Investigation of the geological, technical and economical obstacles for large-scale utilization of geothermal energy from Danish sandstone reservoirs

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The Triassic–Jurassic sandstone reservoirs in the Danish subsurface at c. 1–3 km depth contain an enormous geothermal resource that is currently utilized in only three geothermal plants due to a number of geological, technical and commercial barriers. These barriers have been addressed in the GEOTHERM project funded by Innovation Fund Denmark and recommendations for overcoming the obstacles have been made. Some of the methods that are used in the oil and gas sector have successfully been introduced in the geothermal reservoir evaluations to reduce the risk associated with new exploration wells. Quantitative seismic interpretation proved capable of giving a reliable reservoir characterization with regards to estimation of porosity and sand/clay distribution. Diagenesis modelling gave good estimates of reservoir quality by utilizing the knowledge obtained about depositional environments, petrography, reservoir properties and burial history. Relationships between fluid and gas permeability have been established such that the regularly measured gas permeability can be recalculated to fluid permeability giving a better representation of the reservoir. The composition of the formation water in the three geothermal plants has been measured and used for geochemical modelling to evaluate the risk of scaling, where especially barite showed a tendency to precipitate upon cooling of the brine. Simulations of the thermal development of the reservoirs during long-term geothermal exploitation demonstrate significant heat extraction from the layers present above and below each reservoir, which ensures that only a small decrease in production temperature occurs over several decades. The regional geothermal resource estimation has been updated based on a new comprehensive 3D temperature model of the subsurface, confirming the presence of a huge geothermal resource with wide geographical extend covering most of the country. The causes of injection problems have been investigated including corrosion and scaling processes, showing that careful choice of well-lining and tubing materials besides cautious operation of plants are of utmost importance to prevent problems. A geothermal business case has been developed to give a lifetime assessment
of geothermal plants including feasibility, design, drilling, construction, production and abandonment, showing that the operational costs are closely linked to the existing infrastructure and to the choices made when designing the geothermal plant. In conclusion, the new scientific results and best-practice manuals provide a significantly higher chance of success of new geothermal projects when including the recommended measures to minimize the geological uncertainties and prevent problems during drilling and production.