Progress in CO_2-based EGS

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The concept of Engineering Geothermal Systems (EGS) using CO_2 as a heat extraction fluid has been expanded since it was first proposed. A better theoretical understanding is available for the behaviour in the reservoir, process design, corrosion & condensation issues, and rock geochemistry, although knowledge of some of these systems is incomplete. Sufficient understanding is now available to provide a power plant design given site and reservoir parameters, and viability can be estimated. A number of challenges remain, however, and these must be addressed for the concept to be realisable. Those challenges are contextualised here to provide focus for the most urgent issues to be addressed.

Keywords: Carbon dioxide, CO_2, EGS, enhanced geothermal systems, thermosiphon, hot dry rock, hot wet rock

Introduction

CO_2-based EGS have been discussed previously (Brown 2000; Pruess 2006; Pruess and Azaroual 2006; Gurgenci et al. 2008; Pruess 2008; Atrens et al. 2009a; Atrens et al. 2009b; Atrens et al. 2010). A full discussion of the technical and economic issues related to CO_2-based EGS have been reported (Gurgenci 2009). Many of those issues are broadly applicable to all EGS; those will not be discussed here. There are a number of issues that are unique to CO_2-based EGS. These have primarily been lack of understanding of the process design, performance in the reservoir, CO_2-H_2O interactions, CO_2-H_2O-rock interactions, thermodynamic performance, etc. Some of these issues have been addressed in varying levels of detail.

Many technical challenges for the concept to overcome remain. These can be grouped under two broad categories: general challenges, which are overarching and apply to any use of CO_2 in EGS, and reservoir challenges, which are specific to the reservoir type.

General Challenges

There are a number of challenges that must be addressed to make CO_2-based EGS viable. Each of these is effectively show-stopping if the associated issues are unresolvable

The overarching challenges that must be addressed are:

- CO_2 Sourcing
- CO_2 turbomachinery
- Solubility and reactivity of rock compounds and elements in pure or near-pure CO_2
- Legal/regulatory issues with subsurface CO_2.

Reservoir Challenges

Beyond the overarching issues, there are a number of issues that depend on the type of reservoir being examined. The individual challenges for the different reservoir types are discussed below.

Un-dryable Reservoirs

This term is used to group reservoirs that are well hydraulically connected, and initially saturated or oversaturated with water. This grouping would include hot sedimentary aquifer systems (HSA), and EGS projects such as in the Cooper Basin where high pressure implies long-distance connectivity. These type of systems have an associated challenge of extreme difficulty in creating a dry CO_2-rich operating zone within the reservoir, either due to the large energy input necessary to displace water, or the difficulty in containing CO_2 within the desired region.

Dryable Reservoirs

Dryable reservoirs signify a reservoir grouping of those which are under-saturated with water at the outset, or have a limited initial volume of water that is easily displaceable. Examples of this category are the Fenton Hill reservoir, which was acknowledged as being unconnected and relatively lacking in water content, or the Hijori reservoir system, which experienced significant losses of injected fluid into the reservoir formation (implying an ease in displacing existing reservoir fluids). The challenges associated with systems of this type are the time period required to dry the reservoir, and the profile over time of fluid loss into the reservoir formation.

Wet Reservoir

This category is used for systems that are have a liquid water phase coexisting with CO_2-rich fluid near the reservoir operating zone. CO_2-rich fluid may be produced in this case, allowing a single-loop, but there are important issues of both water and carbon dioxide being present in the reservoir. The challenges associated with this type of system are related to the water-CO_2 relationships: time required until sufficiently pure CO_2 can be recovered, CO_2-H_2O dynamics in the reservoir (horizontally and vertically), rock-water-CO_2 interactions including mineral transformation / dissolution / deposition (permeability change) and geo-sequestration, and the thermodynamic effects of high water content in the CO_2-rich phase.

CO_2-Rich Reservoir

There is also the possibility of operating a CO_2-based EGS system in a reservoir that is already CO_2-rich. This could be a naturally occurring reservoir, or artificial as the result of artificial CO_2 injection for reasons other than CO_2-based geothermal power generation. The challenge associated with this reservoir type is identifying a reservoir that contains or may in the future contain CO_2, and is also suitable for geothermal power generation.

Discussion

There is a continuum between the three former reservoir types, and some of the challenges relating to CO_2-H_2O interactions overlap. Separating reservoirs into the categories discussed above clarifies the range of these interactions that are vital to consider for different situations. The implication of this is that there is an opportunity to target the proposed CO_2-based EGS technology towards situations where the challenges are more readily overcome. This may be useful where there are particular issues related to certain systems that may not be feasibly answered in the foreseeable future, or that may be most suitably be resolved by field trials in a reservoir of a different type.

It is recommended that current goals towards implementation of a CO_2-based EGS power system focus on reservoirs that can feasibly be dried, as these have a smaller number of associated challenges. Reservoirs of this type are also less likely to be targeted for use for water-based EGS, so there is less risk of competitively disadvantaging one technology over another.

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