Course Title: The Physics and Politics of Global Climate Change

The window of the world's energy economy being driven by the rampant use of fossil fuels is beginning to close. Awareness of is this window closing, however, is slow in coming to both the general public and to elected officials, whom generally assume the world is infinite thus allowing the oil to flow forever. However, June 2008 will go down in history as the moment when the price of gas rose to the point that TV commercials about our need to reduce our dependence on foreign oil first appeared. So, yes, awareness has been raised but that doesn't necessarily translate into sensible actions and implementation of new infrastructure Moreover, in the last century it was primarily the US and Western Europe that impacted the world's resources - now that impact has dramatically shifted and the emerging energy footprints of India and especially China, are of global concern. In particular, the growth rate of China since 2002 is so staggering that China is now on pace to surpass US Greenhouse gas emissions in the Summer of 2008! (3 years ago the projection was 2016). Guess What - they did!

Reasonable estimates suggest that fossil fuel production will dwindle to 10% of its current values in the next 40 years. Accelerated fossil fuel dependence in India and China will only serve to shorten, perhaps dramatically, this depletion timescale. Currently, 89% of the world's energy generating capacity is fossil fuel dependent. Thus, optimistically, we have about 40 years left to move from a fossil fuel based energy economy to a sustainable energy economy. Forty years is not a long time - you will still be alive in 40 years! Emerging technologies such as improved solar photovoltaic cells, concentrated solar power, improved wind turbines, clever ocean wave energy devices, advanced gas turbines, hydrogen fuel cells, efficient biomass co-generation facilities, improved energy storage capacity in batteries, ocean thermal electric conversion heat engines, and various alternative fuel pathways for vehicles offer us a wide array of choices for alternative means to derive energy. That is, we can exercise options now - so why the hell aren't we? In addition, individual transportation of human beings by fossil fuel powered vehicles is increasing at an alarmingly rapid pace. In turn, this provides an accelerated input to climate change (a companion or follow up to this course - The Physics and Politics of Climate Change will be offered as an HC 434/441 course this spring). Emerging technologies such as plug-in hybrid vehicles, zinc-air batteries, cellulose based biofuels, hydrogen cars, etc offer promising alternatives to the traditional fill 'er up at the pump status quo.

However, each of these new forms of energy generation has a different environmental and ecological impact and thus this array of choices needs to be evaluated objectively and fairly. In addition, each needs new kinds of infrastructure and distribution systems, so the choice matrix is large. However, the main point is that CHOICES EXIST. The focus of this course, therefore, will be to examine competing alternative energy technologies from the physical, social, economic and humanistic point of view. This course will also focus on the societal/cultural barriers to energy conservation, since clearly; our energy future also depends on our ability to act more conscientiously and cooperatively. In other words,

we will pay some attention to the non-rhetorical question **Why do Humans treat nature as a consumable?**

Currently each form of alternative energy has a passionate set of advocates that insist their form is the "solution". The reality is that regional combinations of different technologies are the only real solution - there is no one answer. The problem is complex at all levels. There are engineering challenges, infrastructure challenges, political challenges, economic consequence, and cultural impediments.
This course will deal with the issues of alternative energy sources and sustainable energy sources both for the purposes of electricity generation and for transportation. The intent is to perform an objective cost-benefit analysis on each form of alternative energy in order to determine what is feasible on a large scale. Full consideration will be given of the ecological footprint of various forms of energy generation since that is what the NIMBY public will react most viscerally to.

The main themes of this class are:

- To critically analyze various aspects of our national energy policy and to construct reasonable future trajectories.
- To gain an understanding of the cost-benefit ratio of various alternative energy sources to see what is feasible on the large scale and what is not. This involves an understanding of both the land and material use of a given technology,
- To understand some of the various obstacles associated with actual implementation of production line alternative energy facilities.
- To do simple calculations regarding the cost of energy usage and the required infrastructure to deliver a certain amount of power.
- To gain an understanding of how difficult it is to overcome culture barriers, knee-jerk reactions and the prevalent NIMBY attitude to actually come up with a working solution.
- To critically examine alternative modes of transportation and their scalablity and/or required infrastructure for fuel production and delivery.
- To further examine the energy problem in a more global context.

