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# Quarterly Research Performance Progress Report

(Period Ending 06/30/2019)

## Coupled Hydrologic, Thermodynamic, and Geomechanical Processes of Natural Gas Hydrate Production

Project Period (10/01/2018 to open)

Submitted by:

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Signature

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U.S. DEPARTMENT OF  
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**NATIONAL ENERGY  
TECHNOLOGY LABORATORY**

Office of Fossil Energy

# RESEARCH PERFORMANCE PROGRESS REPORT

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## ACCOMPLISHMENTS:

### BP1-Task 1.0 Project Management

This project is a companion project to one funded by the Korea Institute for Geoscience and Mineral Resources (KIGAM) under the Joint Korea and U.S. Gas Hydrate Research Program. The KIGAM project is currently investigating nitrogen and air injection as a production technology for suboceanic deposits of gas hydrates, such as those found in the Ulleung Basin of the Korean East Sea. During this quarter the work on the KIGAM project has been focused on developing a mathematical model to compute the equilibria of compositional hydrates, in particular  $\text{CO}_2\text{-N}_2\text{-CH}_4$  and  $\text{O}_2\text{-N}_2\text{-CH}_4$  mixtures. This work supports the numerical investigations of using gas injections to produce natural gas from the UBGH2-6 Site. Dr. Won Suk Lee is scheduled to visit PNNL during the first week of August to discuss progress on this project.

### BP1-Task 2.0 IGHCCS

This quarter saw the conclusion of the submissions by the study participants against the five benchmark problems and the start of manuscript writing for a journal publication. The writing assignments for the manuscript have generally been tasked to the principal investigators, principal USGS advisors, and the problem champions, as shown by the manuscript outline:

- Abstract (White, Kneafsey, Seol)
- Introduction (Waite)
- Participants and Computer Codes (White)
- Benchmark Problem 1 (White)
  - IGHCCS1
  - Problem Description
  - Simulation Results and Comparisons
  - Problem Outcomes
- Benchmark Problem 2 (Gupta)
  - Problem Description
  - Simulation Results and Comparisons
  - Problem Outcomes
- Benchmark Problem 3 (Reagan, Queiruga)

- Problem Description
- Simulation Results and Comparisons
- Problem Outcomes
- Benchmark Problem 4 (Kimoto, Yonkofski)
  - Problem Description
  - Simulation Results and Comparisons
  - Problem Outcomes
- Benchmark Problem 5 (Uchida, Gai, Lin, Myshakin, Seol)
  - Problem Description
  - Simulation Results and Comparisons
  - Problem Outcomes
- Outcomes for Participants (White, Kneafsey, Seol, Waite)
- Conclusions (White, Kneafsey, Seol)

Currently drafts have been written for the Introduction, Participants and Computer Codes, Benchmark Problem 1, Benchmark Problem 2, and Benchmark Problem 3. The teleconferences are now being used to collectively review the draft writeups. A table from the Participants and Computer Codes section of the manuscript is shown below and documents the submissions of the various participating institutions and teams against the benchmark problems.

*Table 1. Participating institutes, institute teaming, submissions against the benchmark problems and computer codes.*

<b>Abbreviation</b>	<b>Institute</b>	<b>Teaming</b>	<b>Problem Submissions</b>	<b>Computer Code(s)</b>
<b>AIST</b>	National Institute of Advanced Industrial Science and Technology	AIST		
<b>Cambridge</b>	University of Cambridge	Cambridge + JOGMEC + UCB		Berkeley-Cambridge THM model – COMSOL FEM Code
<b>CSM</b>	Colorado School of Mines	CSM		
<b>GEOMAR</b>	GEOMAR Helmholtz Centre for Ocean Research Kiel	GEOMAR	1, 2,	TCHM Code for Methane Hydrate Systems
<b>GT</b>	Georgia Institute of Technology	GT + Ulsan		
<b>JLU</b>	Jilin University	JLU	1, 2, 3	HydrateBiot
<b>JOGMEC</b>	Japan Oil, Gas and Metals National Corporation	Cambridge + JOGMEC + UCB		
<b>KAIST</b>	Korea Advanced Institute of Science and Technology	KAIST		K-Hydrate with FLAC2D/FLAC3D
<b>KIGAM</b>	Korea Institute of Geoscience and Mineral Resources	KIGAM		
<b>Kyoto</b>	Kyoto University	Kyoto	4	COMVI-MH
<b>LBNL</b>	Lawrence Berkeley National Laboratory	LBNL	1, 2, 3	T+H with STONE
<b>LLNL</b>	Lawrence Livermore National Laboratory	LLNL + Tongji	1, 2, 3, 4, 5	GEOS
<b>NETL</b>	National Energy Technology Laboratory	NETL + Pitt + RPI	1, 2, 3, 4, 5	MIX3HRS-GM

