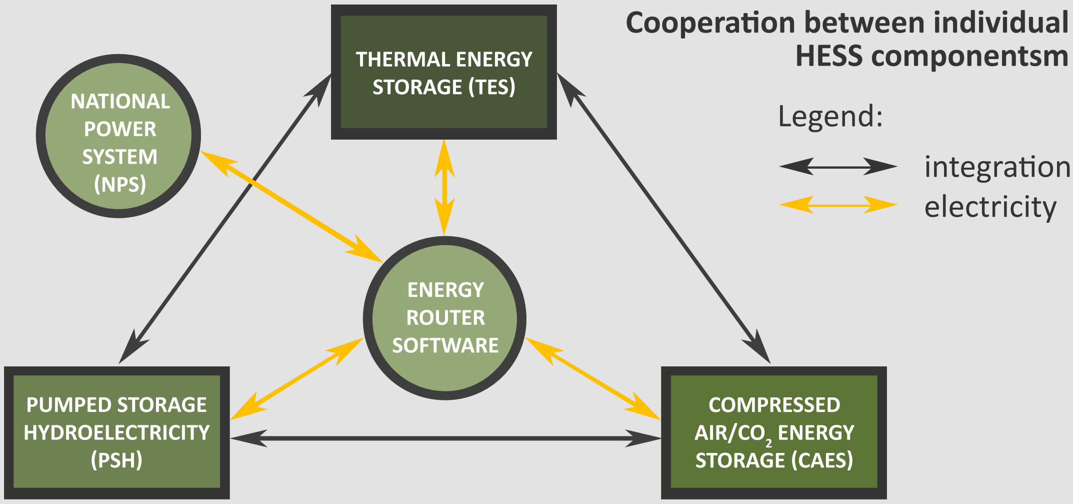
HESS

# NEWSLETTER

## COMPREHENSIVE PUBLIC OVERVIEW OF HESS PROJECT

*January 2024, First Issue*

*Project no: 101112380 - HESS - RFCS-2022*




## PROJECT INFORMATION

**TITLE:**
"Hybrid energy storage system using post-mining infrastructure" (HESS)

**PROJECT NO:**
101112380 (RFCS-2022)

**PROJECT BUDGET:**
2 226 740,2 Euro

**PROJECT DURATION:**
36 months (01.07.23 – 30.06. 26)

**PROJECT WEBSIDE:**
https://www.itpe.pl/en/hess/

## HESS PROJECT GOAL

The project aim is to develop a Hybrid Energy Storage System (HESS) using post-mining infrastructure. The analysis of the possibility of its use for parallel energy storage in: Pumped Storage Hydroelectricity System (PSH), Compressed Gas – Air/$CO_2$ Energy Storage System (CAES) and Thermal Energy Storage (TES) system will be made. The possibility of using geothermal energy and the use and potential storage of $CO_2$ (CCS, Carbon Capture and Storage) will be determined. A method of thermal and mechanical integration of the entire system will be developed.

Co-funded by the European Union

Research Fund for Coal & Steel

Specific requirements by a particular energy storage system are as follows:

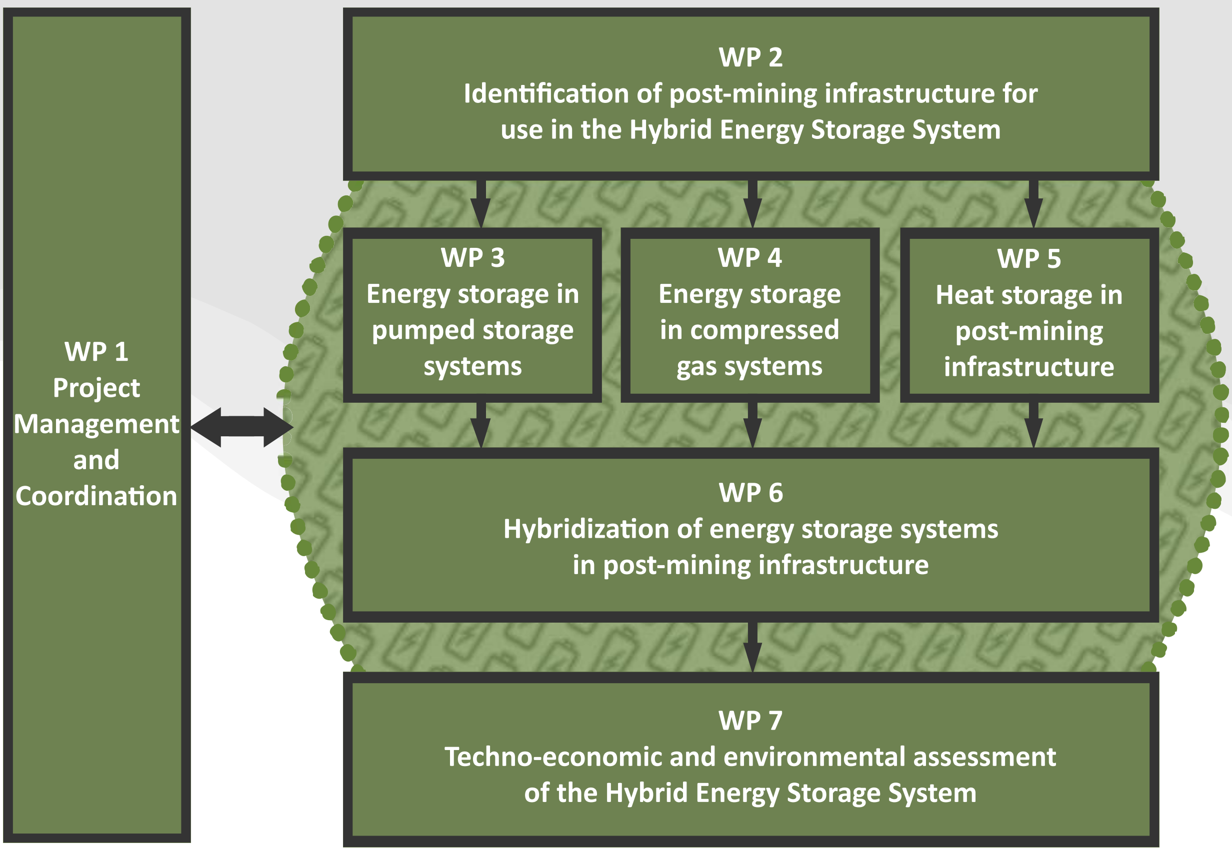
a. for PSH to ensure the tightness of the tanks for a minimum of 10 years,

