2013

ENSC 220: Introduction to Energy Systems—A Peer Review of Teaching Project Benchmark Portfolio

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Benchmark Course Portfolio

ENSC 220: Introduction to Energy Systems

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COURSE ABSTRACT

Introduction to Energy Systems is a cross departmental class as part of the Energy Sciences Minor. The class has a diverse student population and is taught accordingly. Students learn units, magnitudes, terminology, and basic function of current and emerging energy systems. Students finish the semester able to compare and discuss energy systems related to their feedstock, efficiency, capacity factor and environmental impacts. Student learning was evidenced throughout the course in tests, quizzes, writing assignments, discussions, and projects.

INTRODUCTION

Instructor: F. John Hay
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College: College of Agricultural Science and Natural Resources
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OBJECTIVES OF THE COURSE PORTFOLIO

I have three major goals of my portfolio: 1) continue to refine my course through documentation of connections between course learning objectives and course activities showing evidence of backward design, 2) documenting the efficacy of my teaching techniques, 3) learn to apply what I have learned in peer review to my extension teaching.

First, refining my course. I began teaching ENSC 220 starting in 2011. Previously the course was co-taught by two professors who are very experienced at undergraduate teaching. This was my first experience in teaching a full course at the undergraduate level. To that point in my life I had 8 years of experience with Extension education and teaching both youth and adults. In 2011 I organized the course very similarly to how it had been organized previously. The course is subject matter is very broad and covers a variety of topics with a different topic nearly every week. The students were exposed to some topics in a cursory manner and others in great detail with the homework at times unrelated to the course objectives. This outline seemed fractured and led me to explore changes in 2012. Prior to the spring of 2012 I reorganized the course removing some topics in order to give others appropriate depth. The addition of class discussion in 2012 was meant to increase students connection with course content and current events in their lives. I also added to my course objectives a goal to build on the students interest and excitement about energy systems. The peer review of teaching is my current method for refining my course for 2013. The peer review process has strengthened my courses connection between learning objectives, course activities, and assessment of student learning.

Second, the results of my teaching. Beyond test grades, I implemented a pre and post-test to quantify student learning. Additionally I explored how my students' on-line discussion and semester project writings showed examples of student learning.

Third, application of peer review principles. The backwards design model is integral to planning any course. This is also true with extension education, yet many times we skip, ignore, or shorten this process to the detriment of our students. The peer review process has cemented my resolve to implement the backwards design principals in my extension programs and revisit the learning objectives throughout the process. By focusing on learner outcomes I will be able to better plan, execute, and evaluate educational activities which will lead to the desired outcomes. Assessment and evaluation are integral to all forms of teaching and education. Extension education too often focuses on activities and topics rather than learning objectives and outcomes. With clear written learning objectives the evaluation should be clearer. Follow up communication with the audience is challenging in extension education where in many cases learners are reached only for a single day making long term evaluations reliant on follow up communication. The desired outcomes for most extension education goes beyond knowledge gain into behavior change and long term decision making requiring a long term commitment to evaluation. I believe many people in Extension could benefit from a peer review style workshop to help them clarify teaching objectives and evaluation.

DESCRIPTION OF THE COURSE

Course Goals and Objectives

Goals

1. Provide an opportunity for students to discuss current issues related to energy.

2. Provide each student with the terminology and basic understanding of energy systems from which they can then apply to their field of study

Learning Objectives

1. Students will learn and be able to use the units, magnitudes and terminology of major and emerging energy systems.
    a. Student will be able to do basic unit conversion
    b. Students will be able to express energy magnitudes in the appropriate units
    c. Students will be able to use energy terminology appropriately and in context including (Energy, Power, Efficiency, and Capacity Factor)

2. Students will understand and be able to explain major and emerging energy systems including the feedstock, transformation, efficiency, pollution and distribution.

    a. Students will be able to explain efficiency for all major energy systems
    b. Students will be able to evaluate emerging energy systems, identifying major limitations.
3. I want students to have an interest in and excitement about energy and the future of renewable energy.
    a. Students will be able to participate in discussions relating the science of energy systems to current energy issues.
    b. Students will be able to articulate their thought in a public setting (public speaking).

What is your Course?

Energy Science 220 is sophomore level course in the College of Ag. The course is an introduction to energy systems and covers major and emerging energy systems. The student audience is at all levels freshman to senior and has a diversity of majors. Many students are environmental studies and engineering with some coming from liberal arts programs. Energy Sciences 220 is one of four required courses for students to complete an Energy Sciences Minor. In past years a majority have taken it as an elective only and not as part of the minor. All students bring an interest in energy, in particular renewable energy. The class has a prerequisite titled Energy in Perspective taught in the fall of the year focuses on scientific principles and historical interpretation to place energy use in the context of pressing societal, environmental and climate issues. My course follows with a more detailed look at major and emerging energy systems and how energy is transformed from feedstock to more useful forms. The four required courses in the Energy Sciences Minor are meant to build a student's understanding of energy and make them more marketable in their career search.

Description of ENSC 220 in the Undergraduate Bulletin:

Overview of energy systems, sources, transformations, efficiency, and storage. Fossil fuels, biomass, wind, solar, nuclear, and hydrogen. Sustainability and environmental trade-offs of different energy systems.

The above learning objectives will give students a background understanding of how the energy we use was produced and how energy production differs by feedstock and end use. Students who achieve the above learning objectives will have the tools to think critically about energy systems.

I chose to participate in peer review for this course because of its student diversity and the challenges of teaching students with such diverse backgrounds. Over the years students have expressed interest in new and diverse ways to learning. I would like to explore this by exposing students to the information in many different ways to maximize their opportunities for learning.

TEACHING METHODS/COURSE MATERIALS/COURSE ACTIVITIES

Introduction to energy systems is taught as a lecture class and includes elements of on-line teaching. The course consists of lectures, tours, written homework, online discussion forum, quizzes, and a semester project paper and presentation.

Lectures were delivered during the class meeting time from 3:30 to 4:15 on Tuesdays and Thursdays during the spring semester. Lecture topics follow a progression from introduction to energy, power, laws of thermodynamics, and heat engines followed with more detailed lectures on individual energy systems (see **Appendix A**). I share lectures in this class with a lecturer from Electrical Engineering who lectures 20% of the time. He is an electrical engineer and covers solar PV, electrical grid, energy storage, electric vehicles, and hydrogen. His focus on electrical systems allows me to focus my lectures on bioenergy topics within my expertise. The diversity of topics also enabled me to utilize experts to provide guest lectures. Guest Lectures include a Nuclear Engineer (Nuclear systems) and an Ag Engineer (anaerobic digestion).

Tours and demonstrations were used throughout the course to peak students interest and expose students to real world energy systems similar to the ones they have studied in class.

