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NRGY 246.50: Introduction to Geothermal Energy Technology

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NRGY 246.50-74457-AU13-Bowe. Introduction to Geothermal Energy Systems

| | |
|---|---|
| Instructor: Jonathan Bowe Phone: 243-7922 | Class Dates & Location: All lectures will be available online via Moodle. |
| Email: jonathan.bowe@umontana.edu Office Hours: Tue 12:00 – 1:00p.m. in Griz House 08,F. Tech Support: UOnline: 406.243.4999; courseware-support@umontana.edu ; http://www.umt.edu/xls/contact.aspx | Lectures will be recorded live Tues. 9:10 to 11:00 p.m. in HB06 (http://courseware.umt.edu). |

Readiness for Online Learning This is not a suitable course for your first UOnline experience. It requires extensive use of the internet and online research. If you have limited online experience you should go to <http://umonline.umt.edu/StudentInfo> and click on “online course readiness assessment.” Answer the questions there honestly. If you still feel you are ready to take an online course return to the link above and take the “Moodle Tutorial. Contact onlinetutoring@umontana.edu for advice and assistance. If you think your skills are marginal, contact your instructor.

Technical Requirements This course requires a DSL or better connection. You may be able to do some of the work with dial-up, but to take exams and answer question sets you will need to get access to a stable relatively high speed connection. At the University of Montana you can get access at the libraries and computer labs. If you do not live near Missoula, other college campuses or public libraries will usually have systems you can use. When you encounter problems related to computers or connections email your instructor and call their contact number to document your problem. For technical advice about computers, connections or Moodle click on Tech Support in your Moodle menu.

<http://umonline.umt.edu/BlackboardHelp.htm>

Course Overview: **NRG246** – Introduction to Geothermal Energy Systems 3 credits is an introduction to the physical and technical aspects of geothermal energy systems. Topics covered include the fundamental principles of geology and hydrology, heat flow mechanisms, and a consideration of heat exchange systems including: dry steam, flash, binary systems, heat pumps, passive systems. The course also surveys political, economic, ecological, and social aspects of geothermal energy development. Soft energy earth coupling concepts will be included.

Target Student: This course is a key second-year, specialty energy course in the Energy Technology AAS degree program at the College of Technology. It may also appeal to a broader group of students who are interested in environmental issues or investment in green technology and have completed the math and science requirements listed below.

Prerequisite Skills and Knowledge: Prerequisite Math 095, no exceptions. NRG 101, NRG 102, SCN 175N, SCN 176 or other science courses with consent of instructor. Students should have

online experience with Moodle, word processing skills, and online computer, general internet, and research skills. Students should have experience doing online research through

the Mansfield Library web site or a similar university library system.

Course Importance and Relevance: After a 25 year hiatus federal and state governments are beginning to invest time and resources into geothermal research and information dissemination. New environmental and land use guidelines have been developed and geothermal may begin to provide a significant fraction of state and national energy needs. Geothermal technologies range from high tech bore holes miles deep to low tech Earth sheltering of structures with soil and natural Earth materials. If company stock prices reflect reality, in 2009 geothermal energy was a healthy growth industry.

Course Textbooks/Materials; The first list which follows provides a wealth of required information. The second list includes suggestions for students with more background or interest. In the Learning Units you will also find links to these items and there will be links to additional materials that you will access to answer question sets or write papers.

The following required sources can be obtained free of charge by going to the links provided. We suggest you refrain from printing these publications prior to the start of the course, since you may decide you can perform the required tasks without printing. We hope the cost savings will offset the time and trouble required to find these many publications. You will find most of these publications in Moodle ready for you to click on and use. Do Not Download from here.

BLM PEIS Appendix A: Status of US Geothermal Energy and Permitting in the Western States and Tribal Lands (2008) EMPS inc. BLM and USFS. 62 pgs.

http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS_REALTY_AND_RESOURCE_PROTECTION/energy/geothermal_eis/final_programmatic.Par.23512.File.dat/vol3_final_appA.pdf

Groundwater Hydrology (2005) Harvey, Charles, MIT open courseware (Chapters 2-8)

<http://ocw.mit.edu/OcwWeb/Civil-and-Environmental-Engineering/1-72Fall-2005/CourseHome>

Click on 'lecture notes', then specific chapters.

