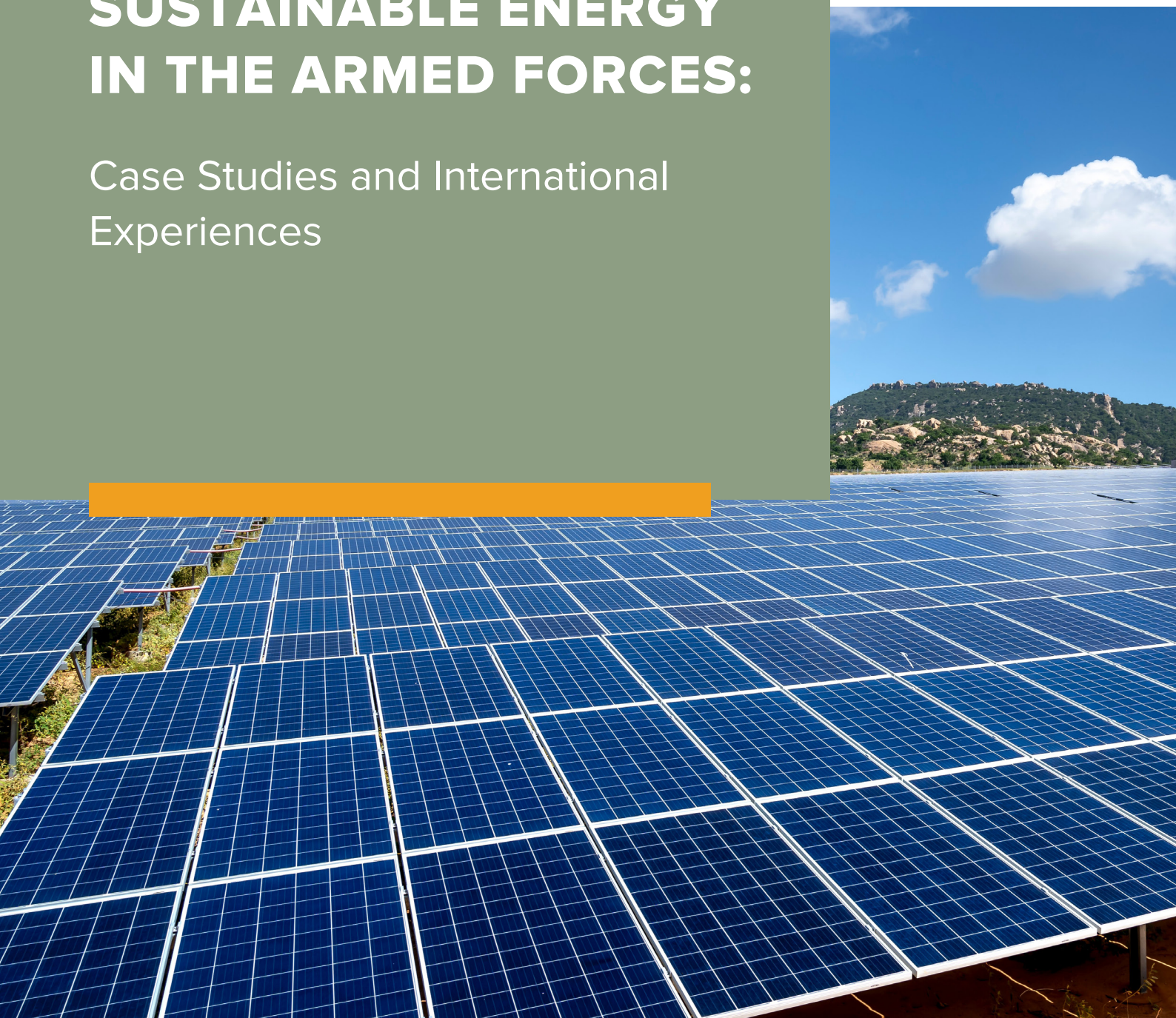
LEBANESE REPUBLIC
MINISTRY OF ENERGY AND WATER

UNDP

FUNDED BY THE EUROPEAN UNION

BEST PRACTICE FOR SUSTAINABLE ENERGY IN THE ARMED FORCES:

Case Studies and International Experiences



Editorial
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Sustainable Energy for Security - Best Practice for Sustainable Energy in The Armed Forces: Case Studies and International Experiences.

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1 Introduction

1.1. The Project

The European Union funded, United Nations Development Program (UNDP) implemented, "Sustainable Energy for Security" (SE4S) project focuses on strengthening the security and well-being of the Lebanese Armed Forces (LAF), specifically the LAF stationed in the North-Eastern border region of Lebanon. The aim of the project is the provision of sustainable energy solutions that, first and foremost, increase the LAF's energy autonomy in the region and enhance the general energy services that achieve a higher ability to observe and carry out the respective security-based operations.

Additionally, these actions build on the Lebanese Armed Forces Sustainable Energy Strategy of 2017 (EU-UNDP CEDRO 4, 2017), endorsed by the Lebanese Ministry of Defense and the LAF.

The LAF Sustainable Energy Strategy endorses Lebanon's Nationally Determined Contribution (NDC) commitment under the Paris Climate Change Agreement of 2015, and commits the LAF built environment to the following targets to be reached by 2030:

- 20% of its total electricity consumption is to be generated from renewable energy sources
- 20% of its total thermal consumption is to be generated from renewable energy sources
- 10% reduction in energy use per square meter

1.2. Best Practice Report

This Best Practice Report focuses on Climate Change, Energy Security and Resilience as one of the main challenges for the Armed Forces worldwide.

Energy is a fundamental enabler for Defence activities and operations. However, Armed Forces' energy requirements are quite vast and continue to rise .In particular, the high dependence on fossil fuels is likely to be hard to sustain in the long term.

Besides, as one of the largest energy-consuming sectors and the world's largest consumer of petroleum[1], Defence has the obligation to be part of the global energy transition process and contribute to the reduction of GHG emissions by changing its energy behavior as well as considering climate change into their strategies.

Hence, a strategic approach to energy management needs to be adopted by Armed Forces, where energy conservation, energy efficiency(EE) measures and the replacement of fossil fuels in favor of renewable energy sources(RES) are key strategies in the path to sustainable energy transition and in enhancing energy security and resilience.

The main focus of this report is to present and share best practices regarding innovative and sustainable energy solutions in the Armed Forces infrastructure and operations.

Some countries have been selected to showcase their extensive commitment to sustainability and climate goals, demonstrated by their energy strategies and activities in the field of military sustainable
energy transition.

[1]NATO ENSEC COE ENERGY HIGHLIGHTS: Energy efficiency and renewable energy solutions in NATO and PfP countries' military operations - FINAL REPORT OF THE STUDY, July 2021

2 Climate Change and Energy Security

Climate change and energy security constitute nowadays major challenges for Nations and their Armed Forces, both home-based and on missions:

•Impact on national security as climate change can deepen current social or political crises, or even trigger new ones.

•Impact on the Military's built and natural infrastructure, missions and operations.

As a result:

•The military has the responsibility to show leadership in environmental and energy sustainability, and the obligation to manage their assets efficiently on behalf of the citizens.

•The military must contribute to the energy transition and integrate climate change considerations into their Defence strategies and policies.

•The military has the obligation to reduce greenhouse gas emissions and to adapt its operations, strategies, and physical assets to climate change impact.

•The military must implement effective energy management and optimization mechanisms, introducing innovative smart energy solutions without reducing military operational capabilities.

2.1 Climate change: a threat to National Security

The documented effects of human-induced emissions of carbon dioxide and other greenhouses gases include changes in the climate system, such as the increase in global average temperature, sea-level rise, and increased frequency and intensity of extreme weather events, which consequently lead to changes in ecosystems, species, human systems, and other aspects of life on Earth[2].

Climate change can act as a threat multiplier because stressors already present around the world (poverty, environmental degradation, political instability, and social tensions) are likely to be worsened by the impacts. The vast geopolitical impacts of climate change include food and water scarcity, degradation of land due to drought, the proliferation of disease vectors, increased likelihood of intra- and inter-state conflict, people displacement and the subsequent degradation of infrastructure and economies, biodiversity, and resources.

Climate change as a national security issue is a challenge for the future military forces because it has potential social and environmental impacts on the military forces' infrastructure, missions and operations:

•Due to more frequent and severe weather events disasters at home and abroad, the Armed Forces may be called more often to support in humanitarian assistance and disaster relief operations, both within and beyond their national borders.

•Climate change can deepen anyone or a combination of current social, political and economic crises or even trigger new conflicts, impacting on national and global security. Therefore, the worsening of the global security situation, the increase in the number of humanitarian catastrophes and the related

[2] Source: https://www.ipcc.ch/

destabilization due to uncontrolled immigration are likely to lead to increased armed forces interventions.

•Climate change affects the daily operation of military installations and activities due to changes in the natural environment of the area of operations and the limitation of the available energy and water. Additionally, climate change might increase the spread of infectious diseases on military bases abroad[3], which, in turn, might also influence the operational capabilities of military missions.

•Climate change poses a real risk to Defence facilities and built infrastructure around the world. Extreme weather events, such as flooding, drought and wildfire can damage Defense facilities and negatively affect military's ability to respond to a crisis.

2.2. Armed Forces and Energy Resilience

The global Defence sector is an energy-intensive sector as energy is a fundamental enabler of military capability. Military forces use large quantities of energy to sustain military infrastructure, bases and camps. Access to adequate, reliable, affordable energy is essential for defence capability and it ensures the operational readiness and responsiveness of Armed Forces.

Energy, often fuel & electricity, is essential for the Land, Air and Naval Forces' operations and therefore must be available in the home country and abroad, over great distances and in very challenging environments. Besides, temporary or permanent military bases in remote locations have to rely not only on diesel but also on diesel transports and availability.

Resilience includes the capability to adapt to a changing environment in order to maintain or rapidly re-establish mission-essential functions in the face of anticipated and unanticipated energy disruptions.
The main energy security challenges are related to the growing dependence of military forces on fossil fuels, and their inefficient energy use during military operations. Overreliance on fossil fuels and the related financial, operational and strategic risks threatens the security of supplies and troops, creates concerns over climate change and has an impact on operational effectiveness.

Increasing the use of renewable energy systems alongside the introduction of energy conservation and efficiency measures can reduce this dependence and therefore increase autonomy and energy resilience.

2.3. Energy Security through Sustainable Development

The European Union (EU) Security Strategy states clearly the close connection between Defence 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[4].

[3] C. E. Werrell and F. Femia, The center for climate and security, "EPICENTERS OF CLIMATE AND SECURITY: THE NEW GEOSTRATEGIC LANDSCAPE OF THE ANTHROPOCENE", June 2017
[4] European External Action Service (EEAS), 20

Defence is among the largest employers and owners of equipment and real property worldwide. The Navy, Army and Air Force operate and train over large areas of land, sea and airspace at home and abroad. Defence, as one of the largest users of energy and emitter of greenhouse gases, has a huge responsibility to show leadership in environmental and energy sustainability, as well as an obligation to manage assets and operations efficiently on behalf of the citizens (taxpayers).

To achieve global sustainable development, a united effort to limit climate change is required. Armed Forces should be involved in contributing to the global effort to reduce its impact on the environment, more particularly with the obligation to reduce greenhouse gas emissions, and to adapt its operations, strategies, and physical infrastructure to a global environment shaped by climate change.

The optimal way to contribute to climate change mitigation is directing toward a sustainable model of military operations to develop resiliency to the oncoming changes, including implementation of new renewable energy and energy-efficient technologies in the sector, the development of natural resource management and improvement of infrastructures. The reduction of dependence on traditional fuel could be achieved by developing efficiency in mobile platforms, either land, air or naval, and fossil fuel-based power generation plants; by using renewable energy systems adapted to the military environment, as well as by smart and decentralized energy management systems and by improving infrastructures where energy consumption is concerned.

In addition to supporting the government's commitment to reduce greenhouse gas emissions, Defence will strengthen its capacity for adaptation to climate change by integrating related measures into its policies and practices. An effective adaptation strategy will mitigate the risks associated with climate change impacts on operations[5].

[5] Department of the Army, Office of the Assistant Secretary of the Army for Installations, Energy and Environment. February 2022. United States Army Climate Strategy. Washington, DC.

3 Energy and the Military

There are multiple reasons why energy matters for the Military:

•**Military capability and operational advantage.** Defense capability is completely dependent on energy. Energy is critically important to ensure the effective fulfillment of military tasks. Energy powers bases and platforms, and fuels the fleets of the Navy, Army and Air Force. Whether it is electricity, fossil fuels or other sources, energy maintains the extensive range of Defence infrastructure and facilities, and sustains every military mission and operation.

•**Security of supply:** Military operational capacity is essentially dependent upon steady and reliable massive amounts of energy and their supply routes, mainly traditional fossil fuels, often coming from foreign countries under challenging contexts. Therefore, to improve the security of supply and reduce operational expenditures, Armed Forces have a strong interest in reducing their fossil fuel dependence.

•**Security of personnel:** Energy supply routes have significantly increased the financial and logistical burden and put military personnel and contractors at risk in convoys. Large amounts of diesel fuel and other cargo are often transported to remote and/or dangerous areas, with increased risk to personnel and equipment. Transporting fuels is not only highly uneconomical but highly dangerous as it costs lives.

•**Cost-savings.** Ministries of Defence (MoDs) have to deal with massive energy costs, due to their dependence on fossil fuels. The volatility of fuel prices poses uncertainties and financial risks. Energy conservation and Energy Efficiency measures, together with the use of Renewable Energy Systems (RES) to operate military infrastructures can produce huge financial savings. Diversifying energy supplies while increasing alternative energy sources in the overall energy mix helps to reduce Defence budgets exposure to the risks of future price instability.

•**Environmental issues:** Military energy demand continues to rise[6], being unsustainable in the long run. Military activities, particularly operations and exercises, involving movement, deployment, sustainment, and redeployment of considerable quantities of equipment and troops, have a significant environmental impact. As a result, the military sector is one of the most energy-intensive and polluting. Therefore, it must contribute to reducing the environmental impact and fulfilling the global CO_2 emission reduction commitment.

Developing sustainable energy solutions, reducing energy consumption and fossil fuel dependency will help reduce the impact on the climate and the environment as well as reduce energy bills.

3.1. Installations vs Operational Energy

According to different characteristics, priorities, and opportunities, military energy needs can be divided into Installations and Operational Energy, reflecting the division between the energy used in facilities and the energy used in military operations.

There is no widely accepted definition of Operational Energy, as the boundary between Operational and Installation Energy remains unclear. A general definition is provided below for

[6] NATO ENSEC COE ENERGY HIGHLIGHTS: Energy efficiency and renewable energy solutions in NATO and PfP countries' military operations - FINAL REPORT OF THE STUDY, JULY 2021

the clarity of the present publication:

•Operational Energy (OE) can be defined as the energy required for training, moving, and sustaining military forces and platforms for military operations. As OE is the energy used to generate and sustain military capabilities, sometimes the term “Capability Energy” is used instead of “Operational Energy”, to reflect the link between energy and military capabilities.

The energy consumption of military operations has increased due to the use of equipment with greater energy demand, inefficiency in using fuel generators in the fields, poor thermal insulation of tents, and lack of awareness of energy consumption control[7].

•Whereas **Installation Energy (IE)** consists largely of traditional energy sources used to heat, cool, and provide electrical power to fixed installation (encompassing diverse building types, e.g., office buildings, barracks, data centers, laboratories, and aircraft maintenance depots) and power non-tactical vehicles.

In terms of energy use at Armed Forces facilities, the military is one of the largest energy consumers worldwide, being largely dependent on a commercial power grid.

Operational Energy is generally the major source of consumption and spending for Defence Ministries. As an example, an estimated 75% of the U.S. DoD’s energy use is for operational use and the remaining 25% is used for installation energy. The U.S. DoD operates over 560,000 buildings and structures at over 500 military installations in the United States and overseas and spends approximately $4 billion a year on energy that powers its fixed installations. In 2017, the U.S. DoD consumed over 85 million barrels of fuel for the operational energy demand at a cost of nearly $8.2 billion. The DoD’s operational energy use is dominated by air and sea platforms of the Air Force and Navy; the Air Force uses roughly half of the fuel consumed by the DoD, and the Navy consumes about one-third[8].

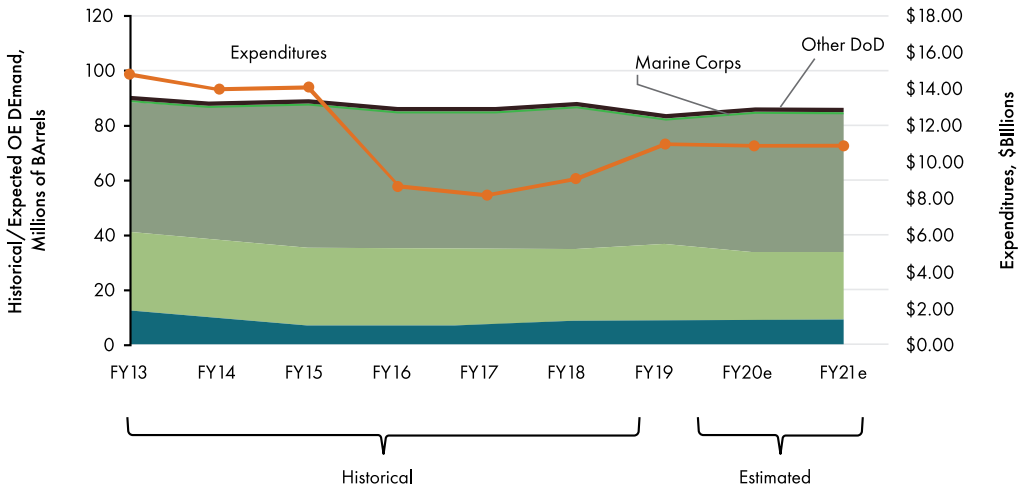


Figure 1: The U.S. military operational energy demand, 2013 – 2021,
Source: U.S. DoD, “Fiscal Year 2019 Operational Energy Annual Report”.