Abbreviation	Institute	Teaming	Problem Submissions	Computer Code(s)
<b>OSU</b>	Oregon State University	OSU		
<b>Pitt</b>	University of Pittsburgh	NETL + Pitt + RPI	1, 2, 3, 4, 5	MIX3HRS-GM
<b>PNNL</b>	Pacific Northwest National Laboratory	PNNL	1, 2, 3, 5	STOMP-HYDT-KE with GeoMech
<b>RPI</b>	Rensselaer Polytechnic Institute	NETL + Pitt + RPI	1, 2, 3, 4, 5	MIX3HRS-GM
<b>SNL</b>	Sandia National Laboratories	SNL	1	PFLOTTRAN
<b>Southampton</b>	National Oceanography Centre Southampton, University of Southampton	Southampton		Hydrate-CASM
<b>TAMU</b>	Texas A&M University	TAMU		CODE_BRIGHT-HYDRATE and T+M(AM)
<b>Tongji</b>	Tongji University	LLNL + Tongji	1, 2, 3, 4, 5	GEOS
<b>UCB</b>	University of California, Berkeley	Cambridge + JOGMEC + UCB	1, 2, 3, 4, 5	Berkeley-Cambridge THM model – COMSOL FEM Code
<b>Ulsan</b>	University of Ulsan	GT + Ulsan	1, 2, 3, 4, 5	Geo-COUS
<b>USGS</b>	United States Geological Survey	USGS		
<b>UT</b>	The University of Tokyo	UT		
<b>UTA</b>	University of Texas at Austin	UTA	1	UT_HYD

The number of study members joining the teleconference has held steady, and the number of participants speaking up has increased with each teleconference. All teleconferences were recorded, and those recordings were posted on the NETL EDX system, along with the slide decks from the presentations. The frequency of the study teleconferences was lessened this quarter, such that there were four held during the quarter:

#### Teleconference #28: April 18, 2019

- Problem Solution Submissions
- Benchmark Problem 1
  - GEOMAR (GEOMAR)
- Benchmark Problem 2
  - Lawrence Berkeley National Laboratory (LBNL)
  - National Energy Technology Laboratory (NETL)
- Status Report on Submissions
- Target Journals
- Draft Outline and Writing Assignments

#### Teleconference #29: May 9, 2019

- Problem Solution Submissions
  - Benchmark Problem 1
    - University of Ulsan (Ulsan)
  - Benchmark Problem 2
    - University of Ulsan (Ulsan)

- Benchmark Problem 4
  - University of Ulsan (Ulsan)
- Benchmark Problem 5
  - University of California Berkeley (UCB)
  - University of Ulsan (Ulsan)
- Publishing, Solution Submissions, and Authorship
- Draft Outline and Writing Assignments
- Building Power Outage at 5 pm (PDT)

Teleconference #30: May 30, 2019

- Status Report on Submissions
- Writing Assignments
- Benchmark Problem 2 (Shubhangi Gupta, GEOMAR)
- Introduction (Bill Waite, USGS)
- Benchmark Problem 1 (Mark White, PNNL)
- Benchmark Problem 4 (Sayuri Kimoto, University of Kyoto)

Teleconference #31: May 9, 2019

- Review of Benchmark Problem 1 (Mark White, PNNL)
- Review of Depressurization Simulations (Maria De La Fuente Ruiz, University of Southampton)

**BP1-Task 3.0 STOMP-HYDT-KE Parallelization**

No accomplishments to report for this task during this quarter.

**MILESTONES:**

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
Nitrogen Injection (KIGAM-funded, Separate, Coordinated PNNL Project #68908)	Conduct a series of numerical simulations using its STOMP-HYDT-KE simulator to assess the feasibility of the nitrogen injection technology for production natural gas.	6/30/2018	Partially completed	Simulations with STOMP-HYDT-KE against a series of nitrogen injection experiments. Dr. Won Suk Lee visiting PNNL during April to discuss next steps. Progress report submitted on 11/30/2018.
IGHCCS2: Benchmark Problems	Complete the submission and reviews of the five benchmark problems.	12/31/2018	Partially completed	Solution submissions continued to arrive from participants, and reviews are being conducted during the teleconferences. New close date anticipated for end of April 2019.
IGHCCS2: Challenge Problems	Develop and issue two challenge problems.	6/30/2019	Not started	Discussions have occurred about what a challenge problem involves.

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
IGHCCS2: Journal Paper	Draft a journal paper on the four benchmark problems.	6/30/2019	Not started	Paper will be started with the completion of the benchmark problem submissions and reviews.
Parallelization: OpenMP	Demonstrate the execution of STOMP-HYDT-KE on eight cores with an OpenMP linear system solver.	12/31/2018	Not started	Not started.
Parallelization: GA	Develop a set of Global Array equivalent subroutines in MPI.	06/31/2019	Not started	Not started.

**PRODUCTS:**

No products to report this quarter.

**IMPACT:**

No significant impacts occurred this quarter.

**CHANGES/PROBLEMS:**

No significant changes or problems, other than the pace of the code comparison study is slower than anticipated. The slower pace is principally due to competing project work for the study participants.

**SPECIAL REPORTING REQUIREMENTS:**

No special reporting requirements occurred during this quarter.

**BUDGETARY INFORMATION:**

Actual Cost (this quarter)	Actual Cost (cumulative for BP)	Funds available (for the BP)	Balance of unspent funds (for the BP)	Actual Cost (cumulative for the full FWP)	Funds available (for the full FWP)	Balance of unspent funds (for the full FWP)
\$21,718	\$83,109	\$151,151	\$68,402	\$83,109	\$151,151	\$68,402

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