Geothermal 101: Basics of Geothermal Energy Production and Use (2009) Edited by Leslie Blodgett and Kara Slack; Geothermal Energy Association. 55pgs.

http://www.geo-energy.org/publications/reports/Geo101_Final_Feb_15.pdf

Geothermal Leasing 101: Federal, State and Private Lands (October 2, 2009) Braff, Andrew T. Wilson Sonsini Goodrich and Rosati, P.C. Presentation at 'Basics of Geothermal Development' Pre-Meeting Workshop, Geothermal Resources Council Annual Meeting, Reno, NV. 92pgs.

<http://www.wsgr.com/attorneys/NEWBIOS/PDFs/braff100209.pdf>

Geothermal Today: 2005 Geothermal Technologies Program Highlights (2005) Green, B.D., Cook, G., Brown, H., NREL, 40pgs <http://www.nrel.gov/docs/fy05osti/38174.pdf>

Geothermal Tomorrow: 2008 (2008) U.S. Department of Energy, 36 pgs.

http://www1.eere.energy.gov/geothermal/pdfs/geothermal_tomorrow_2008.pdf

An Evaluation of Enhanced Geothermal Systems Technology (2008) U.S. Department of Energy 23 pgs., Appendix 5pgs., Glossary 4pgs.

http://www1.eere.energy.gov/geothermal/pdfs/evaluation_egs_tech_2008.pdf

Enhanced Geothermal Systems (EGS) Well Construction Technology Evaluation Report (2008)

Polsky, Yarom; Capuano, Louis; et al., Sandia National Laboratories, 108 pgs.

http://www1.eere.energy.gov/geothermal/pdfs/egs_well_construction.pdf

Development of a High-Temperature Diagnostics-While-Drilling Tool (2009) Blankenship,

Douglas; Chavira, David; et al., Sandia National Laboratories, 63 pgs.

http://www1.eere.energy.gov/geothermal/pdfs/ht_dwd_tools.pdf

Updated U.S. Geothermal Supply Characterization (2007) Petty, S. and Porro, G. Conference

Paper Presented at the 32nd Workshop on Geothermal Reservoir Engineering, NREL, 24 pgs.

<http://www.nrel.gov/docs/fy07osti/41073.pdf>

DOE Geothermal Electricity Technology Evaluation Model (GETEM): Volume I – Technical

Reference Manual (2006) Entingh, Daniel J. Princeton Energy Resources, NREL Subcontract

86 pages. (Available in Moodle)

Geothermal Technologies Program: Multi-Year Research, Development and Demonstration

Plan 2009-2015 with program activities to 2025 (DRAFT VERSION 2008) U.S. DOE, 149 pgs.

http://www1.eere.energy.gov/geothermal/pdfs/gtp_myrrd_2009-complete.pdf

Geothermal (Ground-Source) Heat Pumps. Market Status, Barriers to Adoption, and Actions to

Overcome Barriers (2008) Hughes, Patrick J., Oak Ridge National Laboratory and DOE, 46 pgs.

http://www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf

Geothermal Risk Mitigation Strategies Report (2008) Deloitte Development LLC. DOE, 44pgs.

http://www1.eere.energy.gov/geothermal/pdfs/geothermal_risk_mitigation.pdf

The (REQUIRED TEXTBOOK) "THE SMART GUIDE TO GEOTHERMAL: HOW TO HARVEST THE EARTH'S FREE ENERGY FOR HEATING AND COOLING". Edition 1st. Copyright May 15, 2011, Author, Lloyd, Donal Blaise. Media: Paperback.

The following three textbooks (NOT REQUIRED) are excellent reference books. They are written for students in traditional 4-year engineering programs, and like all textbooks they are quite expensive. Most of the information these books contain is in the required sources listed above. There are copies of two of these books in the UM COT Library and if you are not in the Missoula area you might request your local library or college get a copy instead of purchasing them yourself.

"Geothermal Energy: Utilization and Technology" (2006) Dickson, Mary H. and Fanelli, Mario Editors, Earthscan, 205 pgs. ISBN – 13: 978-1-844047-184-5

For students with Engineering and calculus background:

"Geothermal Energy: An Alternative Resource for the 21st Century" (2008) Gupta, Harsh and Roy, Sukanta, Elsevier, 279 pgs. ISBN: 978-0-444-52875-9

"Earth Sheltered Housing Design: Guidelines Examples and References" (1979) Prepared by The Underground Space Center, University of Minnesota. Van Nostrand Reinhold Company, 318 pgs. ISBN 0-44228821-2 paperback, ISBN 0-442-26157-8 cloth. This is a practical technical book concerning Earth Sheltering. There are new books but none as good as this one.