[7] NATO, 2014

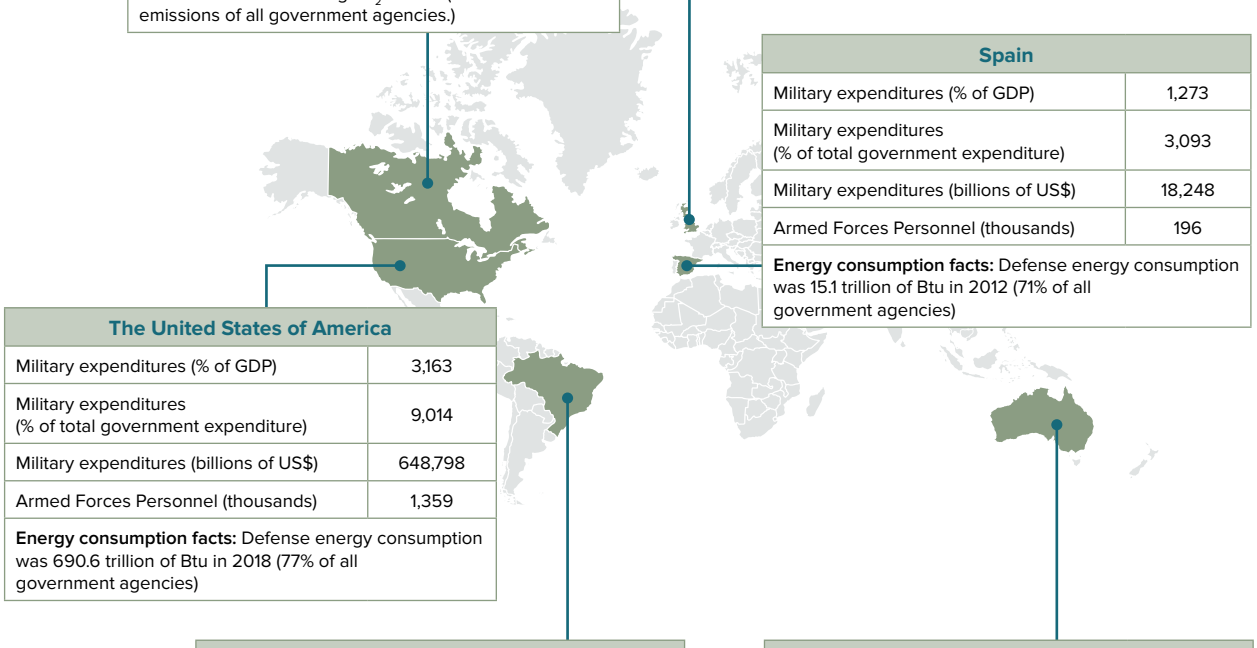
[8] - U.S. Department of Defense. “2016 Opera¬tional Energy Strategy”
- Sierra Hicks, American Security Project, “Pow¬ering the Department of Defense - Initiatives to Increase Resiliency and Energy Security”, Sep¬tember 2017
- U.S. Department of Defense. “Fiscal Year 2019 Operational Energy Annual Report”

3.2. Defence Energy Data

This section attempts to summarize a variety of public Defence energy use data from the few available sources. The objective is to provide some reference data to provide an overall idea of the magnitude of the energy consumption by the Armed Forces worldwide. The data provided under this section reflects the home based / fixed facilities consumptions solely.

The United Kingdom	
Military expenditures (% of GDP)	1,782
Military expenditures (% of total government expenditure)	4,624
Military expenditures (billions of US$)	49,997
Armed Forces Personnel (thousands)	148
Energy consumption facts: Military sector consumed 12.44 trillion of Btu in 2018.	

Canada	
Military expenditures (% of GDP)	1,253
Military expenditures (% of total government expenditure)	3,166
Military expenditures (billions of US$)	21,621
Armed Forces Personnel (thousands)	72
Energy consumption facts: Defense is responsible for 600000 tonnes* of $egCO_2$ in 2017 (62% of all GHG emissions of all government agencies.)	



Spain	
Military expenditures (% of GDP)	1,273
Military expenditures (% of total government expenditure)	3,093
Military expenditures (billions of US$)	18,248
Armed Forces Personnel (thousands)	196
Energy consumption facts: Defense energy consumption was 15.1 trillion of Btu in 2012 (71% of all government agencies)	

The United States of America	
Military expenditures (% of GDP)	3,163
Military expenditures (% of total government expenditure)	9,014
Military expenditures (billions of US$)	648,798
Armed Forces Personnel (thousands)	1,359
Energy consumption facts: Defense energy consumption was 690.6 trillion of Btu in 2018 (77% of all government agencies)	

Brazil	
Military expenditures (% of GDP)	1,475
Military expenditures (% of total government expenditure)	3,896
Military expenditures (billions of US$)	27,766
Armed Forces Personnel (thousands)	730
Energy consumption facts: Ministry of Defense had the 2nd greater electricity expenditure among public agencies in 2017	

Australia	
Military expenditures (% of GDP)	1,892
Military expenditures (% of total government expenditure)	5,122
Military expenditures (billions of US$)	26,712
Armed Forces Personnel (thousands)	58
Energy consumption facts: Defense energy consumption was 15.1 trillion of Btu in 2012 (71% of all government agencies)	

Figure 2. Defense energy status for different countries[9] .

[9] SILVA NETO, Luiz Pereira da; SORGATO, Marcio José. How are the military handling energy? An overview of international status and suggestions for the Brazilian Armed Forces: Technical Report. Campo Grande, 2021.

Some reference data about Military expenditure of Canada, UK, USA, Spain, Australia and Brazil are provided in Figure 2.

The US Department of Defence (DoD) consumed 708,000 billion British Thermal Units (BTUs) (equivalent to 207.5 million of kWh[10]) of operational and installation energy in just one year, accounting for 75% of the Federal Government's total energy consumption[11].

Another NATO country, the United Kingdom (UK), consumed 664 million liters of fuel in 2017/2018, achieving a 10% reduction from the previous year and almost cutting its energy consumption in half since 2009/2010[12] (See Figure 3).

Figure 3. Fuel Consumption-, 2009 to 2018 Source: UK Ministry of Defence, 2018.

In 2019, the consumption of petroleum products by French military vehicles accounted for 835,000 m^3 of oil products[13] and 73% of the military forces' energy consumption is attributed to the energy required to power the fleet of vehicles on land, water and in the air[14].

European Defence Agency (EDA) Energy Data:

In 2016, at the request of its Member States (MS), the European Defence Agency (EDA) started to collect national defence-related energy data with the support of the EDA Energy & Environment Working Group.

[10] 1 btu = 0.000293071 kWh
[11] Robyn D. & Marqusee J., The Clean Energy Dividend: Military Investment in Energy Technology and What It Means for Civilian Energy Innovation, 2019
[12] Ministry of Defence, Annual Report and Accounts, 2018-19
[13] The Left group in the European Parliament - GUE/NGL, Scientists for Global Responsibility (SGR), Conflict and Environment Observatory (CEOBS). "Under the Radar the Carbon Footprint of Europe's Military Sectors".
[14] NATO ENSEC COE ENERGY HIGHLIGHTS: Energy efficiency and renewable energy solutions in NATO and PfP countries' military operations - FINAL REPORT OF THE STUDY, JULY 2021

In 2016 and 2017, the total energy consumption of EDA's Armed Forces amounted to 41,339 GWh and 40,266 GWh, respectively[15]. For reference, the total energy consumption of Member States' Armed Forces equals that of a smaller EU Member State or approximately double that of Lebanon.

Considering EDA's data, a study estimates that the carbon footprint of EU military in 2019 was 24.8 million tCO_2e, which is equivalent to the annual emissions of approximately 14 million average cars[15].

Table 1. EU Armed Forces energy consumption breakdown for 2016-17.

EU Armed Forces Energy Consumption (2016 – 17)

- The EU Armed Forces total energy consumption for 2016 and 2017 is respectively 41,339 GWh and 40,266 GWh.

- Most of the energy consumed, 52% on average, was spent on transportation, 32% for heating, and 17% on electricity.

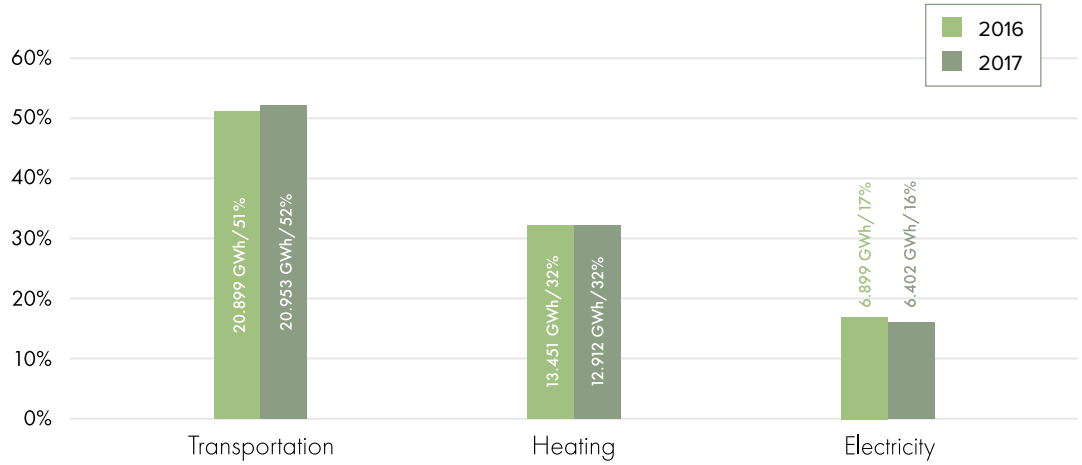


Figure 4. Breakdown of EU armed forces energy consumption for 2017-17[15].

[15] EDA, Defence Energy Data 2016 & 2017 - Fact sheet, June 2019

22 Member States (AT, BE, CY, CZ, DE, EE, EL, ES, FI, FR, HR, IE, IT, LT, LU, LV, NL, PL, PT, SE, SI and UK) provided their national defence energy data sets for the years 2016 and 2017. Those 22 countries stand for 96,9% of EDA Member States' overall defence expenditure, and 90,4% of their total defence staff, according to EDA's 2017 Defence Data. The energy data for 2016 and 2017 is presented in aggregated format.

Conditions apply for the energy data provided by AT (no data on transport fuels for 2016), EL (no data on transport fuels for 2016 and 2017), ES (data for heating does not include natural gas), IT (no data on transport fuels for 2016 and 2017, data on heating is under confirmation, therefore not included in the calculations) and NL (energy produced by solar thermal systems for heating not estimated, data on aviation and maritime fuels is under confirmation, therefore not included in the calculations).

Electricity

- Total EU Armed Forces Electricity Consumption for 2016 and 2017 is respectively 6,988,910 MWh and 6,401,587 MWh.

- Heavily reliant on national grids, small fraction of RES.

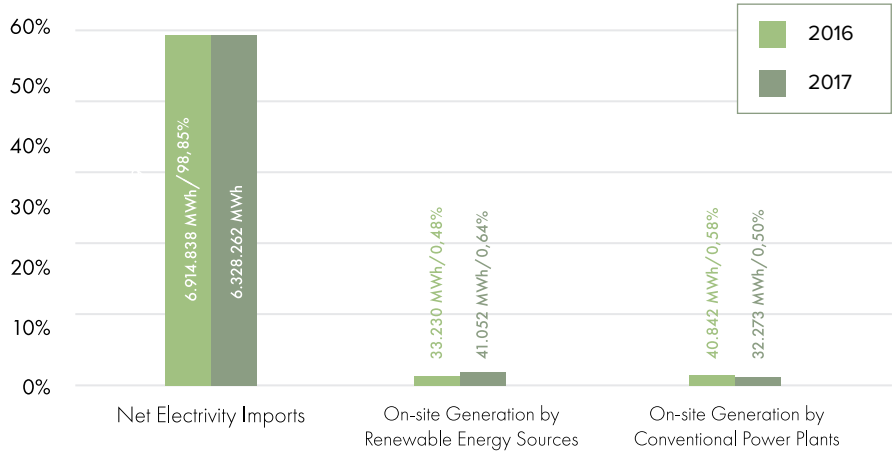


Figure 5. Breakdown of electricity sources for EU armed forces in 2016-17[15].

Transportation

- Total EU Armed Forces Energy Transports 2017: 20,952,656 MWh.

- Transportation fuel was almost entirely composed of emission emitter traditional fuels, 63% of which is Aviation fuel.

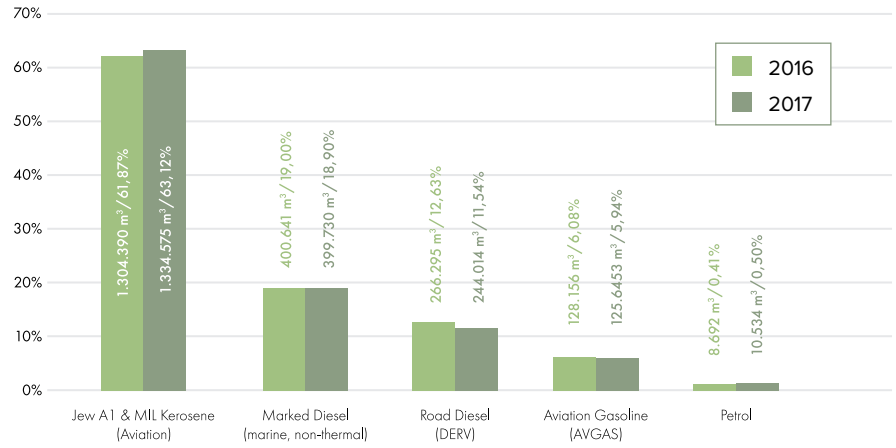
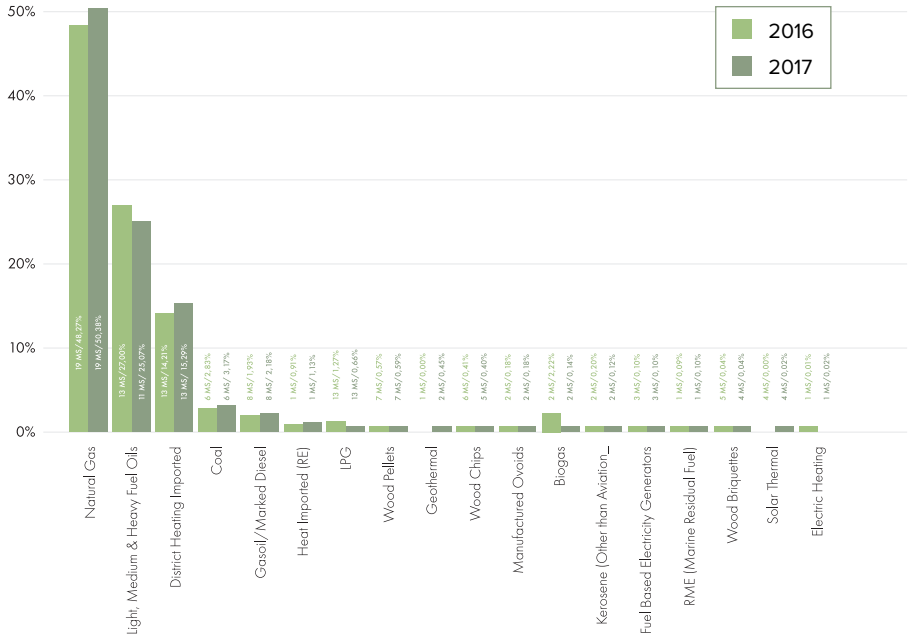


Figure 6. Types and total volumes of energy resources used for TRANSPORT in 2016-17 by the armed forces[15].

Heating	- Total EU Armed Forces Energy consumptions for heating in 2016 and 2017 is respectively 13,451 GWh and 12,911 GWh. - For heating purposes, 18 different energy sources were used. 75% of the total consumption was covered by fuel oils and natural gas, which potentially means a risk of dependencies from non-EU countries.  Figure 7. Energy consumptions for heating for 2016 and 2017 in EU Armed Forces (except IT)[15]
Sources of Information	EDA, Defence Energy Data 2016 & 2017 - Fact sheet, June 2019 www.eda.europa.eu

3.3. Strategic Approach to Sustainable Energy Management

National Defence and Armed Forces should become leaders in contributing to the sustainable development goals of the country through the effective and innovative integration of energy and environmental strategies into their activities supporting the overall Defence Mandate.

Implementing a transition to sustainable energy practices is a big challenge. Ministries of Defence(MoD) need to adopt a strategic approach and they need a framework for action to ensure that they are committed and capable of achieving the results.

When planning for a strategic approach to energy management, it has been considered that two main questions need to be answered: what are the goals? What are the resources to achieve them?

Some of the main considerations to make when planning a Military Sustainable Energy Management Strategy are the following:

1. Define the overall Goals, such as:

- Become more efficient in the use of energy and increase energy security and resilience, by increasing efficiency and/or replacing fossil fuels with cleaner energy sources.

- Reduced Defence environmental footprint: Reduce greenhouse gas emissions and other environmental impacts while adapting to climate change.

- Better-managed energy and environmental performance: Ensure systems and processes are in place to improve energy management, environmental impact and to measure performance more efficiently.

2. Establish the Targets:

- Consider existing National Policy or Regulations (i.e. Energy, Environment) to comply with and/ or to be considered as a guiding reference for establishing the goals and targets.