ENSC 220 Tours 2013:

- East Campus Solar PV array
- East Campus Thermal Plant
- Electric Cars: Nissan Leaf and Tesla Model S (**Figure 1**)
- Bundy Station (LES combined cycle Natural gas power plant in north Lincoln) (**Figure 2**)

Figure 1: Tesla Model S, All electric car outside the lecture hall for the students to view. The model S is a superb example of a state of the art electric car with a 300 mile range.

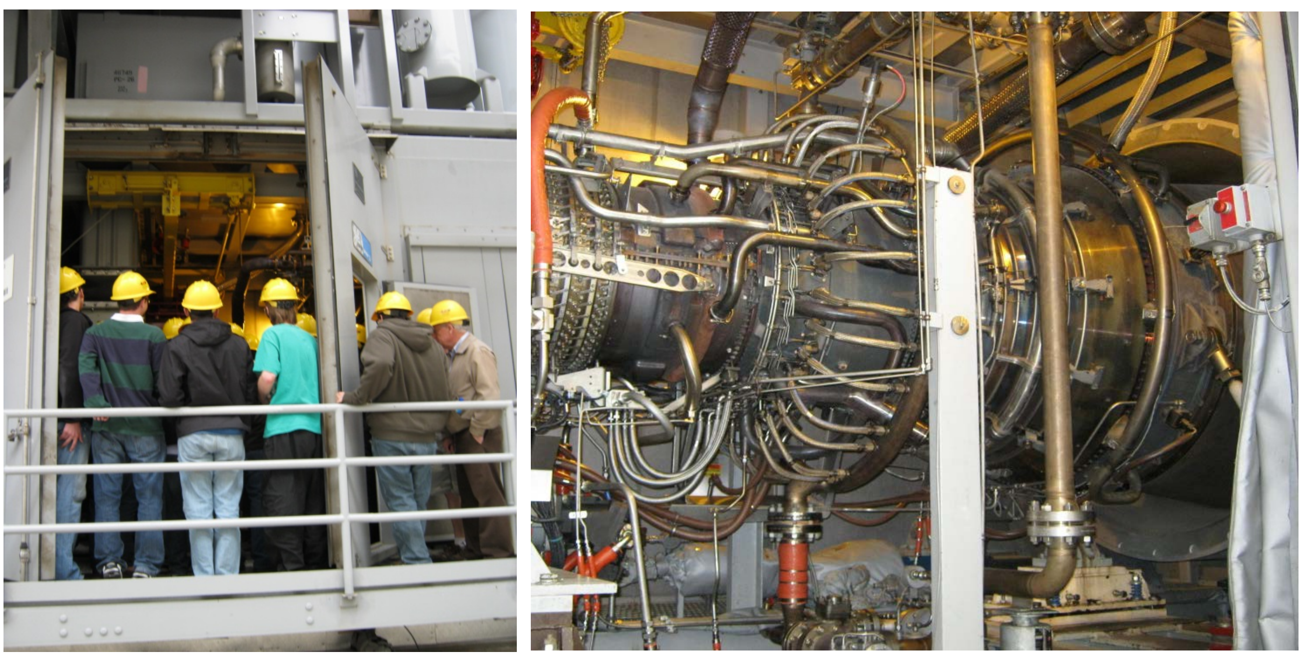

Figure 2: Bundy Station Tour. Lincoln Electric Systems natural gas combined cycle power plant. Students are looking at a 52,000 horsepower jet engine used to provide peaking load electricity to the city of Lincoln.

Homework assignments included one worksheet which includes a problem set meant to teach students to convert units and help them understand energy magnitudes. All other assignments involved writing a paper based on a current article or web video related to an energy topic. The written assignments were turned in using safe assign on blackboard. These homework assignments are intended to engage students to think critically about current events using the information about energy systems they have learned in the class and apply it to an analysis of the article or web video.

Energy science students participated in a discussion forum held online using blackboard. The discussion forum is designed to engage students in discussion with one another and the professor. The discussion forum is split into three separate discussion sessions focused on a specific topic related to what the class is covering at the time. The first forum students discussed fossil fuels, second covered biofuels, and the last focused on sustainability. A rubric is used to grade student's participation in the discussion forum. The rubric allowed students gain points for their posts with short posts worth five points and detailed posts with references worth 30 points. The max points possible to receive full credit are 100 points. The discussion forum is intended to facilitate discussion of energy topics and help students refine their opinions on such topics as sustainability. Students are able to use what they have learned in class to formulate their arguments and back up their statements in the discussion.

A total of 8 quizzes were given through the semester, quizzes were unannounced and given at the beginning or end of the class period. The best six quiz scores counted toward the final grades. By allowing them to drop the two lowest scores students could miss a quiz and not have it hurt their final grade. I found that only a small number of students missed a quiz and received a zero.

A semester project consisting of a paper and presentation is assigned early in the term and completed during dead week. The theme of the project is for students to describe their vision of a sustainable energy future for a select energy sector. Examples of sectors the students selected are electricity in Nebraska, transportation energy in the United States, electrical energy in Denmark, and residential energy use in the United State. Students apply the knowledge gained throughout the semester in forming their sustainable energy plan for their chosen sector. To accomplish the project students need to consider the magnitude of the energy used in the sector and the current energy systems used. Additionally students are able to use what they have learned about clean and renewable energy systems and the limitations of those systems to build their vision. The online discussion on sustainability helped build the students understanding of what it means for a system to be sustainable. The subjective nature of the term sustainable allows students to formulate their own definition or interpretation of the term. For example based on the discussion forum some student believe Nuclear is sustainable and other do not. Similarly some believe biofuels are sustainable while others argued the opposite. These discussions helped students refine their views which were then reflected in the final project submissions. Presentations are all recorded and turned in electronically. Electronic submissions will caused students to explore solve the challenge of finding a recording option. Students performed very well in 2013 and found numerous different ways to record their presentations and submit them electronically. The presentations were graded on their presentation quality (speaking, supporting slides, and the content of the presentation).

Based on peer review of teaching meetings I developed new and more detailed rubrics for grading. This allowed the students to have a more clear view of the point totals they needed to achieve in order to reach their desired grade. In past years I weighted parts of the class with a selected percentage of the grade. This year I changed to by detailing the number of points for each assignment or quiz, with the point totals reflecting the importance. I believe this helped the students better track their grade through the semester. In future years I will request input from the students on how they like or dislike this system.

THE COURSE AND THE BROADER CURRICULUM

ENSC 220 Introduction to Energy Systems is part of the Energy Sciences Minor. The minor consists of four core courses: ENSC 110 Energy in Perspective, ENSC 220 Introduction to Energy Systems, and ENSC 230 Energy, Economics and the Environment, ENSC 300 Energy Science Seminar. These courses provide a comprehensive overview of energy in society, fundamental energy principles, the economics of energy, and the environmental issues related to producing and using energy. Introduction to Energy Systems works to teach the fundamental energy systems, their inputs, outputs and efficiency.