b. for CAES to achieve the working pressure up to 80 bar (air) and up to 20 bar (carbon dioxide), and pressure losses in the sealed mining shaft should be less than 5% of the maximum pressure (during one cycle of CAES operation),

c. for TES to ensure the energy storage temperature up to 500°C and to achieve an energy recovery capacity of at least 1.5 MWt at least 2 hours.

The assumed total energy storage capacity supposed to be min. 30 MWh. On the basis of the energy demand of each HESS component, a method of thermal and mechanical integration of the entire system will be developed. An algorithm for the mutual interaction between the elements of the energy storage system will be developed.

Optimal cooperation of the various elements of the HESS will be supervised by an energy router which will 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 will take into account the possibility of cooperation of multiple HESS systems working in a distributed system. Technical and economic and LCA analysis will form the basis for work on the construction of a pilot plant and industrial implementation of the project results.



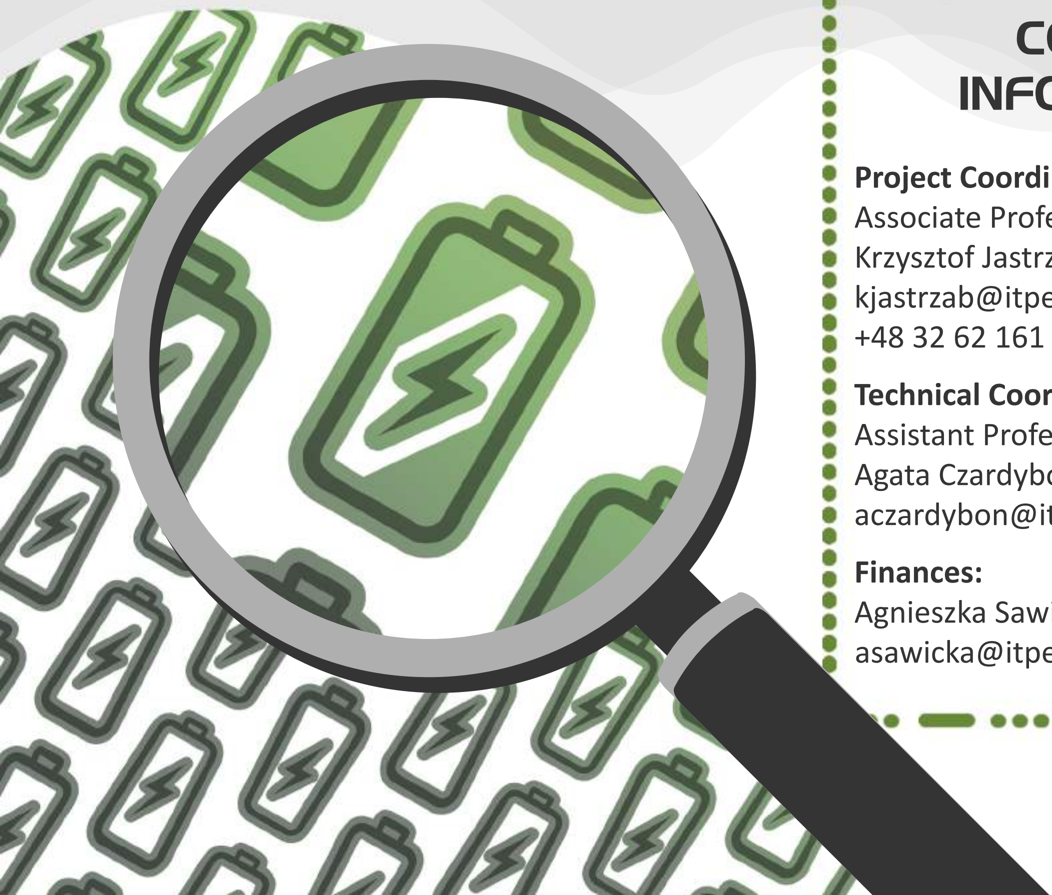

*Overall structure of the project*

# PROJECT MILESTONES

1. Recognition of mine shafts and water reservoirs – M10
2. Parameters of the underground power generation unit and water pumping system – M24
3. System analysis for compressed air storage system – M18
4. Guidelines instructions for compressed  gases storage in mine shafts – M24
5. Selection of accumulation materials – M20
6. Numerical model validation of TES system – M24
7. Technical and process dataset necessary to develop the assumptions for the router, and to carry out the techno-economic and LCA analysis – M26.

| | WP title | KOMAG | ITPE | SUT | VSB-TUO | PV | 2023 | | 2024 | | | | 2025 | | | | 2026 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP 1 | Project Management & Coordination | X | X | X | X | X | | | | | | | | | | | | |
| WP2 | Identification of post-mining infrastructure for use in the Hybrid Energy Storage System | X | X | X | X | X | | | | | | | | | | | | |
| WP 3 | Energy storage in pumped storage systems | X | X | X | | | | | | | | | | | | | | |
| WP 4 | Energy storage in compressed gas systems | | X | X | | | | | | | | | | | | | | |
| WP 5 | Heat storage in post-mining infrastructure | | X | X | | | | | | | | | | | | | | |
| WP 6 | Hybridization of energy storage systems in post-mining infrastructure | X | X | X | X | X | | | | | | | | | | | | |
| WP7 | Techno-economic and environmental assessment of the Hybrid Energy Storage System | X | X | X | X | X | | | | | | | | | | | | |

*Gantt of HESS project*



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# HESS CONSORTIUM

### INSTYTUT TECHNOLOGII PALIW I ENERGII (ITPE)

Leader of the project consortium, formerly Institute for Chemical Processing of Coal, is known as high-scientific level research institution since 1955. It is the scientific back-up of Polish industry with research and development related to fossil and renewable fuels, biomass, waste processing, by-product utilization, environmental protection in industrial and post-industrial activity, improving clean, environmentally safe fuel utilization, and products with special quality features.