- Establish Defence Targets and Objectives in line with National targets.

3. The Implementation Plan:

Changing how energy is managed by an organization requires both resources and capabilities.

- Organizational Management/Energy Managers: Establishment of a special Authority or Department (within the armed forces / miltary corps) with main responsibility and commitment for energy management strategies and activities, sharing of organizational policies and standards, development of responsible energy behavior and environmental awareness as well as for energy projects implementation.

- Data Collection & Monitoring: Collecting and analyzing data concerning energy consumption and production through the establishment of monitoring and measurement stations in military facilities. It is a key aspect of developing and implementing
energy plans.

- Education and Training: Defence shall shift to sustainable operations and reduce overall energy use during military activities and operations, increasing internal energy consciousness and awareness of green practices among personnel through capacity building programs, seminars and workshops

- Develop individual´s energy awareness and behavioral changes

- Promote Energy Conservation through awareness and training

- Training programs, including best practices, lessons learned and guidelines

- Promote and invest in R&D activities as technology and innovation play a crucial role in improving practices supporting the decarbonization of the sector.

- Testing sites, dissemination of results

- Platform for sharing the information and experiences

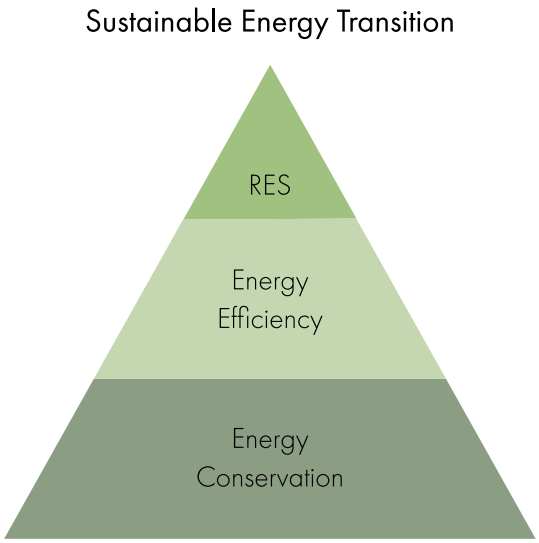
- Strengthen the civil-military co-operation

The overall approach is summarized in Figure 8, a virtuous circle of activities driving sustainability in Defense.

Figure 8. Sustainable Defence key steps. Source: www.eda.europa.eu

Three Energy Management Strategies are described in Table 2, providing a framework for action that can guide any energy management initiative: reducing energy end-use, increasing energy efficiency and optimizing energy supply.

Table 2: Energy Management Strategies

Sustainable Energy Management Strategies:	
1. Promote Energy Conservation: Reduce the energy end-use by ensuring behavioral and operational practices are in place.. The goal is to reduce the amount of energy that is wasted or consumed unnecessarily. 2. Increase energy efficiency in infrastructure by installing energy-efficient equipment and processes (e.g., lighting, heating, cooling and ventilation) to reduce energy use. 3. Increase Clean Energy/Renewable Energy Sources: Optimizing energy supply by reducing the use of fossil fuels and increasing energy diversification with the integration of renewable energy sources (i.e. wind and solar photovoltaic energy).	

3.4. Sustainable Energy Technologies Overview

In this section, some of the energy technologies currently being implemented by MoDs are presented.

Energy Efficiency and Buildings Performance:

- Energy Efficiency in Buildings/Building Retrofit: Implementing for example energy performance contracts (EPCs) at the bases, building retrofitting, building automation, energy consumption monitoring, Energy Management Systems could reduce considerably energy consumption and consequently GHG emissions. These contracts, measured as financial savings compared to an established baseline, is signed with an ESCO.

- Smart camps/More efficient power solutions for Operations: Defence is exploring energy efficiency improvements during major deployed operations to ensure future operations have modern and energy-efficient equipment, flexible and scalable deployable camp infrastructure and utilities that minimize logistical demands and environmental footprint while decreasing costs and risks associated with securing traditional fossil fuel sources.

Renewable Energy Systems: Renewable energy sources such as wind, solar, geothermal (for fixed facilities), synthetic fuels and other energy alternatives will continue to evolve, diversifying energy supply, increasing the security of the fuel supply chain, and helping reduce GHG emissions while ensuring Military operations.

1. Green energy from the grid / Clean Energy Procurement: Purchase clean electricity from regional grids can be a cost-effective way of reducing GHG emissions as well as supporting investments in green infrastructure and clean technology.

2. Renewable power generation: Utility Scale Solar PV and Wind Farms development on Defense installations. As well as distributed smaller-scale renewable energy installation using the renewable resources available on-site.

Solar Energy Systems:

- Solar PV and Thermal
- Including portable/deployable solar PV solutions for operational context (i.e. mobile roll-array solar power plant)

Mobile Hybrid Power Generation System: Smart Hybrid Energy System (SHES) scalable and transportable solution designed to reduce fuel consumption in field operations.

Smart Grids: Defence developing low-carbon micro-grids in military bases. A smart grid is an electrical system, which can include different generation sources, including conventional and renewable, running in combination with energy storage technologies and optimized by smart metering and control algorithms. A microgrid with distributed renewable energy technologies can result in, increased resilience and autonomy, reducing GHG emissions and reliance on fossil fuels. Smart grids also make use of electronic power monitoring and control of the production and distribution of electricity to ensure maximum efficiency from the energy supplied and consumed.

Large Energy Storage and BESS technologies: large energy storage systems play a key role in enhancing the effectiveness of RES technologies and the overall resilience of energy systems, on their bases and mobile missions.

Biomass: Biomass can produce electricity, and at the same time, heat can be recovered and could potentially be used within a district heating system. There are different types of biomass sources including bark, coconut shells, corncobs, energy crops, food waste, sawdust, and wood chips, and there are different types of technologies that can be used for producing electricity from biomass.

Waste to Energy: This technology group refers to any waste treatment process, which creates energy in the form of electricity, heat or transport fuels (e.g. diesel, biogas) from a waste source.

It could include thermal (direct combustion and incineration), thermo-chemical (torrefaction, plasma treatment, gasification, pyrolysis, thermal polymerization, catalytic depolymerisation) and biochemical (composting, ethanol fermentation, and anaerobic digestion)

Alternative Fuels: This includes biofuels, synthetic fuels, synthetic gas, hydrogen, oxygen, and gas (natural, methane, etc.) which can be used in various applications including automotive vehicles, vessels, aircrafts and many types of mobile machinery (e.g., generators and power tools).

Sustainable Transportation: To reduce greenhouse gas emissions, adding plug-in hybrid and electric vehicles for its commercial vehicle fleet, as well as adding the required electric vehicle charging stations.

4 Case Study 1: European Union & NATO Context

The production and use of energy in the EU account for more than 75% of the EU's greenhouse gas emissions. Decarbonizing the EU's energy mix is therefore critical to reach 2030's climate objectives and the EU's long-term strategy of achieving carbon neutrality by 2050.

As one of the largest energy consumers in Europe, Member States' Armed Forces have a role to play in this endeavour. In this context, the ''Climate Change and Defence Roadmap''[16] identifies concrete ways for the EU to be better prepared for the emerging security challenges posed by a changing climate. The Roadmap will contribute also to the objectives of the "European Green Deal" aiming at reducing the emissions in particular in the Defence sector, increasing energy sustainability and prioritizing energy efficiency as part of the collective effort toward climate neutrality by 2050.

Table 3. EU's Climate Change Targets.

Climate and Energy Framework 2030	European Green Deal
Includes the EU's goals for the period 2021-2030. - EU plans to reduce GHG emissions by at least 40% compared to 1990, - Increase the share of renewable energy in the EU's energy consumption to at least 32%, - Achieve a 14% share of renewable energy in the transport sector, and - Reduce energy consumption through improvements in energy efficiency by 2030 by at least 32.5%, relative to a "business as usual" scenario[17].	Presented by the European Commission in December 2019 with the ambition to make Europe a climate-neutral continent by 2050. By 2050, the EU aims to achieve: - 80% to 95% reduction in GHGs compared to 1990 levels[18]; - reach a 75% share of renewable energy sources in gross final energy consumption, including a 97% share of renewable energy sources in electricity consumption[19]

The North Atlantic Treaty Organization(NATO), also called the North Atlantic Alliance, is an intergovernmental military alliance between 27 European countries, 2 North American countries, and 1 Eurasian country. The organization implements the North Atlantic Treaty that was signed on 4 April 1949.
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 Union and NATO, with efforts to reduce energy consumption and increase renewables[20].

[16] EEAS-Nov 2020
[17] EU, Energy Efficiency Directive (EU) 2018/2002 of the European Parliament and of the counci
[18] European Environment Agency, https://www.eea.europa.eu/, 2015
[19] European Commission, Directorate-General for Climate Action, Going climate-neutral by 2050 : a strategic long-term vision for a prosperous, modern, competitive and climate-neutral EU economy, Publications Office, 2019
[20] www.ec.europa.eu

4.1. European Defence Agency (EDA)

The European Defence Agency (EDA), established under a Joint Action of the Council of Ministers on 12 July 2004, supports its 26 Member States in improving their defence capabilities through European cooperation. Acting as an enabler and facilitator for Ministries of Defence willing to engage in collaborative capability projects, the Agency has become the 'hub' for European defence cooperation with expertise and networks allowing it to cover the whole spectrum.

In **2011 the EDA launched "Military Green",** the first European energy initiative in the military. Combining the EU military concept for Environmental Protection and Energy Efficiency, national armed forces priorities and EU directives. "Military Green" defined the concept, the principles and the responsibilities to meet the military's energy and environmental challenges. It attempted to bring all stakeholders together to establish a common understanding of the Defence sector's role in contributing to the EU energy and environmental goals.

In 2012 the EU Military Staff developed the strategic guide "European Union Military Concept on Environmental Protection and Energy Efficiency for EU-led military operations"[21]. Recent data have not been made public.

4.1.1. EDA Energy & Environment Programme

In 2014, EDA's Energy & Environment Working Group (EnE WG) was launched to understand the energy management of military activities and to identify solutions to reduce energy consumption and environmental impact.

Building on previous work conducted under EDA's Military Green initiative, EnE WG was formed to take account of the transverse and complex nature of energy and environmental factors in the Defence sector and to offer a structured approach to all aspects of related issues that affect EDA participating members.

Mission

The EnE WG provides strategically informed advice on Energy and Environmental factors affecting the Armed Forces of Europe, delivering tangible benefits in accordance with participating Member States (pMS) guidance.

The Energy and Environment Working Group supports the participating Member States' collective journey towards increasing the resilience of MoDs, Armed Forces and Defence technological and industrial sectors to existing and emerging vulnerabilities resulting from strategic considerations in terms of energy security and dependence on fossil fuels, resources security of supply, water security and climate change. In this regard, four main work strands are identified[18]:

- Training, Education and Knowledge
- Data Collection & Analysis
- Energy Efficiency & Sustainability
- Alternative Energy Sources: Biofuels & deployable renewable energy technologies.

In 2016, following the request of its Member States (MS), the European Defence Agency (EDA) started to collect national defence-related energy data in the framework of the EDA Energy & Environment Working Group (EnE WG).

[21] www.eda.europa.eu

This activity aimed at gaining a better overview and understanding of the types and volumes of energy resources used by the armed forces on an annual basis. Further to this, this activity was also foreseen as a specific task in the "Climate Change and Defence Roadmap" for the EnE WG.

The Energy Defence Data Collection Analysis and Sharing (E-DCAS) Support Frame study proposes a holistic approach to address the identified need of structuring the energy information collection and analysis to grasp valuable insights, as well as to systematize the process.

Objectives:

- Establish a methodological framework (Standard Operating Procedure-SOP) for collecting and monitoring defence energy data of the pMS, including a defence energy-related terminology.

- Determine a set of quantitative indicators to provide guidance for data collection and analysis as well as recommendations to address data gaps.

- Collect, evaluate and process buildings and transportation statistics among MoDs and provide a snapshot of the current status of the pMS' Defence energy performance.

- Set up a methodology for the continuous monitoring of the building stock.

- Maintain a dedicated webpage for presenting the collected data as well as other communication tools (pp presentations, factsheets, etc.) to raise further awareness and enhance participation.

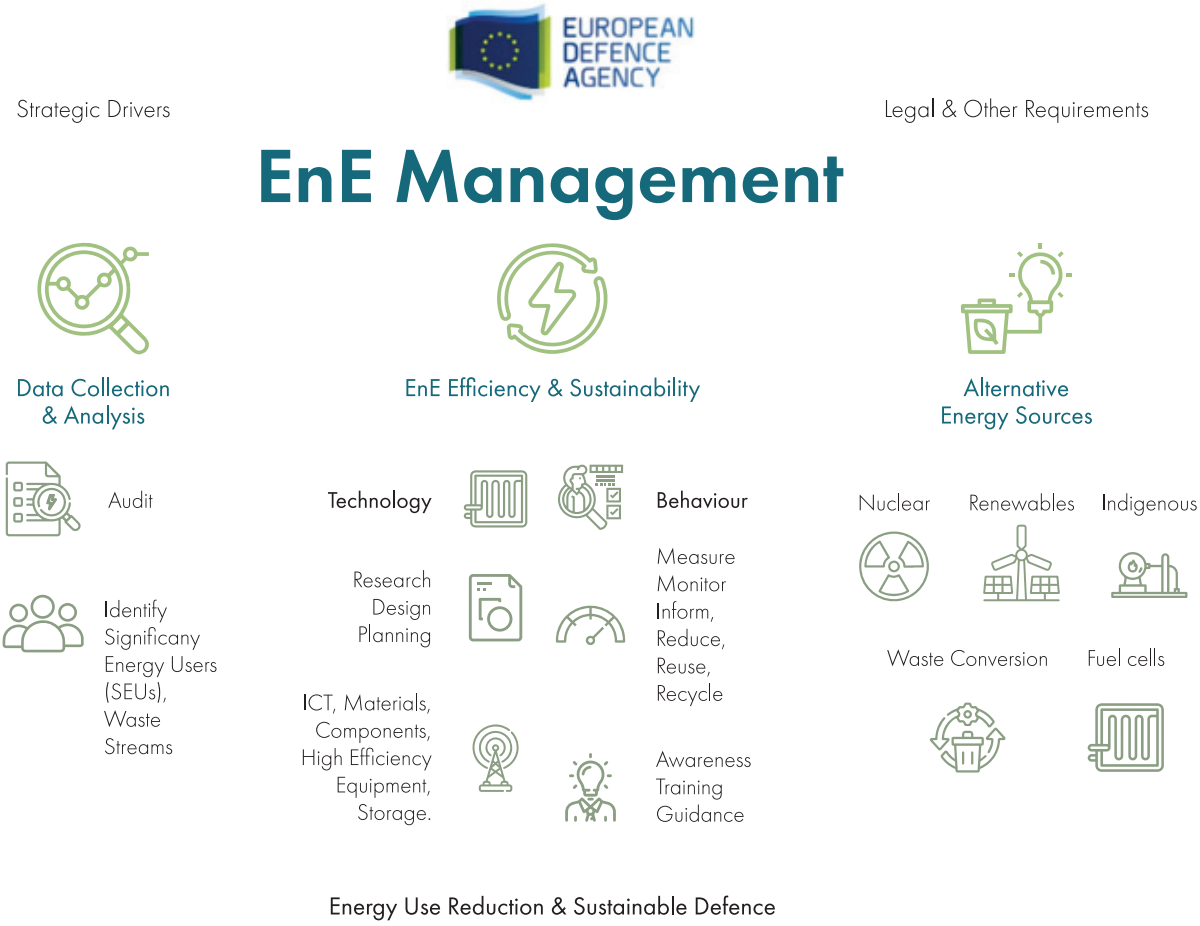


Figure 9. EDA's energy use reduction & sustainable defence. Source: www.eda.europa.eu

A total of ten relevant technological R&T (Research & Technology) priorities have been identified and translated into Technology Building Blocks (TBB). The Working Group TBBs, as they stand today, are the following[22]:

- TBB01 - Alternative fuels and drive/propulsion systems

- TBB02 - Energy storage: electrical, electrochemical, mechanical, structural, and thermal

- TBB03 - Engine and power distribution system efficiency technologies

- TBB04 - Energy management technologies: innovative and efficient systems

- TBB05 - Solar energy generation (thermal and electrical generation)

- TBB06 - Militarization of environmental technologies: water and wastewater

- TBB07 - Energy harvesting/scavenging

- TBB08 - Wind energy

- TBB09 - Energy and environmental technology systems integration

- TBB10 - Militarization of environmental technologies: energy from waste (or waste to energy) technologies

4.1.2. EDA Consultation Forum Sustainable Energy – CF SEDSS

Launched in 2015, the EDA Consultation Forum for Sustainable Energy in the Defence and Security Sector (CF SEDSS) is a European Commission (EC) funded initiative managed by the European Defence Agency (EDA). Its main objective is to create a European Defence energy-related community to promote collaborative research and innovation in the field of sustainable energy, supporting EU's MoDs move towards more green, resilient, and efficient energy models and contributing to the EU's objectives for climate neutrality by 2050.

As the largest European Defence energy community, it provides a unique platform for European experts from the energy and the defence sectors for sharing knowledge and best practices on improving energy management, increasing energy efficiency and buildings performance, utilising renewable energy sources in the Defence sector and enhancing the resilience of Defence-related critical energy infrastructure.

Objectives:

The Consultation Forum helps EU Ministries of Defence and Armed Forces to:

- Improve energy efficiency and buildings performance;

- Utilize renewable energy sources in the Defence sector;

- Increase the resilience of Defence-related critical energy infrastructure

- Address cross-cutting topics such as:

  - energy management and policy;
  - emerging and disruptive energy technologies;
  - funding and financing related topics

[22] www.eda.europa.eu

Building on its large community, know-how and substantial output, the Forum contributes to the EU's efforts to address the links between defence and climate change while contributing to implementing the "European Green Deal".

