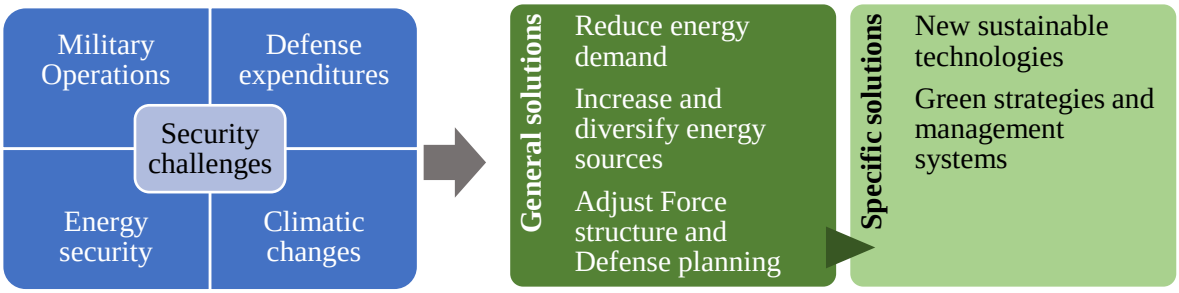
Reference: (NATO, 2006, 2008, 2009, 2010, 2012, 2014b, 2016, 2018b).

Fig. 3. Pillars of NATO Green Defense Framework



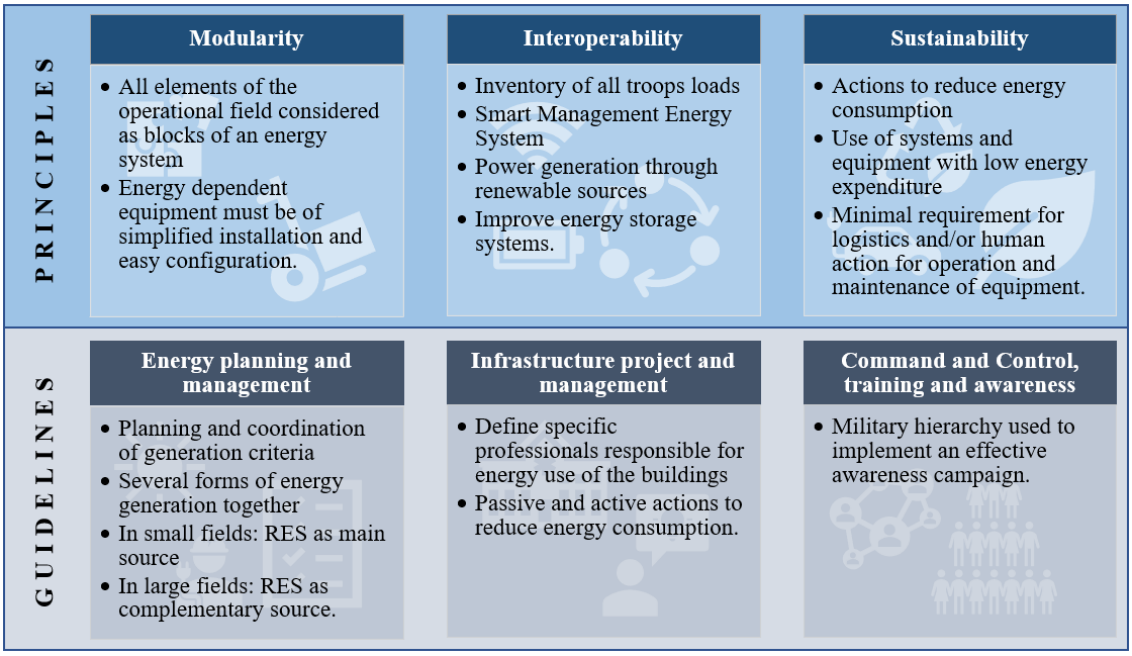
Reference: (NATO, 2014a).

Fig. 4. NATO Green Defense Concept



Reference: (Larsen, 2015).

Fig. 5. Power Generation Policy Principles and Guidelines for Mission Power Infrastructure



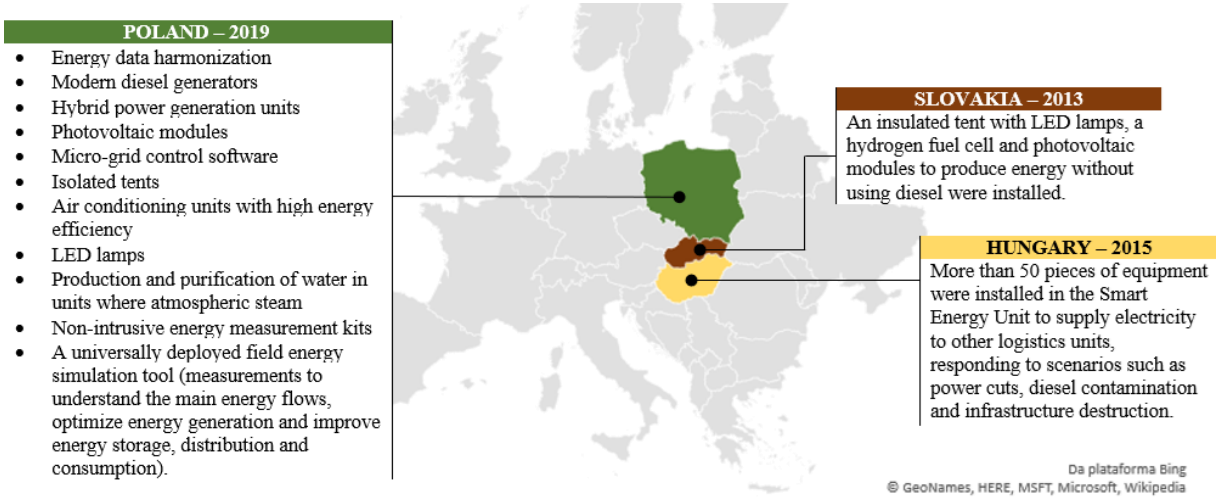
Reference: (NATO, 2014c).

The Framework, the Concept, and this Policy point out the need for a strong and holistic conceptual basis for energy-related issues, with the special attention required from commanders for the effective application of policies in their bases. Once the principles focus on modularity, interoperability, and sustainability, they point out for all-circumstances operations. All the electric-dependent elements for the military activity should be completely tracked and redundant power sources are required, either by multiple external electrical supplies or by local generation and storage. The guidelines made explicit the necessity of having personnel dedicated exclusively to energy-related issues throughout the planning and accountability process.

To work educating and training on energy-related issues in military activities, the NATO Energy Security Centers of Excellence (ENSEC COE) was established, as a strengthening effort to NATO's branches to work for Sustainable Defense, obeying the first pillar of the Green Defense Framework. They are international military organizations aimed to provide expert advice on issues related to operational energy security, through courses and events, such as the Innovative Energy Solutions for Military Applications (IESMA) and the Capable Logistician Exercises (NATO, 2019).

In these exercises, there is a Smart Energy Unit, which aims to demonstrate the potential of innovative technologies to reduce fuel waste in operations, explain the benefits of energy efficiency in increasing operational efficiency, test the interoperability between the technologies and evaluate the NATO standards in this regard. Fig. 6 presents some highlights of the Smart Energy Unit carried out in the Exercises in 2013, 2015, and 2019. In addition to the actions already cited, NATO has also held since 2015 The North Atlantic Council's Annual Seminars on Global Energy Developments and the Strategic Energy Security Awareness Course, as a way to engage other sectors to Defense contributing to a cleaner NATO's energy profile (NATO, 2018a).

