

GeoEE/EGEE 580 - Design Engineering of Energy & Geo-Environmental Systems
F Sc 503 - Problems in Fuel Science

Offshore Methane Hydrates: Their Optimal Recovery and Utilization

Facilitators: D. Elsworth, L. Ayala, S. Eser, P. Flemings

Location: 104 Hosler, 8.00 – 8.50, MTWTF

Credits: 5

Rationale: This **problem-based** class will allow students to connect basic concepts and principles assimilated during prior classes to solve an industrial problem of societal significance. Students will work **collaboratively** as a team to finely prescribe the problem, to gather resources, and to synthesize a solution.

Objective: The principal objective of this problem-based course is to facilitate active and cooperative, or collaborative, learning to solve a contemporary problem in energy and/or the environment. This will be completed via literature search, critical literature review, **concept mapping**, road mapping, and written and oral presentations of results. The development of critical thinking and problem solving skills as a team in academic and industrial settings is the major focus of the course.

Focus: **Offshore Methane Hydrates: Their Optimal Recovery and Utilization**

Methane hydrates are the largest terrestrial fossil fuel resource, and are plentiful in the United States, but remain unutilized.

Students will develop a framework to optimally recover and utilize offshore gas hydrates as an energy source. **Hydrate Ridge**, offshore ~100 km from the Oregon coast, is selected as a prototypical site, for which a wealth of data are available.

Task: Student participants will appreciate the global concerns of CO₂ concentrations in the atmosphere in general, the role of the recovery and utilization of fossil fuels in contributing to these concentrations in particular. In their development of a solution for optimal recovery and utilization of gas hydrates, optimality may be referenced to direct costs, to externalized and deferred costs, or to some other basis.

Participants will understand the chemistry and physics of hydrate formation, their occurrence, stability and global abundance. They will understand methods of locating and characterizing the deposits to determine both the extent of the reserve and resource base, and their salient physical characteristics. They will identify the key societal and technical issues in the safe recovery and utilization of the hydrate resource, compare these options, and evaluate their feasibility in delivering an optimal energy supply. Complete solutions must include a synthesis of methods to identify, recover, transport, and utilize the

methane hydrates. A quantitative approach, including mechanistic, thermodynamic, and kinetic analysis of proposed options must be considered, together with a preliminary economic analysis.

Background: Methane hydrates are ice-like compounds that occur both in polar regions and worldwide in sea-floor sediments on continental margins. The total resource likely exceeds 10^{19} g of methane carbon¹ and is more than twice the total recoverable fossil fuel reserve. As such, hydrates represent a massive, but largely untapped, fossil energy source. Hydrates are a particularly attractive high energy-density resource because they are both widely (geographically) distributed, but remain present at shallow depths, within less than 2000 m of the Earth's surface. Despite their abundance, hydrates remain an underutilized resource, largely due to the high-cost of production. The sudden breaching of carbon-rich hydrate reservoirs has been implicated as a mechanism in past- and future-climate change, and risks associated with production-triggered seafloor instability potentially threaten shoreline communities through the impact of collapse-generated tsunami.

Involvement: Students will collaborate in a team and take charge of the learning process as they attempt to solve the assigned problems. Importantly, they should identify and fully utilize the diverse knowledge within the group – this will identify the key knowledge bases and learning needs required for the re-formulation and solution of a given problem. Students may use concept mapping to formulate the learning issues and map out the relationships between different concepts and principles to solve the assigned problems. Road mapping will be used to develop a strategy and a time line for problem solution. Students will make a critical review of the relevant literature to assess/reassess the proposed concept and road maps. The results of the literature review and experimental or computational work will be conveyed in written reports and oral presentations throughout the semester.

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¹ Kvenvolden, K.A., 1993, Gas Hydrates – Geological perspective and global change. *Reviews of Geophysics*, 31, 173-187.