To address the above-mentioned objectives, EDA has implemented two phases: the first phase took place from October 2015 to October 2017 and the second one was held from October 2017 to August 2019.

Building on the successful outcome of these two phases, EDA and the European Commission launched in 2019 the third phase CF SEDSS III: 2019-2023. Phase III aims at presenting the Defence sector with an economic, operational, and strategic opportunity to reduce reliance on fossil fuels, minimise energy costs and footprint, and enhance operational effectiveness and resilience.

The CF SEDSS III works in close collaboration with EDA's Energy and Environment working group, the European Commission, EEAS and NATO as well as with several European SMEs, academia, research and technology organizations.

To address the higher level of ambition of the project, the CF SEDSS III is organised into the following four working groups:

a) Working Group 1 – 'Energy Efficiency & Buildings Performance', aiming to improve the energy efficiency of the military building stock and fixed infrastructure;

b) Working Group 2 – 'Renewable Energy Sources', aiming to enhance the integration of renewable energy sources in the defence sector (wind, solar, wave, tidal, biomass, geothermal, hydrogen, hybrid systems, etc.);

c) Working Group 3 – 'Protection of Critical Energy Infrastructures', aiming to increase the protection and resilience of defence-related critical energy infrastructure using different tools, guidelines, methodologies, vulnerability measurements, risk assessment plans, etc.;

d) Transversal Working Group with a primary focus on addressing cross-cutting defence energy-related areas, which are of interest to the other three working groups.

Working Group 1 Energyy Efficiency & Buildings Performance	Working Group 2 Renewable Energy Sources	Working Group 3 Protection of Critial Energy Infrastructure
Improve the energy efficiency of military building stock and fixed infrastructure	User renewable energy sources and technologies in the defence sector (generation, conversion, storage and use in transportation)	Increase the protection and resilience of defence-related critical energy infrastructure (tools, guidelines, methodologies)

Transversal Working Group		
Policy & Management Observatory (action plans, human factors, awareness, best practices, skills, etc.)	Technology Research & Innovation Hub (energy management networks, cyber, AI, digitalisation, sensors, micro-grids, etc.)	Financing & Funding Gateway Cell (identiFunding methodology for defence energy projects, ad-hoc, SRSS, ECP, etc.)

Figure 10. Structure of CF SEDSS III Working Groups. Source: www.eda.europa.eu

4.1.3. EDA's Smart Energy Camp Technical Demonstrator (SECTD)

The Smart Energy Camps Technical Demonstrator (SECTD) project is one of EDA's activities aimed to help Member States make their Armed Forces more energy-efficient and environmentally sustainable.

The EDA SECTD project was initially developed at the EU Training Mission Mali (EUTM) at Camp Koulikoro between October 2015 and March 2016. The purpose of the project was to test the practical implementation of an intelligent power management system (energy demand management, renewable production and storage) in a challenging military environment.

Table 4. EDA's Smart Energy Camp Technical Demonstrator project information.

Description	- One building, part of a much larger site, was chosen as test site for an intelligent power management system in a military environment. The whole site was powered by a 1.5 MVA diesel genset without energy storage and no demand management in place. - The elements installed included fixed solar photovoltaic panels on the test building (16KWp), 36.5kWh of energy storage (specific information for storage is not made public), flexible soldier portable solar photovoltaic panels, and monitoring and metering equipment for water and electricity. - Over the six-month test period (between Oct 2015 and Mar 2016), the renewable energy systems were integrated into the existing camp power system (requiring only minimal reconfigurations of the network) and it led to substantial energy management improvements and cost savings. The system was then transferred to EUTM Mali to operate and operation / savings information were not made public. - The project demonstrated the concepts of Generator Management, Energy Storage, Demand Management and Renewable Power Integration.
Results & Benefits	- Rigid PV system on the roof supplied around 80% of the building's peak load (middle of the day). - Demand Management used to reduce the average instantaneous demand by cycling each cooling unit on/off. - Raising the building setpoint temperature from 20°C to 24°C provides a reduced energy demand of up to 50%. - Small portable PV systems tested achieved close to 70% of rated output of the theoretical production capacity. - The overall benefit of these types of systems is that they allow critical assets to remain operational while allowing other less critical items to remain powerless through on/off switching without requiring two distribution networks. - Although the project was conducted in a deployed scenario on a single building, the technologies used and results obtained can be applied to Defence infrastructure in at home scenarios, including large military installations and those operating in remote locations. - The ownership of the demonstrator at the camp was transferred to EUTM Mali to continue its services and renewable energy supplies in the long term under the best technical conditions.

Images	 Figure 11. EDA's Smart Energy Camp Technical Demonstrator. Source : www.eda.europa.eu
Sources of Information	www.eda.europa.eu

4.1.4. RESHUB

"RESHUB", which stands for "Defence RESilience HUB Network in Europe", is a project led by the Slovenian Ministry of Defence (Si MoD) within the framework of EDA Consultation Forum on Sustainable Energy in the Defence and Security Sector (CF SEDSS). This has been completed under three phases: CF I: 2015 – 2017, CF II: 2017 – 2019, CF III (current phase): 2019 – 2023 which is a consultation forum on sustainable energy.

Other participating countries in the project are Austria, Belgium, Germany and Hungary. The project affects the following four EU policy areas: environmental, energy, common security and defence, and transport policy.

The aim of RESHUB is to help build a renewable energy harvesting and hydrogen (H2) energy storage capability and to facilitate cross-Europe transportation, which will lower CO_2 emissions and contribute to energy sustainability in the EU defence and security sector.

In the framework of the RESHUB project the Slovenian Ministry of Defence (Si MoD) is setting up a network of self-sufficient energy hubs in Slovenia. The Ministry is also the holder of the initiative to create similar hubs in the EU.

The project information in Table 5 provides a description of some of the technologies tested and the achieved benefits.

Table 5. RESHUB project information.

Description	- The network of HUBs comprises renewable energy sources, energy conversion and the storage of energy in the form of hydrogen, as well as the production of heat and electricity, incorporating fuel cells and electric and hydrogen charging stations. - The HUBs, to be set up in barracks, are capable of ensuring self-sufficiency for several days and support for both military and civil electric and hybrid mobility. - The military bases or barracks will secure the supply of energy through renewable energy sources: solar power plants, wind power plants and small hydropower plants. A hydrogen (H2) reservoir with a dedicated capacity will be set up and filled with hydrogen derived from hydrolysis, using the energy acquired from renewable energy sources and the power grid, or with hydrogen acquired in the process of natural gas reforming. With electric power from the public distribution system, hydrogen will be produced in cases of electric energy surplus from this system. The connection to the public distribution system will both enable a reduction of surpluses and resolve shortages of electric energy in this system.
Benefits	- By setting up the first five HUBs in the barracks of the Slovenian Armed Forces (under implementation), an estimated reduction of CO_2 emissions of up to 10,000 tons per year is anticipated. - At the same time, such HUBs will make it possible to produce and store energy locally over longer periods of time and thus considerably reduce dependence on external energy sources. - In the event of natural disasters and other crisis situations, the HUBs will represent a source of energy that is both independent (local) and reliable. - The project will support the use of electric-powered vehicles (energy stored in batteries or hydrogen). For the local community they will form the basis of the development of green public and private transport. - The activities of the RESHUB project run parallel to, and are strongly connected with, the activities of the Slovenian Energy and Environment (SiEnE) Partnership, that was established to provide a strategic and comprehensive approach for responding to energy and environmental challenges in defence. - The solutions arising as a result of the RESHUB project will also be incorporated in
Images	Not Available
Sources of Information	http://www.siene.teces.si www.eda.europa.eu

4.2. NATO ENSEC COE

As a primarily military alliance, NATO-allied countries are concerned about energy supply. Considering security implications, NATO's objectives are the following: (i) to increase energy resilience and to contribute to reaching net-zero carbon emissions by 2050 through stable and reliable sources of energy; (ii) to protect energy infrastructure in critical areas; (iii) to diversify power lines and energy sources and the interconnectivity between power networks; (iv) to offer more education and training opportunities; (v) to promote greater awareness and strategic dialogue among allies andpartners as well as cooperation with the private sector, academy, and other international organizations in the search for energetically safe and efficient solutions for the military[23].

The NATO Energy Security Centre of Excellence (NATO ENSEC COE), established in 2012, is a widely recognized international military organization with the aim of providing qualified and appropriate experts advice on questions related to operational energy security. The NATO ENSEC COE is composed of military and civilian experts from NATO and Partner Nations.

The mission of the NATO ENSEC COE is to assist Strategic Commands, other NATO bodies, nations, partners, and other civil and military entities by supporting NATO's capability development process, mission effectiveness, and interoperability in the near, mid and long terms by providing comprehensive and timely subject matter expertise on all aspects of energy security. The mission includes cost effective solutions to support military requirements, energy efficiency in the operational field, and interaction with academia and industry.

NATO Energy Security Centre of Excellence's objectives are the following[24]:

- Provides technical, scientific and academic subject matter expertise in the field of energy security that contributes to risk assessment analysis.

- Provides energy security-related solutions for the development of environmentally friendly and efficient military capabilities in support of Smart Defence.

- Provides scientific, technical and academic analysis on various aspects of energy supply and critical energy infrastructure protection in areas of concern to NATO.

- Supports NATO Operations through targeted technical-scientific assessment, as well as providing advice and solutions for the development of energy-efficient forces.

- Identifies future needs in NATO transformation activities and seeks to prevent or mitigate emergent military threats and challenges, which result from the global scarcity of energy resources and the complexity of the international energy system.

4.2.1. NATO Smart Energy Initiative

NATO's Smart Energy programme began in 2011 with the purpose to improve the energy efficiency of NATO Armed Forces through a wide range of innovative solutions , including renewable energy and intelligent energy management. The

[23] http://www.nato.int
[24] www.enseccoe.org

long-term goal was to introduce energy-efficient technologies that can reduce fuel consumption and related costs in military operations while enhancing interoperability and military effectiveness.

Additional details about the technologies tested are provided in Table 6.

Table 6. Some of the energy-saving technologies tested by NATO.

Description	NATO has been testing energy-saving technologies to make the military more efficient, save cost and reduce reliance on fossil fuels in the field. Here are the different technologies NATO Allies and partners regularly test in the field during military exercises at the Smart Energy Training and Assessment Camp (SETAC) and at the multinational exercise Capable Logistician in 2015 and 2019, a regular exercise for NATO and partner nations to test interoperability and assess NATO standards: 1. Renewable Energy Technologies, mostly solar PV and wind. 2. Portable Solar Panels a. Mobile Roll-Array Solar Power Plant b. Portable trailer with Solar Power System 3. Hybrid Systems Smart Hybrid Energy System (SHES) as a scalable and transportable solution for providing energy-efficient services to military forces in deployed operations. This system combines the traditional diesel generations with solar power generation (PV array) and/or wind energy, energy storage, solar hot water system and waste heat recovery technologies, all connected to a microgrid. 4. Heating / Cooling Innovati insulation materials, Insulated tents and sunshades, heat pump/heat exchanger and capillary conditioner for cooling tents. 5. Smart Hybrid Energy System (SHES) as a scalable and transportable solution for providing energy-efficient services to military forces in deployed operations. This system combines the traditional diesel generations with solar power. 6. Micro-grid / Smart Grid 7. Battery storage systems 8. Energy-efficient tents / Insulated tents 9. LED lighting 10. Energy metering (rapidly deployable) 11. Atmospheric water generator / water purification 12. Portable storage / portable solar arrays, including Soldier wearable power management vests, universal battery chargers and containarised battery solutions.

Benefits	- Recent experiments with camps demonstrated that the combination of Smart Energy production, storage, distribution and consumption in a microgrid instantly reduces diesel consumption by more than 50%.
Images	 Figure 12. Portable Trailer with Solar PV Panels. Source: www.nato.gov  Figure 13. NATO Smart Energy Training and Assessment Camp SETAC 2019. Source: www.nato.gov  Figure 14. Roll-Array Solar Power Plant. Souce: www.Renovagen.com
Sources of Information	www.natomultimedia.tv www.nato.int

4.2.2. Deployable Modular Hybrid Power Generation System

In 2015, NATO ENSEC COE started the Hybrid Power Generation and Management System project (HPGS). The HPGS 2015 Prototype project, developed through Canadian funding, was formally transferred in 2016 to the Lithuanian Armed Forces to be used and tested in NATO multinational exercises and training facilities, as well as in military installations. The key objective of this project was to test the feasibility of such systems for military applications.

The Deployable Modular HPGS uses conventional fuel generators and renewable energy sources, such as wind or solar energy, with energy storage and management solutions. The system will be used to improve energy efficiency and reduce dependence on conventional power sources, therefore, improving the energy supply security of the military camps. Additional details are provided in Table 7.

Table 7. Hybrid Power Generation and Management System (HPGS) project information.

Description	Hybrid Power Generation and Management System (HPGS) main characteristics are: - The HPGS is a mobile energy generation and management system that is robust, modular, simple to deploy, and can supply electrical energy a stand-alone system or it can also be integrated into the existing power grid. - The HPGS is an innovative power generation set that uses conventional fuel, renewable sources - wind and solar energy- and batteries to store the energy and incorporates an energy management system (EMS). - The system components of HPGS, which are housed in two 20 ft (equivalent to 6m) ISO Containers, consist of two 75 kW diesel generators, 25 kWp Photovoltaic PV array (84 modules 300Wp each), 6.5 kW wind turbine (5.3m rotor diameter, 12.5m high) and 100 kWh Lithium MNC battery pack. The HPGS is controlled via Mobile Energy Management System (MEMS). - The HPGS prototype was designed to provide a maximum 150 kW peak power generation and can produce up to 2500 kWh per day supporting approximately a 100-150 pax camp energy needs. **NATO ENSEC COE deployable modular Hybrid Power Generation & management System (HPGS)** Hybrid Power for approx 100 men camp: Technical data: - 2500 KWh/day - 2 x 75 KW Gen - 25 KWp PV - 6.5 KW wind - 100 KWh battery Estimated outcomes: approx 30% fuel saving - + 150% gain in maintenance time - + 30% security (energy autonomy) Funded by GPSF Foreign Affairs, Trade and Development Canada HPGS is the winner of TROPHÉES DE LA TRANSITION ÉNERGÉTIQUE 2016

Figure 15. Deployable Modular Hybrid Power Generation System details

Benefits	Since 2016 Hybrid Power Generation and Management System HPGS was tested and used by Lithuanian Armed Forces and has been tested during military exercises and demonstration events in Europe and also Canada. - The testing period has demonstrated that HPGS can improve energy efficiency and reduce fuel consumption by 20-30% in addition to the reduction diesel generators maintenance time. 9 different operational tests were performed each ranging between 24hours and up to 14 consecutive days. - The use of HPGS facilitates the sustainment of military forces and reduces the logistic footprint of military in exercise and operation, contributing also to the environmental protection. - Improves the operational effectiveness of forces through the maximization of autonomy and strengthening resilience. - Less dependence on fossil fuels and increased energy security in a military infrastructure via battery storage and MEMS. - This new system is capable of supplying power to different field infrastructures.
Images	 Figure 16. Hybrid Power Generation and Management System  Figure 17. Presentation of HPGS in Trident Juncture 2018 Excercise, Norway. Source: www.enseccoe.org.

Images	 Figure 18. Canadian Armed Forces to test the prototype in extreme cold weather environment.  Figure 19. December 2018 - April 2019: Test in extreme temperature, requested by Canadian Government.
Sources of Information	www.enseccoe.org

5 Case Study 2: UK Military

In the UK, climate change is a government priority and the MoD, like all UK government departments, must also contribute to meeting UK government ambitions and targets for sustainability and emissions reduction.
For the MoD, the effects of climate change pose real threats to Defence's ability to meet its strategic objectives. Some of the priorities to take into consideration are the following[25]:

- The type, frequency and location of operations that the MoD might be involved in as a result of climate change.

- Availability and cost of energy, products and services the MoD requires to operate in the future.

- The role of the MoD in co-operating with other government departments to identify and understand the global impact of climate change and its impact on the UK.

- Increasing the resilience of the defence estate to cope with local effects of climate change such as flooding or subsidence.

- Reduction of the MoD's greenhouse gas emissions in line with government targets while maintaining or preferably improving operational capability.

- Utilizing the emergence of low-carbon technologies to reduce dependency on fossil fuels.

5.1. Defence Sustainability Strategy

UK Defence accounts for 50% of the UK Central Government's emissions, approximately 1% of the UK's total greenhouse gas emissions, resulting in carbon emissions from defence capability (vehicles, platforms and associated logistics) accounting for the majority of annual defence CO_2 emissions[26].
MoD consumed 664 million liters of fuel in 2017/2018, achieving a 10% reduction from the previous year and almost cutting its energy consumption in half since 2009/2010. UK Defence has exceeded the 39.9% target for emission reduction, reducing it by 45%.
Energy Strategy and Targets:

- "Sustainable MoD Strategy 2015-2025": This strategy sets out the overarching framework for the Department, including governance and strategic objectives, and supersedes the previous 'MoD sustainable development strategy for 2011-2030'. The strategy delivery is detailed through two 5-year Delivery Plans, 2015-2020 and 2020-2025. The overall strategic objective is to increase energy efficiency strategies and reduce the dependency on fossil fuels, lowering the related risks for businesses and defense capability.