ITPE role in HESS project: Project Management and Coordination (WP1), complicity in determination of possibility of using underground and surface mine infrastructure for HESS (WP2), corrosion and erosion tests of tanks, brine diffusion through the walls tests (WP3), diffusion tests of gases through mineshaft sealing materials (WP4), tests of use PCM for heat storage in post-mining infrastructures (WP5), HESS thermal and mechanical integration (WP6), technical, economic assessment, SWOT analysis, and LCA (WP7).

### INSTYTUT TECHNIKI GORNICZEJ KOMAG (KOMAG)

Is a Polish state-owned research and development organization whose scope of activities includes scientific and research and development projects in the area of mineral extraction and processing, environmental protection, occupational safety, air and land surface protection.

KOMAG role in HESS project: leader of WP2 (“Identification of post-mining infrastructure for use in the Hybrid Energy Storage System”), carrying out works on the development of an underground power generator and pumping system for HESS (T3.1.), participation in HESS thermal and mechanical integration (WP6), and in technical, economic assessment, SWOT analysis, LCA (WP7).

## POLITECHNIKA SLASKA (SUT)

Founded in 1945, is one of the largest and top-ranked technical universities in Poland. Located in Upper Silesia, the most industrialized part of Poland, it is an important hub of industrial research.

SUT role in HESS project: leader of WP3 (Energy storage in pumped storage systems), WP4 (Energy storage in compressed gas systems), WP5 (Heat storage in post-mining infrastructure); participant in works on thermal and mechanical integration of HESS elements (WP6); providing data for technical, economic assessment, SWOT analysis, and LCA (WP7), complicity in determination of possibility of using underground and surface mine infrastructure for HESS (WP2) and WP1 activities.

## PREMOGOVNIK VELENJE D.O.O. (PV)

PV is a technologically advanced company with lignite mining as its primary activity from Slovenia. With an over 147-year tradition in lignite mining, it is firmly rooted in the energy economics.

ITPE role in HESS project: complicity in determination of possibility of using underground and surface mine infrastructure for HESS in Slovenia (WP2), participation in HESS thermal and mechanical integration (WP6), and in technical, economic assessment, SWOT analysis, LCA (WP7).

## VSB TECHNICAL UNIVERSITY OF OSTRAVA (VSB-TUO)

Founded in 1849, is a Czech public university with a long tradition in high quality engineering education and research. These traditional core values have been continually updated to reflect current state of the art technologies and the ever-evolving needs of industry. VSB-TUO has strong links to industry and thrives on applied research, in cooperation with companies and institutions worldwide, in finding innovative solutions to modern day issues.

