NEWSLETTER NO. 5

Fourth Progress Meeting in Zabrze

On 21 November 2025, the fourth Progress Meeting of the H2GEO project was held at the headquarters of the Institute of Energy and Fuel Processing Technology.

During the meeting, the project partners presented the current results of research work concerning the potential use of the separated carbonaceous and mineral fractions. Progress was presented in the gasification of the energy fraction in a fluidized-bed reactor, hydrogen separation from syngas using the PSA method, as well as the production of geopolymers intended for filtration membranes and the use of mineral fractions in the construction and agricultural industries.

Co-funded by the European Union

Research Fund for Coal & Steel

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One element of the meeting was a technical visit to the Clean Technologies Centre (CCT+), during which participants became acquainted with the research and technological infrastructure and the range of new development opportunities offered by the Institute.

Deliverable 4.2 - Set of parameters for H2 separation by PSA method

In Deliverable 4.2, validated operating parameters for hydrogen separation from post-mining waste gasification products using the PSA method were presented. The study confirmed the effectiveness of a layered adsorbent bed based on activated carbon and zeolite for treating representative syngas mixtures.

Breakthrough experiments identified carbon monoxide as the key impurity, enabling the development of two PSA cycle concepts ranging from basic to more advanced configurations. The obtained results provide a solid basis for process scale-up and confirm the capability of the PSA system to produce high-purity hydrogen, while generating a carbon-dioxide-rich off-gas stream with potential for further utilisation.

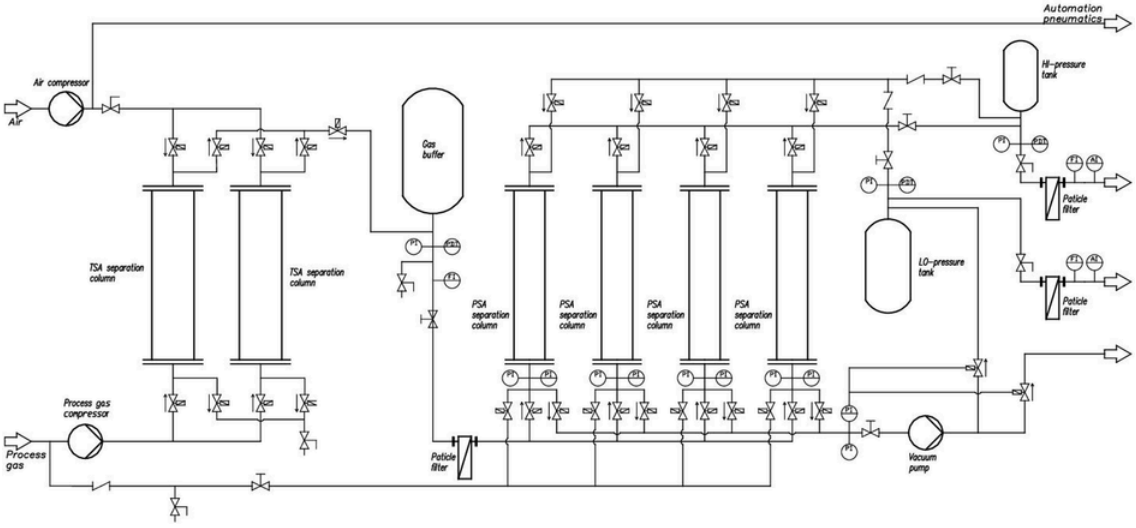

Fig. 1 PSA laboratory setup simplified flowchart

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Deliverable 4.3 - Development, evaluation and validation of the computational model against the operational data obtained during the CBF gasification tests

In Deliverable 4.3, the results of modelling the CBF gasification process using plasma and fluidised bed reactors were presented, with plant configurations optimised for effective heat recovery and electricity generation. Analysis of experimental data enabled the validation of the developed models, which showed good agreement with experimental observations.

Based on the validated models, an integrated hydrogen production process was developed, with fluidised bed gasification selected as the preferred technology due to its higher technology readiness level and suitability for industrial-scale applications. The modelling results indicate that the proposed system enables efficient hydrogen production, while simultaneously generating surplus electricity and recovering sulphur as a valuable by-product.