- "MoD Climate Change and Sustainability Strategic Approach" launched in March 2021 sets out in further detail the strategic ambitions, principles and methods needed to meet the challenge. Some of the objectives are listed below[23]:

  - By 2050, Defence aims to contribute to the achievement of UK`s legal commitment to reach net-zero emissions by 2050 (Net Zero target) by reducing emissions and scaling up the transition to renewables.

  - By 2025: Defence has reduced its built estate emissions by at least 30% to meet the GGC target

  - By 2050, Defense aims at acting and being recognized as a global leader in responding to the emerging geopolitical and conflict-related threats being exacerbated by climate change

[25] www.gov.uk
[26] Ministry of Defence, Climate Change and Sustainability Strategic Approach, March 2021

and reduce carbon emissions.

The Strategy is outlined in the Defence Command Paper, which recognizes the threat that climate change poses to global security and Defence. It aims at ensuring that innovative green initiatives and sustainability-related considerations are embedded in all decision-making areas across Defence.

5.2. Showcased Projects

This section provides information and achievements on some of the projects conducted by the UK Defence to decarbonize the sector.

5.2.1. MoD Lyneham Solar PV Farm

In January 2015, the Defence Infrastructure Organisation run a competition to procure design, funding, construction and commissioning of a 70MW solar park at the Defence Technical and Training College, Lyneham, Wiltshire, on the former RAF Lyneham airbase. Additional information is provided in Table 8.

Table 8. MoD Lyneham Solar PV Farm project information

Description	- MoD 69.8MW solar PV farm in Bradenstoke was completed and commissioned in March 2015 - Bradenstoke Solar Farm spans over 250 acres of the former runway that forms part of the RAF Lyneham base, in Wiltshire - The first to be developed with the British Ministry of Defence MoD. - At the time of its completion, the solar farm was the largest in the UK.
Benefits	- 269,000 solar panels, providing enough energy to power 10,000 homes plus the base military training college on site. - 15,000 Tonnes of CO_2 emissions avoided per year.
Images	 Figure 20. Aereal picture of Lyneham Solar PV plant.
Sources of Information	www.britishrenewables.com www.deegesolar.co.uk

5.2.2. Biogas Plant - RAF Royal Air force Marham

The Defence Infrastructure Organisation (DIO), the part of the Ministry of Defence that manages the Defence Estate, has collaborated with Future Biogas, EDF and Crown Commercial Services and the government's procurement agency to develop a green, sustainable and cost-effective electricity supply for RAF Marham. Future Biogas built and operates the plant.

Table 9. Biogas Plant – RAF Royal Air force Marham

Description	- Norfolk biogas 4.5 MW plant was officially opened in Jan 2019 to provide energy to the airbase RAF Marham, which has become the first UK military airbase to run nearly entirely on green electricity. - This project, in development since February 2015, has been delivered by the Defence Infrastructure Organisation (DIO) through a collaboration between the government and the private sector. - Electricity is provided through "anaerobic digestion" (AD) of locally-grown crops. The gas produced in this process is collected and used to fuel multiple generators producing electricity (utilising 3 x Jenbacher 420 gas engines). - 80/90,000 tonnes of crop per annum feed digesters. Heat, a by-product from the power generation process, is used to dry digestate, returning organic matter back to the land. - Further heat is planned to be used in the future via Economizer SE, a turnkey pre-treatment system for the biogas industry, allowing once unusable produce including straw, husks, shells and wood waste to be introduced to the anaerobic digestion process.
Benefits	- Provides 95% of RAF Marham's energy needs & saves the MoD nearly £300,000 every year. - Help reduce the Ministry of Defence's carbon emissions by 14,000 tonnes of CO_2 annually. - The waste residue from this process can then be dried & used as fertiliser to help grow local crops. - Connecting to the Biogas plant increases power resilience at RAF Marham, by providing multiple pathways to electricity.
Images	  Figure 21. Biogas Plant – RAF Royal Air force Marham. Source: www.clarke-energy.com
Sources of Information	www.gov.uk www.futurebiogas.com

5.2.3. British Army "Project Taurus"

Project Taurus, funded by the Defence Innovation Fund and delivered by the Defence Infrastructure Organisation (DIO), was launched in 2020 at Army Headquarters in Andover to understand and test the potential of Ultra-low-emission vehicles (ULEVs) and their impact on reducing energy consumption and carbon emissions whilst delivering significant cost reductions.

Table 10. Project Taurus information.

Description	- Project TAURUS: A solar carport at British Army Headquarters with electric car charging ports and battery storage. - It consists of 40-space carpark with 10 double electric vehicle charging points and battery storage for up to 20 Ultra-Low-Emission Vehicles (ULEV). - British Army's first solar powered carport delivered on the Army estate was completed in November 2021, available for use by Service personnel, civil servants and the Army's white fleet users (non-combat military vehicles).
Benefits	- Project Taurus showcases the Army's commitment to reduce dependency on traditional fossil-fueled vehicles while increasing renewable energy supply, which will lead to cost savings as well as being a 'greener' alternative. - Over the next 12 months, Project Taurus will deliver similar solar carports and electric vehicle charging at six further bases across the Army Estate, supporting the Defence's ambition to move to a more sustainable future and the Army's target of net zero by 2050. A second phase is planned for six further solar carports across all regions – no further information was made public.
Images	 Figure 22. Solar carport, project Taurus. Source: www.army.mod.uk
Sources of Information	www.gov.uk www.futurebiogas.com

5.2.4. British Army “Project Prometheus”

Project “Prometheus” is one of several sustainable initiatives employed by the British Army to support the UK Government’s commitment to meeting Net Zero Carbon Emissions by 2050 (UK Government`s 2050 Net Zero goal).

Project “Prometheus” pilot solar photovoltaic (PV) project was launched by the British Army in 2021 to showcase renewable energy generation across the Army state, with the goal to reduce carbon emissions and increase sustainability.

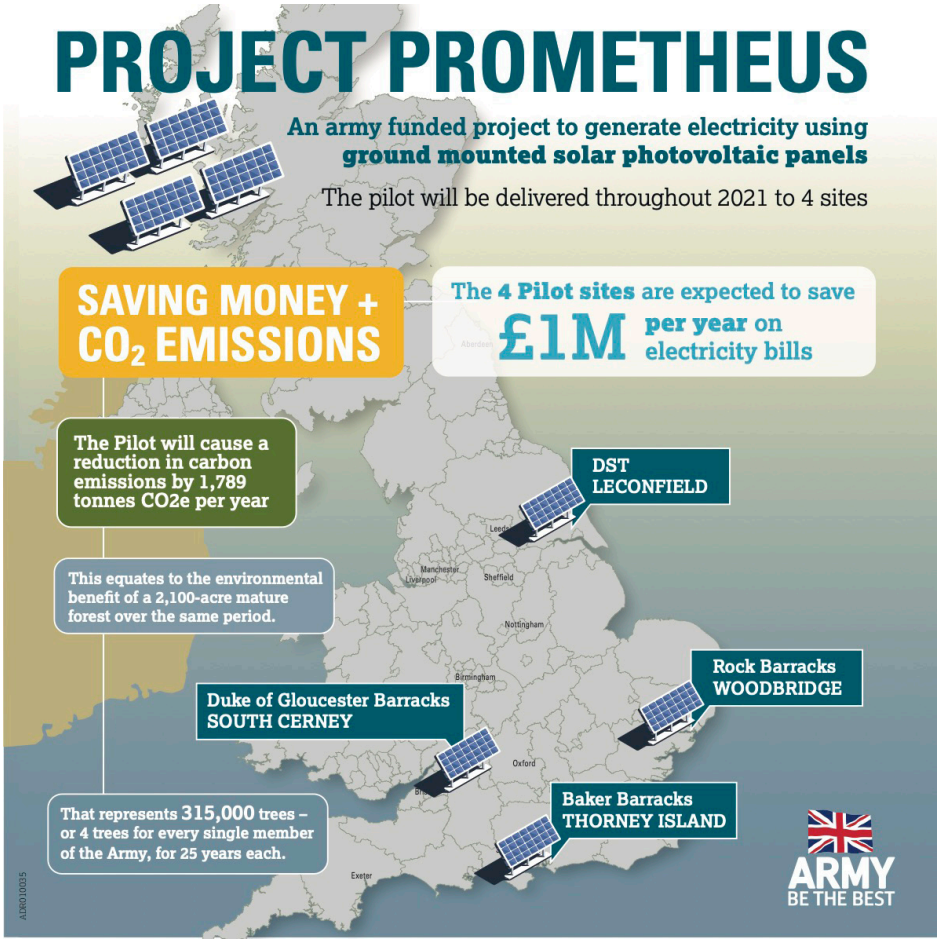


Figure 23. Project Prometheus overview. Source www.army.mod.uk

Additional information about the project is provided in Figure 24 and Table 11.

Table 11. Project Prometheus information.

Description	- Project Prometheus is 200 Million Pounds investment by the British Army into solar PV farms spread over the next 10 years. - The first pilot solar PV farm has been installed at the Defence School of Transport (DST) in Leconfield. Construction of this 2.3MW peak capacity solar farm started in early 2021 and was completed and officially launched by September 2021. Spanning approximately four hectares contains around 4,248 Trina Vertex solar panels. - Construction for the three additional pilot sites is already underway with the Duke of Gloucester Barracks in Gloucestershire, Rock Barracks in Suffolk and Baker Barracks on Thorney Island (Sussex), due to start operation during the year 2022. - The second pilot solar PV farm to be delivered at the Duke of Gloucester Barracks, South Cerney. The solar farm will span approximately 2.3 hectares, with over 3,000 solar PV panels. - After 4 pilot sites are completed, the aspiration is to deliver a further circa 80 solar farms across the Army estate within the decade.
Benefits	- The solar PV farm at DST Leconfield is expected to supply the DST with one-third of its electricity needs. This may include powering accommodation, offices, hangars, classrooms and the gymnasium, whilst any surplus will be exported to the grid. The demonstration PV farm is projected to save 700 tonnes of carbon emissions. - Together, the four pilot sites (with a total installed capacity of 4.4MWp) aim to save £1-million in efficiency savings per year and reduce emissions by 2,000 Tons of carbon dioxide equivalent per year (tCO_2e). - These cost savings will be reinvested into Army infrastructure to help reach the Army's target of Net-Zero by 2050
Images	 Figure 24. One of project Prometheus solar PV farms. Source www.army.mod.uk
Sources of Information	www.gov.uk

6 Case Study 3: Spanish Military

The Spanish Armed Forces are working towards reducing the logistical footprint, improving supply chains, and optimizing fuel consumption by investing in developing certain emerging technologies. To protect the environment and reduce GHG emissions, the Spanish Armed Forces work towards energy transition in national installations and deployable infrastructures.

The Spanish Armed Forces plan to reach progress in the energetic autonomy of the bases through the use of renewable energies and improved energy efficiency, reducing its carbon footprint.

6.1. Defence Energy Strategies and Targets

Strategies & Targets:

- Ministry Directive 107/1997 outlined a firm commitment against climate change to be initiated in the Armed Forces.

- In 2010, the Spanish Ministry of Defence (MoD) published its Strategy Dossier 150 entitled «Security, Energy Model, and Climate Change» which analyzed the emerging interdependence between these three factors and their impact on the strategic scenario of the 21st century. Furthermore, the strategy demonstrates the interest and attention with which the Armed Forces, as one of society's main servants, faces the challenges ahead.

- The Spanish MoD own Instruction on Environmental Sustainability and Energy Efficiency no. 56/2011 of 30 August, updated by 59/2014 of 4 December.

- Ongoing update to the "Strategic Plan 2021-2032 for Energy Efficiency in the Armed Forces" yet to
be released.

- By year 2032, 25% of energy needs are to be provided by RES and reduced energy use and dependency on conventional energy sources by 40%.

- Reduce 40-50% current electricity expenditure which amounts to 72 million euros per year.

- Focused on improving energy efficiency in buildings to reduce the use of conventional energy sources by 30%, implement self-consumption of energy in the military bases via RES installations.

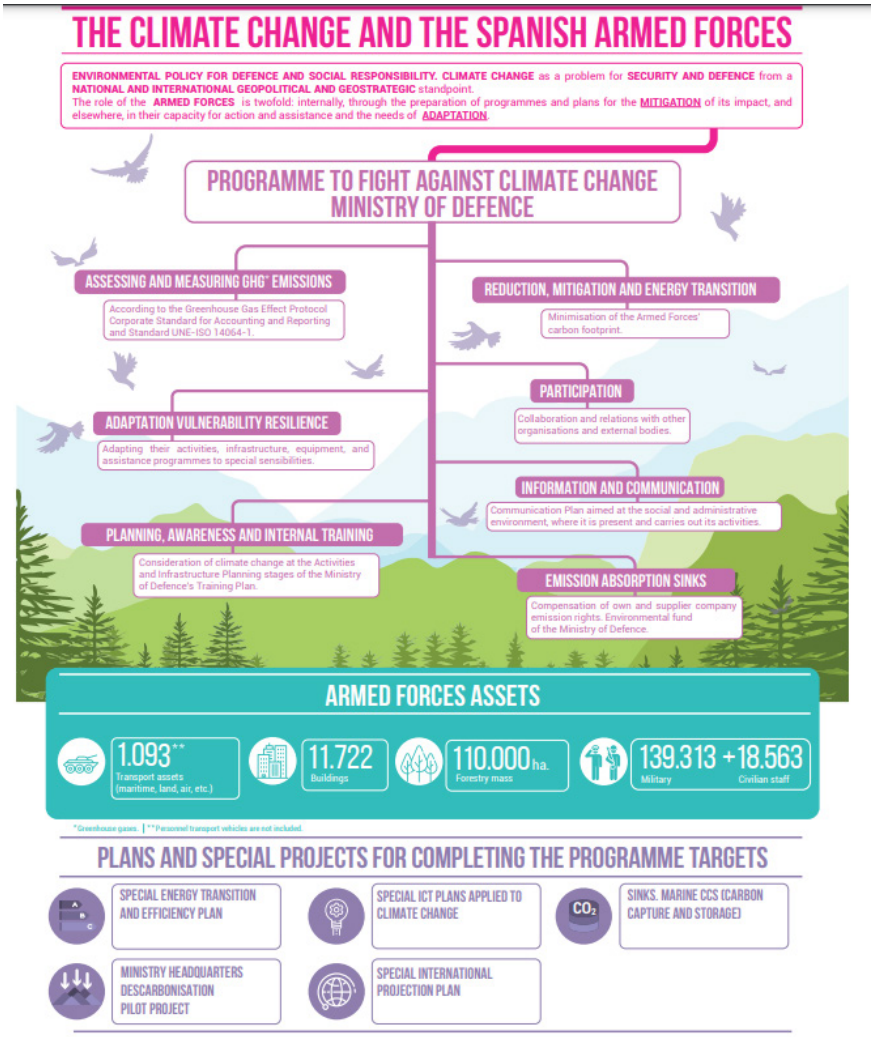


Figure 25. Climate change and Spanish armed forces[27].

6.1.1. ETID Strategy

The Spanish Ministry of Defence has launched the "Defence Technology and Innovation Strategy (ETID) 2020", in the ministry's Research & Technology (R&T) department directly tasked with developing the required military capabilities.

The Defence Technology and Innovation Strategy (ETID) is drawn directly from the Defence Planning process, developing the technology lines and R&D policy guidelines established in the defence planning documents. Its main objective is to define the technological roadmap intended to guarantee that the Spanish Armed Forces possess the technology needed in the future to fulfill their missions.

These so-called Technology Objectives represent the fundamental "building blocks" from which

[27] Spanish Institute for Strategic Studies, Strategic Dossiers 193 B, Climate change and its impact on defence, 2018

the strategy has been constructed and provide a guide to determining the set of R&T (Research and Technology) activities needed for the implementation. The Technological Goals (TG) are grouped into six Functional Areas, which cover the full spectrum of technologies of interest to the Spanish Ministry of Defence.

The Research Development & Innovation (RDI) activities related to Energy Sustainability will be guided by the technological objectives described in Table 12.

Table 12. Spanish Armed Forces Technological Goals (TG). Source: www.tecnologiaeinnovacion.defensa.gob.es

Specific area of action	Technological objectives	Scope
Energy sustainability	Power generation and energy efficiency in isolated bases and infrastructures	Reducing energy dependence and improving energy security at bases, camps and other off-grid infrastructures by developing technologies and adapting and validating them for use in the military environment.
	New propulsion systems for manned and unmanned vehicles	Development of hybrid and electric propulsion systems on manned platforms and unmanned systems to reduce the dependence on fossil fuels for platform propulsion and to improve the mobility and stealth capabilities of the systems.

The Research, Development and Innovation (RDI) guidelines related to Energy for Bases, Installations and Platforms, are organised as shown in Table 13[28].

Table 13. Research, Development and Innovation (RDI) guidelines related to Energy for Bases, Installations and Platforms.

Common Technologies for Bases and Installations, Platforms and Soldiers	
Energy	High-power energy systems Energy harvesting systems Fuel cell systems for use in the military environment Systems for the microgeneration of electric power, such as microturbines or portable generator sets
Bases and Installations	
Power at Bases and Installations	Integrated renewable electric power generation systems for bases in the area of operations Smart electricity grids for defence Self-production of fuels Integrated and efficient air conditioning and Domestic Hot Water

6.2. Showcased Projects

Approximately 250 million euros from the EU Plan "Recuperación Next Generation UE" are to be invested in 165 projects related to energy efficiency in military installations (187 m Euros) and the replacement of the ground fleet in the military bases with electric vehicles including the charging stations (63 m Euros).

