Life Zero Energy Moc
Zero Energy Habitable Mobile Modules in Europe

Life ZEROENERGYMOD

Zero energy habitable mobile modules in Europe

LAYMAN REPORT

Abbreviations

AEM	ANION EXCHANGE MEMBRANE
EPBD	ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE
EU	EUROPEAN UNION
GHG	GREENHOUSE GAS
MODS	MINISTRIES OF DEFENSE
NATO	THE NORTH ATLANTIC TREATY ORGANIZATION
NGOS	NONGOVERNMENTAL ORGANIZATIONS
NZEB	NEARLY ZERO ENERGY BUILDING
SDGS	SUSTAINABLE DEVELOPMENT GOALS
SMES	SMALL AND MIDSIZE ENTERPRISES
ZEM	ZEROENERGYMOD

01

BUILDING A GREENER FUTURE

Imagine living in a comfortable, fully equipped home, right in the middle of the desert, a top a snowy mountain, or deep within a remote forest. Now picture that this home does not need to be plugged into any grid, does not burn a single drop of diesel, and leaves behind zero emissions.

Does it sound futuristic? That is exactly what the LIFE ZEROENERGYMOD project has made possible.

Climate change is reshaping the world around us. More extreme weather, rising temperatures, and growing energy demands are placing huge pressure on how we build and power our living spaces. Buildings account for a significant share of global greenhouse gas emissions, mostly due to heating, cooling, and electricity needs, which are still largely powered by fossil fuels.

TO TACKLE THIS CHALLENGE, THE EUROPEAN UNION HAS LAID OUT BOLD STRATEGIES THROUGH SEVERAL REGULATORY FRAMEWORKS.
These include the European Green Deal, aiming to make the EU climate-neutral by 2050, and the Energy Performance of Buildings Directive (EPBD), which now requires that all new buildings be nearly zero-energy buildings (nZEBs).
The latest 2024 revision of the EPBD goes even further, introducing clear decarbonization targets and promoting the phase-out of fossil fuels in heating and cooling systems. Other key initiatives, like the Renovation Wave, focus on upgrading Europe's aging building stock to meet high energy performance standards.

Yet even with all these efforts, one major gap remains: temporaryand off-grid structures. These are widely used in military operations, humanitarian missions, emergency relief, and scientific expeditions, and most still rely on diesel generators. These systems are not only polluting but also costly and logistically complex.

THE ZEM PROJECT WAS CREATED TO OFFER A SMART, SUSTAINABLE ALTERNATIVE.
It has developed easy-to-transport, plug-and-play living units powered entirely by renewable energy sources like sun and wind, with hydrogen-based storage systems to ensure a constant supply, even in the harshest environments. Originally designed for the military, these modules are now attracting interest from NGOs, researchers, and emergency services across the globe. What follows is the story of how this bold idea became a real-world solution, with proven results, broad applications, and a vision for making clean, off-grid living a reality, wherever it's needed most.

02

A SMART SOLUTION FOR ANYWHERE, ANYTIME

TEMPORARY BUILDINGS ARE OFTEN ANYTHING BUT TEMPORARY FOR THE ENVIRONMENT.

Whether it is a military base, an emergency shelter, or a research camp in a remote location, these structures usually rely on diesel generators, polluting, noisy, and expensive to run. The ZEM project set out to change that. Its goal was ambitious but clear: to create a new kind of infrastructure that is fully autonomous, mobile, energy-efficient, and emission-free, and to prove it works in real-world settings.

At the heart of this innovation is a two-part system: Enermod and Passivmod. Together, they form a plug-and-play habitat that can be shipped, assembled, and operated anywhere, without any connection to the grid or fossil full.

- ↳ **Enermod** is a smart energy unit that harvests power from the sun and wind, stores it in batteries and hydrogen tanks, and delivers energy around the clock no matter the weather.
- ↳ **Passivmod** is a cozy, low-energy habitable module based on PassivHaus standards, designed to stay warm in the cold and cool in the heat, using minimal energy.