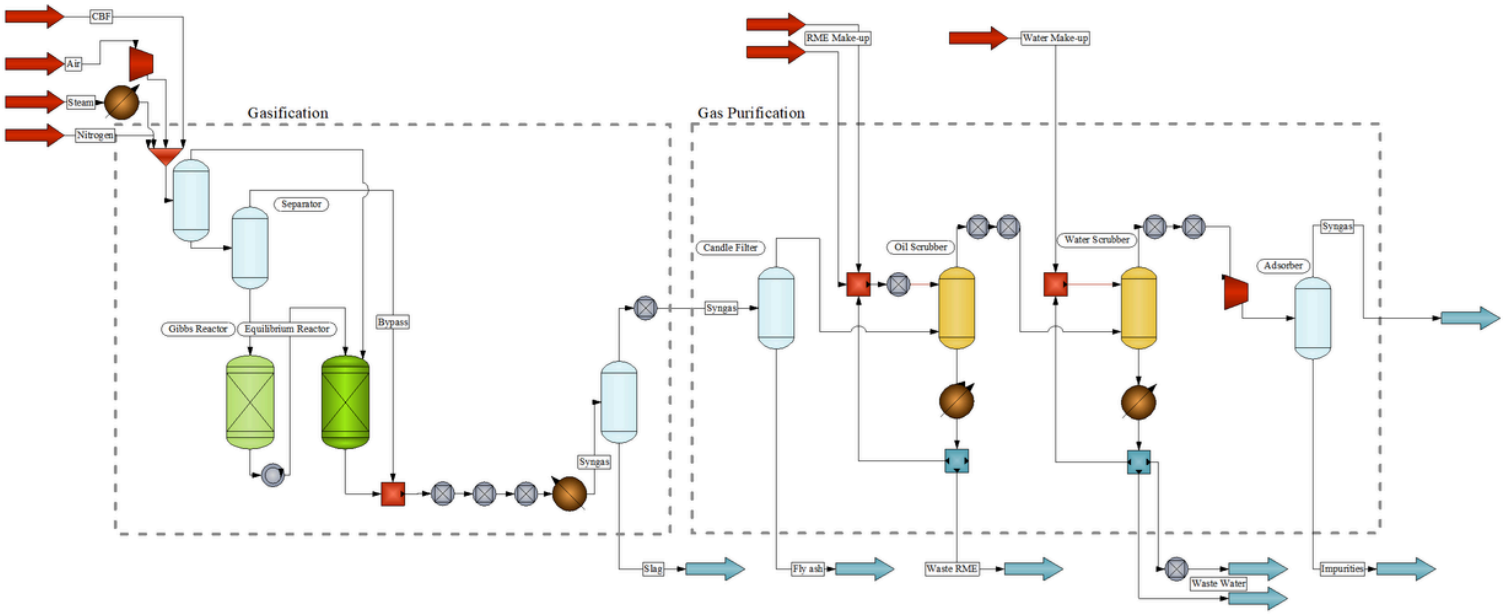

Fig. 2 Process model developed in CHEMCAD for plasma gasification

Deliverable 5.1 - Determination of mineral part properties in terms of thermal processing parameters

As part of Task 5.1, thermal treatment of the mineral fraction from mining waste was investigated using a BFB fluidised bed reactor to identify suitable conditions for geopolymer production.

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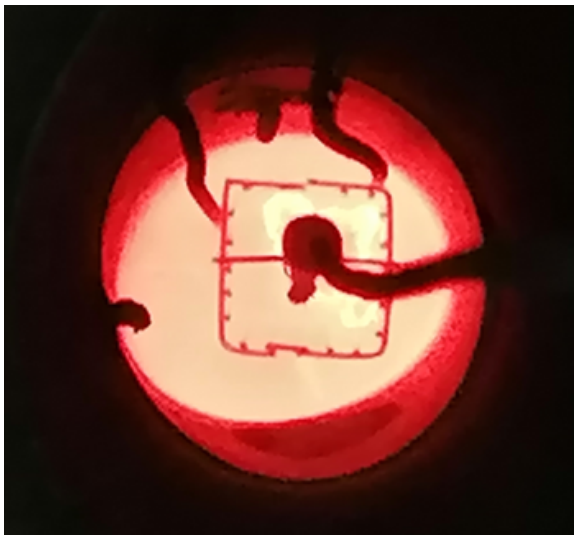

Fig. 3 Fluidization of heated mineral fraction in a BFB reactor

Calcination plays a key role in preparing the material by removing unstable phases and inducing atmosphere-dependent structural transformations, while improper conditions may reduce material reactivity.

The results do not clearly indicate the superiority of the analysed calcination conditions over other methods. Based on geopolymer performance, an atmosphere containing oxygen, carbon dioxide and air is recommended, pending further economic evaluation.

Deliverable 5.2 - Determination of geopolymers properties

The research focused on the development of geopolymer composites based on calcined mineral fractions recovered from mining waste, with particular emphasis on improving workability while preserving mechanical performance over time. The influence of selected chemical admixtures commonly used in cement and concrete technology—including superplasticizers, anti-sedimentation agents and defoaming agents—was investigated when applied individually and in various combinations. Comprehensive physicochemical, microstructural and mechanical analyses demonstrated how mixture composition affects pore structure evolution and strength development during both early curing and prolonged maturation, highlighting the importance of balanced admixture selection for achieving stable and durable geopolymer materials.

