GDR DATA PLAN SUBMITTAL

For

Thomas A. Buscheck
Lawrence Livermore National Laboratory
Active Management of Integrated Geothermal-CO_2 Storage Reservoirs in Sedimentary Formations: Phase 2

SOPO TASKS TO BE PERFORMED AND CORRESPONDING DATA GENERATION:

Task 1.0 – Reservoir Analyses

Task Milestones or Products: Phase 2 focuses on multi-fluid (CO_2 and brine) geothermal energy production and diurnal bulk energy storage within sedimentary formations that are suitable for geologic CO_2 storage. With regards to data generation, Task 1.0 is comprised of two subtasks: one for power generation and one for bulk energy storage analyses. All reservoir analyses are conducted at the reservoir scale, rather than the individual well scale. These analyses use a radially-symmetric axisymmetric model that represents four concentric rings of wells: (1) inner (first) ring of production wells that initially produce brine before producing CO_2 after CO_2 injected in the second well ring arrives at the inner ring, (2) second well ring where CO_2 is injected, (3) third well ring where produced brine is injected, and (4) outer (fourth) well ring where brine is produced. The reservoir-scale analyses can pertain to either horizontal or vertical wells, but do not directly determine individual well rates. Based on assumed well production rates, the required number of production wells is determined and then applied in the Task 2.0 Techno-Economic Analyses, using the DOE GETEM tool. Based on an assumed ratio of injection to production wells, the required number of injection wells is also determined and applied in Task 2.0. For Phase 2, a pressure-management strategy is developed and applied where a portion of the produced brine is diverted for consumptive beneficial use once a target value of overpressure is attained at the ring of brine injection wells. This pressure-management strategy is exercised to demonstrate how integrated geothermal-GCS can be operated to limit overpressure to reduce environmental risks, which is applied to Task 3.0, Environmental Risk Assessment. The results of all of the generated data are presented in Buscheck et al (2016) and are summarized in the Phase 2 Final Report.

Nature of Generated Data: Input and output files from reservoir simulation runs using the NUFT code. The NUFT reservoir models generate histories of brine and CO_2 flow rate, brine and CO_2 enthalpy rate, temperature, and pressure for each of the well rings that are post-processed and assembled in spreadsheets of CO_2 and brine flow and energy production that are described below.

Data Format: ASCII text files of input and outputs of NUFT reservoir analyses, and Excel-readable spreadsheets of energy production and flow rates. Because of the file lengths, the reservoir-model input and output files are saved as **.tar* files, with the name corresponding to the reservoir-scenario directory name.

Data Sharing: There are no restrictions on the data.

Comments: All submitted data is found in major directory Reservoir-Analyses-Data and organized in directories (e.g., CO2-64-3km-120-120kg-125m-65C-25C-30y-smart4-10MPa), corresponding to each of the reservoir scenarios in Buscheck et al (2016). Each directory pertains to a specific reservoir depth and temperature, a net CO_2 storage rate, and a brine injection-well target overpressure. Each reservoir-scenario directory contains all NUFT input and output files and two subdirectories: (1) history-files: containing post-processed NUFT output files that are input to the *histInterpolate3.py* script found in the post-processing directory and (2) post-processing: containing flow and energy summary spreadsheets, with the *.*csv* files being readable by Excel. All spreadsheets were generated using the *histInterpolate3.py* script, which requires the directory structure of the major post-processing directory. The *.*rate* spreadsheets contain histories of (1) brine production rate, (2) CO_2 production rate, (3) net CO_2 storage rate, (4) gross brine power, (5) gross CO_2 power, (6) gross total power, (7) brine pumping parasitic power, (8) CO_2 pumping parasitic power, (9) total pumping parasitic power, (10) total net power, (11) inner production ring temperature, (12) outer production ring temperature, (13) CO_2 injection-ring overpressure, and (14) brine injection-ring overpressure. The *.*cum* spreadsheets contain histories of (1) cumulative brine production, (2) cumulative CO_2 production, (3) cumulative net CO_2 storage, (4) cumulative gross brine energy, (5) cumulative gross CO_2 energy, (6) cumulative gross total energy (7) cumulative CO_2 pumping parasitic energy, (8) cumulative brine pumping parasitic energy, (9) cumulative total parasitic energy, (10) cumulative net energy, and (11) ratio of cumulative parasitic energy to total energy.