During the 110 energy in perspective course the students get a background into what types of energy we use and why, related to the overarching drivers in society. For example students explore the socioeconomic, environmental, and political factors that drive society from using one energy feedstock to another (Why did we switch from wood to coal, whale oil to petroleum oil, etc). Introduction to energy systems is meant to be the second course in the series. Energy Sciences 220 Introduction to Energy Systems is the most quantitative of the four core courses. This course is an introduction to how humans convert energy from less useful forms into more useful forms and the costs and benefits of each system. Students come into the class with a cursory understanding energy feedstocks and sources. For example they know we utilize coal for a majority of our electricity. This course teaches them about the systems used to convert coal into electricity and how efficiency, capacity factors, and pollution outputs affect feasibility. Having the background to compare energy systems prepares students to critically evaluate the costs and benefits of future energy systems such as renewables. The third course in the series focuses on energy policy and the environment. Having taken 110 and 220 students should be prepared for the 230 course on policy with the needed background in how society interacts with energy and how system magnitudes and limitations effect our energy decisions.

ANALYSIS OF STUDENT LEARNING

Students showed evidence of learning throughout the semester. I will present evidence of learning from pre and post-test data, discussion forum submissions, and written presentations. I will focus evidence on the two major course learning objectives:

1. Proper use of units, magnitudes, and terminology of energy.
2. Understanding of major and emerging energy systems including the feedstock, transformation, efficiency, pollution and distribution.

Pre – Post test

Students voluntarily took a pre and post-test. Seventy four percent of students completed both the pre and post-test. Shown in **Figure 3** the average score increased from 124 out of 180 to 145 out of 180 an increase of 17%. The greatest increase was 93 to 158 an increase of 70%.

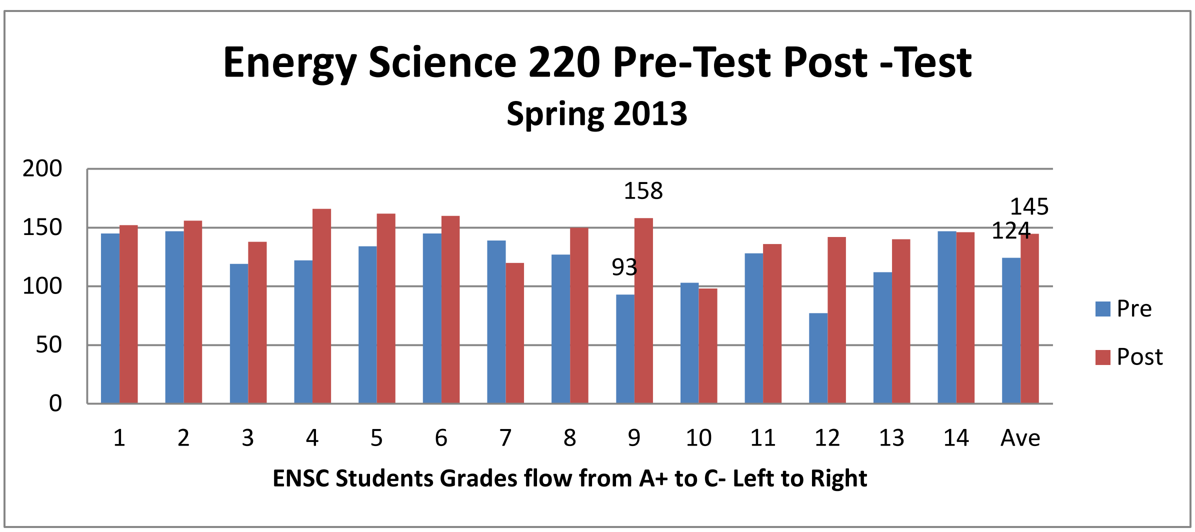

Figure 3: Pre-test Post-test scores for ENSC 220: Introduction to energy systems spring 2013.

Pre and post-test questions were intended to measure learning based on the learning objectives of the course. For example questions #11 and #13 were used to measure understanding of magnitudes and terminology of energy.

Question # 11: A 1000 Megawatt coal fired power plant running 365 days a year 24 hours a day could produce _________ kilowatt hours of electricity?

Student A:

Pre-test	Post-test
Selected answer: 8,760,000	Selected answer: 8,760,000,000
Correct answer: 8,760,000,000	Correct answer: 8,760,000,000

Student A in the pre-test scored an incorrect answer where he did not convert the units of Megawatts to kilowatts. In the post-test he demonstrated his understanding of unit conversion by correctly converting Megawatts to kilowatts and achieving a correct answer. Overall student performance on question #11 improved from 35% correct on the pre-test and 71% correct on the post-test.

Question #13: Put the following fuels in order of their energy per unit volume.

Student B:

Pre-test	Post-test
1. Gasoline	1. # 2 Diesel
2. E10 Gasoline	2. Biodiesel
3. #2 Diesel	3. Gasoline
4. Biodiesel	4. E10 Gasoline
5. E85 Gasoline	5. E85 Gasoline

Student B showed his ability to understand and arrange fuels by their volumetric energy content. This understanding will help him process why certain vehicles achieve higher fuel mileages than others and shows his understanding energy magnitudes. Overall student performance on question #13 was 28% correct on the pre-test and 71% correct on the post-test.

Questions #6 and #16 were used to determine the students understanding of learning objective #2 (understanding of major and emerging energy systems including feedstock, transformation, efficiency, pollution, and distribution)

Question #6: Which fossil fuel produces electricity most efficiently using combined cycle technology?

Student C:

Pre-test	Post-test
Selected answer: Coal	Selected answer: Natural Gas
Correct answer: Natural Gas	Correct answer: Natural Gas

Student C showed his increased understanding of energy systems and their efficiencies. Overall student performance on question #6 was 64% correct on the pre-test and 100% correct on the post-test.

Question #16: Which is the least carbon polluting per BTU output?

Student D:

Pre-test	Post-test
Selected answer: Oil	Selected answer: Natural Gas
Correct answer: Natural Gas	Correct answer: Natural Gas

Student C showed his increased understanding of energy systems and their pollution. Overall student performance on question #16 was 78% correct on the pre-test and 100% correct on the post-test.

Quizzes

I also noticed a trend where quiz grades improved through the semester and for many students the low scores were the first two quizzes in the semester. I have noted this phenomenon before and encourage my students to not worry when the grades on the first quiz are low. **Figure 4** illustrates the trend of higher quiz grades as the semester progresses. I believe this trend is due to the students learning what to expect from my quizzes and thus are better able to prepare.

