NEWSLETTER
No. 7
PUBLIC OVERVIEW OF HESS PROJECT
July 2026, Seventh Issue . Project no: 101112380 – HESS – RFCS-2022

Techno-economic analyses of HESS – from engineering concept to investment feasibility

One of the key objectives of the HESS project was not only to develop innovative hybrid energy storage system based on post-mining infrastructure, but also to verify whether such solutions could be technically implemented and economically justified under real operating conditions.
Within WP7, the project consortium carried out a comprehensive techno-economic assessment of the proposed HESS, integrating the technological solutions developed throughout the project into a complete large-scale energy storage concept. The analyses combined engineering design, process modelling, cost estimation and economic evaluation, providing a solid basis for assessing the implementation potential of hybrid energy storage technologies in Budryk mining areas.

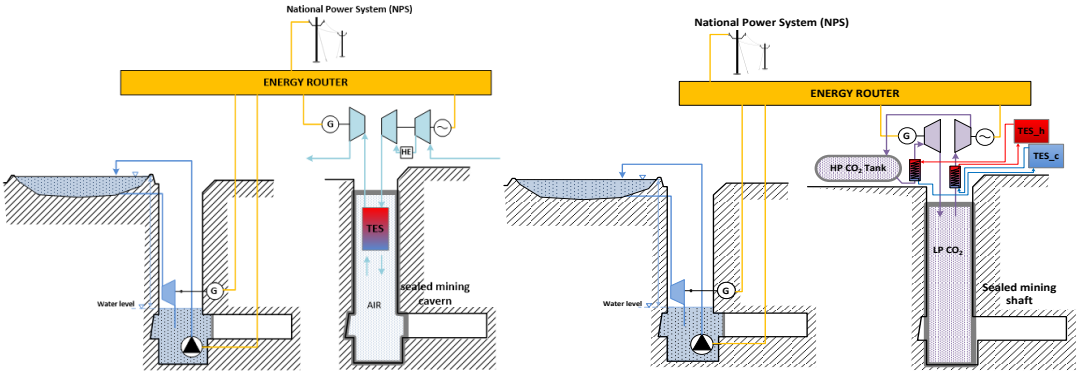
Two alternative HESS configurations

The analyses focused on two alternative HESS concepts:

- Variant 1 – Pumped-Storage Hydropower (PSH) integrated with Adiabatic Compressed Air Energy Storage (ACAES) and Thermal Energy Storage (TES),
- Variant 2 – Pumped-Storage Hydropower (PSH) integrated with Compressed Carbon Dioxide Energy Storage (CCES) and Thermal Energy Storage (TES).

Both configurations utilise Budryk mine II and III shafts as the core underground infrastructure while sharing common elements such as the pumped-storage subsystem, grid connection and energy router. The comparison of both concepts made it possible to identify the technical advantages, investment requirements and economic potential of each solution.

Co-funded by the European Union



Variant 1 Variant 2

HESS operation diagram in two variants

Developing a complete engineering concept

The work carried out within WP7 went far beyond a simple comparison of technologies. A complete engineering concept was developed for each HESS configuration. The project team prepared detailed process flow diagrams describing the interaction of all subsystems, defined the operating principles and technological parameters, identified the required process equipment and characterised the principal process streams and resource requirements.

Particular attention was devoted to the adaptation of post-mining infrastructure. Engineering solutions were developed for shaft sealing, shaft plugs, protective concrete linings and ventilation systems, ensuring safe operation of underground energy storage facilities. Comprehensive mass and energy balance calculations were also performed to verify energy flows and assess the technical feasibility of the integrated systems.

Investment cost assessment

An important part of the study was the estimation of the investment cost of both HESS configurations using the Total Overnight Cost (TOC) methodology.

The analyses showed that:

- Variant 1 (PSH + ACAES/TES) requires an estimated investment of approximately EUR 234.6 million.
- Variant 2 (PSH + CCES/TES) requires approximately EUR 204.3 million, representing a reduction of almost 13% compared with Variant 1.

At first glance, Variant 2 appears to be the less expensive option. However, the comparison also revealed that the lower investment cost is accompanied by a considerably smaller storage capacity.