VSB-TUO role in HESS project: complicity in determination of possibility of using underground and surface mine infrastructure for HESS in Czech (WP2), participation in HESS thermal and mechanical integration (WP6), and in technical, economic assessment, SWOT analysis, LCA (WP7).

# WP1 — Project Management and Coordination

**T 1.1. PROJECT MANAGEMENT AND COORDINATION ACTIVITIES**

The task includes all management and coordination activities carried out during the project to ensure the achievement of the intended project results such as: project meetings organization, project work coordination, archiving data and documents, monitoring and evaluation of project implementation, financial management, and preparing reports for the European Commission.

**T 1.2. PROJECT PROMOTION AND RESULTS DISSEMINATION**

The task goal is project promotion as well as dissemination of results and achievements obtained. Activities under the task include: preparation of papers in scientific journals and patents, participation in conferences, seminars and workshops (i.a. at the Silesian Energy Storage Forum, or the others associations meetings), oral and poster presentations. It is also planned to organize a final international seminar which will be open to stakeholders from different backgrounds expressing interests of mine waste dumps recultivation. Project results will be made publicly available through partners' own network channels, open public reports and an annual e-newsletter available on the HESS project website.

“Communication and Dissemination Plan for Hybrid Energy Storage System (HESS)” has been developed as a deliverable D1.1. (document available at HESS webpage https://www.itpe.pl/en/hess/). The CDP identifies the communication channels and tools according to the needs and capacities of the different stakeholders and users’ groups. It also guarantees that the dissemination activities are highly targeted, in content and method, to achieve the highest possible impact. This document establishes guidelines for efficient internal communication between Partners to foster the successful implementation of the project.

D1.2. - HESS project website has been created by ITPE (https://www.itpe.pl/en/hess/). It contain information about project concept, structure, timeline, Consortium Partners, as well as project progress and action. Scientific publications, conference materials, publishable reports and reviews, annual newsletters, and deliverables achieved within the HESS project will be posted there.

## Expected WP1 deliverables:

D1.1. The communication and dissemination plan (M1)

D1.2. Webpage created and initiated (M6)

D1.3. The comprehensive public overview of the project (M6)

D1.4. Publishable Report (M35)

D1.5. Final international seminar – project results presentation (M36).

# WP2 — Identification of post-mining infrastructure for use in the Hybrid Energy Storage System

**T 2.1. MINE SHAFTS SELECTION**

The task involves work on determining the possibility of using mine shafts for the Hybrid Energy Storage System in three countries: Poland, the Czech Republic and Slovenia.

The data are collected form the mining companies, mining authorities and through personal communication. The number of shafts was collected from the following Polish companies: KGHM POLSKA MIEDŹ S.A, JSW S.A., PGG S.A, SRK S.A, LW BOGDANKA S.A, WĘGLOKOKS KRAJ SP Z.O.O, TAURON WYDOBYCIE S.A., KW KŁODAWA, ECO PLUS, SILTECH. Shafts database contains the following data: the name of the mine shaft, shaft diameter, shaft depth, diameter change with depth, other information and remarks such as: shaft casing type, different shaft-cross section, etc. information on shafts under construction, sunk and decommissioned. Similar databases created for wells in the Czech and Slovenia. The main result of created databases is the ability to estimate the total shafts number in each country which, due to their size can be adapted for energy storage purposes, and total energy storage potential in megawatt hours.

Another objective of the task is to determine the hydrological and geological requirements for the most optimal use for PSH, CAES, and TES elements. These requirements will further help in designing a suitable place for installation so that the potential of the HESS is used as much as possible and at the same time does not cause any damage.

In order to transpose the results of the projects on the European scale it was decided to create a comprehensive assessment tool for analyses and initial estimation of energy storage capacity of shafts. For shafts initially selected for energy storage in HESS, additional information was obtained related to: type of mine shaft casing, condition of the mine shaft casing, number of inlets to the shaft, water inflow to the shaft, average compressive strength of the rock mass surrounding the shaft, and tectonic influences.

The above-mentioned parameters will allow for creation of multi-criteria point analysis, which will enable the selection of mine shafts for energy storage purposes. Every feature included in the first list and the features listed above will be assigned to the corresponding point value. This will allow for the creation of a tool that will verify in an easy and accessible way the possibility of transforming a mine shaft into an energy storage facility.

**T 2.2. UNDERGROUND WATER RESERVOIRS SELECTION**

In order to store water pumped from the surface it is necessary to select and identify workings suitable for the construction of the reservoir. Therefore, it is necessary to select either proper support to prevent the contraction e.g. concrete lining or select parts of the mine where large workings such as pump, machine chambers or shaft stations are available.