The following instrumentation is required for each team

OM-EL-USB Temperature sensor available from Omega.com. Please coordinate with instructor for a group purchase to take advantage of an educational discount.

| Learning Outcomes: | Assessments: |
|---|---|
| 1. Identify the fundamental physical characteristics and processes in geothermal systems | Objective multiple choice exams will evaluate basic level of fluency with terminology and concepts. Short answer and essay questions will evaluate student ability to synthesize disparate facts and processes into comparisons and conclusions not explicitly stated. |
| 2. Differentiate between types of geothermal resources and their location | Objective multiple choice exams will evaluate basic level of fluency with terminology and concepts. Short answer and essay questions will evaluate student ability to synthesize disparate facts and processes into comparisons and conclusions not explicitly stated. |
| 3. Distinguish between the different types of geothermal technologies and appropriate uses of them | Objective multiple choice exams will evaluate basic level of fluency with terminology and concepts. Short answer and essay questions will evaluate student ability to synthesize disparate facts and processes into comparisons and conclusions not explicitly stated. Small groups will research different technologies and present papers in class or on Discussion Board. Each student will be responsible for reading, formulating questions and commenting on group papers. |
| 4. Identify economic costs and benefits of geothermal energy exploitation | Objective multiple choice exams will evaluate basic level of fluency with terminology and concepts. Short answer and essay questions will evaluate student ability to synthesize disparate facts and processes into comparisons and conclusions not explicitly stated. Small groups will research different technologies and present papers in class or on Discussion Board. Each student will be responsible for reading, formulating questions and commenting on group papers. |
| 5. Identify environmental costs and benefits of geothermal energy exploitation | Objective multiple choice exams will evaluate basic level of fluency with terminology and concepts. Short answer and essay questions will evaluate student ability to synthesize disparate facts and processes into comparisons and conclusions not explicitly stated. <u>Small groups will research different technologies and present papers in class or on Discussion Board. Each student will be responsible for reading, formulating questions and commenting on group papers.</u> |

Participation and Grading Criteria:

Class participation is expected and will impact grades. All readings and work should be completed in advance of the due date and time. The online section does not actually meet face to face, thus students are measured by the level of participation (frequency and quality of contributions) in the Discussion Board, timely submission of ALL work, and adherence to the testing schedule. This is not a correspondence course that you can do at your leisure and on your own schedule. The major difference between this course and a face-to-face course is that you do not have to come to a physical location for class.

Written assignments will be graded according to a general rubric (a set of criteria for grading) that will be provided when the assignment is made.

Assessments:

- 1) 3 math exercises @ 16 points each
- 2) 14 question sets @ 12 points each
- 3) 31 pages of papers @ 12 points per page
- 4) 1 comprehensive Exam @ 100 points
- 5) 1 comprehensive Final Exam @ 200 points
- 6) **Lab Exp. @ 112 pts.**

| | |
|--------------------------|--------------|
| Math Exercises | 4.8% |
| Question Sets | 16.8% |
| Papers | 37.2% |
| | |
| 'Mid-Term' Exam | 10.0% |
| Comprehensive Final Exam | <u>20.0%</u> |
| Lab experiment | 11.2% |

Occasionally a Bonus Assignment or activity will be offered. See the detailed course schedule below for assignments and assessments.

Grading Scale:

- A= 100-90%
B= 89-80%
C= 79-70%
D= 69-60%
F= 59% and below

Late Work Policy

Students are required to inform their instructor in advance if any work will be late. Accepted late work will lose 25% per day.

Course Policies and Procedures:

Student Conduct Code

In an effort to ensure that students are informed about the consequences of academic misconduct, the Academic Officers of The University of Montana have determined that the following statement must be present on every course syllabus. You will be held to these standards in this course.

All students must practice academic honesty. Academic misconduct is subject to an academic penalty by the course instructor and/or a disciplinary sanction by the University.

All students need to be familiar with the Student Conduct Code. The Code is available for review online at <http://www.umt.edu/SA/VPSA/index.cfm?page?1321>.

Drop/Add Policy

We suggest that you drop courses early. This will help you avoid two things, wasting time on work you will not finish, and getting an 'F' on your transcript because you miss a drop deadline.
http://www.umt.edu/catalog/policy_procedure.htm

Netiquette

Netiquette is network etiquette -- that is, the etiquette of cyberspace. "Etiquette" means "the forms required by good breeding or prescribed by authority to be required in social or official life." In other words, Netiquette is a set of rules for behaving properly online. You will find a more lengthy discussion of this under 'Course Information in Moodle and you will be expected to follow the guidelines while a student in this course.

