THE NEED TO BUILD AND OPERATE A MOBILE MODULE FOR ENSURING ENERGY AUTONOMY FROM SUSTAINABLE SOURCES (MAES)

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Abstract: *The mobile module for ensuring energy autonomy from sustainable sources (MAES) can solve the problem of power supply in remote areas, providing a flexible and sustainable solution, especially for military applications. Based on renewable sources, MAES ensures energy autonomy, reducing dependence on fossil fuels and minimizing environmental impact. By integrating solar panels, batteries, and smart energy management systems, MAES can provide electricity for a wide range of equipment and applications, from communications and surveillance and security systems to electric vehicles. Its portability and resilience make it ideal for field operations, and unlike generator sets, its silent operation provides thermal and acoustic masking conditions. The adoption of the MAES can enable the armed forces to operate more efficiently, more discreetly and in a more sustainable way.*

Keywords: autonomy and energy independence, thermal and acoustic masking, flexibility, portability, resilience, green energy, critical infrastructures.

MOTTO *"Energy and persistence conquer all things."*
Benjamin Franklin

1. INTRODUCTION

In a world marked by climate change and increasing demand for energy, finding sustainable and efficient energy solutions is a global priority [1]. MAES is one such solution, offering a viable alternative to conventional energy sources.

MAES is a portable, solar-powered electricity storage system that can provide electricity in remote areas or in emergency situations. Composed of photovoltaic panels, batteries and one or more inverters (depending on the destination and size of the load), this system converts solar energy into usable electricity, providing energy autonomy from a clean and (theoretically) unlimited energy source. Its availability, portability and flexibility are ensured by the location of the photovoltaic system on a semi-trailer, towable according to any type of vehicle equipped with a towing system.

According to Eurostat, in chapter 4.2.2. Energy from renewable energy sources in the National Integrated Energy and Climate Change 2021-2030 [2], Fig. 1 highlights the evolution of electricity production from renewable energy sources between 2005 and 2017, by source type. By adopting the MAES in Romania and beyond, in line with Goal7: Affordable And Clean Energy of Romania's Sustainable Development Strategy 2030, it can be reduced dependence on fossil fuels, reduce greenhouse gas emissions and help protect the environment [3][4].

In addition, MAES offers a flexible and scalable solution that can be adapted to a wide range of applications, from powering military equipment to supporting isolated communities.

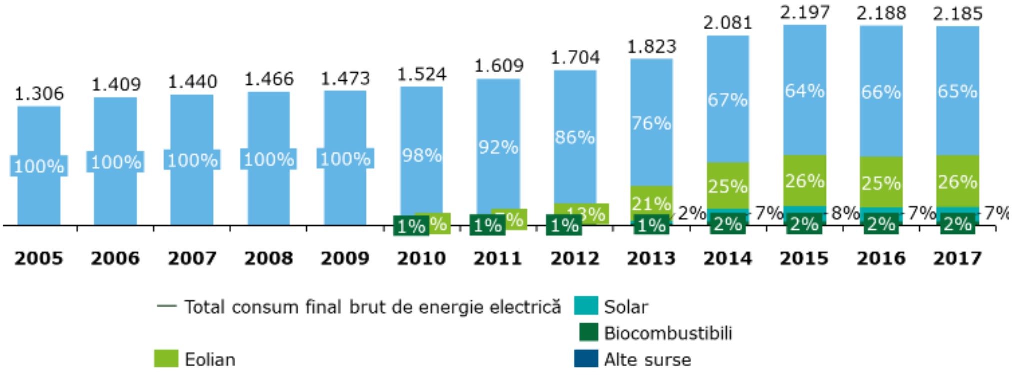

FIG. 1. Evolution of electricity production from renewable energy sources between 2005 and 2017

2. COMPONENTS AND OPERATION OF THE MAES

MAES is an innovative solution for generating and storing electricity, based on renewable sources. Its efficient operation is ensured by a complex interaction between several key components.