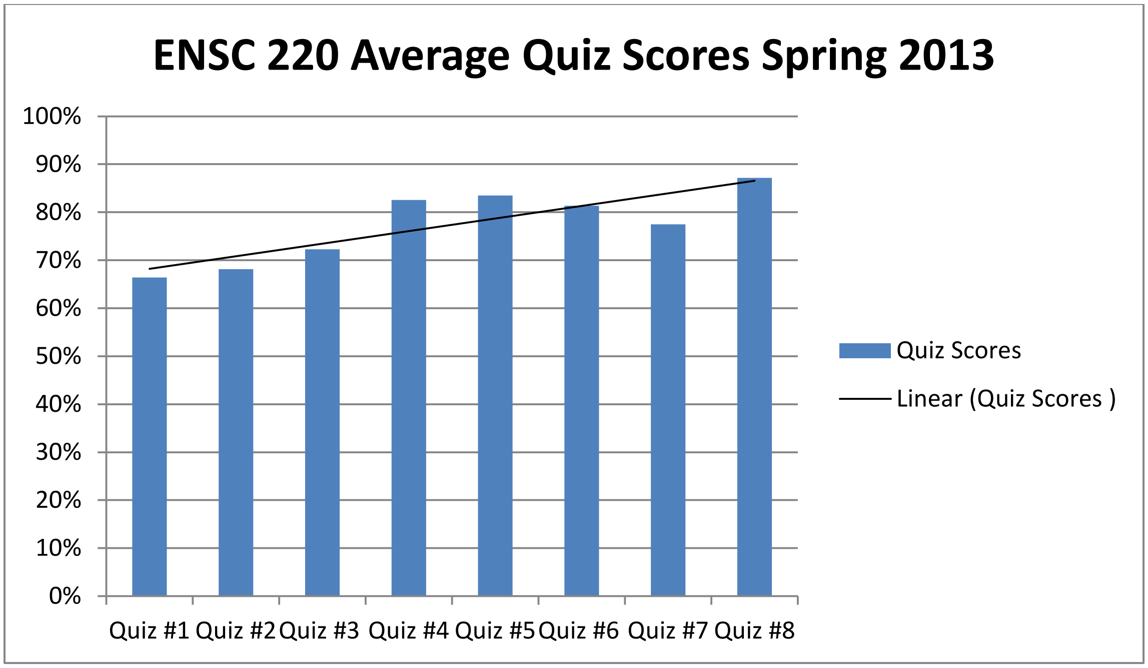

Figure 4: Students achieve higher average quiz grades as the semester progresses

Discussion Forum

Students participated in an on-line discussion forum where they discussed three general topics of fossil fuels, biofuels, and sustainability. Student learning was assessed using excerpts from the discussion where students demonstrated their understanding of one of the two learning objectives.

For example Student E demonstrated evidence of learning objective #2 (understanding of major energy systems efficiencies) by describing the efficiencies of solar PV systems and speculating on the improvements in efficiency over time. Students many times get confused and use the term efficiency inappropriately. In the case of student E he not only uses the term correctly but also uses the correct magnitudes of efficiency for current and emerging solar PV systems. (**Appendix B**)

Important concepts for students to understand are the limitations of current and emerging energy systems. Why a system can or cannot be increased due to physical, social, environmental or economic barriers. Student B does an excellent job in his discussion forum post describing the limitations of hydroelectric power by noting the environmental issues such as ecological damage due to slowed river flows, sediment deposition in addition to human deaths due to dam collapse. His descriptions demonstrate his understanding of why hydroelectric power can be difficult to expand. (**Appendix B**)

Semester Project Papers

Student papers detailed their vision of a sustainable energy system for a selected sector.

Examples demonstrating learning objective #1 (Units, Magnitudes and Terminology)

Student F demonstrated her understanding of units and magnitudes by calculating the potential production wind energy in Nebraska. Additionally she correctly used an often misunderstood concept in her calculations. The concept of capacity factor gives a measurement to the amount of time a power plant is operating. Since the wind does not blow all the time the capacity factor gives a measurement of the amount of time the turbines are running. In the case of Student G she researched and utilized a capacity factor of 41% which is correct for most parts of Nebraska. (**Appendix C**)

PLANNED CHANGES IN LIGHT OF ASSESSMENT AND PORTFOLIO PROCESS

Introduction to energy systems is likely going to transition to an on-line class in 2014. In preparation for this I presented elements of the 2013 class in a format similar to an on-line class. The on-line discussion forum, homework turned in using blackboard, and the semester project submitted in a recorded format are all examples of changes made in 2013. In the coming year I will make the following changes to transition to on-line.

Change made to ENSC 220 for transition to on-line.

- Record all lectures
- Build all quizzes to be given in blackboard
- Plan for live discussion and virtual tour sessions

Changes made to ENSC 220 based on what I learned in Peer Review

- Each year review learning objectives to make them very clear
- Improve how course content is mapped to learning objectives
- Rewrite pre-test and post-test so it is clearly mapped to learning objectives
- Expand student opportunities to tour/experience real life examples of the systems covered in class

APPENDICES

APPENDIX A: SYLLABUS

ENSC 220 – Introduction to Energy Systems
Instructors: F. John Hay (BSE), 250 Chase Hall, 402-472-0408, jhay2@unl.edu
Joel Jacobs (EE), 230D Whittier, 402-472-7958, jjacobs2@unl.edu
Time and Location: 3:30-4:45 pm TuTh, Plant Science 199
Measurable objectives:

a. Identify the technical topics associated with energy today including units, magnitudes and major terms.
b. Demonstrate an understanding of the physical principles of major energy systems, with quantification of common energy magnitudes, flows, and transformations including inputs, outputs, efficiencies and limitations.
c. Identify sustainable energy options and limitations of energy systems

Credit hours: 3 cr.
Required texts: NONE
Course Description: Overview of energy systems, including energy sources, transformations, efficiency, and storage; includes fossil fuels, biomass, wind, solar, nuclear. Sustainability and environmental trade-offs of different energy systems will be explored.
Course level and rationale: A broad introductory course on energy systems will provide the technical background needed for new students in the energy sciences. This course provides the fundamentals of energy systems and a foundation for additional courses in the Energy Sciences Minor.
Assessment plan:

Quizzes: 8 quizzes, top 6 count. 30 pts each	total 180 pts
Discussion Forums: three discussion forums	total 100 pts
Homework: 4 homeworks (30 pts each)	total 120 pts
Final Project: Paper (100 pts) and Presentation (100 pts)	total 200 pts
	Grand Total: 600 pts

Grading Scale

A+, A, A-	B+, B, B-	C+, C, C-	D+, D, D-	F
600-540	539-480	479-400	399-300	299-0

Professor retains the right to scale entire class grades.

Quizzes

i. Quizzes will be unannounced and will be given during class time.
ii. 8 quizzes will be given in class (30 pts each). Scores from two lowest are dropped. Total 180 pts possible
    1. Calculators are permitted for all quizzes.

