EE1000 – Level Course, with the intent to be a CIS Course

Energy from Renewables: Envisioning a Brighter Future

Prerequisites: Admission to the University of Minnesota (completed 11th grade for a CIS course)

Instructor Credentials: A regular faculty at the University of Minnesota.
A "trained and certified" high school Science teacher or a instructor at a community college to be a CIS course.

Course Organizer: Ned Mohan

Proposed Implementation:

Starting in Fall 2016, offer a freshman-level course (depending on demand, possibly offer it every semester, as well as in summer), cross-listed with other departments and colleges. It should meet Liberal Arts requirements of the Environment Theme. Upon its approval, it will be proposed to be a "College In the Schools" course for high schools, to be taught starting in Fall 2017.

It should meet Liberal Arts requirements with the *Environmental Theme*.

Workshop Scheduled: As a means of developing the material and getting the feedback from high school science teachers, a workshop with the same title is be organized at our campus on Saturday April 16, 2016. For organizing this workshop, an amount of $11,500 has been awarded from the Institute on the Environment (IonE) and the University of Minnesota Center for Electric Energy (UMCEE). A proposal is pending for additional $9,750 to the Serendipity Grant offered by the Office of the Vice President for Research at UMN. These funds, if granted, will be used to support one-night of lodging of high school science teachers coming from a distance beyond a certain radius from the UMN campus. The tentative agenda of this workshop is listed at the end of this proposal.

Background of this Course:

Concern for the environment and climate change are burning issues of the day. As a result, **six** Grand Challenge Courses with the GCC designation are approved to be taught in Spring 2016 (3006, 5006, 5008, 3010/5010, 3011/5011 and 3013/5013), one of them in our Dept by Prof. Paul Imbertson.

In light of these courses, why propose another course on this topic? There are some important distinctions between the course being proposed and the courses listed above:

1. None of these courses is at the freshman-level; for them to be approved as GCC, these courses must be at 3000 and/or 5000. For the proposed course, it is too late and it should be taught at the freshman 1000-level.
2. This course will be technology-oriented in the context of deriving energy (primarily generating electricity) from renewables, storage and conservation. Unlike the GCC courses, the proposed course will describe the environmental degradation resulting from our energy usage only briefly. The bulk of the course will focus on the fundamental concepts of using renewable energy and conservation, followed by present and future technologies to solve this problem and highlight their economic success.
3. This course is intended to be a course for the College in the Schools (CIS) program. There are nearly **500** high schools in our state. According to the CIS coordinator at UMN, Julie Williams, **13** HS Principals have already shown interest in such a course at their schools. The CIS program is supported at the federal level and my understanding by talking to Julie Williams is that nearly **40** other states have programs similar to CIS. Our aim is to share the course material with the

interested universities in our state and other states to teach this course. Therefore, the potential is enormous.

Purpose of this Course:

This call-to-action course is to motivate young people in high schools, two-year community colleges and four-year institutions to think about energy. The backdrop of this course will be to briefly describe our use of energy sources at present and its disastrous climatic and geopolitical consequences.

However, the bulk of the course will be optimistic and upbeat, discussing possible approaches, and debating their practicality, by which we can derive energy from renewables, solar and wind, not only to confront global collapse but instead to lead to a brighter future.

This course will highlight ways by which we may reduce our energy use (producing Nega-Joules, just like nega-watts) and the environmental pollution associated with it. As an example, electric vehicles powered by electricity generated by renewables can eliminate gas consumption and greenhouse gases (GHG). According to the Environmental Protection Agency, the average fuel economy of news vehicles in 2014 (http://www.huffingtonpost.com/2014/10/08/average-fuel-economy-record_n_5953968.html) was **24.1** MPG, whereas it is at least four times this number in MPGe (**100** or higher) for electric vehicles.

One-third of our greenhouse gas emissions come from agriculture (http://www.nature.com/news/one-third-of-our-greenhouse-gas-emissions-come-from-agriculture-1.11708), more than either transportation or industry, and therefore where our food comes from and what we eat may be highly consequential than we realize.

In short, such measures will mean using less coal, no fracking and zero imported oil, which is not easy to do by any means, but something that is within reach.

The goal of this course will be that young people starting in high schools become more environmentally-conscience citizens, become ambassadors of sustainability and find their avocation by studying further and work towards this mission.

Why would students be interested in taking this course?

Most students realize climatic and geopolitical consequences of using energy. This course will describe the environmental consequences and discuss potential solutions using renewables and conservation to motivate them to study further and to do research in the area of their choice.