6.2.1. ISDEFE's Headquarter Energy Efficiency Project

Ingeniería de Sistemas para la Defensa de España, S.A., (Engineering Systems for the Defence of Spain) (ISDEFE), is a state-owned public company part of the National Public Sector. ISDEFE is the in-house technical services provider for the Spanish General State Administration (AGE) and it is a part of Spain's Ministry of Defence. The company was founded in September 1985 by a Council of Ministers agreement.

in 2010, due to the growth and changing needs of the company, ISDEFE decided to purchase an obsolete building and transform it into an energy-efficient smart building to become its Headquarters. The defence sector in the EU is one of the largest owners of free land and building stock. Most of the buildings are outdated and do not comply with the current energy performance requirements and legislation. This renovation project is replicable and scalable to other Ministries of Defences' and Armed Forces' office buildings and may serve as an example of a cost-effective deep renovation in the EU defence sector.

[28] STATE SECRETARIAT OF DEFENCE, General Directorate for Armament and Materiel, Defence Technology and Innovation Strategy (ETID), 2020

Table 14. ISDEFE's HQ retrofitting.

Description	- Through this renovation project, an obsolete building was transformed into a highly efficient smart building that can be easily and quickly adapted to changing number of occupants and uses. The interventions were madein the building envelope, building interior fabric and structures and included the installation of highly efficient technical building systems, including solar PV, solar thermal, and cogeneration technologies. No further information was made public. - From the point of view of the facilities, they are equipped with the best technological advances, including sustainable infrastructure, energy efficiency measures, use of renewable energies, recovery of gray water and heat, reduction of emissions and lighting regulation (through lighting control). All technical building systems are monitored and controlled in real-time with a centralised SCADA system which keeps the whole building at the required levels of comfort optimizing the energy consumption. - The renovation project was done in accordance with the current Spanish construction and environmental legislation and energy performance requirements to achieve the highest achievable energy performance rate (B) and energy production for self-consumption. In addition, the project complies with the most stringent security measures required in the defence sector. It is to be noted that letter ratings (A,B,C, etc...) are defined taking into consideration various parameters, including but not limited to: local climate and building use, to this end,units are related / linked.
Benefits	- Extended life and increased commercial value of the building, while fulfilling all energy performance and security requirements - Energy savings (even more than originally estimated) in the project phase and reduction of energy costs. - Flexibility in the reconfiguration of working spaces in accordance with the organisation's different needs, facilitating the collaboration between multidisciplinary work teams and different departments, and a more productive and comfortable work environment. - Easily monitoring and maintenance of all technical building systems and installations through the centralised management and control system. - Capacity for energy consumption analysis and modelling for continuous energy performance improvement through the centralised management and control system. - Centralised management and control systems help in the implementation and follow up of Energy Management Plans aimed at fulfillment of ISO 50001 standard (or any similar) provisions. - All of the overinvestments resulting from key project decisions (replacing of new facade, VRV HR WC air condition system, lighting control system with electronic ballasts) were amortised in less time than estimated in the project phase. Evidence of payback periods of 10.1 years for all the overinvestments.

Images	 Figure 27. ISDEFE's HQ roof. source www.mur-arq.com
Sources of Information	www.eda.europa.eu www.isdefe.es

6.2.2. Smart, Sustainable and Connected Air Base - BACSI

The Spanish Air Force Project **(Base Aerea Conectada, Sostenible, Inteligente (BACSI)** initiative), was launched in mid-2020 and aims at connecting the main elements that make up an air base: people, ideas and hardware.

People constitute the central pillar on which the project is founded since they must be able to be located, share resources and collaborate in a simple way to improve ideas, work processes, initiatives or training programs. For its part, data and information must be easily locatable, accessible and ordered in a standardized and consistent format. Finally, hardware refers to sensors and technological systems, which will sometimes be connected to each other, to databases or directly to people. Connectivity is an enabling condition for the rest of the elements.

Additional information is provided in Table 15.

Table 15. Base Aerea Conectada, Sostenible, Inteligente (BACSI) initiative

Description	- The main objective of the project is to strengthen the resources and increase the productivity and operability of an air base. - Secondly, it responds to the Ministry of Defense's commitment to environmental preservation. The initiative seeks to reduce the environmental impact of the air bases, its largest facilities,. To do this, programs aimed at reducing the consumption of supplies using renewable energies and intelligent digital management tools, eliminating losses and improving waste management. - It is about adapting the current air base model to a more sustainable, responsible and supportive one. It would also be more autonomous from the perspective of energy security and more resilient in the face of threats and emergencies. - The project is structured in six functional areas: Connectivity, Energy Efficiency and Environmental Sustainability, Information and Knowledge Management (GIC) and Process Optimization, Force Protection, Operational Safety and Sustainment 4.0.
Benefits	The Functional Area No2. Energy Efficiency and Environmental Sustainability is based on the optimization of the management of the different supplies that feed a base, including water, gas, fuels and electricity. For this purpose, it will be necessary to install sensors and devices to enhance the connectivity among various elements. This enables the collection, monitoring and processing of consumption data to optimize the available resources, detect losses and waste and finally put in place energy-saving measures. The new regulation of the energy sector, which allows self-consumption, favors the implementation of alternative energy solutions (solar thermal and photovoltaic, geothermal), can significantly reduce the energy bill and increase the resilience of the most critical systems. This functional area includes the following subprojects: - AF2.1 Development of a computer program for digitization, automation and exploitation of environmental and energy management information. - AF2.2 Energy monitoring of Air Bases (Transformation centers, higher consumption facilities, pulse meters in boilers). - AF2.3 Implementation of an Energy Management System based on the international standard ISO 50001. - AF2.4 Design of lighting systems with low energy cost and maximum use of light. - AF2.5 Generation of thermal energy through Renewable Energy Technologies (replacement of fossil fuel boilers). - AF2.6 Energy-efficient design of buildings with bioclimatic parameterization. - AF2.7 Energy storage systems. - AF2.8 Energetically Sustainable Air Base.

Benefits	- AF2.8.1 Generation of renewable hydrogen. - AF2.8.2 Wind power generation. - AF2.9 Design of ultra-fast electric charging points for electric vehicles. - AF2.10 Optimized irrigation systems through artificial intelligence. - AF2.11 Flushing systems for sinks, cisterns and intelligent showers. - AF2.12 Design of intelligent electrical charging points for electric vehicles through the use of renewable energies and accumulators. - AF2.13 Design of electric industrial/collective vehicles. - AF2.14 Development of alternative technologies for aircraft propulsion. - AF2.15 Sound-absorbing asphalt to reduce noise caused by vehicle traffic. - AF2.17 System for the early detection of leaks and robotic repair of pipes. - AF2.18 Water collection and purification system. - AF2.19 Projectable WWTP design with 100% residual water recovery capacity. - AF2.20 Unused aviation fuel recovery system. - AF2.21 Design of a projectable waste management plant. - AF2.22 Reduction of hydrocarbon waters through settling techniques. - AF2.24 Modernization and digitization in the field of avifauna control. - AF2.25 Production of demineralized water. - AF2.26 Manufacture of anticorrosive product based on aloe vera.
Images	 Figure 28. Aereal picture of a solar PV plant powering a nearby airbase. Source: www.ejercitodelaire.defensa.gob.es
Sources of Information	https://ejercitodelaire.defensa.gob.es/EA/bacsi/

6.2.3. Electric and Hybrid Vehicles

ATHEMTO PROJECT – Uro Vamtac Hybrid

The 2015 Estrategia de Tecnología e Innovación para la Defensa (ETID)(Innovation and technology strategy for defence) specifies as a specific objective «to increase the degree of electrification for platforms through the development of hybrid and electric drive technologies. Advantages for Defence related to the electrification of the propulsion systems of land vehicles, such as fundamentally its lower thermal and noise footprints as well as the possibility of having a supply of electrical energy for all auxiliary equipment on board.

The URO VAMTAC Hybrid Prototype has been developed by UROVESA in collaboration with the University Institute of Automobile Research (INSIA), part of the Polytechnic University of Madrid, and within the ATHEMTO project, financed by the Spanish Ministry of Defence MoD. The main objective of the project ATHEMTO has been developing a vehicle demonstrator prototype for operational military transport, with full-electric traction and extended range.

The VAMTAC is a multipurpose vehicle specially created and designed for military use on all types of terrain and in all conditions. Manufactured by UROVESA in Spain since 1998, today it is a leading tactical vehicle with more than 5,500 units (diesel operated) in service around the world with different configurations and applications.

Table 16. Uro Vamtac Hybrid project information.

Description	- Electrically powered variant of the Uro Vamtac military off-road vehicle is being tested. - The system consists of a Diesel engine with an electrical system made of 2 drive electric motors. - The two drive motors together achieve an output of 200 kW (268 Hp) and a torque of an impressive 1,600 Newton meters, as stated by the researchers. - The system is made up of an electrical system responsible for propulsion powered by a battery (of 21 kWh capacity) that allows it to travel up to 40 kilometers in electric mode and propel it up to a maximum speed of 90 km/h - In parallel, a diesel engine, kept at the most efficient speed possible, will allow autonomy to be extended to figures similar to those of the diesel version. - The hybrid system can be operated in different modes: In “Eco” mode where the electric engine (through the fully charged battery) is the primary engine powering the vehicle. in “Power” mode, the maximum possible energy from the combustion engine and the battery is provided for the drive, and in pure “electric” mode.

Benefits	- This model can be driven on roads with slopes of up to 60%, will have up to 3 driving modes, will significantly reduce noise at certain times when the battery is charged, and will also offer high levels of savings with consumption in real-world conditions that the manufacturer has estimated between 20% and 30% compared to the diesel variant. - An alternative in the race to improve energy efficiency and reduce greenhouse gas emissions in one of the sectors with the greatest impact and therefore providing a big demand reduction.
Images	 Figure 29. Uro Vamtac military off-road vehicle. Source www.urovesa.com
Source of Information	www.urovesa.com www.forococheselectricos.com www.topgear-autoguide.com

Project BASCI

Project under BACSI launched in June 2021, a public-private partnership where an electric vehicle will be bested in the Air Force Base in Alcantarilla (Murcia). This is the first step in the transition to energy efficient and energy sustainable model in the Bases.

The Air Force Patrulla Acrobática de Paracaidismo (PAPEA) and Turiscar Ecotrain, focused on offering electric and sustainable transport solutions, have signed in 2021 a collaboration agreement on electrification. This is the the first electric vehicle that will be available to the Air Force, specifically at the Alcantarilla air base, and will be used daily by the components of PAPEA for all their journeys. This alliance is part of the Air Force's Connected Sustainable and Intelligent Area Base (BACSI) project, which was presented in mid-2020. It is also the first step in a process of transforming the facilities and means that PAPEA wants to carry out at its air base to energy efficient, environmentally sustainable and connected that serves as a reference. To do this, it works through agreements/partnerships with regional and national companies that contribute to this transformation.

Figure 30. Electric vehicles for Alcantarilla air base. Source: www.ejercitodelaire.defensa.gob.es

6.2.4. HQ Army Logistics Base

The Ministry of Defence plans to inaugurate the new Army Logistics Base, General Varela, in the year 2026. It is a logistics centre with the highest technological standards, which will group the Army's material maintenance activities in a single facility. The Army has been working on this project for more than 10 years, in order to rationalize its logistical support structures, and to be a reference of energy efficiency in Military Bases, not only in Spain, but in Europe and globally. Thus, the logistics base of the Army in Córdoba is unique and pioneering in the world.

Table 17. HQ Amry logistic base information.

Description	- The Logistics Base will be built over an 85 hectares (850,000 square meters) plot of land in La Rinconada, Córdoba (Spain), starting with the geotechnical study of the soil (in 2022). In 2023, the construction of the base will begin, a complex with 9 large buildings, with expected completion in the first quarter of 2026. - The base will house 3 main areas: logistics area, a command area with an operations center, and the personnel support area. There will be a main warehouse and supply center of 55,000 square meters with advanced technology and robotics; loading dock, as well as a material reception and delivery area with mandatory automation.
Benefits	- The base will be technologically advanced and innovative. The main objective of this project is to improve efficiency and reduce costs in infrastructure maintenance. - The ultimate goal is to reduce the carbon footprint and have modern and environmentally sustainable facilities. - The necessary investment, estimated to be more than 350 million euros, will be amortized in a short period of time according to the Spanish Ministry of Defence.

Images	 Figure 31. Infographic on planned logistic pole in Cordoba, Spain. Source: Ejercito de Tierra - Ministerio de Defensa / RAMÓN AZAÑÓN
Sources of Information	www.defensa.gob.es www.diariocordoba.com

7 Case Study 4: US Military

The U.S. Department of Defence (DoD) is one of the largest single consumers of energy in the world, responsible for 93% of all US government fuel consumption in 2007 (Air Force: 52%; Navy: 33%; Army: 7%. Other DoD: 1%).

The U.S. military's oil consumption fell by 20% between 2007 and 2015, and its investment in renewable energy projects tripled between 2011 and 2015.

In alignment with the National Defence Strategy, U.S. DoD's primary energy program priority is "to ensure the readiness of the armed forces by pursuing energy security and energy resilience[29].

In 2020, US Department of Energy (DoE) and US DoD signed an MOU to establish a framework to collaborate on energy resilience and protection of military installations and Defence critical electric infrastructure.

Congress has decided that military facilities must get 25 percent of their energy from renewable sources by 2025, totalling approximately 3 gigawatts of power production from renewable sources every year.

There are more than 130 MW solar PV systems powering Navy, Army and Air Force bases in at least 31 states and the District of Columbia. The U.S. Army is one of the biggest users of solar PVs.

The Army also has taken an active stance on addressing climate change, with many of these actions originating in broader DOD directives or presidential executive orders. "Army Net Zero Initiative" aims at establishing 25 net-zero installations by 2030, using renewables energy sources.
The U.S. Navy has already started producing or procuring more than 25% of its energy consumption from renewables including the "Great Green Fleet" a carrier strike group relying on hybrid-electric propulsion technology, fuel cells and nuclear power.

Each of the military services established central program offices to coordinate and implement energy resilience and distributed energy projects. The Army Office of Energy Initiatives (OEI), Air Force Office of Energy Assurance (OEA), and Navy Resilient Energy Program Office (REPO) have slightly different roles and responsibilities within their respective corporate structures, but each is responsible for developing installation energy and energy resilience projects.

Strategic plans and regulatory frameworks are constantly developed and published to provide guidelines and milestones to the different offices in place. Two examples are briefly described below:

- Army Installation Energy and Water Strategic Plan (Dec 2020): This Plan establishes the vision, goals, strategic objectives, and targets to further efforts to build long-term resilience, efficiency, and affordability in Army installation energy and water infrastructure supporting critical missions (any US army installation) in the Strategic Support Areas.

- Installation Energy and Water Resilience Policy (Army Directive 2020-03) (Mar 2020): This

[29] U.S. Code, Title 10, Subtitle A, Part IV, Chapter 173, Subchapter I, 2911 - Energy policy of the Department of Defense.

directive establishes energy and water resilience requirements for Army installations in support of the 2018 National Defense Strategy and Army Vision.

7.1. U.S. Army Office of Energy Initiatives (OEI)

The Office of Energy Initiatives (OEI) was established in 2014 under the Secretary of the Army for Installations, Energy and Environment. It serves as the Army's central program management office for the development, implementation, and oversight of privately financed, large-scale, renewable and alternative energy projects. OEI focuses mostly on projects with capacity equal to or greater than 10 MW, although it follows closely also the installation of smaller capacity projects.

Through the OEI, the Army seeks to achieve energy security and resilience on its installations by implementing projects that include energy generation, energy storage, and energy control capabilities, to preserve base operational capabilities during a potential grid disruption, while also working towards the Army's mandate to provide 25 percent of its electricity from renewable sources by 2025, in accordance with the 2007 National Defense Authorization Act.

The OEI's efforts support the implementation of Army energy strategy and policy. In alignment with the overarching National Department of Defence, and Army strategies, 'Army Installations 2025' provides the Army's strategy to ensure their installations remain ready, resilient, and capable of accomplishing their mission of defending their Nation. It is the foundation and vision to support the Army as it transitions, adapts, and improves to meet the demands of the future.

The Office of Energy Initiatives (OEI) collaborates with industry, public utilities, internal Army organizations, and other stakeholders to improve energy resilience in installations through projects that blend generation, storage, and control capabilities.

How the Army OEI pursues installation energy resilience:

- **Power Purchase Agreements:** energy generated by privately owned assets is purchased by the army.

- **Real estate outgrant** (e.g. lease, easement): the army may consider a real estate out grant of land to industry for onsite development of commercial, grid-serving power generation and/or energy storage. The industry provides to the army with the right to power during a utility grid outage via onsite energy generation, storage, and control assets.

- **Utility Energy Service Contract (UESC) / Energy Savings Performance Contract (ESPC):** the army leverages private sector expertise to restore energy equipment. Utility / energy service company provides army with modernized infrastructure and pays upfront costs which the army repays over the course of the contract from savings.

- **Army procured construction / equipment** (for example, military construction, energy resilience and conservation investment program (ERCIP)): army owned energy resilience capabilities are procured using appropriated funding from congress.

As of 2017, the USD DoD counts 17 facilities across the country hosting OEI-backed projects in various stages of development, including a 60 MW of biomass generation at Ft. Drum, NY; a 50 MW of wind at Ft. Hood, TX; a 30 MW of solar at Ft. Benning, GA; and a 14 MW of solar at Camp Shelby, MS. An overview of the US Army current energy portfolio is presented in Figure 32.