TO ENSURE IT COULD PERFORM UNDER PRESSURE, THE SYSTEM WAS TESTED IN SOME OF THE MOST DEMANDING PLACES IMAGINABLE

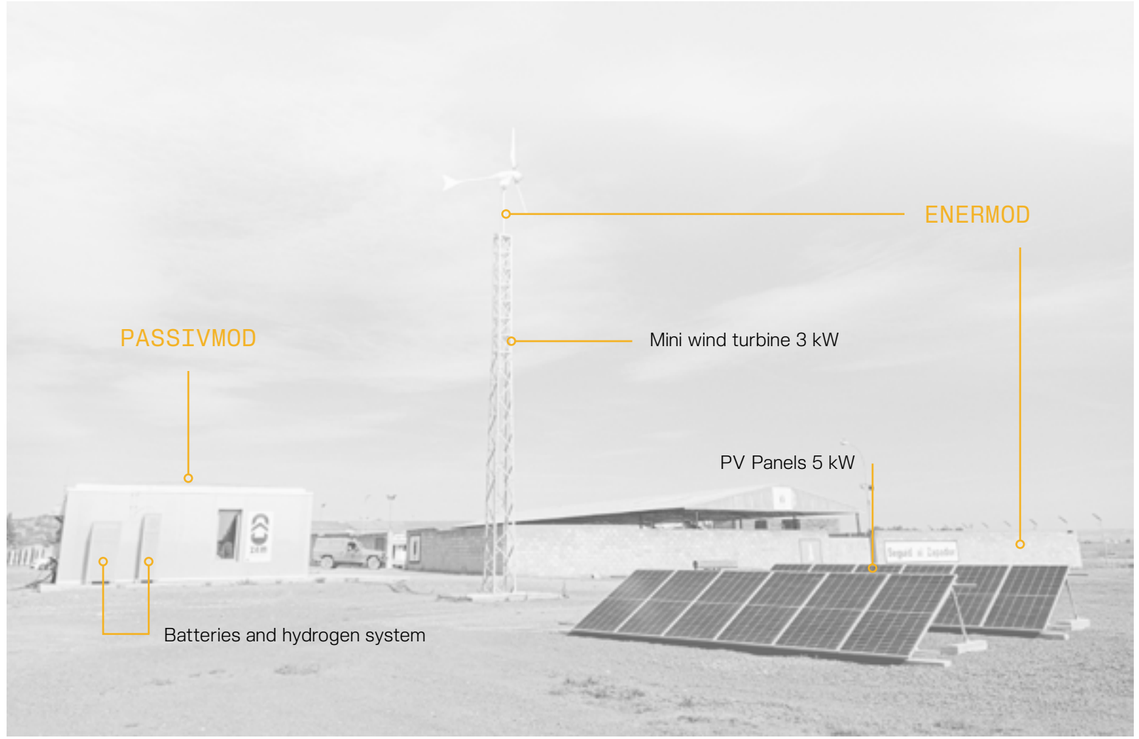
To verify its performance under extreme conditions, the system is currently undergoing testing in Zaragoza and will be tested in Antarctica, considered one of the harshest environments on Earth. By cutting **energy consumption by up to 90%, running entirely on clean energy,** and being easy to install and relocate, ZEM shows how green innovation can meet the demands of our changing world.

ZARAGOZA, SPAIN
Hot, dry conditions like those found in desert regions

GABRIEL DE CASTILLA BASE, ANTARCTICA
Freezing temperatures, remote access, and extreme winds.

How we achieve it?

The ZEM concept centers around two primary components. Together, they deliver a scalable, transportable, and fossil fuel-free infrastructure that supports long-term resilience.



PASSIVMOD · PASSIVHAUS MODULE

A highly insulated and airtight living unit built according to PassivHaus principles. It uses smart design features to reduce energy use by 85-90%, ensuring comfort in any climate.

ENERMOD · ENERGY MODULE

A compact renewable energy generation and storage system that includes solar PV, a mini wind turbine, batteries, and hydrogen tanks. It ensures 100% off-grid operation, even in extreme weather, through hybrid storage (battery + hydrogen).

