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# Synergy benefits in combining CCS and geothermal energy production

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**Abstract**

When injecting $CO_2$ in to a subsoil aquifer for permanent $CO_2$ storage the pressure build up in the regional area encircling the site can extend far beyond the site delineation and mitigation procedures must be considered.
The pressure build up can be controlled by production of water from the aquifer. In that context the synergy effect by combining CCS with geothermal energy production (GE) is obvious; *i.e.* the injection site for CCS may be surrounded by several GE plants, where the GE plants are operated so the net production of water can balance the injected $CO_2$ from the CCS operation sufficiently. Furthermore, the $CO_2$ plume migration may be controlled by operating the different sites as pressure sinks and sources. The paper illustrates the concept for an area in the northern part of Denmark, where a potential CCS site is characterized together with four prospective locations for GE plants. The GE plants are located in a radius of up to 10 km from the CCS site but still outside the closure of the CCS site. The Eclipse 100 reservoir simulator is used for simulations.



*Keywords:* Geothermal energy production; geological $CO_2$ storage; regional model; pressure propagation

## 1. Introduction

In the oil and gas industry voidage replacement is a technique used to balance undesirable pressure reduction, when operating a hydrocarbon field; here a given volume of water is injected to replace the produced hydrocarbon volume. For a geological $CO_2$ storage operation (GCS) the technique can potentially be applied to avoid undesirable pressure increase; here a given volume of water can be produced to balance the injected $CO_2$ volume. A synergy benefit by combining a GCS operation with the

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operation of production of geothermal energy (GE) seems obvious. Simulation studies have shown that the pressure wave propagates much faster and wider than the $CO_2$ plume and affects subsurface volumes that exceeds the extend of the plume (Birkholzer *et al.* [1]).

The geological setting for the two technologies can to some degree be similar, *i.e.* porous and permeable sandstone layers in the subsoil constituting a reservoir or aquifer and in a depth range from approximate 1000 – 3000 m. In more shallow reservoirs the temperature will be insufficient together with the unfavourable thermodynamic state of the $CO_2$ phase. At greater depth the reservoir rock permeability will be limited. The hydraulic capacity and the extension of the reservoirs are critical parameters for the success of the two technologies. An additional demand for a GCS site is the existence of a structural closure of the reservoir combined with an overlying caprock or another type of trap configuration.

The benefits for the GE plants are predominantly in the early site characterization phase, were shared exploration and appraisal cost can reduce the investments for the individual GE development projects. Benefit for the GCS operation is both in the exploration phase and in the operation phase, where pressure propagation can be mitigated through the GE operations, and to some degree in the post injection phase where the GE wells can be used as monitoring wells.

The present study illustrates the concept for an area in the northern part of Denmark, where the Upper Triassic – Lower Jurassic Gassum Formation is the target aquifer. The Vedsted structure, a structural closure in the Gassum formation with an overlying caprock may be a potential storage complex for a GCS operation. Approximate 30 km east of the Vedsted site is located the Nordjyllandsværket power plant, where a possible $CO_2$ capture plant may deliver industrial scale $CO_2$ stream to the GCS site. It is further assessed that the Gassum Formation may be a suitable aquifer for geothermal energy production for the area, which comprises a number of minor villages with combined heat and power plants for district heating.

Relevant geological and geophysical data are analysed to characterise and delineate the reservoir formation. Geological models and reservoir simulation models are constructed and used to investigate a number of scenarios of combining GE and GCS. Simulations of different scenarios, *e.g*. number of $CO_2$ injection wells and injection strategy on the GCS site together with the number and restrictions of the participating GE plants, are presented. Both site specific and regional models are used in the study to capture the scale of the problem together with boundary condition issues when solving the problem. The Eclipse 100 reservoir simulator is used for reservoir simulations. It is per default an isotherm simulator and the optional temperature module is not used in the present work as it is the regional pressure development that is in focus.

Supplementary it is assessed that commercial deployment of a GE plant is more unproblematic and faster achievable than the development of an industrial scale GCS operation so any public perception issues could only benefit from the combination.

## 2. Model construction

### *2.1. Static model*

The regional geological model was constructed from a Top Gassum map (Britze et al., 1991 [2]) and the Vedsted-1 well, an old hydrocarbon exploration well. The regional model covers an area of 100 km x 100 km and is centred around the Vedsted-1 well. Different grid resolution is used; 100 x 100 x 40 and 132 x 124 x 40, where the second grid is refined in the inter-well area to resolve the $CO_2$ plume extension in more details. Lateral grid cell size varies between 1000 m x 1000 m and 200 m x 200m. A vertical grid size of 8 m is used. The structural closure covers an area of approximate 10 km x 16 km. The model is shown in Figure 1.