Catalog Description: (3.0 cr; Prereq – admitted to the University of Minnesota) - Our present use of natural resources and hydrocarbons on a collision course with the environment. General overview of energy usage and contribution to global warming/climate change. Possible solutions to derive energy for renewables for a sustainable future: wind (on-land and offshore), solar (PVs, solar thermal, sun lighting in homes), electrifying transportation, impact of food sector (production, transportation, consumption, diet) in producing greenhouse gases. Fuel Cells, various Energy Storage possibilities, Conservation through LEDs and efficiency improvements in applications where we use energy, Air-conditioning in a hotter world and ground-source heat pumps, Recycling and refuse-derived fuel, Energy Management Apps – weather forecasting for resources and loads, LEED Certification, Architectural Design and Urban sustainability, Net-zero energy homes.

Contact Hours: 3 hours of lecture per week.

Text: *None – course material will be uploaded to the course website during the semester*.

References: Links to latest articles and research findings; those collected so far are listed at the end of this proposal.

In offering this course for the first time, experts in various fields, within and outside UMN, will be invited as guest lecturers occasionally in this course, to learn from them and to request them to develop educational modules for offering this course later on, so they don't have to take the time again to teach this material.

LE Environment Theme: An attempt will be made to obtain the permission for this course to be counted as meeting the Environment Theme of the Liberal Education requirement.

Guidelines for all Theme courses (my answers in blue):

- Thinking ethically about important challenges facing our society and world: Throughout this course, various topics will be discussed in relation to using renewable sources to generate energy and ways to conserve, pointing out the relevance to the environment and the ethics of doing so.
- Reflecting on the shared sense of responsibility required to build and maintain community: It will be constantly emphasized that protecting the environment by deriving energy from renewables and using it efficiently for conservation can be accomplished only if it is taken as a shared responsibility.
- Connecting knowledge and practice: It will be pointed out that the knowledge being imparted in this course is already being put into practice with a great deal of possibility of future innovations and breakthroughs.
- Fostering a stronger sense of our roles as historical agents: This course will foster our role as a historical agent. Surely will be judged by history if we understood the urgency and did not have the moral fortitude to act based on opportunities made possible by technologies at hand.
- This course will be taught by a regular faculty.

To satisfy the Environment Theme requirement, this course meets the following criteria (these all will be fully met**):**

- Raises environmental issues of major significance.
- Gives explicit attention to interrelationships between the natural environment and human society.
- Introduces the underlying scientific principles behind the environmental issues being examined
- Students explore the limitations of technologies and the constraints of science on the public policy issues being considered.
- Students learn how to identify and evaluate credible information concerning the environment.
- Students demonstrate an understanding that solutions to environmental problems will only be sustained if they are consistent with the ethics and values of society.

Final Thought: This course is designed to be taught at high schools as well, through the "College in the Schools" program by "trained" high school teachers. In doing so, high school teachers will be made fully aware that how they teach this course must meet the requirements of the LE Theme of "Environment." In addition to high schools, this courses will be promoted to other 4-year institutions and community colleges in MN.

Tentative Syllabus:

This syllabus will be finalized after the workshop described below where the invited speakers will be urged to contribute material in teaching this course.

1. (2 weeks)
   Our present use of natural resources and hydrocarbons on a collision course with the environment:
   - evidence of climate change
   - our carbon footprint due to conventional sources such as coal, natural gas and oil
   - geopolitical implications
   - What we need to do to create a mindset to be sustainability conscious
   - Ethics of the environment
   - Outcome of the recent climate change conference in Paris in 2015
   - Who resilient is our eco system?

Possible solutions for a sustainable future:

2. (2 weeks)
   Wind: on-land and offshore
   - Fundamentals of harnessing energy from wind
   - On-land and offshore resources
   - Structure and efficiency of wind turbines
   - Correlation between wind prevalence and utility load
   - Cost of wind energy in relation to other sources
   - Challenges to the grid because of wind variability
   - Wind forecasting in day-ahead and real-time markets (first, what are these markets?)
3. (2 weeks)
   Solar: PVs, solar thermal, sun lighting in homes
   - Fundamentals of harnessing energy using PVs
   - Cost of solar cells versus the balance-of-system
   - Structure and efficiency of solar cells
   - Correlation between PV-generated electricity and utility load
   - Cost of solar-electric energy in relation to other sources
   - Challenges to the grid because of PV variability
   - PV forecasting in day-ahead and real-time markets
   - How practical are passive solar-thermal systems?
   - How much bringing sunlight in homes reduce electricity usage?
4. (1 week)
   Energy from Biomass
   - Fundamentals and practicality of using biomass for in fuel for transportation and for generating electricity