Objetives

The main goal was to develop and demonstrate robust, transportable, and easily installable habitable modules capable of operating with zero environmental emissions. The ZEM project specifically aims to:

Off-Grid Energy

Achieve full energy independence through smart energy management and seamless interaction between passivmod and enermod.

Policy Integration

Support integration into policy and regulatory frameworks, recognizing zero-energy modular units as a scalable and sustainable solution.

Climate Resilience

Validate climate resilience by testing in both semi-arid (Spain) and polar (Antarctica) environments.

48-Day Autonomy

Provide long-term energy autonomy, up to 48 days, using hydrogen storage and fuel-cell technology.

EU Climate Goals

Contribute to EU decarbonization goals, aligned with the European Green Deal and Fit for 55 targets.

Wide Adoption

Enable wide adoption across defense, humanitarian, and remote-infrastructure sectors.

Project overview

PROJECT NAME	LIFE ZEROENERGYMOD
COORDINATOR	ARAGÓN HYDROGEN FOUNDATION
PARTNERS	ARPA MOBILE FIELD EQUIPMENT UNIVERSITY DEFENSE CENTER OF ZARAGOZA (CUDZ) B+HAUS EFFICIENT ARCHITECTURE
TOTAL BUDGET	€ 1.178.265
EU CONTRIBUTION	55 % LIFE PROGRAMME GRANT LIFE19 CCM/ES/001327
DURATION	JUNE 2020 – MAY 2025
FUNDING PROGRAMME	EU LIFE PROGRAMME

CONSORTIUM EXPERTISE	ROLE / CONTRIBUTION
ARAGÓN HYDROGEN FOUNDATION	Project coordination Renewable-energy integration Hydrogen technologies and energy management
ARPA MOBILE FIELD EQUIPMENT	Design & production of mobile/temporary infrastructures Construction of habitable modules Hydrogen power system
UNIVERSITY DEFENSE CENTER OF ZARAGOZA (CUDZ)	R&D in energy efficiency and renewables for military & remote environments
B+HAUS EFFICIENT ARCHITECTURE	Architectural & engineering design of PASSIVMOD PassivHaus-certified Sustainable-building expertise

03

BRINGING INNOVATION TO THE MARKET

The ZEM project has delivered a game-changing, market-ready solution that redefines energy autonomy for mobile and off-grid infrastructures. This solution is built around two integrated modules: ENERMOD, a renewable energy generation and storage system, and PASSIVMOD, a high-efficiency, climate-resilient living unit.

Together, they deliver a scalable, transportable, and fossil fuel-free infrastructure that supports long-term resilience.

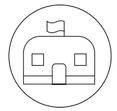
Performance and market impact

The following comparative analysis shows the dramatic improvements offered by ZEM compared to traditional temporary shelters

PARAMETERS	LIFE ZEROENERGYMOD	CONVENTIONAL MODULES
ENERGY DEMAND KWH/M²/YEAR	100-115	3000-3500
RENEWABLE ENERGY SHARE	100% (SOLAR/WIND + HYDROGEN)	0%
GHG EMISSIONS KG CO_2/YEAR	0 KG CO^2	120 TONS CO_2/YEAR
ENERGY AUTONOMY	UP TO 48 DAYS (HYDROGEN STORAGE)	REQUIRES CONTINUOUS FOSSIL FUEL SUPPLY
OPERATIONAL COST SAVINGS	96% SAVINGS	HIGH FUEL AND LOGISTICS COST

Real-World Applications

The ZEM project has proven itself in extreme conditions and is now ready for broad adoption. With its blend of innovation, performance, and flexibility, it offers a powerful tool for building the energy-resilient, zero-emissions infrastructure of the future.