Course Accommodations Statement (DSS)

Students with disabilities will receive reasonable accommodations in this online course. To request course modifications, you will need to contact your instructor as soon as possible. Your instructor will work with you and Disability Services in the accommodation process. For more information, visit the Disability Services website at <http://www.umt.edu/dss/> or call 406.243.2243 (Voice/Text).

Email policy at UM

According to the new University email policy effective on 1 July 2007, an "employee must use *only* UMM assigned student email accounts for all email exchanges with students, since such communication typically involves private student information." This means that you *must* send any correspondence through your GrizMail account. For more information on setting up and using your GrizMail account, please go to <http://www.umt.edu/it/email/studentemail.htm>.

Naming and Submitting Assignments

Please submit all word files as .pdf as MS Word documents

You may cut and paste them in assignment comment boxes or just attach them as local files. Be sure the assignment reflects you as the author and the assignment name and week. ALWAYS keep secure copies of everything you do in this and every course.

Specification for papers

All submitted work should be free of spelling and grammar errors. If you need help with writing go to onlinetutoring@umontana.edu

Turn-around time for grading assignments, providing feedback, etc.

Most instructors want to provide feedback as rapidly as possible, but feel doing quality work for students is paramount. You will get your work back as soon as soon as possible, but the amount of time may vary significantly depending on the amount of time required to read all the papers and analyze the grade distribution.

Detailed Course Schedule (all items subject to change with as much notice as possible):

| Unit / Week | Content | Method of Evaluation/Date |
|-------------|---------|---------------------------|
|-------------|---------|---------------------------|

| | | |
|---------------|---|--|
| Unit 1 Week 1 | <u>Introduction to the Course and Introduction to and Review of Units</u> | |
|---------------|---|--|

(The First three Items here should be used as a reference throughout the course)

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|----------------------|--|----------------------|
| Dimensional Analysis | | Exercises Due Week 1 |
|----------------------|--|----------------------|

| | | |
|---|--|----------------------|
| Development of Basic Units and Units used in Geothermal | | Exercises Due Week 2 |
|---|--|----------------------|

1 Friday

Scientific American Article

Questions Due Week 2

Monday

| | | |
|---------------|--|--|
| Unit 2 Week 2 | <u>National and International Energy Use</u> | |
|---------------|--|--|

Week 2 Assignment 1

Library/Reference Research

Short Answer Essay Questions Due Week 2 Friday

Week 2 Assignment 2

Questions Due Week 2 Friday

BLM PEIS Appendix A: Status of US Geothermal Energy and Permitting in the Western States

and Tribal Lands (2008) EMPS inc. BLM and USFS. 62 pgs.

http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS_REALTY_AND_RESOURCE_PROTECTION/energy/geothermal_eis/final_programmatic.Par.23512.File.dat/vol3_final_appA.pdf

f (This is in Blackboard)

| | | |
|---------------|--------------------------|--|
| Unit 3 Week 3 | <u>Geoscience Review</u> | |
|---------------|--------------------------|--|

Week 3 Assignment 1

John C. Holden's Pie in the Sky: A Cross-Section of Earth. Questions Due Week 3 Wednesday

(Jack is still working on this, he is an artist ... I may refer you to another source. The

questions will be the same.)

Week 3 Assignment 2

Plate Boundaries and Hot Spots

Questions Due Week 3 Friday

Begin assignments for Week 4 Assignment 1 Due MONDAY!

Unit 3 Week 4 Geoscience Review continued

Week 4 Assignment 1 "The Origin of the Ocean Floor" Scientific American Article

Questions Due Week 4 Monday

Week 4 Assignment 2

Hulen Paper on Salton Sea

Questions Due Week 4 Tuesday

| Unit / Week | Content | Method of Evaluation/Date |
|-------------|---------|---------------------------|
|-------------|---------|---------------------------|

Week 4 Assignment 3

Plate Boundaries and Hot Spots

3pg. Research Paper
Paper Due Week 4 Friday

Start looking at the material for Week 5

Unit 4 Week 5 Darcy and Groundwater

(These sources include a lot of math beyond algebra... you can get the concepts without the calculus.)