Course Outline/Weekly Topics: (From the Fall 2009 Version)

Week 1: Course Introduction; Media portrayals of energy crises; historical gas prices; Impact of current financial crises on new energy infrastructure; overview of the energy scale; Peak Oil and refinery limitations. Flows of Oil in the World

Week 2: Basics of electricity; Units of electricity; Understanding your power bill; Power Plant footprints

Week 3: Transmission Line Infrastructure; Transportation habits and potential innovations; Resource depletion timescales; Karl Marx and mass transit.

Week 4: The scalability of various alternative fuels; The promise of switchgrass.

Week 5: All about Wind energy; Levelized Costs; Siting and building a Wind Farm. Google Earth Exercise – find the Wind Farms. Large Scale Fossil Infrastructure

Week 6: Transitioning to a new energy economy; Solar Energy; How a PV Cell works; Solar Concentrator Systems; Emerging Large Scale Solar Projects

Week 7: Energy Storage Systems; Building a Better Battery

Week 8: Energy contained in the Willamette Valley Windstorm of Nov 16, 2009; The Depletion of Platinum; The coming LNG Economy;

Week 9-10: Wave and Tidal Energy; The Gulf Current; OTEC as a global solution; Collective Adolescent state of Humanity

Methods of Instruction and Reading:

Student group presentations will be a featured part of the curriculum. These presentations usually involve different sides of am emerging world issue. Typically there are 4 groups and 3 presentations per term. In addition, there are also individual short paper assignments (3) as well. Readings in this class will consist of topical white papers as well as the research done by the students in connection with completing there various projects.

Course Grading:

In class student participation: 10%
3 Group Projects: 40%
Individual Essay Assignments 20%
Final Exam: 30%

Study Guide for Final Exam:

1. Argue for or against the following economic notion:

   > Continued growth of GDP fosters improved energy efficiency and conservation

2. Explain why the European Union countries serve as good examples of government driven initiatives in the area of renewable energy. Cite some specific projects or policies and discuss why you think Europe is able to better attack this issue than the US.

3. Explain why "Peak Power" is difficult for your local utility to deal with.
4. Explain why transmission lines necessarily carry a high voltage.
5. Discuss the details of how solar troughs work and can be integrated into a solar farm.
6. Explain what might limit the scalability of Solar Stirling dishes as the source of large scale renewable electricity production.
7. Explain the importance of levelized cost in any analysis of the feasibility of some renewable energy technologies.
8. Explain why wind produced electricity is projected to have the lowest levelized cost of any renewable energy technology.
9. Currently there are approximately 30 GW of wind nameplate capacity installed in the US. Let's assume that in the year 2010 we will add 10 GW of new capacity and we will increase that annually at the rate of 25% (so 12.5 GW is added in 2011, etc). Also assume that US electrical consumption increases at 2% per year. Based on these trajectories, in approximately what year will wind energy reach 50% of our total electrical portfolio (solve this problem using the concept of exponential doubling times)
10. Explain why ocean wave energy technology may have some substantial drawbacks
11. Suppose some sunny location has 1 KW per square meter of incident sunlight on it and you want to solve the 100,000 MW near term energy problem with PV arrays. How many square kilometers of PV array would you need? Make sure you properly account for efficiency.
12. Explain the main physical differences between the bird killing wind farms of the 1980's and early 1990's and today's wind farm
13. Ten gallons of gas has an energy equivalent of about 400 KWhs. For a 1500 Kg vehicle, this translates in to an average fuel economy of 25 mpg or a total range of 250 miles. NiMH batteries currently store energy at the rate of 100 watt hours per kg. How many KG of NiMH batteries would it therefore take to duplicate this 250 mile range?
14. The Chevrolet Volt has a battery pack of 16KWH energy storage. If you plug the volt into your 120 V outlet at home on a 15 Amp circuit, how long would it take the volt to charge (and yes, you can actually solve this problem from what you know in this course)- apply Ohms law
15. Give an explanation of why it seems to be that Americans have the attitude that its their manifest destiny to organize and maintain a highly consumptive society
16. How has the US import of oil portfolio (i.e. from which countries do we get our oil) changed over the last 5-10 years?
17. Explain how Hubbert was able to use simple formalism to estimate when peak production/consumption of oil would occur for the US and which factor in this formalism is his prediction most sensitive to.
18. List or describe some of the factors that you believe render the US incapable of long term infrastructure planning.
19. Defend or rebuke the following statement: “Conservation is our best and cheapest energy source”

