Geophysical Research Abstracts
Vol. 15, EGU2013-989-2, 2013
EGU General Assembly 2013

Underground coal gasification with integrated carbon dioxide mitigation supports Bulgaria's low carbon energy supply

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Underground coal gasification allows for the utilisation of coal reserves that are economically not exploitable due to complex geological boundary conditions. The present study investigates underground coal gasification as a potential economic approach for conversion of deep-seated coals into a high-calorific synthesis gas to support the Bulgarian energy system. Coupling of underground coal gasification providing synthesis gas to fuel a combined cycle gas turbine with carbon capture and storage is considered to provide substantial benefits in supporting the Bulgarian energy system with a competitive source of energy. In addition, underground voids originating from coal consumption increase the potential for geological storage of carbon dioxide resulting from the coupled process of energy production.

Cost-effectiveness, energy consumption and carbon dioxide emissions of this coupled process are investigated by application of a techno-economic model specifically developed for that purpose. Capital (CAPEX) and operational expenditure (OPEX) are derived from calculations using six dynamic sub-models describing the entire coupled process and aiming at determination of the levelised costs of electricity generation (COE). The techno-economic model is embedded into an energy system-modelling framework to determine the potential integration of the introduced low carbon energy production technology into the Bulgarian energy system and its competitiveness at the energy market.

For that purpose, boundary conditions resulting from geological settings as well as those determined by the Bulgarian energy system and its foreseeable future development have to be considered in the energy system-modelling framework. These tasks comprise integration of the present infrastructure of the Bulgarian energy production and transport system. Hereby, the knowledge on the existing power plant stock and its scheduled future development are of uttermost importance, since only phasing-out power plants can be economically substituted by low carbon based technologies. Furthermore, the integrated annual load management notably contributes to innovative process integration becoming economic in an energy system affected by low efficiency and flexibility.

Further limiting flexibility, the geographic location of this innovative low carbon energy production technology strictly depends on geological boundary conditions, namely the presence of exploitable coal resources, and availability of energy transport networks to supply potential end users with the product. Hereby, feeding upgraded synthesis gas directly into the Bulgarian gas pipeline network avoiding its conversion into electricity is an alternative approach with relevant economic potentials. For that purpose, the proximity and availability of these transport networks as well as the demand of end users are validated by the integrated energy system model.

Coupling our techno-economic process model to an energy system-modelling framework allows the determination of the future economical potentials and the limitations for the implementation of a low carbon energy production technology into the Bulgarian energy system.
The obtained results show that the Bulgarian energy system can significantly benefit from the integration of underground coal gasification considering carbon dioxide mitigation technologies potentially initiating a continuous substitution of imported fuels by domestic coal resources.