Discussion Forum

iii. Three discussion forums. See schedule for start and end dates.
    1. Need 100 pts total to get full credit

2. 5 points for short comment (must be related to the topic of discussion and add to the discussion, simple agree or disagree statements will not count. Should be more than one sentence)
3. 30 points for well thought out response with details, references also welcome (usually 250 or more words)
4. Each student should participate in all three forums and add at least one 30 point response during the semester.
5. 1 point extra credit for every 10 pts over 100. 15 extra credit max

Homework (all homework will be submitted via blackboard)

iv. Homework will consist to four assignments (30 pts each)
v. Homework will be graded on, quality of writing, and content. (30 pts each)

Semester Project (Small groups assigned by professor)

vi. Paper: 3 pages in length minimum (1 inch margins single spaced 10-12 font times new roman). Explain your route to a sustainable energy system. Your group may sign up to cover energy systems including;
    1. US Transportation
    2. US residential
    3. US commercial/industrial
    4. US agricultural
    5. State (all energy) Choose which state
    6. Country (all energy) Country other than US.
    7. City (all energy) chose a city,
    8. US (electricity only)
    9. Other
vii. Describe the total energy currently used in this sector, including types of energy and magnitudes. Describe and discuss your plan for a sustainable energy future in this sector, include discussion of technologies and their opportunities and limitations. Give examples of what technologies and the major pros and cons, include a discussion of the feasibility of your suggested technologies and their magnitudes. Site all sources.
viii. Presentation: Prepare a presentation explaining your ideas for a sustainable energy future in the sector you selected. Quality of presentation will be graded including voice, appearance, presentation skills, content and visual aids. All presentations must be digitally recorded and submitted electronically. (See John for recording options, Quality of recording is important)
ix. All Presentations will be available via blackboard. Prepare a written review of one other presentation. Write ½ page single spaced review and include in your review a discussion of presentation content, audio, visual appearance. Be honest but appropriate. Reviews will be used as part of the grading.

Office Hours: F. John Hay: Mondays 3:00 – 4:00 pm. 250 Chase Hall or by appointment
Academic Honesty: Unless otherwise stated, all assignments and exams should reflect your

own work. Plagiarism will not be tolerated and you are expected to adhere to the University's Student Code of Conduct which can be found at http://stuafs.unl.edu/ja/code/. If you are uncertain about what constitutes plagiarism, please contact the instructor.

75 Minute Class Schedule Outline (Tentative):

DATE	Topic	Reading	Homework
Jan. 8	Introduction – How we use energy		
Jan. 10	Quantifying Energy	(Hot Air 24-28)	
Jan. 15	Heat to Motion		HW #1 Due Begin Discussion Forum: Fossil
Jan. 17	Thermal to Elec: Coal		Project groups assigned
Jan. 22	Thermal to Elec: Natural Gas		
Jan. 24	Thermal to Elec: Nuclear	Nuclear Power Basics	
Jan. 29	Thermal to Elec: Next Gen Nuclear		HW #2 Due
Jan. 31	Grid and Electricity Distribution		End Discussion Forum Fossil
Feb. 5	Renewable: Hydroelectric		
Feb. 7	Renewable: Wind Physics		Begin Discussion Biofuel
Feb. 12	Heuermann Lecture (Hardin Hall Auditorium)		
Feb. 14	Renewable: Wind Systems		
Feb. 19	Solar Resource	(Hot Air p 38-45)	HW #3 Due
Feb. 21	Bioenergy Photosynthesis and Plants/ Algae		
Feb. 26	Bioenergy Combustion	(Biorenewable Resources Chapter 6.1-6.3)	
Feb. 28	Bioenergy Fermentation	(Biorenewable Resources Chapter 7)	
March. 5	Geothermal		End Discussion Biofuel
March. 7	Renewable: Solar PV and Thermal	Video "The Power of the Sun – The Science of the Silicon Solar cell" by UCTV 21:52 Itunes U or UCTV on the web	Begin Discussion Renewable
March. 12	Transportation and Cars	(Hot Air p 254-262)	HW #4 Due
March. 14	Next Gen Cars		
Spring Vacation March 18-22			
March. 26	Solar Tour		
March. 28	Anaerobic Digestion	(Biorenewable Resources Chapter 6.4)	
April. 2	Energy Conservation		
April. 4	East Campus Thermal Plant Tour		End Discussion Renewable
April. 9	Hydrogen		
April. 11	Storage		
April. 16	Bundy Station Tour		
April. 18	Other Alternatives		
April. 23			Presentation Due
April. 25			Paper Due,
April 27th	Presentation Review due		Presentation Review Due
Monday April 29 8:30-10:30	No Final		

APPENDIX B: DISCUSSION FORUM EXAMPLES

Student E: Showing evidence of learning objective #2 understanding of major energy systems efficiencies. Also his utilization of terms correctly shows he understands the definitions of the terms.

A close runner-up to wind energy, in regards to sustainability, is solar photovoltaic power in my opinion. Just like wind, there are no fuel costs and the only thing that can get in the way of this ultimate fuel source are clouds. And when the sun is shining down on the cells, the very best efficiency's achieved would be around 45 percent, but typically they wouldn't be much higher than about 20-25 percent. I am confident though that as time passes, photovoltaic cells will become more and more efficient. Obviously, there are no greenhouse gas emissions from PV cells. The big issue with solar power is the amount of land area that it takes up. Obviously with these big solar panels, a solar farm would consume a huge amount of land(depending on how many panels). There isn't really any way around this either, but we can locate these large solar farms into an area that can't serve much other purpose, like a desert. Once in a desert, a solar farm then has ample sunlight, very minimal cloud cover, virtually no winter, and has a huge space to sprawl out within. So I would say that solar energy implemented in the proper location is very sustainable.
I guess the underlying message that I've been getting at in the past three threads, is that all forms of energy have their pros and cons when examined under a microscope and that they all have characteristics which support their sustainability and those that could be considered a detriment to their sustainability. But overall, renewables are the way to go; they would be a large improvement to our current situation.
Environmental Impacts from the Installation and Operation of Large-Scale Solar Power Plants
http://www.bnl.gov/pv/files/pdf/229_RSER_WildLife_2011.pdf

Student A: Demonstrating his understanding of the physical, social, environmental, and economic limitations of Coal, Natural Gas, Hydroelectric systems.

Pseudo-sustainability and eco-friendlier energy

There are two sources of power which fit into an odd niche in our power infrastructure: nuclear and natural gas. Both are based on depleteable geological reserves, but both offer energy that is significantly cleaner then the major technology of today (coal.) In order to be completely renewable, a power source must have no net impact on the environment and come from an effectively limitless supply.

