# NEWSLETTER

## No. 2

## PUBLIC OVERVIEW OF HESS PROJECT

*March 2025. Second Issue*

*Project no: 101112380 – HESSS – RFCS-2022*

## Overall objectives of project titled: "Hybrid energy storage system using post-mining infrastructure" acronym HESS

The objective of the project is to design and develop a Hybrid Energy Storage System (HESS) integrating three distinct energy storage technologies: Pumped Storage Hydroelectricity (PSH), Compressed Gas Energy Storage (CGES) utilizing air and/or $CO_2$, and Thermal Energy Storage (TES). The system will utilize the existing post-mining infrastructure to minimize environmental impact and reduce construction costs. The target aggregate energy storage capacity of the HESS is not less than 30 MWh.

On the basis of the energy demand of each HESS component, a method of thermal and mechanical integration of the entire energy storage system will be developed. Optimal cooperation of the various elements of the HESS will be supervised by an energy router. It will also manage energy exchanges with the national power grid for the intake of low-cost green energy and peak energy production. The single HESS energy router system should take into account the possibility of cooperation of multiple HESS systems working in a distributed system.

The project concludes with a comprehensive techno-economic and environmental assessment, paving the way for industrial-scale deployment. HESS offers a sustainable, cost-effective solution for energy storage and post-mining revitalization—supporting the transition to a low-carbon future.

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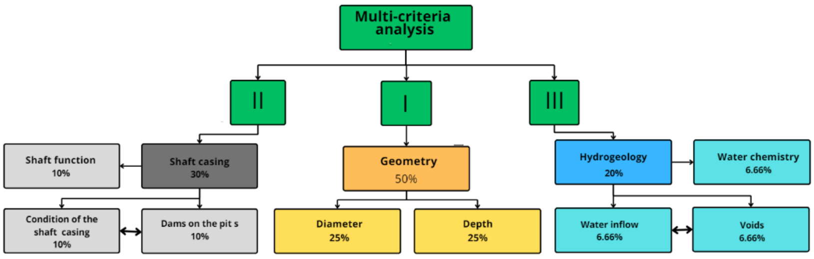
# Work performed and main achievements

## Identification of post-mining infrastructure for use in the Hybrid Energy Storage System

Comprehensive analysis and evaluation of the potential for utilizing underground and surface mining infrastructure for the development of a hybrid energy storage system was conducted in Poland, the Czech Republic, and Slovenia. The hydrogeological and geological criteria required for the optimal deployment of Pumped Storage Hydroelectricity (PSH), Compressed Gas Energy Storage (CGES) using air or $CO_2$, and Thermal Energy Storage (TES) were identified.




A Multi-Criteria Decision Analysis (MCDA) tool was developed to support infrastructure suitability assessment by enabling rapid screening and classification of potential sites based on a wide range of criteria.


The Budryk, Bogdanka and Ruda mines in Poland were rated the best due to their depth, structure and surrounding infrastructure. The shafts in Slovenia and the Czech Republic showed limited potential for reuse, mainly due to their shallow depth and advanced mine closures.

The study confirmed that repurposing post-mining infrastructure in Poland offers strong technical and strategic value, supporting energy transition and decarbonization goals. These findings form a solid foundation for the next project stages, including detailed engineering, economic analysis, and real-world testing.

This works were carried out as part of WP2 (Identification of Post-mining Infrastructure for use in the Hybrid Energy Storage System), the implementation of which was successfully completed on 30.06.2024.

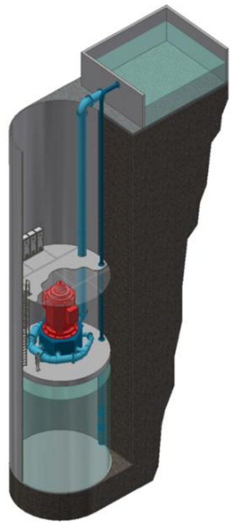
The work resulted in two deliverables:

- ***D.2.1. Guidelines for the adaptation and use of inactive shafts possible for energy storage.***
- ***D.2.2. Guidelines for the transformation of an underground mining excavation into a water reservoir***.