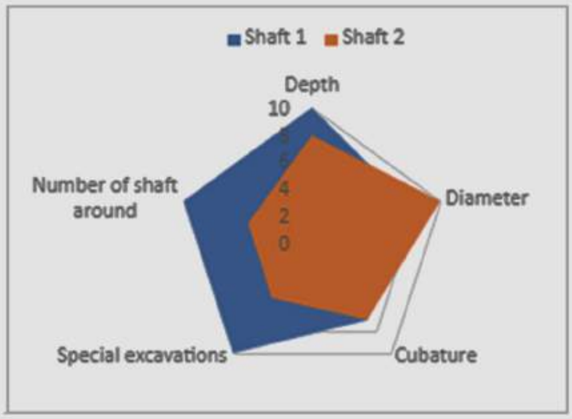
In this task we aim at selection of potential workings and supporting methods that could be suitable for the conversion into underground water reservoir.

SUT, KOMAG, and ITPE will recognize the Polish mines, VSB-TUO and PV will recognize the Czech and Slovenia mines, respectively.

## Expected WP2 deliverables:

D2.1. Guidelines on the adaptation and use of inactive shafts possible to energy storage (M12)

D2.2. Guidelines on the conversion of underground mine working into water reservoir (M12).




| | Shaft 1 | Shaft 2 |
|---|---|---|
| Size Parameters | Points | Points |
| Depth | 10 | 8 |
| Diameter | 8 | 10 |
| Cubature | 7 | 7 |
| Special excavations | 10 | 5 |
| Number of shaft around | 10 | 5 |

*Simple graphical representation of the comparisons of the shafts*

# WP3 — Energy storage in pumped storage systems

### TT3.1. UNDERGROUND POWER GENERATION UNIT AND PUMPING SYSTEM

The optimal type of turbine will be selected depending on the drop and flow rate. Calculations, spatial model and preliminary design will be made. For the assumed turbine power, the volume of water discharged from the upper tank for 4-6 hours of continuous operation of the turbine set will be planned. Selecting the location of the tank should result from the location of the shaft that will be used for the installation.

It is planned to use the mine's main drainage pumps to pump water into the upper reservoir. These pumps will be located below the level of the turbine. The work is performed by KOMAG.

## Expected WP3 deliverables:

D3.1. The pumped storage systems in mine shafts (M30)

D3.2. Technical parameters of the example underground water reservoir model (M18).

### T3.2. CONSTRUCTION AND OPERATION OF UNDERGROUND RESERVOIRS OF PUMPED-STORAGE POWER PLANT (PSH)

In order to store water pumped from the surface it is necessary to select and identify workings suitable for the construction of the reservoir. Three case studies of the mines will be carried out and suitable workings will be selected for further studies. Geomechanical model of the water reservoir will be created by SUT based on the real field data of the rock mass and existing support. Recommendations related to the conversion of underground mine working to underground water reservoir will be made in the form of guidelines. The task will include the selection of construction material for underground water reservoirs in pumped storage power plants. Tests of corrosion and erosion of the tank by internal (water) and external (brine) factors, tests of brine diffusion through the walls of the underground tank and PSH circulating water treatment will be performed by ITPE. The possibility of using geothermal energy carried with the circulating water stream in the PSH will be analysed.

# WP4 — Energy storage in compressed gas systems

### T 2.1. MINE SHAFTS SELECTION

The WP4 research is divided into two parts - thermodynamic calculations (SUT) and laboratory studies (ITPE and SUT). Thermodynamic part will be based on numerical studies of thermodynamic processes involving compression, storage and expansion of gases. The concept of adiabatic energy storage in compressed air (ACAES) involves using a sealed mine shaft as a compressed air reservoir. In this system, the heat of air compression is stored in TES and stored with the air in the underground postmining infrastructure. During the system's discharging stage, the expanded air absorbs heat from the thermal storage before being directed to the expander. This idea was granted a patent by the European Patent Office (no. EP20000302). The concept of energy storage in compressed $CO_2$ includes a closed gas compression and expansion system with an underground high-pressure tank. Analogously to the ACAES system, a heat storage tank is used. Thermodynamic studies estimating the energy potential of the proposed systems will be based on system solutions previously proposed as patent applications [Pat.239532] by SUT research team. Previous studies have shown that using a 60,000 $m^3$ mine shaft as a compressed air reservoir, it is possible to achieve a system with a potential of 140 MWh, assuming a maximum air pressure of 5 MPa. Using an analogous mine shaft, a system with an energy potential of about 80 MWh was obtained for a $CO_2$ compression and storage system.

The second part of research focuses on developing adequate strategies for operating the systems in relation to their power, taking into account the system's instantaneous need to interact with energy storage systems. In order to quantitatively investigate the phenomenon of gas permeation ($CH_4$, air) from the shaft to the stored $CO_2$ as well as the reverse, the diffusion of $CO_2$, methane and air through the sealing materials under conditions of varying pressure will be studied. Laboratory-determined diffusion coefficients through various materials will allow determination of total $CO_2$ loss from a low-pressure reservoir. In addition, methods of obtaining $CO_2$ in the amount necessary to start up and operate energy storage using compressed $CO_2$ will be analysed.