Fig. 6. Highlights of the Smart Energy Unit in NATO Capable Logistician Exercises



Reference: (Michaelis, 2019).

SENT elaborated a comprehensive report in 2015 based on responses from 13 countries to a Questionnaire on energy efficiency initiatives carried out in the country. Among the best practices made explicit in the document is, for example, the privatization of energy services in military installations, which allows companies from the private sector to install up-to-date technologies, becoming responsible for all maintenance in the military installations. The report showed that most national efforts are focused on improving energy efficiency for infrastructure within countries and only a few nations address energy efficiency during military missions. Although many NATO-allies have invested significantly in research and have successfully implemented energy efficient technologies and the existence of a desire and willingness to share knowledge and work collaboratively, most national initiatives were being conducted in isolation from other nations and there is a lack of cooperation among the defense, scientific, industrial, and operations communities (NATO, 2015).

The study concluded that an energy efficiency strategy or structure and an official representative were needed to centralize all matters relating to this so that the topic became part of NATO's organizational structure, conducting a more systematic approach to energy in countries, especially integrating energy with other sectors. For this purpose, public strategies, studies, reports, and articles on energy efficiency were made available to the public on the NATO LibGuide electronic platform "Smart Energy", serving as a sharing tool for allied countries as required in one of the pillars of the Green Defense Framework (NATO, 2015). The main fields in which energy efficiency actions are taking place according to SENT Report are cooling, heating, and ventilation systems in buildings; the reduction in fossil fuel use and GHG emissions; the integration with renewable energy sources; and adaptation to climate change. Among the main needs founded in the experiences reported by the countries are the need of modeling the military environment in energy terms, demonstration of efficient technologies, and make interoperability between technologies in the same military exercise (NATO, 2015).

The SENT report recommendations are important to be considered. They emphasize the need to having a robust, strong, clear, and standardized view of energy-related issues in NATO's military activities, putting great importance on the human factor, either by improving inside awareness or looking outside for contacts that add knowledge for the improvement of energy resilience and security in Defense actions (NATO, 2015).

3.2 NATO allies

3.2.1 United States of America

The US DoD is the largest energy consumer among American federal agencies, accounting for 77% of the energy consumption of all federal agencies in 2018 – 690.6 trillion Btu (USA,

2019h). Although large, this percentage is the minimum of the historical series that started in 1985, when US DoD's participation was 86%. This reduction was due to the implementation of mechanisms to meet the federal government's goals regarding energy use. Some American federal laws applied to public agencies and followed by the US DoD are listed in Fig. 7.

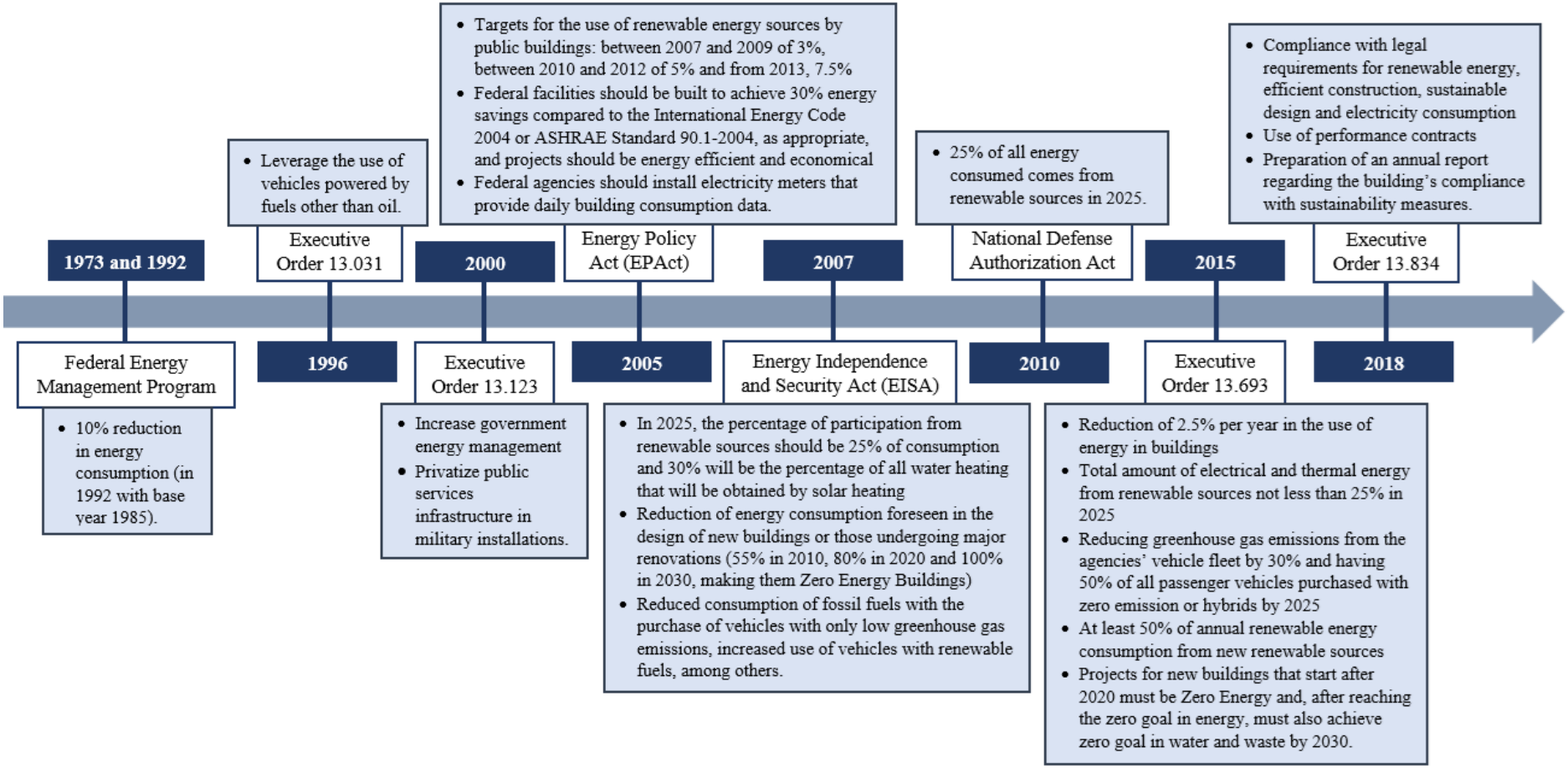
A greater interest in new technologies for energy supply to the American Armed Forces was driven by bad experiences with the provision of fuel for troops during conflicts in Afghanistan and Iraq (Nyitrai, 2017). At that time, there was a clear relationship between the demand for fuel on the battlefield and the number of military personnel killed in tank-protection actions on trains (Deloitte, 2009).

The US DoD in 2009 began to account for the real cost of logistics for diesel oil used for power generation and transportation. The results showed that many costs were far beyond what was imagined (the kWh produced by a diesel generator costing almost 16 times higher in wartime compared to the national average cost in 2011) (Closson, 2013; Nyitrai, 2017). Also, the increase in the oil price in the 2000s, culminating in the oil crisis of July 2008, meant that the DoD's spending on oil reached almost US$ 18 billion (Closson, 2013). Regarding the impact of fluctuating oil prices on military activities, a study warned for the need for greater attention from decision-makers concerning the availability of energy sources for military activities (Liska & Perrin, 2010).