20. Explain how a hierarchical world view naturally leads to treating nature as a consumable.
21. In your view, what is the most frightening and near term real world impact of the Chinese Sledgehammer?
22. Demonstrate that 10s of thousands of megawatts of electricity generation, on the scale of US electrical consumption could be saved through the wide spread use of CFLs.
23. What is cellulosic ethanol and why does it hold more promise than grain based ethanol as a source for biofuels?
24. Is Marx full of crap on his characterization of the state of mind of capitalist laborer or might he actually have real insight here?
25. What is the main "physics" problem that limits the ultimate real world efficiency of a PV cell?
26. Conceptually explain how one can determine the depletion timescale of a physical resource and what determines the uncertainty in that determination.
27. What is the best evidence that we are currently in a situation of "Peak Oil"
28. Argue for or against the following proposition:

"Global Cooperation" is fundamentally against human nature.

29. Explain what Sam would need to do in order to avoid Ralph discovering the Iron Axe
30. Explain how this course has increased your overall awareness and understanding of the current state of the world and its trajectory.
31. Argue for or against the viability of Tidal Power as a source of " Green Energy" for the Pacific Northwest.
32. Conceptually describe how a phased approach, using various bridging energy technologies, to our energy problem is the most sensible long term energy plan that we can implement.
33. Under what kinds of conditions would the dedicated production of Hydrogen be practical and/or a reasonable investment.
34. Explain how flow batteries serve as a scalable solution to energy storage.
35. Provide what you think should be the single biggest argument that can be made against investing in the importation of LNG as our near term energy plan.
36. Provide an overview of the challenges that OTEC presents in terms of its ability to be a world energy solution.
37. Argue for or against the following proposition - "We are culturally hardwired to continue to follow BAU"
38. Explain how the current architecture of our electrical grid does not easily allow for capacity additions from renewable energy sources.
39. According to the "Bothun Index" - why does Wind energy have such a large relative advantage compared to other renewable technologies?

Course Title: The Physics and Politics of Global Climate Change

Course Description:

The potential for significant Global Climate Change is likely the most severe and economically costly problem of this century. Effective solutions to mitigate its effects will require an unusually high level in international cooperation and thus this topic necessarily brings with it different cultural perspectives. For instance, China keeps posing the fairly logical argument that until they reach the same level of per capita energy consumption as the US, they are not going to cooperate much on reducing their carbon footprint. Unfortunately, the climate system can not withstand this potential perturbation by China. As awareness of this issue increases, so does the amount of miss-information, myth propagation and political agenda. It thus becomes important to focus on this issue in an objective, scientific manner so that the ambiguities are clearly revealed.

I believe that a basic understanding of the Greenhouse effect is something that every college graduate should be able to articulate and therefore a proper class should be constructed to facilitate such articulation. Moreover, global climate change is an excellent example of a situation where you can build a very scientifically plausible and compelling case, but you can not yet scientifically prove that such climate change is human induced. As a result, this topic lends itself to an in depth exploration of the science/policy interface where decisions and future policy implementation necessarily will be made on incomplete data. Therefore, I think a comprehensive course on this topic will serve the HC students quite well in their overall academic preparation and will also immerse them in the noisy data that the science of Global Climate Change must necessarily deal with as well as the international nested conundrums that make the formulation of sensible policy difficult. Indeed, since 2003 the rate of greenhouse gas emissions from human activities has essentially doubled relative to the 1950-2000 baseline –we are therefore, losing ground on this issue at an increasingly rapid rate.