MILITARY AND DEFENSE
Secure off-grid operations

HUMANITARIAN RELIEF
Humanitarian missions requiring clean, fast-deployable housing

REMOTE INFRASTRUCTURE
Scientific expeditions in remote regions

DISASTER RESPONSE
Emergency response teams in disaster zone

ENERMOD
A Breakthrough in Renewable Energy Autonomy

ENERMOD is a **fully autonomous energy unit** that integrates solar photovoltaic panels, a mini wind turbine, battery storage, and a hydrogen energy system. This hybrid approach eliminates the intermittent challenge of renewables, ensuring reliable off-grid energy supply. It uses a dual storage system, short-term batteries for daily use and long-term hydrogen storage for extended autonomy of up to 48 days. The system **is also modular and adaptable to different geographic or energy requirements.**

3-5kWp

Hybrid renewable system generating 5kWp with solar and 3kW with wind.

14.4kWp

Battery capacity of 14.4 kWh offers 2-day autonomy.

2.4kW

AEM electrolyzer (2.4 kW) converts excess energy into hydrogen at 35 bar.

48days

Hydrogen storage extends autonomy up to 48 days.

0CO_2

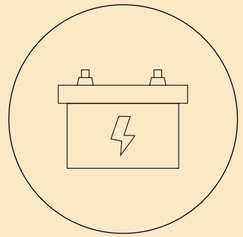
Zero CO_2 emissions due to complete replacement of fossil-fuel generators.

100%

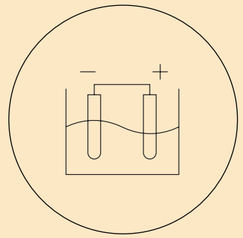
High-efficiency hydrogen fuel cells ensure continuous supply.

How ENERMOD functions

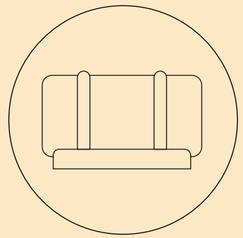
Ensures full autonomy through smart integration of renewables and hydrogen technology



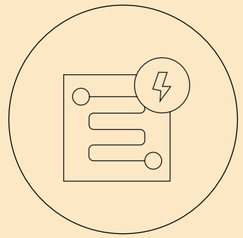
GENERATION AND STORAGE
Excess renewable energy is stored in lithium batteries (up to 2 days of autonomy).



HYDROGEN PRODUCTION
Once batteries are full, excess energy powers an AEM electrolyzer to produce hydrogen.



HYDROGEN STORAGE
Hydrogen is stored first in a low-pressure buffer, then transferred to a high-pressure tank.



ENERGY SUPPLY
When renewables are insuficient, stored hydrogen is converted into electricity via a fuel cell.

PASSIVMOD Rethinking Energy Efficient Habitats

PASSIVMOD is an **ultra-low-energy living unit designed using PassivHaus standards.** With superior insulation, airtight design, high-performance windows and doors, and smart ventilation with heat recovery, it maintains thermal comfort in all climates.

92%

Heat recovery ventilation recaptures up to 92% of warmth.

85%

Thermal insulation cuts heat loss by 85%.

2.4kWh

Energy use under 15 kWh/m2/year vs. 250-300 in traditional shelters.

2030

Meets NATO and EU energy standards (including PassivHaus).

04
UNLOCKING THE COMMERCIAL POTENTIAL

High-potential markets for ZEM were identified based on geographical, economic, and operational needs. Market assessments highlight the strongest demand in Europe, North America, and parts of Asia- regions with strong investments in clean energy and hydrogen-based technologies.