The US DoD has also been concerned with the effect of climate change and natural disasters on military installations, as well as on the Force's operations (USA, 2019k). The American Armed Forces have to meet various objectives and submit to different restrictions with a focus on obtaining energy at the lowest possible cost but with high reliability and minimum vulnerability, so as not to impair military operation (USA, 2019a).

The Operational Energy Strategy was launched in 2009, which resulted in an internal plan composed of actions such as measuring operational energy consumption and adopting energy policies in military education and combat activities (Closson, 2013). The US DoD Instruction 4170.11, launched in 2009 and updated in 2018, established a decentralized energy program with public and private funds for the facilities' energy management. The facility managers became responsible for raising awareness, developing and implementing energy projects, and ensuring that the projects they developed would follow sustainability principles and meeting federal energy objectives (USA, 2018a). Table 1 presents the main points of this Instruction.

Fig. 7. Timeline of some US government actions towards more energetically sustainable public agents



Reference: (USA, 2015; Zhivov *et al.*, 2013; USA, 2019j, 2019a, 2019n, 2019i).

Table 1 Strategies for Instruction 4170.11 implementation

Strategies of implementation	Guidelines
Awareness campaign	Training and education, with advertising campaigns Recognize the facilities that have best-implemented energy-saving measures Promote a show with facilities where energy efficiency measures are well implemented.
Investments in water and energy efficiency	Use of equipment with EnergyStar® seal or equivalent An incentive for buildings to participate in the EnergyStar® Building Program Solar water heating Analysis of the cost of the building's life cycle Energy-saving performance audits and contracts Partnerships with the private sector to finance actions.
Energy resilience	Identification of critical energy demand Preparation for emergency energy situations Attention to infrastructure, equipment, fuel, and power generation system tests (diesel generators and renewable energy sources distributed generation) Constant vulnerability assessment resulting from the interruption of the energy supply. Purchase energy from renewable energy sources or generate, in the barracks, energy from alternative renewable sources, such as wind, solar, biomass, geothermal, etc. On-grid and off-grid solutions should be sought when they are economically viable Competitive opportunities in the electricity and natural gas markets (e.g. large-scale purchasing).
Energy efficiency measures	Use of energy control and management systems or other similar technologies Each body must establish specific policies and criteria for the installation of meters to verify the consumption of all types of energy in buildings Identification of load reduction techniques for buildings and facilities.
Privatization of facilities	Establishment of a privatization program for military installations, whenever economically viable and without jeopardizing the security of operations.

Reference: (USA, 2018a).

The Assistant Secretary of Defense for Sustainment (ASDS) is responsible for several programs and initiatives that aim to comply with national laws on the subject, such as a specific program for energy resilience, which the main goal is to get a cost-effective, energy-saving, and mission-adapted solution for the energy supply of the military bases. The utility privatization initiative also is very interesting, once military installations benefit from the innovative practices, by the reliability of updated, sage, and environmental-friendly energy systems, and by the private sector financing and efficiency. It results in energy at a lower price and the military can keep them focused on essential defense missions and functions. The ASDS also recognizes military installations successful in making resources available and developing innovative solutions to address the complexities of operating the facility, by giving them the Chief's Annual Award for Installation Excellence (USA, 2018a, 2019g, 2019c, 2019e).

Besides that, distributed generation was incentivized (USA, 2019f) and there is an office specialized in promoting energy resilience initiatives, keeping in touch with other federal

agencies, the private sector, and energy utilities. Also, reports are sent to Congress on power outages in barracks (USA, 2019d) and the US DoD drafted documents aimed at improving efficiency in military logistics, and investments in technology took place through public-private partnerships (Closson, 2013).

Among the several regulations that the US DoD is launching to leverage energy efficiency actions in its buildings, stands out the Unified Facilities Criteria (UFC), which are a compilation of criteria that the department's facilities should follow to comply with federal regulations about energy efficiency and renewable energy sources use. A review of the key points of some of them is shown in Table 2.

Table 2 Key points of some US DoD United Facilities Criteria

Year	UFC	Key points	Reference
2008	Energy conservation	Realization of Energy Compliance Analysis for buildings, proving by computer simulation the energy savings provided for in the project and the cost analysis of the project building life cycle.	(USA, 2008)
2018	DoD Building Code (General Buildings Requirements)	Standard sustainability criteria for all DoD construction projects Audit mechanisms to verify and guarantee the fulfillment of the criteria for military constructions Consideration of associated climate impacts.	(USA, 2019b) (USA, 2019k)
2018	High Performance and Sustainable Building Requirements	Brings a holistic view of the building, considering all its systems in an integrated and multifaceted way, evaluating the strategies adopted, the location and the suitability of the project to the location (orientation, thermal insulation, the potential for lighting and solar heating, accessibility, etc.), as well as establishing commissioning strategies Life-Cycle Cost Analysis, comparing, still in the design phase, net savings between at least three different design alternatives that meet the same performance requirements but differ to initial and operating costs Ratifies or establishes new goals to reduce energy consumption and provides recommendations regarding the health of the occupants of the barracks, the type of material used in buildings, care with the use of water, correct disposal of waste, ways of measuring energy consumption, and considerations about the risk of climate change for military buildings Encourage barracks for local renewable generation in facilities or throughout the facility.	(Fuller, 2016) (USA, 2018b)

The US Army has its strategy related to energy (Energy Security & Sustainable (ES2) Strategy), which is considered a turning point in the Army's approach to this subject. It's based on the principle of energy resilience and realizes the new foundations underlying

combat as energy, sustainability, security, resilience, and rapid change (USA, 2015). Some US Army actions are noteworthy, such as the energy benchmarking of military buildings, the establishment of energy use goals according to building type and climatic zone, and a Net Zero Initiative was launched to implement the zero-energy concept to the Army's military bases, testing ZEB technologies in concepts. The pilot project had 17 installations covering a great diversity of types of buildings within the Army (USA, 2017a, 2017b; Dorvee, 2018; Kingery, Keysar & Harrover, 2019; USA, 2016).

3.2.2 United Kingdom

The United Kingdom has shown a commitment to establishing energy as a high priority parameter in foreign policy, with a focus on protecting energy supplying branches and engaging with energy producers by encouraging investment in a transition in the use of oil and gas, increasing-price stability, promoting the growth of low carbon technologies, encouraging energy efficiency, and improving the reliability of energy supply (HM Government, 2010).

The UK Ministry of Defense (MOD) established the Defense Sustainable Development (SD) Strategy, whose principles are the resilience of defense in face of current and future environmental, social and economic threats, and the minimization of the negative impacts of defense activities on the environment, the population, and the economy. The objective is to prioritize sustainable development so that all Departments make their policies, build their buildings, and purchase goods and services in a sustainable way (UK, 2011).

Among the objectives of this strategy, there is an expected reduction of the Armed Forces' dependence on fossil fuels for operations (18% by March 2020) and of GHG emissions from the infrastructure and logistics of the Defense (the government target is 80% less consumption in 2050 than in the 1990s). Besides, there is a commitment to seek sustainable construction. For this, all locations, activities, and equipment must have an Environmental Management System, which will serve as a reliable database (UK, 2011, 2019b).