### T4.1. COMPRESSED AIR ENERGY STORAGE IN POST MINING INFRASTRUCTURE

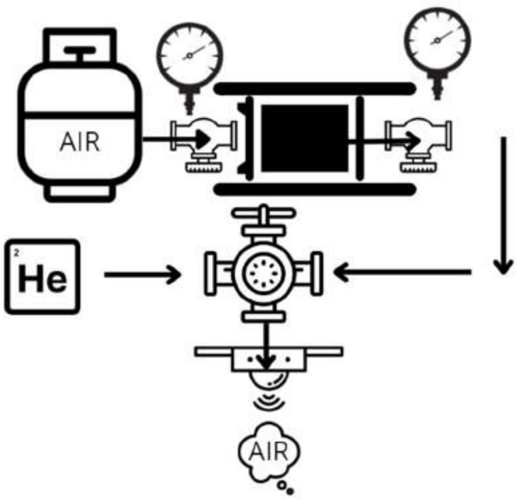
The most important issue in case of compressed gases storage is the integrity of the post-mine shaft, its mechanical resistance and proper sealing that will prevent pressure losses. For that purpose a series of laboratory strength tests of the casing as well as air permeability tests will be conducted. Specific strength tests of the mine shaft casing will be carried out on samples acquired from selected mines. Samples will be cored from various depths and selected casing materials. The selection of locations will be based on the age of casing, type of casing and its deterioration. It is planned to test samples from both the inner part of the shaft and outer part which is in contact with the rock mass. This should show the effect of corrosion and deterioration on the casing strength. Next, proper lining methods will be identified. Suitable methods of sealing/ /protection of the casing in order to increase the strength parameters and to achieve proper sealing of the shaft casing under cycling pressure and different gases ($CO_2$/air) depending on the type of compressed gas energy storage will be assessed. To assess the best possible material various mixtures will be tested on strength and air permeability.

Tests planned as part of WP will provide results that allow for setting basic guidelines and challenges related to the compressed gases storage in mine shaft. The first element to be checked is the decrease in the strength of the mine shaft casing over time. It is necessary to determine the change in the compressive strength parameters of the concrete from which the mine shaft is built, which will be transformed into energy storage tank. As a result of the work carried out, an average decrease in concrete strength will be determined, which will allow for more precise selection of the parameters of the future energy storage.

So far preliminary tests were carried out on samples taken from a mine shaft of one of the mines of the Silesian Coal Basin. The obtained results showed a six percent decrease in compressive strength compared to the technical design.

*Mine shaft sample used to develop methodology of compressive strength changes during time*

As part of work on determining the gas permeability through concrete samples of the shaft lining, a carrier gas diffusion test stand was developed. The Carrier Gas method is based on measuring the concentration of gas downstream of the sample. This makes it possible to is to measure even trace amounts of gases passing through the sample, the amount of which would be impossible to identify with even the most sensitive pressure gauges.




*Carrier Gas method diagram*

The permeability test methodology includes the following steps: adaptation of the samples used for the compressive strength for the permeability test stand, performing diffusion test using the carrier gas method, coating the samples with different sealing materials, repetition of diffusion tests with coated samples, comparison of test results and selection of the preferable liner.

The above test will allow to check the permeability of the concrete lining of the mine shaft and will allow to select insulating materials suitable for the transformation of the mine shaft casing into energy storage.

## T4.2. COMPRESSED $CO_2$ ENERGY STORAGE IN MINE SHAFT

The task includes thermodynamic studies of energy storage systems within $CO_2$ compression in underground infrastructure. Studies of $CO_2$ loss during cyclic operation will be conducted and potential pathways for system acquisition and replenishment will be recognized. The migration of $CO_2$ into the rock mass as a potential method of partial carbon dioxide storage will be analysed as well. Issues related with $CO_2$ storage under supercritical conditions and potential methods of compressed mixtures of $CO_2$ with gaseous impurities will be studied.
Research on diffusion of $CO_2$, methane and air through mineshaft sealing materials will quantify these processes. Potential $CO_2$ contamination problems in a low-pressure reservoir will be recognized, and solutions leading to sealing of reservoir coatings will be proposed.

The erosion study of $CO_2$ pressure vessels will be conducted. Based on results, a preliminary techno-economic analysis will be made as an input to subsequent WPs.

As part of the task, work has been undertaken to construct an in-house computational model of the compressed carbon dioxide and compressed air energy storage system. It will include a section for compression and expansion of $CO_2$ or air, as well as its storage in an underground tank located in a post-mining mine shaft or shaft space (for compressed air). The computational model will be set up so that the system's output can be scaled, potentially enabling the selection of the optimal system scale relative to system requirements. The model will also make it possible to determine the maximum storage pressures for $CO_2$ or air, the power consumption for its compression, and the size of any heat exchangers supplying heat to the expanded gas. As a target, the energy potential of the compressed air energy storage system was assumed to be 140 MWh at a maximum gas pressure of 5 MPa. The maximum potential of the energy storage system in compressed carbon dioxide will be 80 MWh.