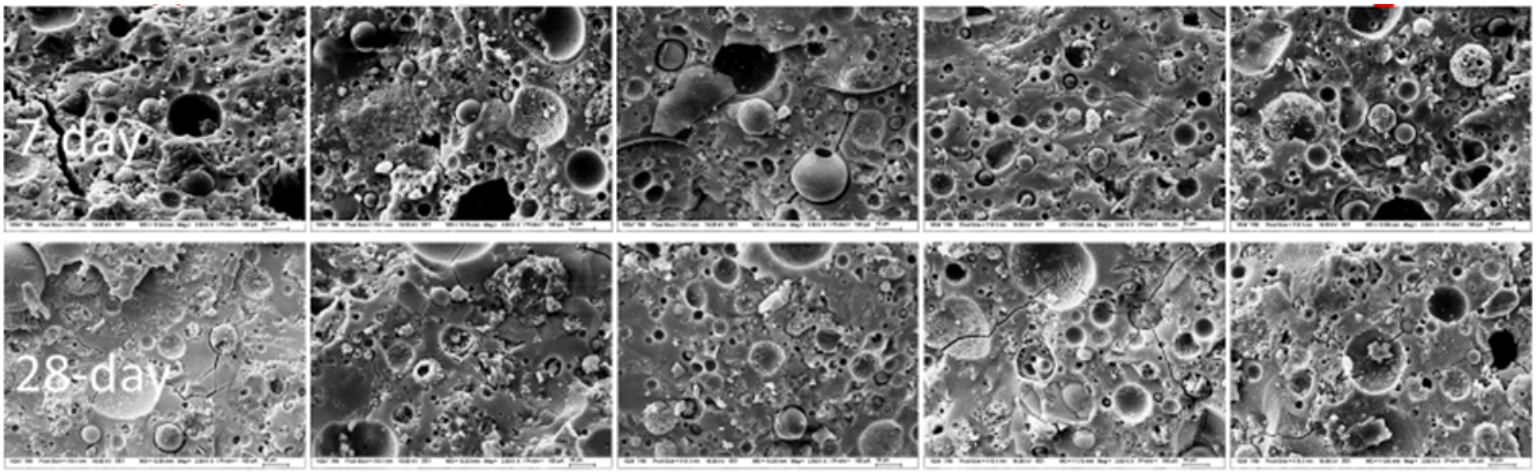

Fig. 4 Comparison of the microstructure of 7-day geopolymers (on the top) and 28-day geopolymers (on the bottom)

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Deliverable 5.3 - Development of methods of using mineral fractions in new building materials and in agriculture

As part of Task 5.3, a "Zero Waste" approach to the management of post-mining mineral waste was developed, involving fraction separation and processing into high value-added products using modern materials engineering techniques.

Fig. 5 Photos of the produced geopolymer granules based on fly ash and mining waste

The application of an alkali-activated fly ash geopolymer matrix enabled the production of durable granulates and structural composites, allowing full utilisation of the waste stream. The use of an intensive counter-current mixer made it possible to combine mixing and granulation in a single process step, reducing activator consumption and yielding dense, self-hardening granulate with high mechanical strength and effective heavy metal stabilisation.

Studies based on pot experiments and field cultivation on the Panewniki waste heap confirmed the potential of mineral waste fractions as functional components of reclamation substrates. Due to their mechanical stability and drainage properties, mineral materials effectively support the reclamation of post-mining areas when used in engineered soil mixtures.

Effective application requires combining mineral fractions with fertile soil and, where appropriate, mineral fertilisation, enabling successful vegetation establishment under challenging conditions. Mineral waste is best suited as a stabilising or transitional layer in reclamation systems, in line with circular economy principles.

Fig. 6 Pot experiment 40 days after sowing

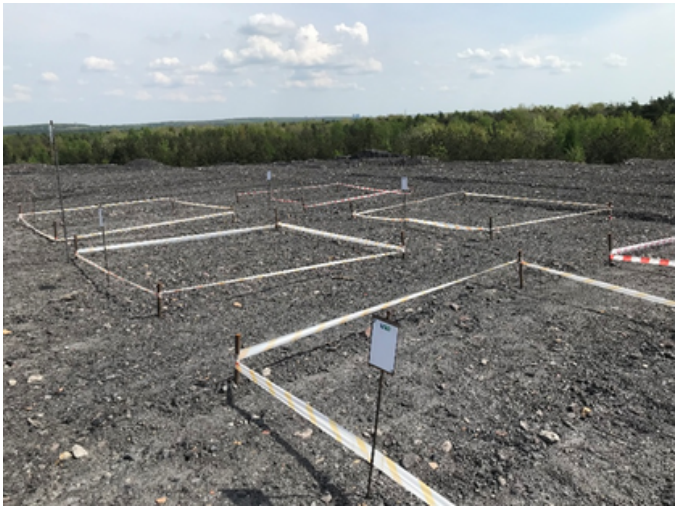

Fig. 7 Research plots on the elevated dump plateau with the Panewnicki Forest in the background