Defense infrastructure management is a priority in this strategy, bringing positive impacts even on communities close to the bases. There are also actions to improve the transparency and accountability of agents responsible for sustainable development, with the definition of the SD Management Framework, which contains an overview of government officials, management documents, reports, and the training process (UK, 2011).

Concerning buildings, the UK MOD specified standards for energy, water, waste, and fuel infrastructure on military bases and guided how data should be structured and what information requirements are needed to support facility management. For building management, the Generic Base Architecture approach is used, to improve the effectiveness and efficiency of the installations, through the standardization of the interfaces of

integrated systems. The concept behind this is modular open-standard system architecture, integrating the efficiency of equipment, vehicles, and services within a military installation, increasing operational agility and reducing cost (UK, 2014).

Also, there are some energy awareness initiatives within barracks. The Strategic Behavior Change Program covers the use of energy, waste, and water, and offers a series of initiatives since 2015, such as the development of an electronic learning module on the consumption of facilities, research on practical alternatives to the wide range of existing behavioral models and theories, the energy reuse of waste and an Infrastructure Management System (UK, 2018).

3.2.3 Spain

The Spanish Ministry of Defense launched the Defense Technology and Innovation Strategy (ETID, Spanish abbreviation), which is a public reference tool to improve coordination and more efficiently manage research and technological innovations within the Ministry. The ETID objectives are to develop more efficient systems for energy generation, storage, and management, and diversify the energy supply chain through renewable energy sources, which reduce the oil dependence and the environmental impact (España, 2010, 2015).

The Technology and Innovation Portal of the Ministry of Defense works integrating the entire national technological community of Defense, concentrating publications of various research from the private sector related to the area of technological innovation in Defense. The works deal with options for micro networks applied to military bases, efficient energy storage systems, feasible analysis of self-supply of military bases with renewable energy sources, portable solutions for energy supply, autonomous photovoltaic systems, integration of electric power generation in buildings, medium power wind systems, etc. (España, 2018, 2011).

3.2.4 Canada

The Canadian Department of National Defense (DND) launched the Defense Energy and Environment Strategy (DEES) in 2017, setting guidelines and targets for sustainability in the Canadian Armed Forces (CAF). This document jointly meets the demands of Canada's new Defense Policy, NATO, and the UN Paris Agreement, besides improving the operational readiness and resilience of CAF. Its objectives are divided into 4 areas: energy efficiency, sustainable operations, sustainable acquisitions, and sustainable real estate. Regarding the measures to be implemented in buildings, stands out the Building Certification requirement, the designation of energy managers, the implementation of energy performance contracts, and of opportunities to use clean energy at all bases (Canada, 2017).

There are several studies before the launch of the current DEES dealing with the energy management of CAF: (Ghanmi, 2013) simulating energy consumption in military operations and (Vlachopoulos *et al.*, 2015; Basso, 2012; Vlachopoulos & Basso, 2013; Kegel *et al.*, 2013) considering more energy-efficient options, sustainable and energy-conserving for military buildings. Besides, there are environmental management studies with a focus on waste reduction, including considering zero-waste options (Friesen, 1998; Pascariu, 2016). However, studies on the insertion of renewable energy sources are still lacking beyond those already carried out by (Labbé *et al.*, 2014; Labbé, 2016).

3.3 Australia, an example from a major non-NATO ally

Following the mandates of the Energy Efficiency in Government Operations (EEGO) Policy, the Australian Department of Defense has developed a comprehensive energy management strategy installing meters at the bases, aiming for better monitoring and energy management, with clear end-use (Australia, 2007b).

The Defense Energy Policy established that Australian Defense is committed to reducing energy consumption, GHG emissions, and demand, to promote permanent cultural change concerning energy management across the organization, and to demonstrate to all stakeholders the need to continuously improve energy performance with appropriate targets and benchmarks. The components of this Policy are functions and responsibilities, awareness and training, business processes and systems, energy performance and monitoring, and follow-up (Australia, 2007a). The 2014-2019 Defense Estate Energy Strategy established four objectives: improve the efficiency of existing equipment and assets, provide new equipment and efficient infrastructure, conduct energy-saving behavior, and use energy from alternative and renewable sources (Australia, 2014).

Withal, the Department of Defense required, in its Smart Infrastructure Handbook, that should be considered the inclusion of a wide area of renewable generation and storage in buildings, smart grids, and the generation and storage of renewable energy sources in small- and large-scale (Australia, 2019).

3.4 European Union

Aiming to comply with the European Union's legal requirements regarding the care of the environment in military activities, the European Defense Agency (EDA) launched, in 2011, an initiative known as Military Green (Nyitrai, 2017). The initiative's vision was "to act as a European driver for effective and sustainable defense and crisis management through a proactive increase in energy and environmental responsibility" (Rempling, 2013).

In 2012, the EU Military Staff developed the European Union Military Concept on Environmental Protection and Energy Efficiency for EU-led military operations, which is a strategic guide on how to take into account energy efficiency and the use of renewable energy sources in military operations, establishing responsibilities for all agents involved (Nyitrai, 2017). The areas of activity are to prevent and to reduce environmental damage, to do waste management, to increase energy efficiency, to recover negative environmental effects, and to protect environmental facilities and resources (EEAS, 2012).

The Energy and Environment Programme was launched to create and comprehensively understand the energy management of military activities, besides, to identify solutions that integrate both energy reduction and low environmental impact (EDA, 2015b). One of the noteworthy actions of this program was the Power Purchase Agreements. It is a business model in which military bases from 7 member states jointly participated in a single contract, reducing implementation costs. The investment came from public-private partnerships and consisted of installing modules for photovoltaic generation on the roofs and the ground of military installations. The program also launched the Smart Energy Camp Technical Demonstrator works as a platform for testing an intelligent demand management system in the military environment. In this context, different photovoltaic modules technologies in different climatic conditions, as well as storage options and the collection of reliable data for energy benchmarking. The program is also conducting the Consultation Forum for Sustainable Energy in the Defense Sector. It is a set of plenary and working groups with energy and defense experts together to share energy management information and best practices (EDA, 2012b, 2012a, 2015a, 2019a, 2017b, 2016).

The Consultation Forum brought interesting insights to understand how energy efficiency has been implemented in the military context in the EU. The first phase presented some obstacles for the fulfillment of the legislation related to energy, such as lack of connection among the plans for energy acquisition, energy efficiency, maintenance, and awareness of energy consumption; segregation of functions (who manages the resource is not who holds the budget) causes a disincentive to energy efficiency actions; lack of benchmark and adequate data on military buildings; high return on investment for projects with alternative sources; lack of resources to implement measures to improve energy efficiency; and lack of awareness and knowledge about ways to finance it. Besides that, Defense restrictions also make access to energy management, energy generation, and energy efficiency technologies more difficult compared to the civilian environment (EDA, 2017a). These problems are related to the low participation of renewable energy sources in the energy matrix of the European Armed Forces – in 2017, only 0.64% (41,052 MWh) of energy consumption came from renewable generation on-site (EDA, 2019b).

The second phase sought more tangible projects, such as the reformulation of the standards for Nearly Zero Energy Buildings, the viability of district energy projects, and the development of more intelligent buildings and smart grids of easier implementation (EDA,

2017a). Understanding the difficulties in obtaining financial resources for the development of energy efficiency projects in military installations, since they are public entities, EDA has sought to guide them in search of financing for such investments in public and private investment funds (Rempling, 2013). A methodology was adopted combining several proposals collected with possible financing opportunities, facilitating implementation (EC, 2019). Furthermore, opportunities for financing to energy efficiency projects are published in annual reports and a digital platform was made available in 2019 to verify which kind of funding a given project can be applied to receive resources (EDA, 2019c).