Week 5 Assignment 1

Multiple Choice Questions

Due Week 5 Wednesday

"Darcy and His Law" Website by Glenn Brown at Oklahoma State

<http://biosystems.okstate.edu/Darcy/index.htm>

Week 5 Assignment 2

Multiple Choice Questions

Due Week 5 Friday

MIT open courseware "Groundwater Hydrology" Course Chapters 2 through 8

<http://ocw.mit.edu/OcwWeb/Civil-and-Environmental-Engineering/1-72Fall-2005/CourseHome>

/ (These are in Blackboard)

Unit 5 Week 6 Geothermal Basics

Brief Overview History of Geothermal in the U.S. (No Assignment)

<http://www1.eere.energy.gov/geothermal/history.html>

Week 6 Assignment 1

Multiple Choice Questions

Due Week 6 Wednesday

PowerPoint Slide Show (Part 1 only)

“Geothermal 101: Geology and Geothermal Resources, Geothermal Leasing”

(2009) BLM (This is in Blackboard) Download or view at

http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS_REALTY_AND_RESOURCE_PROTECTION/_energy/geothermal_eis/workshops.Par.68406.File.dat/3_Geothermal_Leasing.pdf

Week 6 Assignment 2

Multiple Choice Short Answer

Due Week 6 Friday

“Geothermal 101: Basics of Geothermal Energy Production and Use” (2009)

Download or view <http://www.geo-energy.org/publications/reports.asp>

(Through page 27 for this week)

Questions and
Short Answers

| Unit / Week | Content | Method of Evaluation/Date |
|-------------|---------|---------------------------|
|-------------|---------|---------------------------|

Week 6 Assignment 3

Geothermal Exploration Paper

Due Week 7 Monday

Geothermal Exploration Induced Polarization Resistivity and Magnetometers.

Research Paper 2 pg. max

Discussion

Board

Unit 6 Week 7 DOE Views of Geothermal Developments This Decade

Paper from Week 6 Due Monday

Week 7 Assignment 1

Multiple Choice Short Answer

DUE Week 7 Wednesday

“Geothermal Today: 2005 Geothermal Technologies Program Highlights” (2005) Green, B.D., Cook, G., Brown, H., NREL, 40pgs. (In Blackboard)

<http://www1.eere.energy.gov/geothermal/pdfs/38174.pdf>

Week 7 Assignment 2

Multiple Choice Short Answer

Due Week 8 Monday

Questions for Assignment 2 come from the following two publications.

"Geothermal Tomorrow: 2008" (2008) U.S. Department of Energy, 36 pg.

http://www1.eere.energy.gov/geothermal/pdfs/geothermal_tomorrow_2008.pdf

Brief look at Geothermal Power Plant Technologies

<http://www1.eere.energy.gov/geothermal/powerplants.html>

Unit 7 Week 8 Enhanced Geothermal Systems

Questions from Week 7

Week 8 Assignment 1 Multiple Choice Short Answer

“An Evaluation of Enhanced Geothermal Systems Technology” (2008) U.S. Department of Energy 23 pgs., Appendix 5pgs., Glossary 4pgs. (In Blackboard)

http://www1.eere.energy.gov/geothermal/pdfs/evaluation_egs_tech_2008.pdf

***If you have a serious research interest in some aspect of geothermal other than wells talk
 ***with me prior Week 8

Week 8 Assignment 2 Begin Reading and commenting on Discussion Board

“Enhanced Geothermal Systems (EGS) Well Construction Technology Evaluation Report” (2008) Polsky, Yarom; Capuano, Louis; et al., Sandia National Laboratories, 108 pgs. (In Blackboard)

http://www1.eere.energy.gov/geothermal/pdfs/egs_well_construction.pdf

Student Questions and Discussion over pages 1 -22 on Discussion Board

(Due Monday of Week 9)

| Unit / Week | Content | Method of Evaluation/Date |
|-------------|---------|---------------------------|
|-------------|---------|---------------------------|

Week 9 Assignment 1 Continue comments on Discussion Board “Enhanced Geothermal Systems (EGS) Well Construction Technology Evaluation Report” (2008) Polsky, Yarom; Capuano, Louis; et al., Sandia National Laboratories, 108 pgs.

http://www1.eere.energy.gov/geothermal/pdfs/egs_well_construction.pdf

Student Questions and Discussion over Pgs. 22-54
 Thursday

Student questions and Discussion on
 Discussion Board

Week 9 Consider...