Course Schedule and Assignments

Date/Week	Topic
Week 1 (beg)	Introduction of the problem and discussion of course procedures and logistics for problem-based learning.
1 (end)	Presentation and discussion of individual and team concept maps (or any other format used) for defining the learning issues; student responses to assigned reading materials.
2 (mid)	Student presentation and discussion of learning issues for solving the problem.
3 (end)	Student presentation and discussion of individual and team road maps for solving the problem
5	Presentation of a critical literature review and reassessment of the proposed road map for solving the problem; finalize the team road maps .
6	Presentation of progress
7	Presentation of progress
8	Submission of the literature survey and submission and presentation of progress report and a comprehensive plan for future work
9	Feedback from faculty facilitators
10	Revision and modification of critical literature review . Presentation of critical-path plan for recovery-through-utilization and identification of final work-plan activities
11	Presentation of progress
12	Presentation of progress
13	Presentation of progress
15	Presentation of progress and submission of final report
15	Final Oral Examination

Grading

Your course grade will depend on three components:

30%	Team work
50%	Individual presentations and final exam
<u>20%</u>	Peer evaluation
100%	

The factors contributing to grades in these assigned distributions include:

1. **Team work (30%).** This grade will be determined from an assessment of *critical and creative thinking, problem solving skills, and clarity and integrity* of reports and presentations.
 - a. 15% Concept Map (or identification of learning issues).
 - b. 15% Road Map.
 - c. 20% Literature Review.
 - d. 15% Progress Reports.
 - e. 10% Oral Presentation.
 - f. 25% Final Report.
2. **Individual presentations and final exam (50%).** This grade will be determined from individual presentations throughout the semester and a final oral exam on the whole problem at the end of the semester. The following factors will be considered as equally important in assigning the grades for individual work.
 - a. Understanding of the problem and the related background issues,
 - b. Critical and creative thinking,
 - c. Problem solving skills and cooperation with other team members, and
 - d. Clarity and integrity of presentations (progress and final).

For the final oral exam, each student will give a 25-minute presentation of the final report and be questioned on the important learning issues for the whole problem.

3. **Peer evaluation (20%).** This grade will be determined from confidential assessments (grades) from your team members. Each student will assign an individual **confidential grade** to each of her/his team members to evaluate their contribution to the learning issues, including **leadership, resourcefulness, creativity, and peer teaching** effort. The criteria for the grade for peer evaluation will be discussed in the first class meeting. The overall peer evaluation grade for each student will be calculated as the mean of the assigned grades after discarding the top and bottom grades.

Some Initiating (PSU) Resources

1. *Ocean Drilling Program Data Repositories.*
 - a. [Hydrate Ridge \(Oregon\)](#).
 - b. [Blake Ridge \(North Carolina\)](#).
2. *General*
 - a. Holder, G.D., and Bishnoi, P.R. (2000) Gas Hydrates: Challenges for the Future. Proc. Third Int. Conf. on Gas Hydrates, Salt Lake City, USA. July. Annals of the New York Academy of Sciences ; Vol. 912, 1044 pp.
3. *Legislative*

- a. Boatman, M. C. and Peterson, J. (2000) Oceanic Gas Hydrate Research and Activities Review. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region. Gov. Doc. No.: I 72.12/3:2000-017. 68 pp.
- b. United States Congress. (1999) S. 1418, The Methane Hydrate Research and Development Act of 1998. Hearing before the Subcommittee on Energy and Environment of the Committee on Science, U.S. House of Representatives, One Hundred Fifth Congress, Second session, September 15, 1998. U.S. Govt. Print. Off. 257 p.

4. *Geological*

- a. Henriot, J.-P. and Mienert, J. (1998) Gas Hydrates: Relevance to World Margin Stability and Climate Change. Geological Society special publication No. 137. 338 p.
- b. Max, M.D. (2000) Natural Gas Hydrate: in Oceanic and Permafrost Environments. Kluwer Academic Publishers, Dordrecht and Boston. 414 pp.
- c. Paull, C.K. and Dillon, W.P. (2001) Natural Gas Hydrates: Occurrence, Distribution, and Detection. Monograph. Amer. Geophys. Union. 315 pp.

5. *Engineering*

- a. Carroll, J. J. (2003) Natural Gas Hydrates: a Guide for Engineers. Gulf Professional Publishers. Amsterdam. 270 pp.
- b. Sloan, E. D. (1998) Clathrate Hydrates of Natural Gases. 2nd ed., Marcel Dekker, New York, 705 pp.
- c. Sloan, E. D. (2000) Hydrate Engineering. Soc. Petroleum Engrns. Monograph, Vol. 21. 81 pp.

6. *Energy and Fuels*

- a. Makogon, Y. F. (1997) Hydrates of Hydrocarbons. Penn Well Publishing Co. Tulsa, Oklahoma. 482 pp.

Academic Conduct: Penn State's policy on academic integrity applies to all aspects of course deliverables. Students must work collaboratively in groups, and are expected to expend similar effort. Further details are available at:

<http://www.ems.psu.edu/students/integrity/index.html>