3.5 United Nations

The UN has shown concern for the protection of the environment and the management of natural resources at a global level, including the military actions that the armed forces of the countries of the organization carry out in conflict areas, the peacekeeping missions. Peacekeepers' operations are responsible for a considerable share of the United Nations' energy consumption and, to mitigate it, the UNEP has an initiative known as "Greening the Blue", referring to the color of the helmets that the military use in these peacekeeping missions, which is blue. The objective is to reduce the consumption of natural resources and the production of waste, reduce potential conflicts with local communities, protect the environment, make UN operations a reference for sustainable practices, and reduce the cost of peacekeeping missions, improving peacekeepers' self-sufficiency and resilience (UNEP, 2019).

The UN started this journey with the 2007 United Nations Climate Neutrality Strategy, with the commitment of all agencies, funds, and programs to move towards climate neutrality – fully offsetting carbon dioxide emissions generated by its activities –, making the UN more sustainable with the quantification and efforts to reduce greenhouse gas emissions by its organs (UN, 2014). A survey carried out in 2008 identified that the energy consumption of peacekeeping missions accounted for more than half of all UN consumption. As a result, the 2009 Environmental Policy for UN Field Missions was developed, providing guidelines for environmental care in peacekeeping missions as well as requiring that each mission establish its environmental policy and control measures for each phase of the mission, to improve the operational performance of the troops and the effective implementation of the legal requirements of peacekeeping missions (UNEP, 2012).

This policy was assessed in the 2012 Executive Summary of Greening the Blue Helmets. Regarding the limitations made explicit by this report, it's important to mention the lack of awareness about the types of efficient technologies available within the standards required by the UN material acquisition channels, the lack of training of personnel in the mission regarding environmental care, the lack of tools to attest the conformity of environmental practices and the non-sharing of good practices among different missions (UNEP, 2012).

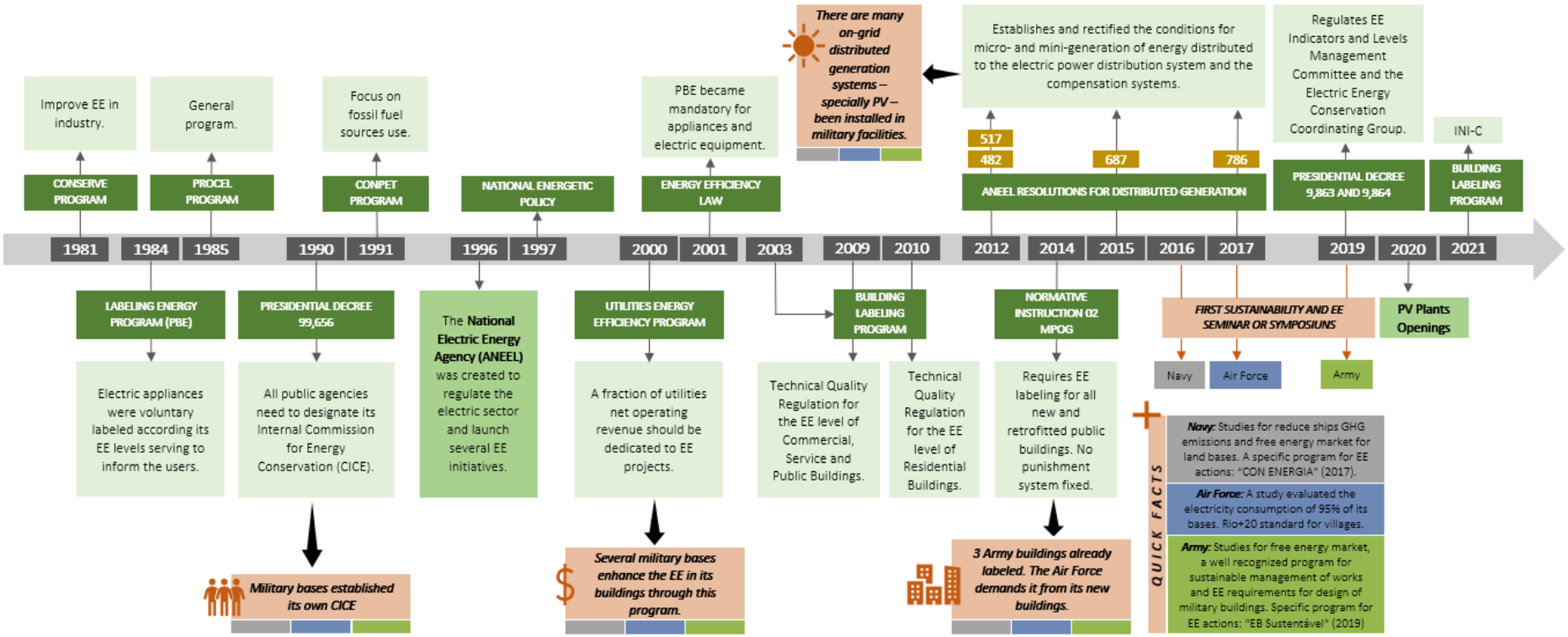
In response to the report's recommendations, electronic training modules were developed to support UN peacekeeping missions in better management of the environment resources (Scott & Khan, 2016) and the new UN strategy emerged, focusing on five areas: energy, water used, and wasted, garbage, impact on wildlife, and environmental management systems. This strategy aims, by June 2023, to make UN peacekeeping missions "responsible, achieving maximum efficiency in the use of natural resources and operating with minimal risk to people, societies, and ecosystems, contributing to a positive impact on them, whenever possible" (UNEP, 2019). For this, the UN is committed to improving efficiency, achieving climate neutrality by 2020, and internalizing its Sustainable Development goals in its processes. Among the actions shown in the 2012 and 2018 Greening the Blue reports, can be found the use of renewable energy sources to substitute diesel generators in the bases, zero-energy offices around the world, energy management systems for buildings and vehicles, and awareness campaigns (Nyitrai, 2017; UNEP, 2012, 2018b, 2018a; WFP, 2018).

3.6 Brazil's background

The energy concerns of the Brazilian Armed Forces are mainly related to military installations, with a scarce approach for military operations. The Brazilian Ministry of Defense (MD) launched the Green Defense Book in 2017, in line with the update of the official Brazilian Defense-related documents. The document addresses several actions by the military Forces regarding environmental management, recovery, support, and sustainability. Regarding the latter, there are three perspectives defined by the MD: the ideal use of energy; the handling of residues and substances; and how military installations are built and maintained (Brasil, 2017).

However, it was not found any legislation dealing with energy efficiency and the use of renewable energy sources published by the MD. Some references to sustainability are found in *MDLegis*, the web-platform of MD legislations', focusing mainly on environmental damage analysis. The Green Defense Book is an information document, not containing targets or obligations established for the application of Defense agencies. It just ratifies the constitutional commitment of the Armed Forces regarding environmental care (Brasil, 2017). Beyond that, there is no data on energy consumption of military buildings or operations, even in the recent report published in a milestone work between the Brazilian Company of Electric Energy (EPE, Portuguese abbreviation) and the International Energy Agency (Brasil, 2020c). Despite this, the three Forces have developed actions and are publishing or working on legislation regarding these themes, most of them not still open source. The Armed Forces are taking such actions motivated by the energy-related laws, actions, and decrees for public agents in Brazil. Fig. 8 presents a timeline of them, presenting the main points, and how these government actions are influencing military bases.