A particular case study for this course will be the various forms of “The Carbon Tax” which have been proposed and whether or not there is really any accountability or verification or “fair trade” in these proposed systems.

The first 2/3 of this course will focus on the data and science of Global Climate Change – its potential drivers and impacts as well as the various kinds of measurements which can be made to verify (or possibly refute) this phenomena. We will begin with simple models of our atmosphere to show how the burning of fossil fuels at a rapid pace naturally leads to the enhanced greenhouse effect. This beginning serves as the basic tie in to the Energy Footprints course. We will also study, in detail, the volatility and variability of climate baselines particularly in a regional context to emphasize the point that real climate change may be difficult to detect. The latter 1/3 of the course will focus on the politics of Global Climate Change in terms of protocol implementation and resistance, the interactions between ambiguous scientific data and public policy, and the needs for new

energy sources as one way to mitigate this problem.

In this latter 1/3 of the course, we will also introduce the BRIC (Brazil, Russia, India, and China) dynamic to show how the energy footprint of BRIC is the major driver in this century of our potential climate path and how this all potentially relates to international carbon trading, carbon caps and carbon taxation.

This course has three principal objectives:

* To introduce students to the science of climate change and the latest research that leads to the current grid models of climate change.

* To emphasize the difficulty of accurately characterizing the nature of climate and therefore to determine a baseline from which climate change can be reliably measured.

* To analyze potential social and political consequences of global climate change and the various efforts currently underway to lessen its overall impact.

Course Outline/Weekly Topics (From Spring 2009 Course):

Week 1: Course Overview; A New world order – how the global economic meltdown might affect the rate of climate change; The response of Arctic Ice to global warming.

Week 2: Sea level change; Methane and Global Warming; The Greenhouse effect; Ice Core data; Using the Global Warming Simulator

Week 3: Climate Model Uncertainties; The Uncertain Role of Clouds; Carbon trading/financing; Carbon Storage and Climate Change Mitigation; Carbon Capture and Storage – can we really do it

Week 4: IPCC Storylines and Scenario Overviews; Climate Proxy Data

Week 5: Are Hurricanes Smoking Guns? Urbanization Effects and Temperature Bias; US Carbon Emission profile; Carbon Emission Profiles for other countries; Google Earth exercise: Find the Big Power Plants

Week 6: Economics of Climate Change; Identifying extreme climate events; Peak Oil: Real or Not;

Week 7: Regional Climates and Regional Climate Change; Resource Depletion timescales; Population Growth Models; Difficulties with accurate population projections

Week 8-10: Population growth and carbon dioxide emission modeling; US vs China consumption/emission patterns; Carbon Cycle; Our Saturated Oceans; The Age of

Enlightenment – really? American Attitude Survey; Trends in Consumption; Containerization and consumer product growth; Our future trajectories.

Methods of Instruction and Reading:

Same as described in the Energy Policy class.

Course Grading:

Same as described in the Energy Policy class with the important exception that the third presentation is usually a 15 minute video piece and many of these are uploaded to you tube. The best example is this http://www.youtube.com/watch?v=Ex_9YmPhTfA

Study Guide for the final Exam:

