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ANALYSIS OF THE POSSIBILITY OF USING CO₂ AS A WORKING FLUID IN UNCONVENTIONAL GEOTHERMAL SYSTEMS IN POLAND

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Abstract

Enhanced Geothermal Systems (EGS) are unconventional geothermal systems, unlike classical systems, where an energy carrier is underground water accumulated in a geothermal reservoir. They make it possible to utilise geothermal energy, when hydrogeothermal conditions of a given location (poor reservoir parameters of rocks or no connection to a supply zone) make it impossible to obtain a suitably high performance of boreholes. The article describes the possibility of utilisation of CO₂ as a working fluid in such unconventional geothermal system. In typical EGS water is the medium intermediate with energy exchange. Because of the superior thermodynamic properties of CO₂ and the need to reduce atmospheric carbon emissions, an EGS running on CO₂ instead of water as heat transmission fluid would be sufficiently attractive (Olasolo, 2018). In this case the CO₂ will be extracted from exhaust gases coming from a biomass-based power or heating plant. The exhaust gases will undergo a process of CO₂ purification and separation. Carbon dioxide after receiving energy from the rock matrix can be used as an energy carrier for its direct or indirect use. According to the nomenclature used in geothermal energy, direct use means obtaining energy for heating purposes, indirect use means transforming geothermal energy into electricity. In order to determine the effects of the systems, mathematical and numerical modelling of heat and mass transfer will be used.

This work describes the assessment of the possibility of cooperation within one installation of two renewable energy sources of biomass and geothermal energy. The cooperation of the source does not look like in a case of typical hybrid energy sources. Both work separately but one depends on the other. Biomass can be used as an energy carrier. The flue gas generated during the combustion of biomass is subjected to separation and treatment. Carbon dioxide is separated. The calcium looping CO₂ capture might be used (Gładysz et al. 2018). The remaining gases are discharged into the atmosphere in terms of composition in number it is mainly nitrogen, water vapor and oxygen. The recovered carbon dioxide is used in the geothermal system as a working fluid. The technology of obtaining heat from hot dry rocks is used here. Carbon dioxide seems to be an interesting working medium in these systems. It is characterized by low viscosity and chemical inertness towards the installation elements. The CO₂ losses will be covered on an ongoing basis with CO₂ recovered from the exhaust of the biomass installation. The proposed solution is touching with three important points, as it emphasizes the usage of renewable energy sources (by means of biomass and geothermal energy), the increase of energy utilization efficiency (by means of cogeneration of heat and electricity) and decarbonization (by means of CO₂ capture, utilization and permanent storage) of the energy sector. All of this leads to the possibility of obtaining a so called negative CO₂ emission and at the same time to increase the economic profitability as a result of the synergy between those three pillars. The proposed heat source configuration allows to meet the requirements for the district heating system to be qualified as 'efficient district heating and cooling' in accordance with the EU Directive 2012/27/EU (Gładysz et al. 2019b).

The selection of an optimum structure for the location of EGS systems utilising CO₂ as a working fluid covered the analysis of geological and hydrogeothermal conditions, suitable for the construction of both EGS systems, and possibilities of underground CO₂ storage (Sowizdzał et al. 2019). For this reason, since the basic geological condition decisive about a possibility of storing large CO₂ amounts underground is the occurrence of sedimentary rocks with large thickness, considerable spread, with good collection properties, having an insulation rock overburden, the area of Krośniewice-Kutno, located in the central part of the Polish Lowland, has been considered to be the most prospective zone for the location of an EGS system using CO₂



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as a medium. In this area the most prospective horizon for EGS location is clastic deposits of the Lower Triassic. The top of the reservoir of more than 1000 m thick, is behind at depths 5000-5500 m below sea level and the temperature within the reservoir is in the range 165-195°C. The porosity of reservoir rocks is approximately 2.5%, while the permeability is about 0, 1 mD (Sowizdżał et al. 2013, 2016a and 2016b).

Base on selected geological structure Krośniewice-Kutno the energy and environmental analyses were done. The combine heat and power (CHP) installation with thermal power 22.2 MW was assumed. It was assumed that biomass used as the energy carrier has the lower heating value (LHV) 9.5 MJ/kg. The steam generated by boilers has 53 bars and 480°C and it's directed to the turbine. The outlet steam before condenser has pressure 0.04 bar. The efficiency of CO₂ capture is assumed as 90% (purity 99.5%). The energy consumption of the CO₂ capture is assumed with reasonable value 3.36 MJ/kg_{CO2}. Captured CO₂ has temperature 35°C and it's compressed do the 130 bar and injected to the well for injection with flow rate 190 kg_{CO2}/s. About 5% of the injected flow of CO₂ is assumed to be sequestered (9.5 kg_{CO2}/s). Because of the high demand of energy in the CO₂ capture unit the average efficiency of the system might be expected as 24.82% net (Gładysz et al. 2019c), electrical efficiency net might be expected as ~14% (Gładysz et al. 2019c). The electrical efficiency of the sCO₂ unit was estimated based on (Gładysz et al. 2019a) in function of flow rate and wellhead pressure.

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