Nuclear is, speaking only in terms of environmental impact and death counts, the safest and cleanest form of non-renewable power. In some (specific) cases, it is possible for a coal plant to produce more radioactive waste materials (by mass) then a nuclear plant in a single year. Based on this, it seems like environmentalists should be lining up to cheer on nuclear power. However, it is still not truly renewable since it uses uranium as a fuel, and uranium is inherently a limited resource. This, combined with a few well-publicized accidents and cultural paranoia have prevented this. Ultimately, while it is not sustainable, nuclear power is theoretically the most sustainable of the non-sustainable power sources. I need to stop saying sustainable.

The other, less contentious power source is natural gas. It isn’t so much that natural gas is more sustainable as there is less variation in opinion. It is cleaner then coal, but still produces greenhouse gasses and is based on a limited resource. There are an estimated 184,000 cubic kilometers of natural gas in the world, but that amount is replenished on a scale measured in millions of years, and as such will deplete with any significant extraction. As such, its use can never be truly sustainable (unless we are speaking in terms of geologic time, in which case even coal is theoretically “renewable” and sustainable,) although it is theoretically still more sustainable then other fossil fuels, and can potentially act as a gateway technology for more sustainable alternatives (biogas, methane digestors, etc.) This does not take into account ecological damage associated with fracking.

Ultimately, while not truly sustainable, natural gas and nuclear power are theoretically less damaging then other power sources (again, coal and oil,) and are therefor closer to being renewable.

Source: http://chartsbin.com/view/elx (natural gas estimate)

Student F: Demonstrating his understanding of the energy units, magnitudes.

Is Renewable Energy Sustainable Energy?

For this statement, I will be looking at renewable energy sources, and determining if they are sustainable. For an energy source to be sustainable, it can’t harm the ability of future generations to obtain energy. Also it has to be reliable and produce energy at any given time.

I will begin with hydroelectric power, our biggest source of renewable energy today. Hydroelectric energy is a renewable energy, but can it sustain the world’s demand for electricity indefinabley? Hydro produces its power by gravity and natural water cycle. This means that we can obtain energy year after year, with little input. The issue with dealing with hydro alone is the limited output. Of the world’s electricity, 20% is produced from hydropower.

According to a paper by the International Hydropower Association, the world has an estimated 14,370 TWh/year of potential hydropower. We are currently using 8082 TWh/year of that potential. I looked at data from World Bank, and the found that the world consumes 2,807 kWh of electricity per capita, I also found what the earth's population is; 6,973,738,433. By doing a little math I came to the conclusion that the world's electricity demand is around 17.15 exaWh/year. That's a far cry from 14,370 TWh/year. From this I can determine that we cannot produce enough hydropower electricity alone to supply the world's electricity needs.

If we can't be sustained off of hydropower alone, then it's doubtful we can sustain life from any other one renewable resource, but for this discussion I'm talking about all renewable resources. Let's add them up and see if we can produce electricity only from renewables. If we add every renewable energy source (wind, solar, ethanol, geothermal, ect.) the picture starts looking better. The potential is there; we just don't have the demand or technology to harvest all this energy.

In conclusion, renewable resources are a vast area in energy science. We have limited technology and a lack of demand. Once these both increase, then the idea of sustainability will become a more feasible idea. In this discussion I defined sustainability, talked about hydropower, and touched on the renewable energy as a whole. In a hundred years, renewable and sustainable energy will be paired together more often; we can sustain ourselves off of this technology. Renewable energy can be sustainable energy.

Sources: -World Bank

-http://www.ieahydro.org/reports/Hydrofut.pdf

-http://www.resilience.org/stories/2012-04-26/can-renewable-energy-sustain-consumer-societies-save-friday

APPENDIX C: SEMESTER PROJECT PAPER

Nebraska's residential energy use and its renewable energy capabilities

ENSC220 Semester Project Paper

By: Students F & G
The analysis of energy use for any location of interest involves looking at the overall energy infrastructure and what sources of energy the location uses. The state of Nebraska will be used in our analysis with the residential sector as the main area of focus. The residential sector was selected because it can provide a perspective for all socioeconomic classes in terms of the upfront cost and how important it is for such energy innovations to become feasible. Energy saving actions like turning of lights when leaving the house or changing incandescent light bulbs to compact fluorescent can only go so far in terms of reducing the reliance on non-renewable fuels.

By assessing how much the state of Nebraska can provide in terms of using renewable energy, it can provide a clear prospective on what the upfront cost might be. Most importantly, this estimate of the upfront cost might be high but will eventually be outweighed by the long-term benefits. These benefits like reducing our reliance to purchase more fuel while using a regenerative source of energy is something that makes this analysis worth the assessment. The main areas of discussion include Nebraska's current residential energy use, Nebraska's renewable energy potential (geothermal, solar, and wind), the pros/cons of renewable energy sources, and plan for sustainable energy use for Nebraska's residential sector.

Nebraska's current residential energy use:

According to the Energy Information Association (EIA), Nebraska's Energy consumption by end-use for the residential sector is 19.6% or **165.4 trillion BTU (453.3 billion BTU daily).** (EIA, 2011)[1] The term "end-use" is also known as secondary energy and is defined as all sources of energy that results from transformation of primary sources. (UN- Concepts and Methods in Energy Statistics, 1982) [2] The two main purposes for energy use in the residential sector include heating and electricity generation. Heating application for residents provides space heating via furnace, water heating, and kitchen heating. The electricity application provides energy for appliances, electronics, and air conditioning.

For the state of Nebraska, heating applications mainly use natural gas as a resource. The U.S. EIA Nebraska Energy profile shows that 63.8% of natural gas is used for residential heating. Nebraska's source of natural gas comes from interstate transfers of is supplied from the Rocky Mountain Region, Texas, and Oklahoma panhandle area producers via pipelines. For electricity generation, Nebraska mainly uses coal with a net generation of electricity of 2,365 thousand mWh. Coal fired power plants supply two-thirds of Nebraska's electricity generation, nuclear power under three-tenths, and hydro electric power as the remainder. (EIA, 2011)[1] Almost all of Nebraska's source of coal is received by rail from Wyoming.

Other smaller proportions of electricity generation would be Nebraska's two nuclear power plants located along the Missouri River on the States eastern broader. In addition, Nebraska also uses small hydroelectric dams along the Platte River and produces a small amount of energy from wind power.

Nebraska's renewable energy potential:

The magnitude of Nebraska's renewable energy to satisfy the residential sectors consumption of 165.4 trillion BTU will be used in the analysis. The Natural Resource Defense Council (NRDC) provides an overview of Nebraska's renewable energy potential. Resources that will be classified as renewable energy include geothermal, wind, and solar. Since only a small amount of energy can be derived from hydropower in Nebraska, it will not be included as a high energy potential.