Work on the development of individual energy systems is carried out within the framework of parallel work packages until the end of 2025: WP3 Energy storage in pumped storage systems, WP4 Energy storage in compressed gas systems, WP5 Heat storage in post-mining infrastructure.

## Energy storage in pumped storage systems

Detailed design assumptions for a 10 MWh PSH system were developed. Comprehensive re-evaluation of candidate mine shafts, previously identified in WP2, was conducted. Based on geological, structural, and operational criteria, the Budryk II and Budryk III shafts were selected as the most technically suitable configuration for PSH system implementation. For this selected shaft pair, a series of hydraulic and mechanical calculations were performed to verify the system's ability to achieve the target energy storage capacity and performance parameters. The optimal turbine type was determined based on a detailed analysis of the anticipated flow rates and pressure conditions. In addition, conceptual design assumptions for the underground power generation unit and the associated pumping infrastructure were formulated, considering space constraints, access, and operational safety.



Utilizing site-specific geotechnical data, including the mechanical properties of the rock mass and existing shaft lining conditions, a numerical geomechanical model of the planned underground water reservoir was developed. This model enabled the simulation of mechanical behavior under dynamic loading conditions and informed the selection of reinforcement strategies to ensure structural stability and long-term performance. Work results were described in ***D.3.2. Technical parameters of the example underground water reservoir model***.

To select of construction and lining materials for the underground reservoirs, a series of laboratory tests were conducted, including assessments of corrosion resistance, erosion durability, and permeability under representative environmental conditions. The results of these tests provided critical input for material specification and design life estimation.

WP3 activities resulted in the advancement of expertise in the modelling and conceptual design of PSH systems utilizing post-mining infrastructure, with a strong emphasis on both technical and economic feasibility. Methodological framework for the designation and assessment of underground workings intended for energy storage applications was developed. This methodology incorporates key rock mass parameters, shaft geometry, support conditions, and hydromechanical properties, enabling systematic evaluation and future scalability of similar energy storage concepts.

## Energy storage in compressed gas systems

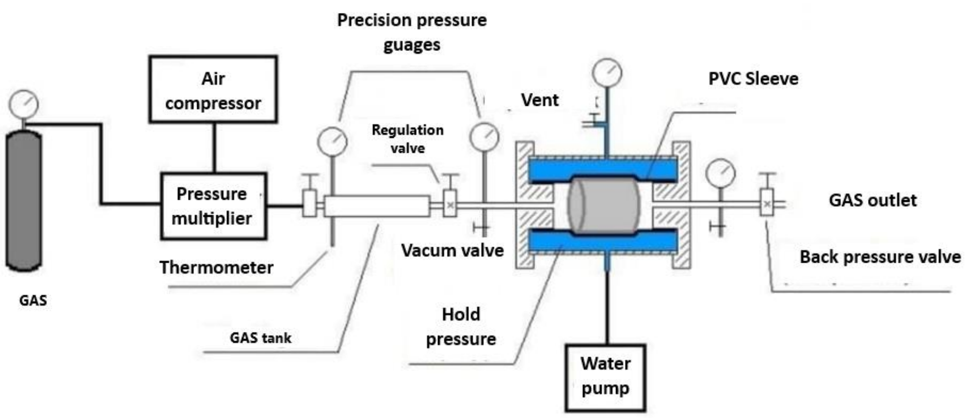
Extensive thermodynamic modelling was carried out using in-house computational codes. The subject of the study were adiabatic energy storage systems in compressed air and in compressed carbon dioxide. The work resulted in a multi-variant analysis, based on which variants of the studied systems were recommended for further work. The focus was that the identified variants should be characterised by acceptable operating parameters, energy indicators and the possibility of integration with an energy router.