Photovoltaic panels are the fundamental element of the system, directly transforming solar radiation into electricity through the photovoltaic effect. Solar cells, the basic units of panels, are made up of semiconductor materials, such as silicon, that generate an electrical voltage when exposed to photons. The efficiency of a photovoltaic panel, i.e. its ability to convert solar energy into electricity, is influenced by factors such as the type of solar cells (monocrystalline, polycrystalline, amorphous), the operating temperature and the angle of incidence of solar radiation. Monocrystalline cells, for example, offer the highest efficiency, but they are also the most expensive.

The electricity produced by photovoltaic panels is stored in batteries, which act as **energy reservoirs**. The most used batteries in photovoltaic systems are lithium-ion batteries, appreciated for their high energy density and long lifespan. The energy storage capacity in a battery is influenced by factors such as electrochemical chemistry, physical size, and operating conditions. A battery management system (BMS) is essential for monitoring battery health and optimizing charging and discharging processes.

The inverter plays a critical role in converting direct electricity (DC) generated by photovoltaic panels and stored in batteries into alternative energy (AC), which is the form of energy used in most electrical applications. The type of inverter used (on-grid, off-grid, hybrid) depends on the system configuration and the specific requirements of the user. Conversion topologies such as MPPT (Maximum Power Point Tracking) and PWM (Pulse Width Modulation) are used to optimize the inverter's energy efficiency.

The Energy Management System (EMS) is the brain of the MAES system, coordinating and optimizing the operation of all components. EMS monitors real-time solar energy production, energy consumption, battery charge status, and adapts system parameters to maximize efficiency and ensure safe and reliable operation. Advanced control algorithms, such as MPPT and self-consumption maximization algorithms, are implemented in EMS to optimize the use of generated energy.

The interconnection of all these components into a coherent system allows for the efficient conversion of solar energy into usable electricity.

Photovoltaic panels capture solar energy, batteries store it, the inverter converts it into alternating current, and the energy management system coordinates the entire process. All these deliverables wherever the beneficiary's interests require it, in conditions of increased mobility in terms of the placement of the MAES on a semi-trailer type mobile platform that also allows the optimal orientation of the panels towards the solar source.

3. ADVANTAGES AND BENEFITS

MAES represents a significant paradigm shift in the energy field, offering a viable and sustainable alternative to conventional energy sources. These systems, mainly based on solar energy, are designed to operate independently of the electricity grid and classic generator sets, thus ensuring an autonomous and reliable energy source.[5]

One of the most important advantages of the MAES is **the energy independence** it offers and implicitly operational availability. By eliminating dependence on centralized power grids, these systems allow access to electricity even in isolated or hard-to-reach areas. Appropriately sized to the consumption requirements of the beneficiary, MAES can provide energy 24/7 (**UPS function**).

In addition, MAES contributes significantly to the **reduction** of greenhouse gas emissions, thus aligning itself with the global Sustainable Development Goals.

Resilience is another key feature of ESAM systems. They ensure continuity of power supply, even in extreme conditions such as natural disasters or grid outages. Also, **the long-term costs** associated with using MAES are significantly lower compared to those of conventional energy sources, due to reduced energy bills and maintenance costs [6].

The versatility of the MAES is another important aspect. They can be adapted to power a wide range of applications, from street lighting systems to industrial equipment. In rural areas, MAESs can be used for drinking water supply, public lighting, communications, and other critical infrastructure. In the industrial sector, these systems can power equipment in isolated areas or with limited access to the grid.

All these benefits can make a significant contribution to the military sector, offering flexible and efficient energy solutions. These systems allow armed forces to operate in remote areas without being dependent on existing energy infrastructure, thus ensuring increased operational autonomy.

The mobility and compact dimensions of MAESs make them ideal for quick transport and installation in different locations, offering flexibility in carrying out operations. Also, the resistance to attacks and modular configurations that allow redundancy make these systems a safe and reliable choice in hostile environments.