Wind potential:

Currently Nebraska has 294 megawatts for wind energy, which is enough to power 80,000 homes. Also, Nebraska has the 4th largest wind resource in the country but is very far from that capacity with 294 megawatts. According to the National Renewable Energy Laboratory, Nebraska has the potential to build 7,800 megawatts of wind power by the year 2030. (NRDC, 2013) [3] This is under full capacity and is not taking the capacity factor into account. The capacity factor is the actual production over the maximum production. The AWEA Wind Power conference in California looked at the average wind farm capacity factor for several states in 2006. The highest wind capacity factor achieved was 41% with Nebraska and Oklahoma tied. This is taken into account with the calculations below. (AWEA Wind power 2007 Conference) [4]

7,800,000 kilowatts x 24 hours= 187,200,000 kWh/daily x 3412 BTU=
Wind Capability 638,752,915,310 BTU daily if running full capacity.

638,752,915,310 BTU x 0.41=
Wind Potential 2,618,886,953,000 BTU for 41% capacity daily

Geothermal potential:

From google.org, the leading investors in enhanced geothermal technology stated that at least 2% of the deep geothermal energy in Western Nebraska could produce the equivalent of 57 gigawatts of power. (NRDC, 2013) [3] Such power is about 8 times the capacity of the states current total electricity generation.

57 giga watts x 1,000,000,000 watts= 57,000,000,000 watts/ 1000= 57,000,000 kilowatts x 24 hours= 1,368,000,000 kWh daily x 3412 BTU=
Geothermal Potential 4,667,616,000,000 BTU Daily

Solar Potential:

The Natural Resource Defense Council claims that Nebraska's solar potential has yet to be explored. The National Renewable Energy Laboratory (NREL) lists all the States in the U.S. in terms of their solar index as the determinant for solar power potential. Nebraska is ranked as 13th in solar potential with a solar index potential of 0.89. The solar index was calculated as the average number of hours of peak direct sunlight hours per year from 1960 to 1990. (NEO, 2010) [5]

0.89 solar index x 40 = 35.6 W/m2 on average

0.0356 kW/m^2 x 24 hours= 0.8544 kWh/m2 x 3412 BTU=

Solar Potential 2915.21 BTU/m^2 on average daily

According to David Llorens from One Block Off the Grid, most solar panels are around 11-15% efficient. To determine the cost to capture such energy depends on technology of the solar panel as well as the solar panel material. (Llorens, 2012)[6]

PROS/CONS of Renewable Energy Sources

Geothermal PROS:

Looking at the renewable energy potentials of Nebraska, one resource that seems to be the most constant in terms of power would be geothermal energy. A significant promotion of geothermal power would be that it does not vary based on weather or precipitation patterns unlike solar and wind power. Geothermal seems to produce the most energy on a daily basis and can play a factor for satisfying the residential consumption of 165.4 trillion BTU. Geothermal potential of 4.26 trillion BTU would completely satisfy a years worth of residential energy demand of 165.4 trillion BTU by 38 days. However, being that such energy sources only come from Western Nebraska, it might be a renewable resource for the Western Region of Nebraska with the rest of the state under solar or wind energy.

One technology to consider with geothermal would be using the dual flash geothermal plant. According to the Geothermal Energy Association, 2007 estimates the generation costs for a 50 MW geothermal binary plant at $92 per megawatt hour and for a 50 MW dual flash geothermal plant at $88 per megawatt hour. (GEC, 2012)[7] So it is cheaper per mega watt to use flash geothermal technology versus binary.

Geothermal CONS:

Implementing geothermal energy can be very expensive in terms of drilling. In fact, a large proportion of the upfront cost of geothermal energy comes from the drilling procedure. There is a high capital investment for exploration, drilling wells, and plant installation. Google.org claims that at least 2% of the deep geothermal energy in Western Nebraska could produce the equivalent of 57 giga watts of power. The elevation of Western Nebraska is 4500-6000 ft above sea level and is higher in elevation than eastern Nebraska (Geology.com, 2013) [8]. The Wellcost Lite model shows that it will cost $1 million to drill to 6,500 feet (U.S. DOE, 2012) [9]. Since google.org doesn't provide exact depth for the 2% of energy that can produce 57 GW it will be difficult to determine the overall cost of drilling for geothermal energy in Nebraska. However, since it takes 6000 feet to reach sea-level that might be deep enough to obtain adequate geothermal energy and will cost less than $1 million. This might be a positive factor for geothermal energy in Nebraska.

Wind Energy PROS:

Since Nebraska is the 4^{th} largest wind energy resource; it is capable to increase its energy potential. As discussed in class, the horizontal Axis Wind Turbine has the highest power coefficient. The wind potential for Nebraska can be more than 2,618,886,953,000 BTU for 41% capacity depending on the height of the turbine, type of turbine, and rotor diameter. Having the most effective wind turbine design can make wind energy more appealing especially when using a large rotor diameter size, greater turbine height, and a horizontal wind turbine type. Plus win energy is a clean energy resource and does not produce emissions.

<u>Wind Energy CONS</u>:

One negative factor that wind energy has is the fact that wind energy is inconsistent and unpredictable. This is why the wind capacity factor is taken into account since wind turbines likely do not run close to maximum capacity and will fluctuate on a daily basis.

Other challenges wind turbines have would be how it impacts the wildlife in terms of bird and bat fatalities. Additionally, wind energy can be very expensive especially when it comes to the most effective wind energy design. According to the Windustry website, smaller farm or residential scale turbines cost less overall, but are more expensive per kilowatt of energy producing capacity. Wind turbines under 100 kilowatts cost roughly $3,000 to $8,000 per kilowatt of capacity. So a 10 KW machine would cost $30,000-$80,000 (or more) depending on the tower type, height, and the cost of installation. (Windustry, 2012)[10] Since Nebraska has the potential to build 7,800 megawatts (7800000 kW) of wind power by the year 2030 this would probably cost $23,400,000,000 – $62,400,000,000 based on the per kW rate. This can be cheap for commercial use but can be a challenge in regards to residential use and will require governmental subsidies.

<u>Solar Energy PROS:</u>

Like wind energy, solar energy is infinite in supply and can offer Nebraska a strong potential as an energy resource. Beyond the urban areas of Nebraska, the rural residents, especially within the agricultural sector, would greatly benefit solar energy. The ability to harness solar energy in remote locations that are not linked to a grid is something that can be a huge benefit for communities that are less populated through out Nebraska. Although the upfront cost of a solar panel is expensive, once installed, the panels can provide a free resource of energy that will pay off in the coming years. (Clean-energy-ideas, 2012)[11] Maybe areas that are limited economically can be provided with solar panels by a governmentally funded program. That way, such areas can save money and further strengthen their economic status.