## Expected WP4 deliverables:

D4.1. Thermodynamic analysis of the proposed systems (M18)

D4.2. Guidelines for the baseline condition of the reference shafts (M30)

D4.3. Lining materials selection and properties (M27).

# WP5 — Heat storage in post-mining infrastructure

### T5.1. EXPERIMENTAL STUDY OF HEAT STORAGE MATERIALS AND THERMAL ENERGY STORAGE TANK

The task includes an experimental of the potential for heat storage in post-mining infrastructures, which will be carried out by SUT and ITPE. The optimal method of heat storage - sensible in single-phase materials or sensible and latent in phase-change materials (PCM) - will be determined. Energy storage materials corresponding in their thermo-physical parameters to the requirements for typical heat storage installations will be selected.

Experimental studies of the processes of charging, storing and discharging heat are performed on laboratory stand in SUT, including measurements of the temperature of the accumulating material and the pressure drop of the heat transfer medium. The parameters of the laboratory stand correspond to the development in the mine shaft. Experimental tests are carried out on two variants of the laboratory stand: without the use of thermal insulation and with the use of thermal insulation with a thickness of 50 mm.

As part of the task work on developing a methodology for selecting the optimal accumulation material used for heat storage in HESS has been done.

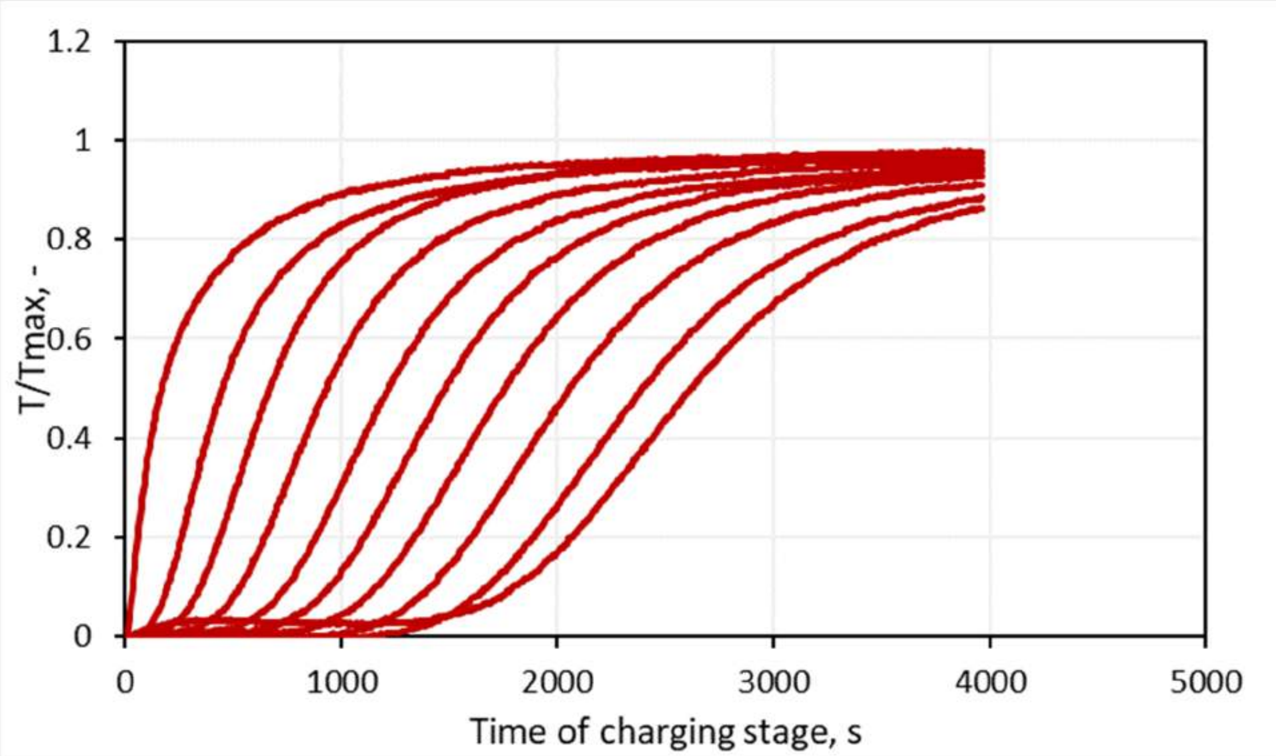
The storage energy materials will be ranked by evaluating them according to several defined categories, including:

- maximum operating temperature, temperature of phase change and internal structural changes,
- heat capacity and its dependence on temperature,
- thermal conductivity coefficient,
- inertness to other materials,
- market availability.

The temperature rise of the rock material is measured at the determined values of the mass flow of air and the maximum temperature of the inlet air. An example of the results of the increase in the temperature of the rock material along the axis of symmetry of the tank is presented in the figure on the next page.

The experimental series was carried out at a maximum air temperature of 353 K and a mass flow rate of 256 kg/h.