1. Physically explain how the presence of a planetary atmosphere leads to a "greenhouse" effect.
2. Described the components and pathways of the global carbon cycle.
3. Why does water vapour act as the primary greenhouse gas on the Earth?
4. What are some of the components that determine the overall change in sea level?
5. Explain why, in the longer run (e.g. greater than 100 years) methane is likely to be the dominant greenhouse gas in the Earth's atmosphere
6. Explain why the "hockey stick" diagram is not particularly compelling evidence that supports the case for global warming.
7. Demonstrate that 10s of thousands of megawatts of electricity generation, on the scale of US electrical consumption could be saved through the wide spread use of CFLs.
8. Describe why the rapid loss of sea Ice seen in 2007 and 2008 in the Arctic Ocean may be a signature of a tipping point in the climate system
9. What one piece of evidence that you have been exposed to in this class is most convincing to you that global climate change is actually occurring.
10. Explain what the two biggest sources of physical uncertainty are in our current climate modeling.
11. Draw a diagram/concept map of a situation that represents a positive feedback loop in global climate change.
12. Summarize the fundamental differences between the 4 main stories of the IPCC.
13. Describe some of the potentially difficulties associated with carbon emission space and a carbon market.
14. Describe the basic technology that can be used for the storage or sequestration of carbon. What are some of the potential problems associated with this/these methods?
15. Explain what the "wedge" approach is to achieving Carbon stabilization and provide examples of what practices or requirements are needed to secure one wedge.
16. Argue for or against the following economic notion: Continued growth of GDP fosters improved energy efficiency and conservation
17. Briefly explain why the emerging energy footprint of China is so threatening and why it compromises the ability to reach certain stabilization levels of CO2.

18. Explain how Hubbert was able to accurately estimate when peak production of oil would occur in North America. What factors went into his analysis.
19. What is the best evidence that we are currently in a situation of "Peak Oil".
20. What is cellulosic ethanol and why does it hold more promise than grain based ethanol as a source for biofuels?
21. Summarize the principle sources of carbon emission and identify whether or not they are increasing with time and if so, what is driving the increase.
22. Summarize some of the difficulties associated with global population projections.
23. Which kind of population model makes the most sense to you and why?
24. Conceptually explain how one can determine the depletion timescale of a physical resource and what determines the uncertainty in that determination
25. Explain some of the root causes of the current global food crises.
26. Explain why the oceans are tending to get more acidic as a result of increasing atmospheric concentration of C02
27. Explain how the rapid loss of summer sea ice in the Arctic affects the overall energy balance of the Earth
28. Explain why decadel variability makes the actual detection of any real climate change difficult.
29. Explain why the Energy Policy Act of 2007 essentially has no balls.
30. Detail one example of what is predicted to be a large scale regional climate change that will occur in the US.
31. Explain what you think is missing in our current economic models of future climate change and why current models are largely inadequate.
32. Detail some reasons why the detection of actual, regional climate change, is very difficult to establish in a reliable manner.

Open Ended Course Thematic Questions

33. List or describe some of the factors that you believe render the US incapable of long term infrastructure planning.
34. If someone put you in charge to come up with an effective economic method of mitigating climate change, what would your method be and how would you implement it?
35. Explain why Americans are emotionally wedded to the Business As Usual trajectory
36. Explain how a hierarchical world view naturally leads to humans treating nature as a consumable.
37. Using the survey that was presented in class, summarize the basic American attitudes about global warming
38. Argue for or against the following proposition:
"Global Cooperation" is fundamentally against human nature.
39. Make a bumper sticker of your superbowl commercial message of 7 words or less.

Student Statement from **Katie Dwyer**:

Despite the Clark Honors College's best intentions, it is possible for a liberal arts student, such as myself, to escape from four years at the University of Oregon without extensive exposure to concrete scientific training. It's obvious why: a student who is studying Comparative Literature probably doesn't have the skills for a seminar in quantum physics or organic chemistry, even if she had the inclination. From what I have seen, the CHC does offer a few upper-division science courses which can engage students from varying backgrounds, but has to walk the delicate line between interesting, 400-level seminars and limited math and science skills in students.

I have participated in Professor Greg Bothun's Global Energy Policy class twice now: once as a student and once as a teacher's assistant. I found the teaching style to be engaging, but I appreciated the class mostly because it brought me into a foundational understanding of the state of global energy consumption today. I was able to engage in complex systems of innovative energy generation plans on a critical and informed level, rather than simply having a politically-motivated opinion based solely on rhetoric.