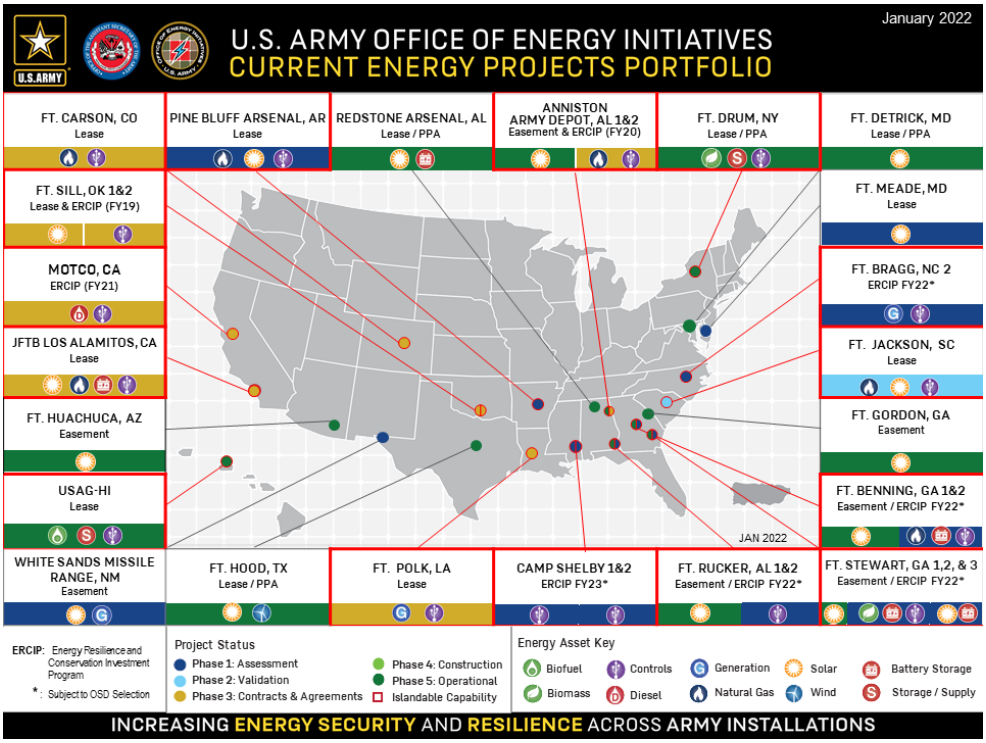


Figure 32. US Army current energy portfolio. source www.asaie.army.mil

7.1.1. Schofield Barracks, HAWAII ENERGY RESILIENCE & SECURITY PROJECT/Schofield Generating Station & Microgrid

The U.S. Army Office of Energy Initiatives (OEI) and U.S. Army Garrison-Hawaii (USAG-HI) collaborated with the Hawaiian Electric Company to develop a 50MW biofuel power generation plant at Schofield Barracks. The project became operational in May 2018. It enhances the resilience of the Oahu electrical grid and during emergencies is capable of providing Schofield Barracks, Field Station Kunia, and Wheeler Army Air Field with firm and flexible energy generation.

Schofield Barracks is one of the installations that make up USAG-HI (part of the 22 Army installations and sub installations on the Island of Oahu and Hawaii) was established in 1908 to provide a base for the Army's mobile defense of Pearl Harbor and the entire island.

Table 18. Biofuel power generation plant at Schofield Barracks project information.

Project Details	- Located on the Schofield Barracks Army installation, the 50-megawatt (MW) multi-fuel reciprocating engine plant is a collaboration between the Army and Hawaiian Electric Company - Hawaiian Electric's 50-megawatt Schofield Generating Station was commissioned in 2018. and the plant is implemented on a eight acres land at Schofield Barracks. The Army is leasing this land to the developing company. During normal operations, SGS sends power to the grid. - In the event of a power grid disruption, the plant is capable of providing fully the electrical demand of Schofield Barracks, Field Station Kunia and Wheeler Army Air Field. - The plant is the only baseload power generation facility on Oahu located above the tsunami inundation zone. It provides "black start" capability and enhances grid resilience to benefit the Army and the community. - Approved by the Hawaii Public Utility Commission, the Hawaiian Electric Company developed, financed, and constructed the Schofield Generating Station. The latter owns, operates, and maintains the plant. - The Schofield Generating Station has a minimum of 30 days' worth of fuel storage, including five days of supply onsite. - The project includes a 35-year lease to the Hawaiian Electric Company for approximately eight acres of land on Schofield Barracks with a 10-year renewal option
Results & Benefits	- During a major outage (i.e. caused by a Hurricane), the Schofield Generating Station will be able to power up a utility-owned microgrid consisting of three U.S. Army installations in Central Oahu. the three installations can be islanded and powered with 100% renewable energy from the Schofield-based power plant. Using SGS as the primary source of power supplemented by the Army's rooftop PV on the bases, the Hawaiian Electric-U.S. Army effort helps advance energy resilience and security for the Army. - SGS is the only power plant on Oahu that is located inland, protected from the potential impact of storms, tsunamis and rising sea level. Although capable of operating on biodiesel or diesel, since commissioning it has operated solely on 100% locally refined biodiesel. - locally and sustainably produced biodiesel that powers the Schofield-based power plant is fuel made from food waste - The facility, owned and operated by the Hawaiian Electric, is the first on the island to use flexible and efficient generators that will complement increasing levels of solar and wind power on the Oahu grid.

Results & Benefits	- Designed and built by the Hawaiian Electric to be fuel-flexible, able to use biofuel and contribute to the state's renewable energy progress - Schofield Generating Station was projected to reduce oil use by about 26,000 barrels annually.
Images	 Figure 33. inside the biofuel power generation plant at Schofield Barracks. Source: US Army  Figure 34. Aerial view of the Biofuel power generation plant at Schofield Barracks. Source: US Army
Source of Information	www.army.mil www.hawaiianelectric.com

7.1.2. Fort Carson Battery Energy Storage System

The Battery Energy Storage System (BESS) installed in November 2019 at Fort Carson, El Paso County in Colorado, is the largest stand-alone battery on a Department of Defense installation. The new BESS is mostly used for peak shaving, reducing electricity use during peak demand periods.

Since most of Fort Carson's energy bill is related to its maximum demand, the BESS is discharged when Fort Carson is paying the highest rate . And charged during periods where there is less electricity demand. This service of the BESS directly reduces Fort Carson's utility bill.

Table 19. Fort Carson Project information.

Description	- The BESS project at Fort Carson is part of an energy savings performance contract signed between the US Army with engineering firm AECOM, to finance, design and construct the $8 million battery system. - Fort Carson military base is the 10th largest military site in the U.S., home to more than 13,000 troops and 982 facilities. - The 4.25MW/8.5MWh lithium battery system consists of thousands of small lithium storage cells, organized into modules and racks, inside more than a dozen, 5-by-12-foot containers located at the utility substation off Minick Avenue - Typically the BESS charges overnight when energy costs are lower, and discharges during the late afternoon, when Fort Carson experiences its maximum electrical demand. - BESS is controlled by a highly sophisticated predictive control system
Benefits	- The BESS offsets the high energy demands placed on Fort Carson's power grid, especially during summer cooling season, ultimately increasing power grid resilience - The BESS system is estimated to reduce the Fort Carson's billed peak electric use by an average of 9% every month, which will save Fort Carson approximately 525,000 USD a year. - The plant will help the base optimize its solar photovoltaic assets & will be used for microgrid support. - The BESS system project aligns with the Army's increased focus on energy resilience & cost savings. - Other initiatives noted in Fort Carson's nomination included the improvements to the installation's energy management control system (EMCS) and the expanded use of electricity-conserving LED bulbs and fixtures to reduce electrical consumption. The EMCS is an automated system designed to set temperatures within buildings based on occupancy periods. During 2019, the EMCS, which controls more than 380 buildings on post, saved enough energy to power an estimated 1,521 homes for a year.

Images	 Figure 35. Trasportation of the BESS to Fort Carson. Source: www.hnc.usace.army.mil
Sources of Information	www.hnc.usace.army.mil www.aecom.com www.fortcarsonmountaineer.com

7.1.3. Tooele Army Depot TEAD

The U.S. Army Corps of Engineers in partnership with Utah's Tooele Army Depot are developing renewable energy projects as part of the Army's Energy Conservation Investment Program, designed to increase renewable energy consumption on military installations in order to provide environmental and tactical benefits.

Table 20. Tooele Army deport project information.

Description	- The following energy systems are part of Tooele's Path to Net Zero program: - Tooele Army Depot (TEAD) currently has one operational 1.5MW commercial wind turbine completed in 2010, and one operational 1.8MW commercial wind turbine completed in 2016. Both turbines will generate nearly 60% of the depot's energy needs. - Tooele Army Depot concentrating solar power (CSP) Project: A 1.5 MW Stirling solar array, consisting of 429 Stirling engine solar dishes spread across 15 acres (each collector PowerDish 3.5 KW) and the 1.5 MW Turbine Capacity (Heat-Transfer Fluid Type: Helium), started in 2012 and is now in the final phases of constructing and testing, expected to provide approximately 30% of the depot's annual electric energy need. - Tooele 10-acre 2MW Solar Photovoltaic Array that offsets Tooele Army Depots (TEAD) energy consumption from the local utility while allowing excess power generated to be sent to the local utilities electrical grid via the existing net metering station. Tender launched in June 2021. - BEES 1MW/1MWh lithium-ion grid-tied battery energy storage system to the Tooele Army Depot (TEAD) in Tooele, Utah. The Go Electric system will serve as a critical component of the facility's self-sufficient microgrid, providing the depot with energy security and resiliency. - Additional energy projects in design and construction phases include the installation of a microgrid with 1.0 MW utility scale battery, an Energy Management Control System (EMCS), installing new natural gas lines connecting the system to remote areas of the installation and replacing inefficient HVAC and industrial processing units, and replacing an outdated utility scale standby generator with new high efficient generators.
Benefits	- Once all projects are complete, TEAD will become Net Zero energy use and increase energy resiliency to the point that installation operations can continue even at times of commercial utility outages. This will allow the storage installation's crucial operations to continue unburdened by traditional power grid failures or black outs.
Images	 Figure 36. Tooele Army Depot concentrating solar power (CSP) Project. Source: www.army.mil
Sources of Information	www.epa.gov www.army.mil

7.2. Air Force Energy Program

The Assistant Secretary of the Air Force's Energy, Installations and Environment's (SAF/IE) Energy Program is responsible for the strategic management and oversight of the Air Force's energy efforts, partnerships, and program and policy development across the Air Force enterprise. The program supports the overall Air Force Energy Vision of Enhancing Mission Assurance through Energy Assurance, which reflects the Air Force's emphasis on energy resilience.

The Department of the Air Force Office of Energy Assurance (OEA) was established in February 2016 by the Secretary of the Air Force and Chief of Staff to serve as the aggregator for installation energy and water resilience initiatives. Led by energy, policy, engineering and acquisition experts, OEA conducts holistic, data-driven analyses that identify opportunities for energy and water infrastructure improvements to meet mission requirements and provide actionable solutions[30].

7.2.1. Deployable Energy Systems

Providing power to remote military installations is crucial to maintain operativity. AFRL Air Force Research Laboratory's Advanced Power Technology Office (APTO) leads the innovation from the front and is developing rapidly deployable, off-grid energy solutions with renewable energies and battery systems, for remote military sites.

The AFRL APTO forward operating base of the future project plays a critical role in changing the way forward deployed forces will power missions in the future.

If successful, the APTO team will recommend the technology to Air Force Civil Engineering Center and other potential users for inclusion in Forward Operating Bases and deployment equipment packages. The added capability would make deployed forces more self-sustainable and energy-resilient, reducing the logistic burden of fossil fuels.

EARRS, which stands for Energy Assurance at Remote Radar Sites managed by the AFRL Advanced Power Technology Office (APTO), is a year-long demonstration effort involving two different power generation technologies installed at isolated locations in Alaska and Hawaii to demonstrate rapidly deployable, off-grid energy technologies for increased mission energy resiliency in remote locations.

[30] www.safie.hq.af.mil

Table 21. Deployable wind energy systems information.

Description	- In Kotzebue, Alaska, where the Pacific Air Forces Regional Support Center and 611th Civil Engineer Squadron operate a remote radar range 40 miles north of the Arctic Circle - Demonstrating an energy-harvesting wind turbine. - Here the AFRL team installed two wind turbines that are expected to generate 12 kW (in total) of power to offset the grid load. - The unique aspect of these wind turbines is their transportability, ruggedness, and easy installation that make them ideal for this austere environment. - The towers, developed by ARE Telecom & Wind, were palletized at the request of AFRL to make them easily transportable and able to be quickly set up by a small crew. The AFRL team assembled and installed the 50-foot assembly in under four days with five people. - The goal of this initial effort was to evaluate the performance of the turbines before recommending the addition of more units to cover the entire load
Images	 Figure 37. Wind turbine in US military base. Source www.dla.mil Photo by Capt Jason Goins
Sources of Information	https://www.wpafb.af.mil/

Table 22. Deployable solar energy systems information

Description	- On Mt. Koke'e, Hawaii, the EARRS project will demonstrate self-sufficient, rapidly deployable power-generation, along with a revolutionary lighter-weight and durable solar panel design. - These new panels are capable of being shipped and installed quickly and are impact tolerant. - The solar panels, developed by California-based Armageddon Energy, differ from traditional panels in that instead of being encased in glass, the solar cells rest atop a foam board and are encased with a transparent laminated coating. This assembly makes the cells 50% thinner and 33% lighter. It also makes them extremely durable. - Traditional solar panels will no longer function if the glass enclosure is broken. However, the new design can endure a puncture or breakage, with the non-damaged area remaining fully functional. The lighter-weight design also enables easier setup and installation.
Images	 Figure 38. Solar panels on Mt. Koke'e, Hawaii. Source: University of Dayton Research Institute/AJ Mouser
Sources of Information	https://www.wpafb.af.mil/ https://www.dla.mil/About-DLA/Images/igphoto/2001779271/

Air Force expeditionary energy demo: Part of AFRL APTO Forward Operating Base of the Future demonstration is one complete expeditionary microgrid system at Basic Expeditionary Airmen Skills Training (BEAST), at Lackland Air Force Base AFB in San Antonio, Texas.

The APTO "Building the Forward Operating Base of the Future" project plays a critical role in changing the way forward deployed forces will power missions in the future. It uses alternative energy sources, energy storage technologies, and secure smart grid technology to demonstrate how the Air Force may reduce its reliance on diesel fuel at forward operating bases.

The on-going project(Phase 1; end in 2017, Phase 2: ongoing with no end date made public) hopes to meet the Air Force Civil Engineering Center's 2035 vision to create a totally deployable, self-sustaining power system.

Table 23. APTO Forward operating base project information

Description	- The project evaluates energy reduction technologies such as shelter insulation and efficient heating, ventilation and air conditioning systems HVACs. - Monocrystalline silicon solar panels are placed on top of each tent for energy production. - Mobile Energy Storage, Management System: Housed in a 10-foot-long trailer, a mobile, hybrid energy storage and management system able to supply renewable energy power for forward operating bases is the latest addition to the APTO-led effort to meet the long-term energy needs of military forces. - Batteries and a microgrid command, control and communication software package can act as a power source, better able to supply on-site, mobile energy for expeditionary forces. - The team is also working with industry to create a lightweight wind power package. This would employ a ground-based system with a bladed turbine that can be cranked up into the air to generate wind power.
Images	 Figure 39. APTO Forward operating base. Source: DLA website, U.S. Air Force photo/ Jason Goins
Sources of Information	www.defence.gov www.wpafb.af.mil

Solar Powered Integrated Structures

United State Air Force (USAF) continues its development of rapidly deployable, solar-powered structures in moments of crisis, to support personnel, equipment and operation centers. These structures need to be agile in that they must be easy to set up quickly and be independently powered. Additionally, the structures can provide climate control.

The USAF's Rapid Sustainment Office RSO's goal is to increase mission readiness by rapidly identifying, applying, and scaling technology essential to the operation and sustainment of the United States Air Force.

Table 24. Solar power integrated structures information.

Description	- Mobile solar-powered tents provide shelter, power, climate control, and flexibility for military and security applications. - The USAF's Rapid Sustainment Office (RSO) to manufacture up to 40 Solar Powered Integrated Structures for development and testing in 2022. - These structures will be provided to seven different USAF end users. These users will range from the Pacific Air Forces (PACAF) to the United States Air Forces in Europe (USAFE). - They are fully self-sufficient, and each structure will include Environmental Control Units (heating and air conditioning), energy storage, lighting, power, and backup generators for cases of inclement weather. - These products transcend the traditional model and will operate as a hybrid power solution, using solar as a primary source and generators as a backup source. - This program is a continuation of a successful 2019 Air Force Small Business Innovation Research (SBIR) Program for Rapidly Deployable, Solar Powered Structures program through the RSO. The RSO's mission is to identify, apply, and scale small business innovations through a competitive awards-based program - Pvilion's solar technology is significantly lighter and more adaptable than traditional solar options. It is integrated entirely into a system already being installed; i.e., a tent, shade canopy or hangar with fully integrated photovoltaic fabric panels, Pvilion's structures allow for the multi-capability use by providing power, shelter, lighting, and climate control.
Images	 Figure 40. Flexible PV modules integrated in tents.  Figure 41. Pvilion's mobile solar powered tents
Sources of Information	www.aerodefensetech.com www.pvillion.com

7.2.2. Edwards AFB Solar Project

A solar PV project to develop what could be one of the largest solar photovoltaic arrays in the country and the largest solar project ever for the Department of Defense at Edwards Air Force Base, California.

Under the Air Force's Enhanced Use Lease program, special purpose entities managed by private developer Terra-Gen, LLC, incrementally lease and develop the property in exchange for cash or in-kind consideration at or above fair market value. The Air Force Civil Engineer Center, a primary subordinate unit of the Air Force Installation and Mission Support Center, manages the program.

Table 25. Edwards AFB Solar Project information.