5. (1 week)
   Electrifying transportation; using compressed air for storage in automobiles
   - Electric and Hybrid-electric vehicles
   - Batteries for automotive application
   - Compressed-air automobiles
6. (1 week)
   Fuel Cells and Energy Storage
   - Fuel cell fundamentals and types of fuel cells: pros and cons
   - How does the efficiency of fuel-cell systems compare with natural-gas turbines
   - Battery fundamentals and types of batteries: pros and cons
7. (1 week)
   Conservation through LEDs and Efficiency Improvements
   - LED fundamentals and their comparison to incandescent and CFLs
   - Efficiency improvements by using adjustable-speed drives in motor-driven systems
8. (1 week)
   Conservation in the Agriculture sector: eating local, greenhouses using grow lights, soil-sensors and irrigation, affordable vegetables leading to less-meat diet
   - Various parts of the food sector: energy required and production of greenhouse gases
   - Effect of growing local in greenhouses using LEDs
   - Soil sensors, drones and irrigation to reduce water usage
   - Effect of various diets on the environment
9. (1 week)
   Air-conditioning in a hotter world: Fans versus air conditioning – central air conditioning, ground source heat pumps; zonal air conditioning
   - Air-conditioning is a major load particularly in a hotter world, leading to a positive feedback
   - How can central heating and air-conditioning be avoided to reduce energy consumption
   - Do ground-source heat pumps make sense?
10. Miscellaneous (2 weeks)
    Recycling – refuse-derived fuel
    Energy Management Apps – weather forecasting for resources and loads – using the Internet of Things
    LEED Certification, Architectural Design and Urban sustainability
    Net-zero energy homes
11. Field Trips to Renewable Energy Sites whenever possible

All through the course, critical thinking and decision making on socio/economic impact of energy and usage and possible solutions for sustainability will be promoted.

Relationship to Student Outcomes:

In accordance with ABET accreditation criteria, all engineering programs must demonstrate that their students achieve certain outcomes. This list of outcomes may be found on the ABET.org website. Of the outcomes listed in the ABET criteria (enumerated as (a) through (k)), this course teaches skills which help the student achieve the following outcomes:

(a) an ability to apply knowledge of mathematics, science, and engineering

(e) an ability to identify, formulate, and solve engineering problems

(i) a recognition of the need for, and an ability to engage in life-long learning

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context, and

(j) a knowledge of contemporary issues.

Note: The proposed 1000-level courses is very different from EE2701, which is highly technical and incorporates what students learn in three senior-level courses (EE4701, EE4721 and EE4741), of course in a simplified manner, in the context of utilizing renewables and conservation.

Environment Theme:

The backdrop of this course will be to briefly describe our use of energy sources at present and its disastrous climatic and geopolitical consequences. Given that, our ethical responsibility is to explore alternate ways so that our children and grandchildren have a future! Moreover, the energy system underpins modern society and links critical food, transportation, health, and water infrastructures across multiple spatiotemporal scales. Driven by the goals of sustainability and resilience, our energy system is rapidly undergoing fundamental transitions in form and function. How we harness and use energy connects new technologies, societal values, policies, institutions, and laws. This course focuses on energy-generation opportunities, particularly electrical, using renewables, embedded within existing and future power systems infrastructure to be rapidly acceptable in societal and policy context. This course spans the management of the variability of renewable resources, explores the role of storage and demand, while ensuring economic and social sustainability.

This course will be optimistic and upbeat, and will show that we can meet this challenge by shifting to renewables for generating energy/electricity and using it efficiently. In doing so, various possible sources and approaches will be discussed and compared in terms of their practicality, by which we can derive energy from renewables such as solar and wind, not only to confront global collapse but instead leading to a brighter future. In concrete terms, if such measures are implemented, it will mean using far less coal, no fracking and zero imported oil, and will have a profound impact on society.

This course will result in students as informed and engaged citizens with the possibility of developing innovative technologies in their career by combining compelling ethical urgency raised by climate change and, with the underpinning of technological knowledge, making the difference by convincing communities, investors and policy makers that the changes are not only ethical but are sound business practices as well. Many scientists are sounding the alarm bell that unless the problem of greenhouse is addressed, a point of no-return will be reached soon resulting in migrations and global conflicts like the world has never seen before. In this sense, all of us will be judged by history if we understood the urgency and did not have the moral fortitude to act based on opportunities made possible by technologies at hand.