*A TES tank without thermal insulation*




*Temperature distribution in rock material during charging stage*

## T5.2. NUMERICAL MODELLING OF THERMODYNAMIC AND FLOW PROCESSES IN THERMAL ENERGY STORAGE TANK

The task involves deciding on a methodology for selecting a method for simulating heat transfer and fluid pressure drop processes in a Thermal Energy Storage tank.

A proprietary numerical model will be developed using the Python programming language in the Matlab environment by SUT. The numerical model will allow one-dimensional simulation of heat transfer processes between the gas and the heat storage material. In addition, a two-dimensional numerical model will be created using ANSYS Fluent software.

Comparison of the obtained results will allow determining the degree of accuracy of the one-dimensional heat transfer against the two-dimensional model. In particular, the effect of simulating the radial temperature distribution of the storage material on the overall efficiency of heat storage processes will be evaluated. The one-dimensional numerical model will be enriched with the methodology for calculating the machinery (compressors, expanders), which are necessary for determining the operational parameters of compressed gas energy storage systems. Both the one-dimensional and two-dimensional models will be validated using experimental results performed on a laboratory bench.

### Expected WP5 deliverables:

D5.1.Thermal energy storage material studies (M12)

D5.2.TES performance report (M30).

# WP6 — Hybridization of energy storage systems in post-mining infrastructure

## T6.1. INTEGRATION OF PARTICULAR COMPONENTS OF THE HESS

Task goal is thermal and mechanical integration of individual HESS components (PSH, CAES, TES) assuming an energy capacity of 10 MWh of each system component. The amount of heat generated and the heat demand of individual HESS elements will be determined. An assessment will be made of the possibility of using geothermal heat from groundwater. As part of the mechanical integration, the impact of pressure changes will be determined in individual HESS elements. Use of the hydraulic pressure of the water column in the well for the initial compression of $CO_2$ will be analyzed.

Mechanical optimization of HESS elements will be carried out. Thermal and mechanical integration will be performed by ITPE with the participation of other consortium members.

## Expected WP6 deliverables:

D6.1. Integration of particular components of the HESS (M33)

D6.2. Energy router software (M33).

## T6.2.DEVELOPMENT OF AN ENERGY ROUTER CONCEPT

As part of the task, a concept of an energy router will be developed, the role of which will be to effectively manage energy flows in the power system. All work on the development of the router will be coordinated by ITPE, and the main contractor will be KOMAG.

The router will collect data on current and archived system parameters, which requires the creation of computer application with a database. The energy management system will integrate the operation of all HESS modules. In addition, the router will cooperate with external producers of "green energy" and recipients of stored energy. In cooperation with the National Power System, the router will control and manage the energy flow, taking into account the supply and demand for energy, with particular emphasis on HESS economics.

The main assumptions of the router's operation will be related to the optimization of the operation of individual warehouses, minimization of energy acquisition costs, estimation of the amount of stored energy and correlation between subsystems. The router software will be integrated with the energy router hardware module. This will enable real-time control of individual energy storage subsystems, i.e. PSH CAES, and TES. The developed intelligent energy router will enable unattended operation of the entire HESS system.

# WP7 — Techno-economic and environmental assessment of the Hybrid Energy Storage System

### T7.1. TECHNICAL-ECONOMIC EVALUATION OF THE HESS

Aim of task is to assess the technical feasibility of the developed HESS technology based on the research results conducted in the previous stages of the project. It will be performed in the form of a Preliminary Feasibility Study. Basic technological parameters description of facilities and equipment, properties of the media used, their mass and energy flows will be presented.

Economic analysis will allow determining estimated investment outlays, operating costs and indicators for assessing economic profitability. Various system operation strategies will be considered, taking into account periodic fluctuations in energy prices on the market.

As a summary, SWOT analysis will be carried out. The strengths and weaknesses of the developed technology will be determined, as well as the threats arising from the environment in which it will be implemented (market changes, new trends, changes in the regulatory environment, political changes, etc.). Analysis and assessment of the project's potential will demonstrate whether it is justified and feasible in the proposed technological system.

Technical and economic assessment as well as SWOT analysis for the HESS will be performed by ITPE. Data necessary to carry out the analyzes will be provided by all consortium members of the HESS project.

### T7.2. LIFE CYCLE ASSESSMENT OF THE HESS

LCA to will be perform by ITPE in cooperation with the other project partners. The main objective of the environmental life cycle analysis is to assess the environmental risks of three different energy storage systems (TES, CAES, PSH), as well as to compare their ecological impacts in the main impact categories. The LCA will cover all relevant stages of the life cycle, i.e. the production stage, the operational stage and the end-of-life stage. This approach will allow you to assess which phase of the installation's life cycle has the greatest impact on the environment. A comprehensive LCA analysis of the Hybrid Energy Storage System will enable the identification of key stages negatively affecting the environment and their minimization.

## Expected WP7 deliverables:

D7.1. Techno-economic assessment of hybrid energy storage technology in post-mining infrastructure (M36)

D7.2. Life cycle assessment (LCA) of the HESS (M36).