European market

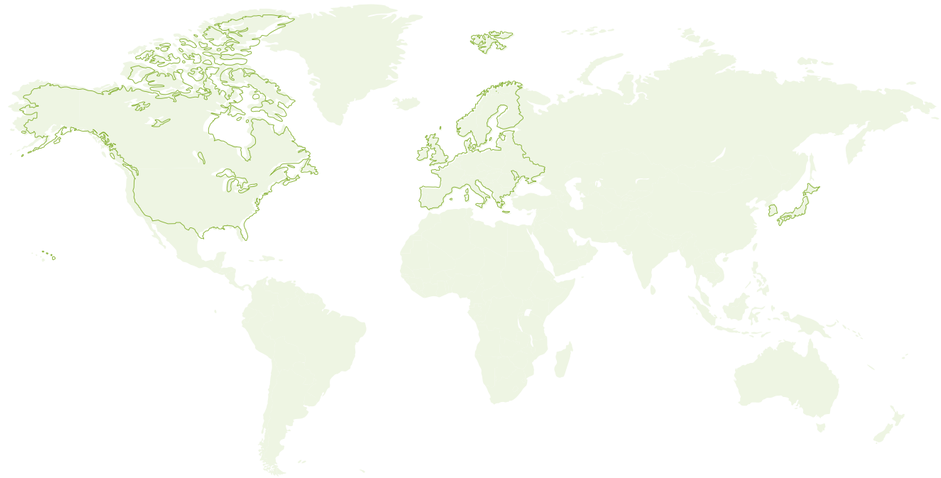
Europe is the primary target due to strict energy efficiency policies and strong climate commitments. The EU Green Deal and revised EPBD (2024) drive demand for sustainable, modular infrastructure.

DEFENSE AND MILITARY
NATO and EU member states require self-sufficient infrastructure for bases and field operations. ZEM meets these needs with energy, autonomy and mobility.

SCIENTIFIC RESEARCH
Remote research stations in Antarctica and similar environments benefit from energy-efficient, off-grid modules like ZEM.

DISASTER RELIEF AND HUMANITARIAN AID
Organizations like the Red Cross and EU Civil Protection Mechanism seek rapid deployment, clean energy shelters for crisis response.

CONSTRUCTION AND MINING
Remote projects often require temporary structures. ZEM offers sustainable, energy-autonomous alternatives.



International market

Beyond Europe, significant international market opportunities exist in North America and Asia, particularly in regions where modular, self-sustaining infrastructure is in demand.

UNITED STATES AND CANADA
Net-zero targets, off-grid infrastructure investments, and defense operations make ZEM attractive.

JAPAN AND SOUTH KOREA
Leaders in hydrogen energy adoption, these countries are potential adopters for urban sustainability and defense.

Environmental benefits

The ZEM system provides measurable environmental and economic benefits, making it a highly scalable solution for large-scale deployment. Key environmental benefits include:

96%

Reduction in energy consumption: Modules designed under the PassivHaus standard allow for a reduction of more than 96% in energy consumption compared to traditional solutions.

13.47 MWh

More than 13 MWh produced during the project demonstration, approximately 4.49 MWh/year.

360 tons CO_2

Prototype emission savings compared to conventional solutions: 120 tons of CO_2 per year.

135,180 l

Fossil fuel savings compared to conventional solutions: 45,060 liters of diesel saved per year (3 years x 45,060 liters = 135,180 liters of diesel saved during the project demostration)

5.21 tons NO_x

Prototype emission savings compared to conventional solutions: 1.74 tons of NOx per year.

Economic Growth Potential

Construction industry contributes 15.3% of CO2 emissions, underlining the need for sustainable alternatives. Market research confirms cost reductions, especially for military and humanitarian users. Rising EU and NATO budgets for energy-autonomous infrastructure boost demand for ZEM.

Market applications and bussines model

The **business strategy includes two commercialization models** to cater to different market segments and financial structures:

- **Direct sales:** Targeting governments, defense ministries, construction firms, and research institutions for permanent or semi-permanent deployment.
- **Rent model: I**deal for humanitarian organizations and short-term operations, providing flexible and cost-effective deployment.

Competitive advantages and market readiness

The ZEM is positioned as a market disruptor due to its unique competitive advantages:

- **Fully autonomous** energy generation using solar, wind, and hydrogen storage.
- **Proven performance** across **climates** from of Spain to Antarctic.
- **80% reduction in operational costs** compared to diesel-powered systems.
- **Compliance with EU green infrastructure** and energy efficiency policies.

05
EUROPEAN ADDED VALUE

ZEM plays a key role in achieving the EU's energy and climate goals, aligning with the European Green Deal, EPBD (2024), and Fit for 55 package. The project proves that zero-emission, energy-autonomous mobile habitats are viable and scalable.