Fig. 8. Timeline of Brazilian energy-related laws, actions, and decrees with impacts for military bases and some quick facts about specific actions from Armed Forces



References: (Altoé *et al.*, 2017; Brasil, 2020a; PBE, 2020; Brasil, 1990; ANEEL, 2020a, 2020b; Brasil, 2019e, 2001, 2019c, 2019b, 2018, 2017; ANEEL, 2012, 2021; Peccini, 2017; Brasil, 2014, 2019a, 2019d, 2020b; BRASIL, 2021)

Military bases established their Internal Commission for Energy Conservation (CICE, Portuguese abbreviation) and are using financial resources from utilities to improve their energy efficiency. Thanks to the excellent availability of solar irradiation in Brazilian territory and the National Agency of Electric Energy (ANEEL, Portuguese abbreviation) regulations about distributed generation, there are several initiatives for on-grid generation, beyond some other initiatives for off-grid solutions for isolated bases, in the Amazon and Wetland Regions. Some of these bases received, even in the 1980s and 1990s, micro and mini hydroelectric plants (Huss, 2020).

Despite the requirements of Normative Instruction 02 of MPOG (Brazilian Ministry of Planning, Budget, and Management), as there was not a framework to a wide labeling implementation neither a punishment for no fulfillment, the number of military buildings proven as efficient according to the Building Labeling Program is short. Although, energy-related concerns are becoming more common to military leadership and the Forces are working towards more efficient use of energy, especially in its buildings. There are specific programs with this goal and events happening for sharing knowledge and increase awareness. However, these actions do not have Brazilian MD as ahead. Furthermore, it is noteworthy that MD is not being considered in the national context as a protagonist of energy actions. Its representatives were not required to be part of either the Energy Efficiency Indicators and Levels Management Committee or the Electric Energy Conservation Coordinating Group, both instituted by the Brazilian Federal Govern in 2019 (Brasil, 2019c, 2019b).

4. Results and discussion

Four different big areas in which the policies and actions are taking place in the military environment worldwide were identified:

- Framework: how the military organizations conceptualize and build their solutions to answer the energy-related problems is a starting point for energy precisely understanding and organization.
- Personnel-related issues: understand what role the user has in the process transition for energy resilience is essential for military commanders to choose the best guidelines to have energy-focused troops. The military energy-related behavior greatly influences the results of the policies and actions carried out in the framework.
- Sources of energy: the concept of energy security and resilience assumes the need to have redundant and abundant sources of energy. What is been employed in the military world to consider the different ways to energetic supply the military facilities and operations might help the Brazilian Ministry of Defense in this sense.
- Buildings and installations: the buildings are responsible for a large part of energy consumption worldwide and it is no different in the military context. Discover what is been proposed to mitigate the high consumption of energy by military facilities is helpful.

The highlights of all these categories are presented in the following subsections and, for each category, an insight for application in the Brazilian Armed Forces will be stated. If they become effective, it is believed that the Brazilian Armed Forces become more like the military environment around the world regarding energy efficiency, renewable energy sources use, and sustainable development, especially considering the country's recent acceptance as a major non-NATO ally. The Brazilian MD was considered as a centralizing body for energy efficiency actions of the Armed Forces, as happens in the countries and organizations studied. However, if such a structure is not chosen or possible, the reported actions and policies can be applied by the Armed Forces singly

Table 3 summarizes the energy-related actions and policies in the four categories. This summary table might omit information about actions and policies once this research was based only on public domain documents and probably there are many military documents, either in international organizations or in specific countries, that are of restricted access. As previously pointed out, this report's main goal is to bring insights to the Brazilian Armed Forces through a picture of how energy-related actions and policies are taking place around the military world, and not to exhaustively present all military information about this subject.

Table 3 Summary of energy-related actions and policies in military context around the world and special focus on Brazil (continue)

Category	Actions and policies	NATO	EU	UN	US	UK	Spain	Canada	Australia	Brazil			
										MD	Army	Navy	Air Force
Framework	Framework or strategy established	●	●	●	●	●	●	●	●				
	Concept defined	●		●									
	Energy resilience approach	●	●	●	●	●	●	●	●				
	Zero energy approach		●	●	●		●	●					
	Considerations about climate change	●			●								
	Goals clearly established			●	●	●		●					
	Official publications	●	●	●	●	●	●			●			
	Specific program or body designated	●	●	●	●	●	●	●	●		●	●	●
	Audit mechanisms for control of criteria fulfillment				●								
	Annual reports with actions carried out demanded		●		●								
	Specific software/platform/portal for sustainable actions	●	●		●	●	●				●		
	Sustainable acquisition	●	●	●	●	●	●	●	●		●		
	Funding solutions (public and private sectors)		●		●							●	●
	Cooperation with academy, industry, utilities, and other countries	●	●		●	●	●				●	●	●
Personnel-related issues	Personnel designated	●	●		●	●		●					
	Qualification of professionals	●	●		●	●	●				●	●	●
	Chain of command use for improving the effectiveness	●			●	●			●				
	Focus on energy saving behavior and awareness	●	●	●	●	●		●	●		●	●	●
	Military health				●								

Legend: ● means identified actions/policies. Blank camps mean not identified, but not necessarily no existent.

Table 3 Summary of actions and policies in energy efficiency in military context around the world and special focus on Brazil (final)

Category	Actions and policies	NATO	EU	UN	US	UK	Spain	Canada	Australia	Brazil			
										MD	Army	Navy	Air Force
Sources of energy	Portable energy solutions for deployed troops and integration between renewable and non-renewable energy solutions (cogeneration)	●	●	●	●		●	●					
	Specific camps for energy-related technologies	●	●	●	●								
	Low-carbon or electric vehicles			●	●	●		●					
	Diversification of power lines	●			●								
	Distributed generation using renewable energy sources (on-site or off-site)	●	●	●	●		●	●	●	●	●	●	●
	Energy storage systems	●	●	●	●		●		●				
	Large-scale renewable sources generation				●		●		●				
	Smart grid solutions	●			●		●		●		●		
	Free energy Market				●						●	●	
Buildings and installations	Labeling programs for buildings				●	●		●			●		●
	Metering, monitoring and management energy system	●	●	●	●	●	●	●	●				
	Utility privatization for military bases	●			●								
	Established energy use goals and benchmarking mechanisms	●	●		●								
	Energy performance contracts				●			●					
	Load reduction techniques	●			●								
	Life cycle cost analysis				●								
	Simulation programs for evaluation of efficiency in buildings				●								
	Awards related to good actors in sustainability				●								
	Zero energy program				●								
	Use of efficient equipment	●	●	●	●	●	●	●	●		●		

Legend: ● means identified actions/policies. Blank camps mean not identified, but not necessarily no existent.

4.1 Framework

Among the organizations and specific countries analyzed, all have a framework, or a strategy set up for military actions in energy efficiency, renewable energy sources, and sustainability except Brazil. These strategies or frameworks were found in Defense Structure, encompassing all activities or bodies of this area. NATO and the UN also defined specific concepts regarding it. This signals that for the military to obtain a correct approach to energy, the leadership must establish a structure that allows a holistic view to be implemented in the entire organizational structure of the armed forces. As much as initiatives at the end of the line may contribute, a vision whose approach is structured from top-to-down seems to be understood as essential for the military world.