Description	- In August 2021, Terra-gen had completed financing on the initial phase of its Edwards Sanborn Solar Storage facility in Kern County, CA. At this first phase, the solar Storage facility is composed of 346 MW of solar modules and 1,501 MWh of battery storage. - The project is built on a land leased from Edwards Air Force Base. Mortenson is the EPC contractor, First Solar is supplying the solar modules, & LG Chem and Samsung are supplying batteries. - Financing for the project includes $804 million senior secured credit facilities comprising a $400 million construction and term loan facility, a $328 million tax equity bridge facility, and a $76 million construction and revolving letter of credit facility. - Terra-Gen expects the initial phase scheduled to be fully operational by the second quarter of 2022. The subsequent phases of the project will be financed later and come on-line in the second half of 2022 and early 2023. When complete, the near-term phases of the Edwards Sanborn Solar Storage franchise will comprise 760 MW of solar and 2,445 MWh of energy storage and is expected to be the world's largest integrated solar powered battery storage project.
Benefits	- The first phase capacity is expected to produce clean energy for more than 158,000 homes and displace more than 307,000 tons of CO_2 annually.
Images	 Figure 42. Solar panel array at Edwards AFB. Source: Air Force photo by Giancarlo Casem
Sources of Information	www.afimsc.af.mil

7.2.3. Cape Cod US Air Force Microgrid

Otis Air National Guard Base developed a military microgrid on Cape Cod, Massachusetts that made the Otis Air National Guard Base electrically self-sufficient. All of the power will come from renewable energy. The grid-connected microgrid will serve as a model for similar Air National Guard and Department of Defense projects.

Table 26. Cape Cod US Air Force Microgrid project information

Description	- The US DoD first wind-powered microgrid, completed in August 2018. - The Otis microgrid includes: a 1.5-MW wind turbine, a 1.6-MW diesel backup generator, an intelligent, 1.6-MW/1.2-MWh Ecoult Ultrabattery® Battery Energy Storage System (BESS) and Raytheon's Intelligent Power & Energy Management(IPEM) Microgrid Control System (MCS)
Benefits	- Otis Microgrid: Cape Cod Military Base to run fully on renewable energy. - Expect to save the Air National Guard between 500,000 USD and 1 million USD per year, achieved through energy savings and new revenue. - The Otis Microgrid Project is not just a cost-effective initiative; it demonstrates how to create energy value and resilience through the forward-thinking and informed use of new digital power technologies. - The key benefits to the DoD include cyber-secure grid-interactive services, standby generators with "layered resilience" and operational benefits with sustainable capacity. - The project exemplifies new energy thinking and the use of emerging technologies to increase organizational capacity to anticipate, respond, recover, and adapt in the face of adverse events, change, and uncertainty – in other words, resilience.
Images	 Figure 43. Wind turbine in Cape Cod US Air Force. Source: DVIDS Hub  Figure 44. Otis Microgrid. Source: Typhoon HIL
Sources of Information	David H. Altman, ESTCP, Hybrid Micro-grid with High Penetration Wind for Islanding and High Value Grid Services Typhoon HIL

7.3. U.S. Navy Renewable Energy Program Office (REPO)

The Department of the Navy (DoN) is pursuing new renewable energy generation to improve energy security, operational capability, strategic flexibility and resource availability.

For this purpose, the Navy established the Renewable Energy Program Office (REPO) in 2014 to advance the integration of renewable energy into the electrical grid that serves naval installations and set an ambitious goal to reach 1 gigawatt (GW) capacity of RE by the end of 2015.

The Navy has exceeded that goal: currently, two-thirds of all energy used to power naval bases comes from renewable sources, mainly solar and wind with a cumulative capacity of 1.2 gigawatts of energy.

REPO is responsible for the overall planning, coordination and integration of renewable energy projects into the DoN (Navy and Marine Corps) activities with execution and management control. REPO is a multidisciplinary team designed to partner with the DoN regions and installations to implement cost-effective large-scale (defined as 10MW or greater) renewable energy projects that leverage private sector financing. Some of the REPO project opportunities locations and capacities are shown in Figure 45.

The Department of the Navy is utilizing third-party financing mechanisms to build renewable energy projects. It will integrate mission-compatible and cost-effective renewable energy sources, based on analyses of operation impacts and energy return on investment (eROI) including complete lifecycle cost analyses. Projects will be developed without added cost to taxpayers by using existing third-party financing mechanisms such as power purchase agreements, joint ventures, and real estate out grants. The energy produced or procured from these projects will cost less or at least no more than what the DoN is currently paying for brown power[31].

REPO is using 3 main acquisition models or procurement processes to meet the Navy's renewable energy goals[28]:

- Model 1: off-base generation for on-base consumption. DON purchases new RE generation from a third-party. This benefits the DON by providing long-term cost stability and power diversity

- Model 2: on-base generation for off-base consumption. Third party builds, owns and operates RE asset on DON land. Through the out grant, the DON receives energy security-related in-kind contribution. This benefits the Navy because it can generate value from underutilized land and often the lease terms integrate additional energy security provisions for the base in case of a supply disruption.

- Model 3: on-base generation for on-base consumption. Third party builds, owns and operates RE asset on DON land, the DON consumes power output. The DON gets energy security, power diversity and cost stability. All the energy produced through this model would be consumed on the base and it allows the Navy to try and meet one of its other goals of supporting onsite microgrid development and infrastructure upgrades.

[31] Marines official website. www.mcicom.marines.mil

Figure 45. DON REPO project opportunities. Source www.mcicom.marines.mil

In summary, REPO has been pursuing the following energy resiliency initiatives:

1. Bring renewable energy projects in procurement online.

2. The DON will continue to explore and deploy the next level of energy technology advances such as battery storage, electrification, fuel cells and microgrids to further enhance the DON's energy security, operational capability, strategic flexibility and resource availability.

3. Utilize third-party financing to build DON resiliency by leveraging technologies such as battery storage, fuel cells, microgrids and distributed generation.

7.3.1. YUMA Microgrid

The U.S. Marine Corps (USMC) partnered with Arizona Public Service (APS) to install a 25 MW microgrid in the Marine Corps Air Station (MCAS) in Yuma, Arizona. The project was completed in December 2016.

This project will make MCAS Yuma 100% resilient to external grid failures. In the event of a system-wide grid outage, the microgrid will provide enough backup power to cover the entire base's current and projected energy requirements, ensuring no disruptions to the base's mission.

Some of the microgrids features and facts are described below[32],[33] :

- APS owns, operates and maintains the microgrid facility at MCAS Yuma, under a 30 years lease.

- The microgrid ensures there are no interruptions for the mission.

- In exchange for the use of DON land to house the microgrid, APS provides in-kind services in

[32] Marines official website. www.mcicom.marines.mil
[33] www.eei.org

the form of backup power to cover 100 percent of the base's energy requirements in the event of external grid disruptions, ensuring no interruptions to MCAS Yuma's mission.

- The microgrid can provide power to the MCAS Yuma installation within 30 seconds of an outage, ensuring key mission priorities are not disrupted.

- During normal operating conditions, the microgrid also provides APS customers with grid stabilization. In the event of a grid frequency disturbance, the microgrid will switch on automatically.

- Since being deployed in late 2016, the microgrid has been energized more than 144 times for frequency response grid stabilization.

- MCAS Yuma's microgrid provides value to all APS customers. Energy can be drawn from the microgrid during times of peak energy use which provides local customers with reliable power when energy demand is highest. Additionally, this microgrid can also avoid the expense of building additional infrastructure to meet customer peak demands.

- The facility is monitored 24/7 and the APS-designed microgrid controller constantly monitors the commercial grid and forecasts both outages and frequency events.

Figure 46. Microgrid in the Marine Corps Air Station (MCAS) in Yuma, Arizona. Source: www.eei.org

7.3.2. MCAS Miramar Microgrid

MCAS Marine Corps Air Station Miramar in San Diego developed a microgrid that can power the entire installation for three weeks using landfill gas, solar energy, storage, diesel generation, and natural gas. The base has worked with state and municipal partners in innovative ways at each stage of its energy resilience project development. The base is continuing to explore the expansion of the microgrid using new technologies.

Table 27. MCAS Miramar Microgrid project information.

Description	- The microgrid installation at MCAS Marine Corps Air Station Miramar completed in March 2021 is one of the most energy-forward defence installations in the nation. - Marine Corps Air Station Miramar contains 23,000 acres (93.077 million square meters) and is located 10 miles (16 km) north of downtown San Diego - About 9,300 Marines and sailors are assigned to MCAS Miramar, of whom 20 percent are deployed at any given time. An additional 1,700 civilians work at the installation - The state-of-the-art system incorporates a combination of natural and conventional energy sources, including 3.2 MW landfill gas, 1.3 MW PV and solar thermal energy, 3 MW natural gas and 4 MW diesel, and 2MW/2MWh lithium-ion battery storage to fully power MCAS Miramar for up to 21 days in the event of an emergency or a blackout. - The Miramar landfill sits on approximately 476 acres (1.96 million square meters) on the south end of the installation. The Navy leases the landfill property to the city of San Diego and all waste management operations at the landfill are run by the city. - In addition to the base-wide microgrid, Miramar hosts a building-level microgrid that integrates multiple types of battery storage, controllable solar PV and electric vehicles.
Benefits	- The base has an installation-wide microgrid that is capable of supporting 100-plus facilities for three weeks, including critical missions such as the flightline. - To strengthen and expand energy resilience across its installations. - The microgrid has a sophisticated control system that allows it to automatically optimize generation and shed load. These capabilities enable the base to create additional revenue and savings by offsetting electricity purchases from the grid, reducing peak demand charges and participating in utility demand-response programs. - The microgrid allows the base to function in autonomy base but also connected to the national grid. - Since commissioning, the system has provided over $90 million in energy savings.

	 Figure 47. Carport soSolar cuitions in Miramar air station Car Source U.S. Marine Corps
Sources of Information	-Marines official website, www.marines.mil -Association of Defense Communities, Beyond the fence line: Strengthening Military Capabilities Through Energy Resilience Partnerships, Nov 2018

7.3.3. MCRD Parris Island Microgrid

In 2015, the U.S. Marine Corps Recruit Depot (MCRD) Parris Island started a comprehensive energy project with the overarching goal of modernizing the infrastructure and enhancing the resiliency of the installation. The depot is responsible for training more than 20,000 recruits annually, playing an integral role in the readiness of the USMC to deploy troops globally at a moment's notice.

Table 28. MCRD Parris Island Microgrid project information

Description	- Developed by Ameresco in 2019, the 10 MW microgrid is designed to withstand storms and earthquakes at the US Marine Corps Recruit Depot (MCRD) Parris Island, in South Carolina. - The $91M energy savings performance contract (ESPC) energy as a service (EaaS) partnership, features energy efficiency and RES, on the 8000-acre (32.37 million square meter). - As a third-party financed contract vehicle, the ESPC required no upfront capital from MCRD Parris Island. Annual energy and water cost savings generated by the improvements over the ESPC's performance period will repay the third-party financing that funded project implementation. - In addition to designing, engineering and constructing, Ameresco is a responsible for the operation and maintenance (O&M) of the project's energy assets for the duration of the 22-year performance period. - The goal is to ensure resilience by providing uninterruptible power in support of critical training operations. - The microgrid comprises: - Replacement of a power plant with 3.5 MW of combined heat and power and three diesel backup generators

	- 5.5 MW Solar PV installed at carport and ground-mount sites. - Advanced Battery storage system capacity of 4 MW/8 MWh - Intelligent microgrid controls to ensure power supply in the event of central grid outages - A variety of energy conservation measures have been adopted to optimize efficiency and reduce reliance on the main utility grid.
Benefits	- The project has reduced lifecycle energy and water costs across 120 facilities and delivered energy security through over 10MW of onsite renewable energy production. - Combining the strengths of the new on-site distributed generation, cogeneration, energy storage and high-speed, secure microgrid controls, The microgrid delivers a layered defense against threats to the power supply, and sustains training operations during periods of uncertain supply. - Parris Island will save $6.9M annually in utility costs,. - Reduce utility energy demand by 75% a. - Reduced water consumption by 25% on campus. - 10+ MW onsite renewable energy generation for reduced utility costs when the grid is healthy, and reliable steam and power to the mission when the grid is down. - Maximize onsite production, stabilize output and support Depot grid during contingencies with BESS. - Sustain mission-critical activities with automated generation dispatch via microgrid controls. - Combined annual carbon reduction of 37,165 metric tons of CO_2.
Images	 Figure 48. MCRD Parris Island Microgrid
Sources of Information	https://www.ameresco.com/portfolio-item/parris-island/

8 Conclusions

Energy is a key enabler of Defense capability. The majority of the Armed Forces' activities and tasks are dependent on it, whether conducted at the extensive range of Defence infrastructures and facilities or during a military mission and operation. Access to adequate and reliable energy is critical to ensure the operational readiness and responsiveness of the Armed Forces.

The Defence sector is accountable for a considerable share of global energy consumption and related emissions, being one of the largest employers and owners of land, equipment and assets worldwide. Fossil fuels are the dominant energy source, particularly for operational use, creating a dependence that leads to the following concerns: (i) security and stability of the supply, (ii) safety of the personnel, (iii) financial impact due to fuel price volatility and (iv) environmental impact and sustainability on the long term.

This last concern gains increasing relevance from a global and local perspective, considering the current and foreseen impact of human activities on the planet's climate and natural ecosystems. **Armed forces are directly and indirectly affected by the consequences of climate change.** On the one hand, Defence facilities and built infrastructure around the world are subject to extreme weather events, such as flooding, drought and wildfire, causing potential damages and affecting negatively the military's ability to respond to a crisis. On the other hand, climate change is likely to impact existing environmental and social stressors around the world, creating or worsening humanitarian crises and therefore military needs. Social tensions, economic crises and political instability can be exacerbated by some of the direct consequences of environmental hazards, such as food and water scarcity, degradation of land due to drought, proliferation of disease vectors, people displacement and consequent mass migrations patterns. In addition, more frequent and severe weather events disasters, both within and beyond their national borders, may require the Armed Forces to support humanitarian assistance and disaster relief operations.

Therefore, **the Military must contribute to the transition to sustainable practices and clean energy,** reflecting the countries' commitment to reducing their impact on the environment. The Armed Forces have the responsibility to show leadership in this global effort and the obligation to manage efficiently and in a sustainable way their assets and resources on behalf of the citizens. Mitigation and adaptation strategies shall be studied and put in place to contain the existing and potential consequences of climate change and maintain military operability and readiness in any circumstances.

Three main strategies can provide a framework for taking action: (i) **Promote Energy Conservation,** increasing energy awareness and conservation measures across the sector. Training, organizational management and energy data collection and monitoring are effective tools to achieve better practices and reduce energy waste. (ii) **Increase Energy Efficiency** by replacing obsolete machinery, installing high-efficiency equipment (i.e. lighting, HVAC and processes) and implementing intelligent energy management and building automation systems. The objective is to optimize energy consumption. (iii) Reduce fossil fuels consumption and **scale up renewable energy** share (i.e. wind, solar and biomass) as well as diversify the energy mix. This allows for reducing the environmental footprint.

Retrofitting of existing assets and deployment of new technologies and better practices shall also increase the **Armed Force's energy resilience** and its ability to respond to anticipated or unanticipated energy disruptions. Research and innovation shall be promoting and testing innovative technologies for energy generation and management to improve further efficiency and resilience.

In addition, **these measures can lead to financial benefits.** Reduced energy consumption generates savings in the operational costs of military bases and facilities. Renewable energy technology Levelized Cost Of Electricity (LCOE) has dropped consistently in the past years, reaching lower values compared to fossil fuel generation, particularly in areas relying on diesel generators.

Currently, **Defence sectors in many countries have already entered into a process of energy transition** and they are undertaking many significant and positive actions to reduce energy consumption, fossil fuel dependence and greenhouse gas emissions from military activities and operations. MoDs are establishing long-term strategies and plans aimed at achieving national and international objectives of improving energy efficiency and reducing carbon emissions, without affecting their military capabilities.
According to the case study review performed, some of the key measures and technologies in the Defence sector are:

- **Energy Efficiency.** Retrofit of existing facilities with high-efficiency machinery or building automation solutions to optimize energy consumption, using sensors and algorithms. Third-party companies are often contracted to sign Efficiency-as-a-Service (EaaS) or Energy Savings Performance (ESP) Contracts.

- **Utility-scale RE plants.** Large-scale renewable energy plants are installed on Defence land. The project can be financed directly by the DoD or developed with a third-party company as Power Purchase Agreement or similar contracts.

- **Energy Storage Systems.** Large-scale storage systems can be used as backup, alternatively to diesel generators, as well as for different services, such as peak shaving or power quality support. Storage is useful for increasing the capacity of the system to absorb and store non-dispatchable renewable power. It is an essential component to reach full autonomy and independence from fossil fuels. Moreover, increasingly compact storage technologies increase portability and deployment during missions.

- **Decentralized Renewable Generation.** Decentralizing and diversifying the generation of electricity and other energy uses is crucial to increasing self-sufficiency and resilience in off-grid remote mission/bases. Currently, solar photovoltaic and wind energy are the most used and researched. Different shapes, materials and technology are being tested to increase portability, efficiency and capability of integration in structures, shelters or garments.

- **Microgrids.** A small network with local sources of supply, conventional or renewable, and storage capacity. Intelligent energy management systems are integrated to optimize demand management and ensure the continuity of the supply. They can be stationary for fixed bases and mobile (tactical) ones for contingency bases.

- **Electric and Hybrid Vehicles. Reduce** transportation emissions through the hybridization of the available vehicles fleets. The combination with renewable energy powered recharge structures, such as Solar PV carports, could fully decarbonize the sector. The application in missions is also interesting.

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