Based on extensive thermodynamic analysis, it was determined that the minimum diameter of the mine shaft should allow for the construction of a TES tank with an internal diameter of at least 5 meters. For a mine shaft with a diameter of 9m, a mine shaft of at least 750m in length is necessary to obtain an energy storage system with a capacity of 80MWh.

Studies results were described in detail in ***D.4.1. Thermodynamic analysis of the proposed systems*** *and in the journal Energies.*

***J. Ochmann, M. Jurczyk, K. Rusin, S. Rulik, Ł. Bartela, W. Uchman; "Solution for Post-Mining Sites: Thermo-Economic Analysis of a Large-Scale Integrated Energy Storage System" Energies 2024, 17(8), 1970, https://doi.org/10.3390/en17081970****)*

WP4 focuses on gas permeation and $CO_2$ contamination in low-pressure underground reservoirs. Experimental work investigates the diffusion of air, $CO_2$, and methane through sealing and lining materials under conditions representative of repurposed mine shafts. $CO_2$ leakage rates and changes in gas composition over time will be quantified. Additionally, methods for compressing $CO_2$ mixed with trace contaminants are being explored. The goal is to ensure long-term integrity and containment of storage systems built on post-mining infrastructure.




Protective coating systems for concrete substrates will be assessed with respect to their mechanical durability, chemical resistance, and barrier performance against gas permeation. The study will focus on polyurea, polyurethane-based coatings, and epoxy resin systems, all of which are considered as viable candidates for deployment in mine shaft environments characterized by elevated humidity levels, pressure variability, and exposure to chemically aggressive agents.

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## Heat storage in post-mining infrastructure

In the framework of this work package, an analysis of available heat storage materials in terms of their suitability and cost-effectiveness for use in large-scale energy storage systems (single-phase materials and phase-change materials) was performed. Materials were selected that can be used at three temperature levels: 100°C, 300°C, 500°C. Methodologies for their assessment were developed using criteria analysis in terms of: thermal properties, physical properties, chemical properties and economic factors. A preliminary selection of materials for further research within the HESS project was made.

Experimental tests were performed using solid ceramic materials. These materials have demonstrated favourable thermophysical performance with regard to heat storage; nevertheless, their elevated cost does not currently allow it to be used on an industrial scale. Experimental studies are also being conducted with thermal energy storage tank, with the objective of investigating the potential for heat storage in natural rock materials and providing experimental data for the validation of numerical models.

Studies results were described in detail in ***D.5.1. Thermal energy storage material studies*** and in the journal Energies.

***M. Jurczyk, T. Spietz, A. Czardybon, S. Dobras, K. Ignasiak, L. Bartela, W. Uchman, J. Ochmann ("Review of Thermal Energy Storage Materials for Application in Large-Scale Integrated Energy Systems — Methodology for Matching Heat Storage Solutions for Given Applications Energies" Energies 2024, 17(14), 3544, https://doi.org/10.3390/en17143544)***

WP6 includes work related to the thermal and mechanical integration of three energy storage systems. The router developed within the project will optimize energy flows between the energy storage systems, enabling flexible adaptation of the system to changing operating conditions and current energy needs. An energy router was designed, purchased and built. The control cabinet was modified to adapt to the required hardware changes. A server responsible for network communication and a controller equipped with an operator panel were installed. The individual components of the system were integrated into a coherent infrastructure.

As part of the HESS project implementation, 3 milestones have been achieved so far:

- ***Recognition of mine shafts and water reservoirs. Indication of at least 1 location from each country with 10 MWh min. storage capacity meeting the assessment criteria - 30.04.2024.***
- ***System analysis for CAES system. Selection of two optimal configurations of energy storage system - 31.12.2024.***
- ***Selection of accumulation materials. Ranking of the selected materials in terms of their suitability for TES according to their heat capacity, mechanical strength, and market availability and cost - 25.02.2025.***

**We invite you to explore more details of the work on the HESS project website https://itpe.pl/en/hess/**

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