NATO, the UN, and the EU have placed energy resilience as a primary and motivating factor for energy efficiency actions in the military environment. Specifically, the US, the UK, and Spain have also used the concept of energy resilience to prepare their troops. Actions related to this concept involve a zero-energy approach to military buildings and operations (military installations – fixed or on a mission – with reduced energy demand and that generate, locally, a quantity of energy from renewable energy sources at least equal to the demand). In the EU, the actions of the military arose in the wake of specific targets for all new public buildings to be proven to be zero-energy as of December 2018 (EU, 2010). At the UN, there are offices around the world that are self-sufficient in energy. The US, Spain, and Canada have also developed actions with this zero-energy approach. Although the US Army has an exclusive zero-energy initiative, the US DoD prefers a more general approach, with a portfolio of options of a realistic approach to being tried rather than isolated actions, considering several influences: renewable resources availability, energy security, financial and human resources and objectives to be achieved (Anderson *et al.*, 2011).

Within energy resilience and underpinning the UN concerns over climate change, NATO and the US are interested in the impact of such changes on military bases. The US even pointed out the need for constant assessment of military bases in the mapped areas as potentially affected by climate change.

Although in all international organizations and the countries considered there is a concern with energy resilience as a guide for energy efficiency actions, no action neither an official document was found from the Brazilian MD or the Armed Forces dealing with this matter. This may be due to the Brazilian history of no participation in wars. However, the country's constant participation in UN peacekeeping missions and its entry as a special non-NATO ally make this approach urgent for the Brazilian military.

Notwithstanding the existence of many reports and documents pointing towards greater energy efficiency and use of renewable energy sources by their Armed Forces among the countries and organizations presented here, only the UN, the US, the UK, and Canada have clearly defined objectives and goals, some audacious. In other cases, there are suggestions

but not objectives established with well-defined deadlines and accountability ways that enable the execution of actions more effectively. Some countries have official publications regarding military energy efficiency actions, but some documents are only informative or suggestive, such as the Brazilian case, while others are more definitive about goals and accountability systems for measuring energy efficiency progress in the military.

Virtually all countries and organizations, except for the Brazilian MD, have already designated specific professionals to deal with matters relating to energy efficiency, which, with a clear role, team, and constant reports, is seen as especially important for the effectiveness of the actions, and in some countries, there are specific programs or agencies to act accordingly in the Armed Forces. Cooperation between countries to exchange information about energy efficiency, as well as with academia, industry, utilities and the private sector has been considered essential by several countries and organizations and it has happened at some level, but there is still much to improve (EDA, 2017a; Nyitrai, 2017; Danezis, 2017).

Control and audit mechanisms for monitoring the actions required by the energy efficiency policies launched are also important. Annual audits and reports have been required by the US and the EU. Several countries have internet domains or specific sustainability programs that can serve as a basis for exchanging information, such as NATO *LibGuide*. Brazilian Army has OPUS (Unified Works Process System, Portuguese abbreviation), a platform already recognized as useful in sustainable management and which can have its functionalities expanded to concentrate information, data, reports, etc. concerning energy efficiency, renewable energy sources, and sustainability within the Army and serve as a model for Brazilian MD (Brasil, 2020d).

In almost all countries surveyed, information on sustainable procurement was found. As public bodies, the Armed Forces face restrictions related to public administration (EDA, 2017a). The biggest problem, however, concerns the budget for carrying out energy efficiency actions. Difficulties were recognized regarding the difference between public agents who manage and make use of public resources and how the bids are made, which makes energy efficiency actions discouraged. Besides, the difficulty of obtaining financial resources to fund the projects makes their development slow. The EU and the US have proposed clear solutions for financing energy efficiency actions, with resources from both the public sector (defense-dedicated funds) and the private sector. In the Brazilian case, there is a mechanism that has been used by the Air Force and the Navy for small energy efficiency improvements, which is participation in public calls from ANEEL that allow the execution of energy efficiency measures within the bases using resources from the utilities, but the resources from this program are short and just allow the development of simple actions. It’s desirable to build a mechanism for Brazilian military decision-makers to improve its energy efficiency and the use of renewable energy sources in the bases with appropriate resources.

As was seen, there is still not a framework established in Brazilian MD neither a convergence point in the energy-related actions and legislation carried out by the Armed Forces singly. It's different from all organizations and countries that were presented. In all of them, despite its dissimilarities, a common point was the existence of a framework or a body that centralizes energy efficiency actions in the Defense environment. Because of it, the first insight can be stated as follows:

> **First insight:** *Build a Framework encompassing energy efficiency, sustainability, and renewable energy sources.*

To put it in practice, we suggest:

- Define a green concept that will underly all actions and legislations
- Establish specific agents in all command chain
- Establish a specific body and/or program within the Ministry of Defense to head the specific bodies of the Armed Forces, supporting and guiding them
- Provide a centralization of legislation on the topic and establish clear targets, objectives, and goals for compliance by parts of the Armed Forces, with mechanisms for punishment and rewards systems, in all chain of command - from commanders to soldiers and civilians who work in Defense agencies
- Create a common open-source internet website, concentrating all documents and news about these issues, allowing external queries for sharing policies, actions, technologies, and reports
- Conduct studies related to a Brazilian Armed Forces approach to energy resilience and zero-energy concepts, paving the way to specific programs relating to these two concepts
- Promote energy-related events within the Ministry of Defense, bringing together the actions of the three forces, to create a network of professionals to exchange experiences and information
- Establish, at the Ministry level, a step-by-step methodology for the Armed Forces to obtain public or private financing for their energy-related projects
- Develop legal support to facilitate biddings
- Strengthen relations between MD and other public agents that act in the energy field (Mines and Energy Ministry, Energy Research Company, ANEEL, etc.)
- Take advantage of market opportunities for energy savings (energy performance contracts, free energy market, public-private partnerships for renewable energy sources implementation)
- Promote cooperation among the Army, Navy, and Air Force research centers
- Work for partnerships with industry and private sectors to test the projects studied, in peace and under hypothetical combat conditions

4.2 Personnel-related issues

According to personnel-related actions, there was almost a consensus in this study to the need to pay attention to the responsibilities of the military in general regarding energy efficiency. The awareness of the military regarding the essential role of energy is a determining factor for the effectiveness of all actions and policies implemented. (Delgado & Shealy, 2018) pointed out that to enhance energy efficiency in the government environment, it's necessary to align decisions taken by the energy managers with behavioral science.

Once the hierarchy is a characteristic of the military, NATO, the US, the UK, and Australia have used the chain of command to actions become indeed effective. Also, the qualification of professionals in this area is something particularly important for the advancement of energy efficiency in the military, as well as the designation of military personnel responsible for the energy management of their respective bases, fully supported by their commanders.

Some studies also consider how essential is to identify and address deep uncertainties in energy research and development for setting priorities across energy portfolios and suggest multicriteria analysis to help the decision-makers to get effectiveness in the actions implemented (Hamilton *et al.*, 2013; Lambert *et al.*, 2011).

Keeping in mind the great importance that the military team has for a more energy resilient Force, the second insight for the Brazilian Armed Forces is:

> **Second insight:** *Increase military awareness about energy's special role for success in a 21st-century warfare context*..