In regards to solar panel technology, one innovation to consider would be dual axis solar panels that track the orientation of the sun. Dual axis solar panels can increase the energy output of PV systems by about 30-42% versus a single axis by 11-15%. (Eco-smart, 2011) [12] By using a dual axis solar panel it can increase the capture of Nebraska's solar potential of 2915.21 BTU/m^2 depending on the size of the solar panel. One solar panel product to consider is the D-80 dual axis tracker that has a module surface area of 85 m^2. One panel of D-80 can capture about 40% of 247,792.85 BTU (2915.21 BTU/m^2 x 85) to equal 99,117.14 BTU captured for electric generation on average daily.

<u>Solar Energy CONS:</u>

One thing to take into consideration is how sensitive solar panels can be when it comes to being in the shade. When a solar panel is shaded it prohibits the electric current that can result in compromising the whole system's energy output. This might be a disadvantage for residents living in forested areas. (Solarchoic.net) 13

In regards to providing energy for residence using the D-80 technology, its increase energy efficiency is still not enough to be considered as the main renewable energy supply and will need to be combined with other sources like wind and geothermal. For instance, 40 panels of D-80 solar plant with 40% efficiency on a daily basis based on average solar index can satisfy the energy consumption of Nebraska's residents of **165.4 trillion BTU** by 41,727,898.92 days. That's clearly not enough power and would be tremendously expensive. Speaking of expenses, another major con of solar panels would be the large upfront cost. A D-80 panel plant at 1 MW (1000 kW) would cost about 7 million dollars and a single D-80 panel with 11 kW and 85m^2 dimension would cost $77,000. This would be expensive for any standard household. However, the high cost could be purchased under government subsidies that can supply energy to power grids for residents in larger cities like Lincoln or Omaha.

- **Sustainable Energy Plan**

After analyzing the renewable energy potentials of Nebraska and looking at the pros and cons of each resource based upon cost and types of technology to consider, a sustainable energy plan can be used to satisfy Nebraska's residential energy consumption on a daily basis. Partnered with the U.S. Census Bureau's site, the indexmundi.com will be used to determine the population estimates by county to determine population density between regions of Nebraska (indexmundi.com, 2010) [14]. Based on the total residential consumption of 164 trillion BTU for a year, it provides an estimate of 453,254,794,500 BTU for daily residential consumption. This is the amount that the sustainable energy plan will strive to satisfy. The main points of the plan are as follows:

  - **Provide geothermal energy to the residents on the western side of Nebraska.**

- Western Nebraska ~9% of total population
A daily consumption estimate for Western Nebraska Residents=
40,792,931,510 BTU (9% of 453.3 billion BTU)
Geothermal power potential= 4,667,616,000,000

4,667,616,000,000 BTU Geothermal power potential - 40,792,931,510 BTU total daily consumption for Western Nebraska=

4,626,823,068,000 BTU of extra geothermal energy for Western Nebraska residents daily
(Could go toward other sectors like commercial or Industrial)

Total Cost:
According to the California Energy Commission, 2007 estimates the generation costs for a 50 MW dual flash geothermal plant is $88 per megawatt hour. Google.org claims that at least 2% of the deep geothermal energy in Western Nebraska could produce the equivalent of 57 giga watts of power.

57 GW= 57,000 MW x 24 hours= 1,368,000 mWh x $88= $120,384,000 (Plant Installation) + $1,000,000 (drilling) = $121,384,000

Cost of Geothermal= $121,384,000

Disadvantage- Can only transport to Western parts of Nebraska since Geothermal can only provide energy for surrounding areas.

- **Follow the claim made by National Renewable Energy Laboratory that 7,800 MW of wind energy will be provided by 2030 but only for central and eastern part of Nebraska.**

  -Central Nebraska ~13.5 % of total population
  Daily consumption of Central Nebraska Residents= 61,189,397,260 BTU (13.5% of 453.3 billion BTU)

  - Eastern Nebraska ~77.5 % of total population
  Daily Consumption of Eastern Nebraska Residents= 351,272,465,700 BTU (77.5% of 453.3 billion BTU)

  Total Daily for Central and Eastern Nebraska = 412,461,863,000

  Wind power daily= 2,618,886,953,000 BTU for 41% capacity daily

  2,618,886,953,000 BTU Daily Wind Potential -412,461,863,000 BTU total daily consumption for Central and Eastern Residential Nebraska=

  2,206,425,090,000 BTU of extra wind energy for Central and Eastern Nebraska residents daily
  (Could go toward other sectors like commercial or Industrial)

  Total Cost:
  According to the National Renewable Energy Laboratory, Nebraska has the potential to build 7,800 megawatts of wind power by the year 2030. According to the Windustry, Wind turbines under 100 kilowatts cost roughly $3,000 to $8,000 per kilowatt of capacity. We'll assume there will be establishments of turbines under 100 KW.

  7,800 MW = 7,800,000 kilowatts x $3000 =
  $23,400,000,000

  7,800 MW = 7,800,000 kilowatts x $8000=
  $62,400,000,000

  Cost of Wind= $23,400,000,000 to $62,400,000,000

- **Install two D-80 Solar power plants that is at 220 kW capacity to accommodate days when wind energy is below its 41% capacity. Plants will be located near the most populated cities for residential areas- Omaha and Lincoln.**

Solar Panel (D-80)= 99,117.14 BTU per solar panel (11 kW per panel)

20 D-80 solar panels total (10 for Lincoln and 10 for Omaha)

Total daily solar power energy for Omaha and Lincoln= 1,982,342.80 BTU

Total Cost:
$77,000 per D-80 solar panel x 20 D-80 solar panels= $1,540,000

Cost of Solar= $1,540,000

- **Conclusion**

Based upon the claims of Nebraska's energy potential and plans for future energy installment, clearly such renewable energy innovations will more than satisfy the residential sector. With extra energy from wind and geothermal totaling to 6,833,248,158,000 BTU, this amount can be distributed to other sectors like commercial or industrial. It is important to note that wind energy capture in Nebraska on average is 41% efficient but this doesn't necessarily mean that it constantly stays at 41% throughout the year. That is why the solar D-80 panels will be provided for densely populated areas like Lincoln and Omaha to serve as a back up when wind energy is inadequate. The total cost of the sustainability plan for residents in Nebraska comes to ~ $235,222,924,000. Obviously that is a lot of money and a large proportion of it comes from wind energy. Though the solar and geothermal are hypothetical, the wind energy of 7,800 megawatts of wind power by the year 2030 is a claim. Such large amount of wind energy will be monumental for Nebraska's energy supply. Despite the large upfront cost the long term benefits of becoming more of an independent resource is crucial and can help even the country overall to overcome using resources that are finite in supply. The technology is out there it just requires making such innovations more feasible whether by means of governmental subsidies, tax shifts, or any other form of financial assistance to make this sustainable energy plan possible.

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