Work on field lab data... and begin working on your 4 page paper

Week 10

Unit 7 Week 11 Enhanced Geothermal Systems continued

Week 11 Assignment 1 Continue Lab Data Due Week 11 Monday

“Enhanced Geothermal Systems (EGS) Well Construction Technology Evaluation Report” (2008)
 Polsky, Yarom; Capuano, Louis; et al., Sandia National Laboratories, 108 pgs. (In Blackboard)
http://www1.eere.energy.gov/geothermal/pdfs/egs_well_construction.pdf

Student Questions and Discussion over Pgs. 56-104 Due Week 11
 Monday

Student questions and Lab Data

Week 11 Assignment 2 4 page paper on EGS Wells Due Week 11 Friday

Week 11 Study for Comprehensive Exam Monday of Week 12 (80% prior readings,
 20% EGS Well) Multiple Choice Questions and Short Answer Essay

Week 12

Comprehensive Exam Monday of Week 12 (80% prior readings, 20% EGS Well)
 Multiple Choice Questions and Short Answer Essay Week 12 Monday ‘Mid-Term’ EXAM

| Unit / Week | Content | Method of Evaluation/Date |
|-------------|---------|---------------------------|
|-------------|---------|---------------------------|

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|----------------|-------------------------------------|--|
| Unit 8 Week 12 | <u>Economics and Federal Policy</u> | |
|----------------|-------------------------------------|--|

“Updated U.S. Geothermal Supply Characterization” (2007) Petty, S. and Porro, G. Conference
 Paper Presented at the 32nd Workshop on Geothermal Reservoir Engineering, NREL, 24 pgs.
<http://www.nrel.gov/docs/fy07osti/41073.pdf>

“DOE Geothermal Electricity Technology Evaluation Model (GETEM): Volume I – Technical Reference Manual” (2006) Entingh, Daniel J. Princeton Energy Resources, NREL Subcontract 86 pages. (Available in Moodle)

Week 12 Work on Paper (3 pages or less) Summarize “Petty” and indicate weakness of GETEM

Week 13

3 Page Paper Summarize “Petty” and indicate weakness of GETEM
 Monday

Due Week 13

Unit 8 Week 13 Economics and Federal Policy

Chapters 7, 8 and 9 (You read parts of this publication in Week 6)

“Geothermal 101: Basics of Geothermal Energy Production and Use” (2009) Edited by Leslie Blodgett and Kara Slack; Geothermal Energy Association. 55pgs.

http://www.geo-energy.org/publications/reports/Geo101_Final_Feb_15.pdf

Required paper Due Week 13 Wednesday

“Geothermal Technologies Program: Multi-Year Research, Development and Demonstration Plan 2009-2015 with program activities to 2025” (DRAFT VERSION 2008) U.S. DOE, 149pgs.

http://www1.eere.energy.gov/geothermal/pdfs/gtp_myrd 2009-complete.pdf

Required paper Due Week 13 Thursday

Week 13 Discussion Board for you to discuss issues with writing your
 5 page paper that is due next week This Discussion Week 13 Friday

Week 14

5 page paper from Week 13 Due Week 14 Monday

| Unit / Week | Content | Method of Evaluation/Date |
|-------------|---------|---------------------------|
|-------------|---------|---------------------------|

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|----------------|----------------------------------|--|
| Unit 9 Week 14 | <u>Low Enthalpy Technologies</u> | |
|----------------|----------------------------------|--|

Heat Pumps

"Geothermal (Ground-Source) Heat Pumps. Market Status, Barriers to Adoption, and Actions to Overcome Barriers" (2008) Hughes, Patrick J., Oak Ridge National Laboratory and DOE, 46 pgs.

http://www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf (In Blackboard)

Required Discussion Board for this paper Due Week 14 Friday

Earth Sheltering

See syllabus for suggested source or find your own, research to be cited in your paper.

2 Pg. paper on Heat Pumps and Earth Sheltering (Due Week 15 Monday)

Catastrophic Events and Electric Power Production

Week 15

2 page paper from Week 14

Due Week 15 Monday

Unit 10 Week 15 Sustainability and Environmental Impacts

Read Chapters 6 and 10

"Geothermal 101: Basics of Geothermal Energy Production and Use" (2009) Edited by Leslie Blodgett and Kara Slack; Geothermal Energy Association. 55pgs.

http://www.geo-energy.org/publications/reports/Geo101_Final_Feb_15.pdf

Week 16 Final Exam

Final Exam will become available MONDAY of Finals Week.

The Final Exam is comprehensive. You will get details regarding the Final later in the term.