I feel that it is especially important for the non-science majors to have access to courses like this Energy Policy colloquium. Because of Professor Bothun's approach to the math and “hard science” background of this topic, students like myself can have a basic understanding of the physics of electricity and power generation with which to study the larger questions of energy in a globalized world. I felt that my background in literature and sociology were respected and useful in participating in discussions of various energy policy options or production techniques.

But more important than my individual pride at an informed opinion of the relative benefits of wind power vs. wave energy generation, it is extremely important that the non-science students are prepared to participate in the global issues that are founded in science. While I did not look forward to fulfilling my science colloquium requirement, I see it now as an essential practical component of my education at the Clark Honors College. I have the basic knowledge, the research skill set, and a model of critical thinking which I will now apply to all science-related study and debate for the rest of my college career and post-grad life.

Example Student Essay:

Sterling Lentz
HC 434
English Essay
December 9, 2008

Humanity in the Industrial Revolution: *Divulgence of the Divine Substance*

And then god said, "Let Us make man in Our image, according to Our likeness; and let them rule over the fish of the sea and over the birds of the sky and over the cattle and over all the earth, and over every creeping thing that creeps on the earth." Genesis 1:26

And so the destiny of man was set before man itself was even created by the almighty God. Ever since civilization was born on the shores of the Euphrates, man has possessed an innate sense of entitlement to the fruits of nature. The Industrial Revolution was merely a test of this sense, a gauge measuring human evolution. Had humans evolved sufficiently to be able to recognize the scope, scale, and impact of their consumption or had humans, greedy and cruel, only spent their time on Earth devising new and more efficient ways of mining the planet and in doing sowing the seeds of their species own destruction? Humanity failed.

Science is a powerful tool. One that, when handled correctly, can reap benefits beyond the human imagination. But, when handed improperly, science can become as great an evil as there ever was. The Industrial Revolution heralded a new age of arrogance for humanity. An age marked by a belief in a manifest destiny underpinned by ravenous and wreckless resource consumption at all costs. Science was bridled and steered, exploited in order to exploit elsewhere. Some would suggest that the arrogance of humanity lies in their belief that science was *their* tool to be utilized as a device

capable of delivering the riches of modern life. However, humanity's real arrogance lies in their collective belief that they could effectively manage their own greed and avarice by self-policing. Beginning in the cradle of civilization, humans have shown themselves to be resource addicts rationalizing their actions through the word of God. Any true addict knows that they are their own worst enemy.

Humanity's soul is demonstrated by the species' ability to survive over time. Yet, as the Industrial Revolution fell upon man it all but sealed the its disastrous fate. There is little hope that our species will be able to restrict the use of the proverbial iron axe after eons of steady use. Civilization has been granted the god-given right to pillage the Earth and all its treasures. Why stop now when mankind is merely executing the orders of the Lord?

More troubling still is the fact that the Industrial Revolution gave us the hyper-efficient fruits of our labor and spawned an entire global economy predicated on artificial consumption. Consuming more than you need became no more gluttonous than eating when you were hungry. The Revolution created a system where the health of a national economy was directly correlated to a steady, marked increase in GDP year after year after year. Such as system, as Dorothy Sayers once put, "is a society founded on trash and waste, and such a society is a house built upon sand." Yet humanity continues as if resources are infinite and the Earth can facilitate growth year in and year out until the end of time.

Humanity having lost its soul three hundred years ago, it is difficult to imagine a scenario in which it got it back, in which there was a re-enlightenment and everyone realized the errors of their consumptive ways. This difficulty is a result of the historical

place of consumption and resource exhaustion in our society. Humans only know how to use and no nothing of conservation. Civilization is likely to continue consuming until there is no more resources to power an annual increase in GDP. And at that moment, a saying from a culture long ago marginalized to extinction will ring truer than ever:

> “Only when the last tree has died and
> The last river has been poisoned and
> The last fish has been caught,
> Will we realize that
> We cannot eat money"
>
> -19th Century Cree Native America Proverb