Variant 1 provides approximately 131 MWh of combined storage capacity, whereas Variant 2 offers approximately 56 MWh. Consequently, although Variant 2 requires lower total investment, its specific investment cost per unit of stored energy is more than twice as high.

The results indicate that total investment cost alone does not provide a sufficient basis for comparing alternative energy storage technologies. Investment expenditure should be evaluated together with the storage capacity delivered by each system.

Co-funded by the European Union
Research Fund for Coal & Steel

Operating costs and economic assessment

In addition to investment costs, comprehensive operating expenditure (OPEX) analyses were performed. The assessment included both fixed operating costs, such as maintenance, inspections, personnel and technical supervision, and variable costs associated primarily with electricity consumption during charging and system operation.
Expected revenues were estimated using electricity price arbitrage based on Day-Ahead Market data for 2024. This enabled realistic estimation of annual operating income for both HESS configurations under representative market conditions.

Can HESS be economically viable today?

To answer this question, the HESS project team calculated the principal financial indicators used in investment appraisal, including:

- Net Present Value (NPV),
- Internal Rate of Return (IRR),
- Simple Payback Time (SPBT),
- Levelized Cost of Energy (LCOE).

The results clearly indicate that, under the adopted assumptions and current electricity market conditions, revenues generated solely through electricity price arbitrage are insufficient to ensure the financial viability of either HESS configuration.
Both analysed variants produced negative NPV values, while acceptable rates of return could not be achieved. These results demonstrate that electricity arbitrage alone cannot currently recover the investment and operating costs of large-scale hybrid energy storage systems.

What drives the cost of hybrid energy storage?

The LCOE analysis provided important insight into the cost structure of the proposed systems.
More than three quarters of the total levelized cost were found to originate from capital investment, making CAPEX by far the dominant contributor to the overall cost of electricity storage.
Operating and maintenance costs accounted for a considerably smaller share of the total cost, highlighting that reducing investment expenditure is the key challenge for future deployment of underground hybrid energy storage technologies.

The role of external financial support

Recognising the importance of capital investment, WP7 also included a sensitivity analysis examining the effect of non-repayable grant funding.
Two grant scenarios were analysed:

- 50% investment support,
- 80% investment support.

The results demonstrated that grant funding significantly reduces the calculated LCOE in both HESS configurations. Nevertheless, even under the most favourable funding scenario, the analysed systems did not achieve positive economic indicators under the assumed market conditions.
These results underline that future commercial deployment of HESS technologies will require not only investment support but also additional revenue streams, further technological optimisation and appropriate market mechanisms recognising the value of long-duration energy storage.

Co-funded by the European Union

Looking ahead

The techno-economic analyses carried out within WP7 represent one of the most comprehensive assessments performed within the HESS project. By combining detailed engineering design with investment and operational cost analyses, the project has established a robust framework for evaluating hybrid energy storage concepts based on post-mining infrastructure.
Although current economic conditions indicate that electricity arbitrage alone is insufficient to ensure commercial viability, the analyses clearly demonstrate the technical feasibility of the proposed HESS concepts and identify the key factors influencing their future competitiveness. The results provide valuable guidance for further optimisation of hybrid energy storage technologies and support future industrial implementation as Europe continues its transition towards a low-carbon and resilient energy system.

SWOT analysis – implementation potential of HESS

SWOT assessment confirmed that the main strengths of HESS concept include the reuse of existing post-mining infrastructure, technical feasibility of the proposed configurations, and their contribution to the energy transition and sustainable redevelopment of former mining areas. The analysis also identified key barriers, including high capital investment requirements, the current lack of dedicated regulatory frameworks and the dependence of economic performance on future electricity market conditions. Results of the Life Cycle Assessment showed that the environmental performance of HESS is determined primarily by electricity consumed during operation rather than by system construction, indicating that future decarbonisation of the electricity sector will further improve the environmental benefits of the technology. Overall, the SWOT analysis confirmed the strong long-term potential of HESS while identifying the key technical, economic and regulatory challenges that should be addressed before large-scale deployment.

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

Co-funded by the European Union