Assignments, nature of assessments, student projects

1. There will be a weekly homework assignment that will be collected and graded. Solutions will be provided subsequently. These assignments will count 15% towards the grade.
2. The homework assignments will have 4-5 problems to promote and assess the comprehension of the course material. In addition, there will be a descriptive/qualitative question that will ask students the relevance of the material covered in that week to Sustainable Electricity Supply.

3. There will be two mid-term exams, each 15% of the grade. The Final Exam will be comprehensive of all the material discussed in the course and will determine 45% of the grade.
4. There will be a student project based on possible research topics/papers discussed in the beginning of the semester. In this, students will be asked to pick one of the topics of their choice write a research paper describing the impact of carbon-based fuels on the environment and how using energy from renewables and conservation can lead to sustainable electricity supply. This research paper will count 10% towards the grade.

Student Learning Outcomes

At the time of receiving a bachelor's degree, students: (my response in blue)

- Can identify, define, and solve problems. Climate change as the problem, students will be identify the source and understand and compare various solutions.
- Can locate and critically evaluate information. In the beginning of the course, students will be informed of the sources available to them for further investigation.
- Have mastered a body of knowledge and a mode of inquiry. Students will certainly understand the basis of harnessing renewable energy and conservation and inquire about continuing development.
- Understand diverse philosophies and cultures within and across societies.
- Can communicate effectively. The intent if this course is that with the technological underpinning, students will be able to communicate to policy makers in making the right decision.
- Understand the role of creativity, innovation, discovery, and expression across disciplines. Students will learn through their research that beyond technology, their adaptation will depend of creativity and consensus building across disciplines (economics, policy, etc.) to succeed.
- Have acquired skills for effective citizenship and life-long learning. One of the goals of this course is to make students informed and engaged citizens with a passion for combating climate change.

References – Links for further investigation

Environmental Pollution:

http://www.cnn.com/2015/09/29/opinions/sutter-beef-suv-cliamte-two-degrees/

http://www.cnn.com/2015/12/12/opinions/sutter-cop21-climate-reaction/index.html

http://www.bbc.com/news/science-environment-24021772

http://www.bbc.com/news/science-environment-34920941

http://www.bbc.co.uk/news/resources/idt-5aceb360-8bc3-4741-99f0-2e4f76ca02bb

http://www.bbc.com/news/science-environment-35040477

http://www.bbc.com/news/science-environment-35029962

http://www.bbc.com/news/world-asia-china-35026363

http://republicen.org/

http://www.slate.com/articles/technology/future_tense/2015/05/republican_bob_inglis_is_america_s_best_hope_for_near_term_climate_action.html

http://www.merchantsofdoubt.org/

http://www.nytimes.com/2015/08/14/world/asia/study-links-polluted-air-in-china-to-1-6-million-deaths-a-year.html?action=click&contentCollection=Asia%20Pacific&module=RelatedCoverage&region=Marginalia&pgtype=article

http://www3.epa.gov/climatechange/ghgemissions/sources/agriculture.html

http://www.fao.org/agriculture/lead/themes0/climate/en/

https://en.wikipedia.org/wiki/Sherburne_County_Generating_Station

http://www.nytimes.com/2015/10/10/opinion/exxons-climate-concealment.html?action=click&pgtype=Homepage&module=opinion-c-col-left-region&region=opinion-c-col-left-region&WT.nav=opinion-c-col-left-region&_r=0

http://www.cnn.com/2015/11/23/opinions/opinion-roundup-climate-change/index.html

http://blogs.wsj.com/indiarealtime/2015/06/23/chinas-air-is-much-worse-than-indias-world-bank-report-shows/