Any users intending to use the NUFT input files submitted to the GDR will need to obtain a licensed copy of the NUFT code executable from LLNL.

Task 2.0 – Techno-Economic Analyses of Levelized Cost of Electricity (LCOE)

Task Milestones or Products: GETEM (Geothermal Electricity Technology Evaluation Model) is a tool developed for the U.S. Department of Energy that evaluates different geothermal production scenarios. The techno-economic analyses were conducted with an advanced copy (April 2015 Beta version) of the newest release of GETEM (DOE, 2015). This advanced copy of GETEM incorporates updated information about economic factors, such as well drilling costs; it also has many unlocked user options that were locked in the preceding version of GETEM (DOE, 2012). The unlocked options were used to modify several assumptions, such as well drilling rates in sedimentary rock. Well costs assume vertical wells and that the ratio of injection wells to production wells is 0.75. The assumptions used to apply GETEM are described in Buscheck et al (2016).

Nature of Generated Data: All of the data is contained in GETEM *.*xlsm* Excel files, which include all inputs and outputs.

Data Format: All data is provided in GETEM Excel *.*xlsm* spreadsheets.

Data Sharing: There are no restrictions on the data.

Comments: All submitted data is found in major directory GETEM-Data, and organized into directories for the three respective reservoir depths, broken down to green-field cases, which includes all well development costs, and brown-field cases, which assume that all injection and production wells are already in place from a previous reservoir operation. The *.*xlsm* filenames denote the reservoir depth, CO_2 net storage rate and brine injection-well target overpressure.

Task 3.0 – Environmental Risk Assessment

Task Milestones or Products: Overpressure at the brine-injection wells is assumed to be a suitable metric for the potential for induced seismicity. Instead of conducting Coulomb-stability analyses to determine critical pore pressure for triggering slip on well-oriented faults at a specific site, we developed a pressure-management approach for keeping the maximum overpressure, which occurs at the brine injection wells, below a target overpressure (Buscheck et al., 2016). When CO_2 is the supplemental fluid, it will likely come from a fossil-energy plant where it has been captured. If this involves a long-term commitment to receive the CO_2 at a pre-determined rate, there will be limited flexibility in varying the CO_2 injection rate to remain below a target overpressure. Rather than vary the CO_2 injection rate, we divert a small portion (< 5% for a net CO_2 storage rate of 120 kg/sec) of produced brine for beneficial consumptive use, such as fresh water generated by reverse osmosis or flash distillation, or power-plant cooling (Buscheck et al., 2016). As a CO_2-geothermal reservoir operation approaches the end of its economic life, the option would exist to increase the brine net-removal rate to reduce overpressure, possibly to zero by the time of site closure. In this way, CO_2 storage permanence would be further assured, and it would also be possible to reduce the required duration of post-closure monitoring at the site.

Nature of Generated Data: See Task 1.0.

Data Format: ASCII text files of input and outputs, and Excel spreadsheets.

Data Sharing: There are no restrictions on the data.

Comments: The reservoir analyses in Buscheck et al (2016) address Task 1.0.

References

Buscheck, T.A., Bielicki, J.M., Edmunds, T.A., Hao, Y., Sun, Y., Randolph, J.B., and Saar, O.M., 2016. Multi-fluid geo-energy systems: Using Geologic CO_2 storage for geothermal energy production and grid-scale energy storage in sedimentary basins. *Geosphere*, in review.

DOE, 2012, GETEM–Geothermal electricity technology evaluation model, August 2012 Beta, USDOE Geothermal Technologies Program.

DOE, 2015, GETEM–Geothermal electricity technology evaluation model, April 2015 Beta, USDOE Geothermal Technologies Program.