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A wet reclamation method combining water, compost and seeds was identified as an effective alternative to conventional dry techniques for post-mining waste heaps. By enabling uniform seed distribution and early vegetation development, the approach improves greening under difficult site conditions while reducing dust, limiting erosion and accelerating biological activation of degraded substrates.

Deliverable 5.4 - Development of the method for recovery of minerals and chemicals with initial evaluation of its profitability

The objective of this Deliverable was to assess the potential of post-mining waste derived from coal beneficiation processes as an unconventional source of rare earth elements (REEs) and other mineral raw materials. The studies demonstrated that the mobility and recoverability of REEs are strongly dependent on the mineralogical composition of the material and the applied processing route, with individual elements responding differently under identical technological conditions.

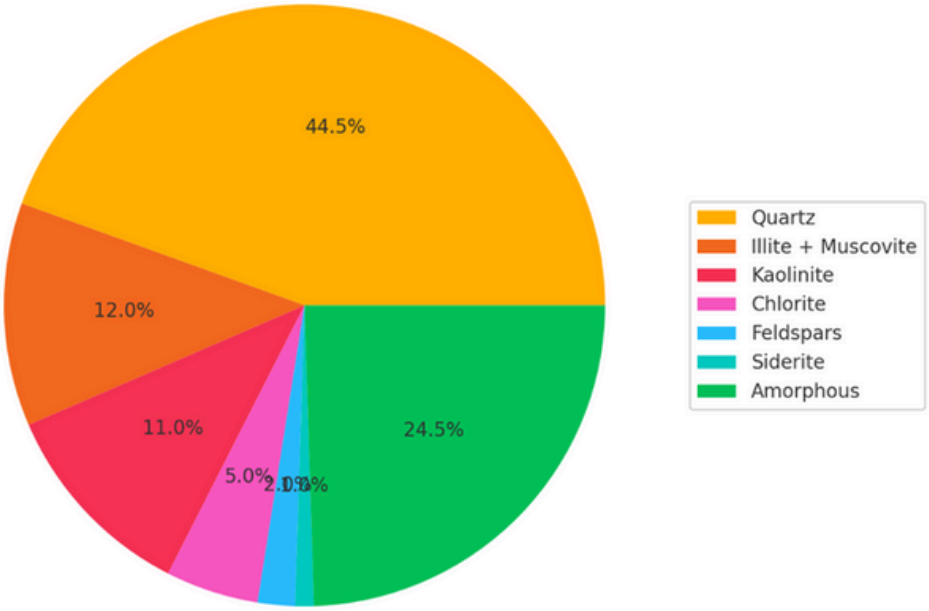

Fig. 8 Mineral Phase Composition of Sample

The application of hydrometallurgical methods confirmed the technical feasibility of REE recovery, but only when intensive processes are applied, which in their current form exhibit limited economic viability. In contrast, electrostatic and magnetic separation methods generally did not enable effective REE enrichment, indicating the absence of economically justified REE concentrations in the investigated materials.

At the same time, it was confirmed that the analysed waste can be utilised in the production of construction materials and as a source of critical metals, enabling its management in accordance with circular economy principles.

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Milestone 5 – First demonstration of continuous long-term gasification of the coal-containing fraction

A key milestone was achieved with the first demonstration of continuous long-term gasification of the coal-containing fraction. Within Task 4.2, an extended gasification test was conducted in a pilot-scale, non-pressurised gasification unit at the Clean Coal Technologies Centre in Zabrze. The study confirmed stable and repeatable process operation under continuous conditions, in line with the project objectives, validating the suitability of the coal-bearing fraction for long-term gasification and representing an important step towards further technology development and scale-up.

Milestone 6 – Compressive strength of geopolymer concrete

Another important milestone was achieved within Work Package 5 through the successful production and testing of geopolymer concrete based on a calcined mineral fraction obtained from waste rock beneficiation. The concrete was prepared using commonly applied mineral aggregates and a binder combining conventional cement with the calcined mineral fraction, activated using an alkaline solution. The obtained geopolymer concrete achieved compressive strength in accordance with the project assumptions, confirming the technical feasibility of incorporating processed mining waste into concrete materials and highlighting its potential for application in the construction sector.

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