The MAES is **scalable**, which means that a consumer's need for increased power can be met by connecting multiple units in parallel. In this way, an adequate amount of modules can be deployed in the field that provide adequate resource management. Through the use of renewable energy sources, MAESs contribute to reducing the carbon footprint of military operations, aligning with global efforts to combat climate change. In addition, the low operating and maintenance costs make these systems a profitable long-term investment.

MAESs **significantly improve the living conditions of** military personnel, ensuring a stable supply of electricity to bases, camps and checkpoints, even in the most remote areas. These systems also allow personal electronic equipment to be charged, facilitating communication and morale boosting.

In the field of special operations, MAESs offer discreet and efficient solutions, being able to power specialized equipment such as drones and surveillance systems. The ability to operate in **silent mode (thermal and phonic masking)** is essential for missions that require discretion.

4. PRACTICAL APPLICATIONS OF MAES SYSTEMS

MAES can cover a wide range of applications in various sectors, thus demonstrating the versatility and efficiency of these technologies.

In the military field, MAESs can be an autonomous and reliable source of energy in areas of operations, often remote and with limited infrastructure. These systems can power communications equipment, charging stations for drones and electric vehicles, as well as lighting systems in areas of operations. The mobility and strength of MAESs make them ideal for use in harsh environments.

In areas affected by natural disasters or armed conflicts, MSEAs can play a key role in providing electricity for essential services. Mobile hospitals, refugee centres and rescue operations can benefit from the energy provided by these systems, thus ensuring access to drinking water, lighting and communications, even in extreme conditions.

The events industry has widely adopted MAESs as an environmentally friendly and efficient alternative to diesel generators. These systems can power stages, lighting systems, audio equipment, and other facilities needed to organize outdoor events. MAESs significantly reduce noise and polluting emissions, contributing to the organization of more sustainable events.

In rural areas, where access to the electricity grid is limited or non-existent, MAESs offer a viable solution for electrification. These systems can power drinking water pumps, irrigation systems, refrigerators for food storage, and support the development of small local businesses, thus helping to improve the living standards of rural communities.

5. CONCRETE EXAMPLES OF USE CASES

Systems with characteristics similar to MAES have demonstrated remarkable versatility, being successfully implemented in a variety of contexts and sectors. Here are some concrete examples that illustrate the impact of these systems:

Following catastrophic events such as earthquakes, hurricanes or armed conflicts, the MAESs have proven to be a quick and efficient solution for the supply of electricity in the affected areas. For example, in the aftermath of the earthquake in Haiti, MAESs were used to power mobile [7] hospitals, refugee centers, and communication systems, thus ensuring the survival and recovery of affected communities.

In many rural areas, far from conventional power grids, MAESs have provided electricity, lightingband other strictly necessary appliances, greatly improving the quality of life [8]. For example, in isolated communities, these systems powered water pumps, street lighting, and made it possible for small local businesses to develop.

Industries, especially those in remote areas or with limited access to the electricity grid, have benefited significantly from the implementation of MAES. For example, in the mining industry, these systems powered drilling and lighting equipment in underground mines, reducing costs and environmental impact.

MAESs have also found applications in the transport sector. Charging stations for electric vehicles, especially in rural areas or national parks, are often powered by MAES systems, contributing to the development of infrastructure. Ships and ferries can also be equipped with MAES systems to reduce emissions while stationary in ports.

In the field of education, MAESs have facilitated access to technology and knowledge in remote areas.

Schools and universities in developing countries have benefited from these systems to power computers, laboratories, and other educational equipment.

Also, in the field of scientific research, MAESs have been used to power measuring instruments and laboratory equipment in remote areas or in extreme conditions.

Ecotourism hotels and resorts have adopted MAESs to reduce their carbon footprint and provide a more sustainable experience for customers. These systems can power the rooms, restaurants, swimming pools and other facilities of the accommodation units.