Resilience

One of the key challenges in Europe's energy is ensuring a secure, reliable energy supply while transitioning away from fossil fuels. The ZEM project enhances Europe's energy resilience by:

- Reducing dependence on imported fossil fuels, **replacing diesel generators** with on-site renewable energy sources (solar, wind) and hydrogen storage.
- Providing a climate-resilient solution, **validated under harsh weather conditions.**
- **Offering modular, mobile, and easy-to-install energy infrastructure,** ensuring rapid deployment for emergency response, disaster relief, and military operations, reinforcing European defense and humanitarian efforts.

Climate

Contribution to environmental and energy goals. The EU has set ambitious climate targets, including **reducing greenhouse gas emissions by 55% by 2030 and achieving carbon neutrality by 2050.** The ZEM project directly supports these efforts by:

- Developing energy-autonomous modules that reduce reliance on fossil fuels, contributing to the EU's decarbonization strategy.
- **Supporting the Renovation Wave**, which aims to double the rate of energy-efficient building renovations by 2030.
- Enhancing the EU's Hydrogen Strategy by **integrating hydrogen-based energy storage into mobile infrastructures,** reinforcing Europe's leadership in renewable energy innovation.

By proving that zero-emission mobile infrastructures can be successfully implemented, the project provides a scalable, replicable model for use in both urban and remote settings, positioning Europe at the forefront of energy-efficient construction.

Prosperity

Economic and Social Impact. Beyond its environmental benefits, the ZEM project contributes substantial economic and social value, including:

- **Strengthening the European clean-tech industry,** including sustainable construction, renewable energy, and hydrogen storage technology.
- **Creating new market opportunities for European small and midsize enterprise**s (SMEs) and research institutions, fostering innovation in modular architecture, energy efficiency, and off-grid infrastructures.
- Addressing critical social and humanitarian needs, **by providing sustainable living solutions** for refugee camps, disaster-stricken regions, and remote communities, reinforcing Europe's leadership in green humanitarian aid.

Additionally, through extensive knowledge dissemination, including workshops, conferences, and stakeholder engagement initiatives, the project has actively influenced EU policy frameworks, accelerating the adoption of zero-energy infrastructures in future European urban and defense strategies.

Scale

One of the most significant aspects of ZEM is its scalability and potential for replication across European regions. The project demonstrates a successful model for energy-autonomous, mobile housing solutions, which can be adapted to various applications, including:

- Military and defense applications, **reducing operational energy costs and improving sustainability** in NATO and EU defense operations.
- Emergency response and disaster relief, **providing rapid-deployment housing solutions** that ensure energy security for affected populations.
- Sustainable urban expansion, integrating zero-energy modules into EU smart city initiatives to **improve sustainable urban infrastructure.**

Through collaborations with EU institutions, national governments, and industry stakeholders, ZEM has paved the way for scaling up green mobile infrastructure across Europe, positioning the EU as a leader in climate innovation, energy efficiency, and sustainable construction.

The project ZEROENERGYMOD - LIFE19 CCM/ES/001327 has received funding from the LIFE program of the European Union. The contents of this website reflect only the authors' view and LIFE Program is not responsible for any use that may be made of the information it contains

Contact information

PROJECT COORDINATOR
Fundación Hidrógeno Aragón (FHa)
Walqa Technology Park, Ctra. N 330a Km 566.
22197 Huesca, Spain

+34 974 215 258
info@hidrogenoaragon.org
lifezeroenergymod.eu/en/

FOLLOW US FOR UPDATES ON

References

EPBD. (2024).
Directive (EU) 2024/1275 on the Energy Performance of Buildings (EPBD, recast). Official Journal of the European Union, L 123, 8 May 2024. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024L1275

European Environment Agency (EEA). (2022)
Greenhouse gas emissions from energy use in buildings in Europe.
Retrieved from https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-energy

Green Policy Platform. (2024).
Global Status Report for Buildings and Construction 2024. Retrieved from https://www.greenpolicyplatform.org/research/global-status-report-buildings-and-construction-2024