As suggestions of actions in this way, we propose the Ministry of Defense to:

- Regulate the CICE actions to improve its effectiveness
- Establish a specific month for energy awareness in all Defense system
- Use the hierarchy and chain of command to turn actions effective, having a top-to-bottom approach (strengthening commands mentality to correct implementation)
- Provide a behavioral study about the military use of energy to identify the user's bad habits and better apply the actions and policies
- Demand annual reports from the barracks and the Armed Forces on the energy-related actions implemented

4.3 Sources of energy

Still based on the concept of energy resilience, many countries have been concerned with carrying out military exercises considering alternative solutions for the supply of energy,

either by diversifying the power lines (like the US and NATO especially do), either by testing various forms of generation on-site, with a mix of renewable and non-renewable sources together. Outside of Brazil, only in the UK and Australia have found no such actions. The three international organizations and the US even carry out actions in specific fields dedicated to the testing of energy-related technologies. The interest of some countries in this regard also affects the vehicles used, with goals of increasing the use of low-emissions or electric vehicles.

Distributed generation has been widely used in the global military context, including in Brazil. Along with distributed generation, studies on the use of energy storage systems have also been carried out. The storage expands the possibilities of supplying the military bases, since it allows the subsequent use of the generated energy, freeing the bases from the high prices of the utilities and avoiding discussions regarding compensation systems, as is the case in Brazil and all procedures for changes in legislation for distributed generation in the country. In this sense, (Hartranft, 2007) argues that barracks should have a grid whose topology provides resources for innovations in energy supply and maximizes the use of renewable energy sources, considering the local energy storage and the reduction of grid interaction, together with the implementation of efficiency measures and with the energy supplied by the concessionaires.

The US, Spain, and Australia also have incentives for large-scale distributed generation, and within the context of the Brazilian Army Program for Sustainability, this is a considered possibility. NATO and some countries have paid attention to smart grid solutions and the US and the Brazilian Army and Navy consider large-scale energy purchases as a solution to reduce energy costs.

The need for having different ways to energy supply the military bases is answered by the third insight:

> **Third insight:** *Improve the energy portfolio of the Armed Forces by using renewables and alternative solutions*

As suggestions for fulfilling this insight, we propose the Ministry of Defense to:

- Stimulate small- and large-scale distributed generation with diverse renewable energy sources.
- Give special attention to isolated bases, implementing off-grid generation to reduce logistic costs and GHG emissions for diesel generators and improve comfort for the military body on these bases.
- Provide solar photovoltaic, biomass, hydrogen, wind, etc. prospection for implementation of such renewable energy sources according to different climatic conditions.
- Leverage the use of storage systems in on-grid or off-grid installations.

- Create an easy platform for analyzing technic-economically the feasibility of renewable energy sources projects.
- Qualify academic personnel in renewable energy sources, distributed generation, storage energy systems, smart grid solutions, etc
- Study the feasibility of using electric or low-carbon vehicles in administrative (in the first moment) and operational missions and start pilot projects of this implementation.

4.4 Buildings and installations

The buildings are responsible for great energy consumption worldwide, both in the civilian and military contexts. Because of it, the military organizations are special concerned about them. Most countries and organizations place great importance on energy control, measurement, and management systems at their bases. This even makes it possible to define consumption patterns, as well as to establish limits for energy consumption. Some countries encourage buildings in their Armed Forces to label their buildings according to international standards, such as LEED. Almost all countries surveyed also pointed to the use of efficient equipment at their bases. NATO and the US score techniques to reduce demand for their facilities and encourage the bases to have their utilities privatized, which enables greater savings of resources and energy, since private companies can keep the facilities up to date by market trends, in addition to allowing the military to stay focused on the core activity. The US and Canada also established that their buildings must have energy performance contracts, which allows for a constant assessment of how energy efficiency measures have been implemented and their effectiveness. Some actions are exclusive to the US Armed Forces, such as building projects considering the entire life cycle analysis, using simulation programs for the evaluation of energy efficiency, and awarding facilities better managed concerning energy efficiency.

The priority that buildings and installations require in energy concerns is provided by the last insight:

Fourth insight: *Work toward efficient military facilities.*

In this way, we propose to the Ministry of Defense to:

- Determine energy metering, monitoring, and control system for military installations
- Establish specific demands for designers to follow to fulfill energy efficiency and sustainability principles.
- Leverage the widespread use of simulation tools for performance evaluation, the establishment of specific criteria for designers to follow, life cycle cost analysis, etc.
- Provide an energy monitoring program, with the acquisition of smart meters for all bases.

- Provide benchmarking of military installations' energy consumption. It would help to assess what energy efficiency measures and renewable energy sources solutions could be encouraged in a customized way.
- Establish consumption standards and indicators and create an award for military installations with better indicators.
- Demand more complex energy-efficient requirements for military works.
- Evaluate and support the privatization of military installations.
- Launch a zero-energy installation program, with a tailored concept, an appliable methodology, and a pilot project to gradual evaluation and implementation.

5. Conclusions

This study considered actions and policies related to energy efficiency, sustainability, and use of renewable energy sources in military activities in international organizations (NATO, the UN, and the EU) and specific countries Armed Forces (the US, the UK, Spain, and Canada – all NATO allies – and Australia – a major non-NATO ally) to propose some insights to Brazilian Armed Forces once Brazil was accepted by the US in 2019 as a major non-NATO ally. Considerable research was carried out on some internet websites with information about the military and the subjects looked for (NATO *LibGuide*, the UN and European Commission sites, specific Ministry of Defense, or similar agency internet domain and so on).

The results carried out that among the organizations and specific countries analyzed, all have a framework, a strategy, and a concept set up for military actions in energy-related issues, what not happens still in the Brazilian Armed Forces. This well-defined and organizational structured approach is essential for a holistic perspective and to ensure the effectiveness of the implementation of the actions and policies that will be launched. The international military focus is tackling environmental care with an underpinning concept, specific for military operations and installations: energy resilience, which points to the security once means the ability to always keep energy supply safely for military operational performance.

Defense in Brazil has not a framework established to energy subject and the Ministry of Defense has a timid role in this matter. Fortunately, the Brazilian Army, Navy, and Air Force have developed singly several actions, especially to improve energy efficiency in its installations through utility partnerships and using renewables sources for distributed generation, but there is still a long way to turn the energy approach in the Brazilian Armed Forces to international levels.

For this, it is important to structure an MD framework concentrating on the actions and policies in this matter, serving as a support and supervisor for all Defense agencies towards higher energy resilience in military installations and operations. This work presented four skillful insights in the main areas that energy needs to be considered: structuring the organization to handle energy appropriately; giving to the military body the essential role that they have in the way for energy resilience; diversifying the military energy matrix using renewables and alternatives solutions; focusing on major consumer villains, the military installations. Several specific suggestions for implementation were presented in each area to facilitate the application in the Brazilian military context. Among the actions and policies that are taking place around the military world, can be cited: zero-energy installations; energy management systems; distributed generation in small- and large-scale; specific personnel and/or body dedicated to energy issues in bases/Forces; awareness campaigns; use of command chain to the effectivity of actions and policies; goals established for energy

consumption reduction; electric vehicles; budget and funding solutions; demand labeling systems for buildings; public-private partnerships; energy benchmarking; military exercises to test new energy technologies.

At long last, as Defense becomes more accurately dedicated to improving energy efficiency and renewable energy sources use, it will strengthen Brazilian industry and technological private research and development both to Defense market and for all society, heating the Brazilian economy in this time of resumption of economic growth thought added value to energy-related products and technologies.

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