The examples presented clearly demonstrate the versatility and impact of EAW systems in different sectors. From providing electricity in disaster-affected areas, to supporting economic development in rural communities and facilitating scientific research, ESMs play a key role in the transition to a more sustainable and equitable energy future.

6. TECHNICAL, ECONOMIC, LEGAL AND ENVIRONMENTAL CONSIDERATIONS FOR THE IMPLEMENTATION OF MAES SYSTEMS

The correct sizing of a MAES system is very important to ensure an adequate and efficient power supply. This involves a careful assessment of energy consumption, the availability of renewable resources (sun, wind) and the site-specific climatic conditions. Factors to consider include:

- **Energy consumption**: the power required to power electrical equipment and appliances is evaluated.
- **Renewable resources:** The energy potential of available renewable sources, such as solar radiation and wind speed, is analysed.
- **Climatic conditions:** Seasonal variations in energy resources and the impact of weather conditions on the performance of the system are considered.

The investment costs for a MAES system include the purchase and installation of components, such as solar panels, wind turbines, batteries, and inverter. Operating costs are related to maintenance, component replacement, and auxiliary power consumption. The lifespan of the components of a MAES system can vary significantly, from a few years for batteries to decades for solar panels. Maintenance costs are influenced by the complexity of the system and the operating conditions.

MAES systems have a significant positive impact on the environment, helping to reduce greenhouse gas emissions and promote the use of renewable energy. However, it is important to assess **the impact of these systems throughout their entire life cycle,** from component production to disassembly and recycling.

- **Production:** The production of solar panels and wind turbines involves energy consumption and greenhouse gas emissions. However, the energy generated by these systems over their lifetime quickly offsets these initial emissions.
- **Operation:** During operation, the MAES systems do not produce direct emissions of pollutants.
- **Disassembly and recycling:** At the end of their life, MAES components must be properly disassembled and recycled to minimize environmental impact.

The implementation of the MFA systems is significantly influenced by the legal and political framework. Regulations on renewable energy and energy efficiency vary from country to country, but generally encourage the development and use of these technologies.

- **Renewable Energy and Energy Efficiency Regulations:** These regulations set national targets for renewable energy production, provide financial incentives for investment in ESAM systems, and promote energy efficiency in different sectors.
- **Financing and incentive programs:** Governments and financial institutions offer a variety of financing programs and incentives to support the implementation of MAES systems, such as low-interest loans, grants, and green certificates.

The successful implementation of an ESAM system requires a detailed analysis of technical, economic, legal and environmental aspects. Through careful planning and evaluation of the specific factors of each project, significant benefits can be achieved in terms of energy autonomy, cost reduction and environmental protection.

CONCLUSIONS

The mobile module for ensuring energy autonomy from sustainable sources (MAES) represents a strategic solution for the military sector, offering a series of advantages that can transform the way operations are carried out in the field.

The ability of these systems to generate electricity in isolated areas, without being dependent on infrastructure, makes them indispensable in remote missions or in conflict zones. The MAES ensures increased energy autonomy, reducing vulnerability to attacks on conventional power grids and thus increasing operational resilience. In addition, by using renewable sources, these systems contribute to reducing the carbon footprint of military activities, aligning with global efforts to protect the environment. Investments in the development and implementation of the MFA are essential to modernize the armed forces and enable them to meet the complex challenges of the 21st century.

This innovative technology not only improves operational efficiency, but also helps boost troop morale by providing increased comfort in conflict zones. Therefore, it is imperative that the authorities pay particular attention to the promotion and implementation of the MFA within military structures, recognizing the transformative potential of this technology.

In conclusion, MAES represents a strategic investment with a positive impact on both military efficiency and the environment. By adopting this technology, the armed forces can become more agile, more sustainable and better prepared to face the challenges of the future.

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