Climate Change, Environmental Consequences:

https://www.youtube.com/watch?v=ZzCA60WnoMk

http://climate.nasa.gov/

http://climate.nasa.gov/evidence/

http://www.nytimes.com/2015/10/27/science/intolerable-heat-may-hit-the-middle-east-by-the-end-of-the-century.html?mabReward=A6&action=click&pgtype=Homepage&region=CColumn&module=Recommendation&src=rechp&WT.nav=RecEngine&_r=0

http://www.michaelgreenstone.com/adapting-to-climate-change/

http://www.michaelgreenstone.com/linking-air-pollution-mortality/

http://www.aspenideas.org/speaker/m-sanjayan

http://extremeicesurvey.org/

http://www.bbc.com/news/science-environment-33209548

Food:

http://www.bbc.com/news/science-environment-34899066

http://www.ghgonline.org/methanerice.htm

http://www.bbc.com/news/science-environment-34541077

http://www.cnn.com/2015/09/29/opinions/sutter-beef-suv-cliamte-two-degrees/index.html

http://www.nytimes.com/2015/09/20/opinion/sunday/nicholas-kristof-the-fake-meat-revolution.html?action=click&pgtype=Homepage&module=opinion-c-col-left-region&region=opinion-c-col-left-region&WT.nav=opinion-c-col-left-region&_r=0

http://www.lumigrow.com/applications/commercial-greenhouses/

Population, RPS, Data, Textbooks, Maps:

http://www.rachelcarson.org/Default.aspx

http://www.bbc.co.uk/news/resources/idt-5aceb360-8bc3-4741-99f0-2e4f76ca02bb

http://www.eia.gov/electricity/

http://en.wikipedia.org/wiki/World_population

http://www.dsireusa.org/

http://www.washingtonpost.com/graphics/national/power-plants/

http://www.ren21.net/status-of-renewables/global-status-report/

http://www.lucas-nuelle.com

http://www.bbc.com/future/sponsored/story/20150715-the-great-transition

https://www.whitehouse.gov/climate-change

https://www.whitehouse.gov/the-press-office/2015/08/03/fact-sheet-president-obama-announce-historic-carbon-pollution-standards

http://www2.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants

http://www.vox.com/2015/7/29/9066685/coal-oil-solar-maps

http://www.pewresearch.org/fact-tank/2014/07/11/half-the-worlds-population-live-in-just-6-countries/

http://www.census.gov/popclock/

http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC

http://en.wikipedia.org/wiki/List_of_countries_by_energy_consumption_per_capita

http://cmi.princeton.edu/ wedges/game.php

http://www.withouthotair.com/

http://solar.maps.umn.edu/app/

http://electrical-engineering-portal.com/

http://topics.nytimes.com/top/news/business/energy-environment/solar-energy/index.html?inline=nyt-classifier

Automotive:

http://www.ngvglobal.com/blog/audi-introduces-natural-gas-powered-a4-avant-g-tron-0702

https://www.fueleconomy.gov/feg/evtech.shtml

http://www.plugincars.com/cars

http://www.cyme.com/

https://physics.ucsd.edu/do-the-math/2011/08/mpg-for-electric-cars/

www.edmunds.com/fuel-economy/decoding-electric-car-mpg.html

https://www.youtube.com/watch?v=K9m9WDxmSN8

Solutions:

responsiblebynature.com/choices/windsource-infographic?noredirect=1

http://www.capstoneturbine.com/

http://money.cnn.com/video/technology/2015/09/10/elon-evolution-fuel-cells-that-power-apple-google-coca-cola.cnnmoney/

http://www.cooperindustries.com/content/public/en/power_systems/products/power_engineeringsoftware/power_quality/cymevvo.html

http://www.cyme.com/

http://batteryuniversity.com/

http://pveducation.com/

http://energy.gov/eere/fuelcells/fuel-cells

http://www.energystorageexchange.org

http://www.bloomenergy.com/fuel-cell/solid-oxide/

https://renewables.gepower.com/wind-energy/technology/integrated-storage.html
https://www.hpematter.com/issue-no-6-fall-2015/lithium-ion-battery-could-how-well-reinvent-grid

Tentative Agenda of the Workshop

Funded by: The Institute on the Environment (IonE), and University of Minnesota Center for Electric Energy
Co-sponsor: The College of Science and Engineering

Workshop on

"Energy from Renewables: Envisioning a Brighter Future"

Saturday April 16, 2016

University of Minnesota Campus, Minneapolis, MN

Workshop Objectives:

- Discuss our use of energy and its environmental consequences leading to climate change
- Describe the fundamentals related to harnessing energy from renewables, storage options, conservation
- Learn from projects that are technically successful and economically viable
- Explore potential options leading to less Coal, no Fracking and zero Imported Oil!
- Promote the lessons learned, and the material collected, throughout the nation and beyond

Target Audience:

- High School Science teachers from throughout Minnesota
- All students
- Educators from UMN and all other 2-year and 4-year colleges and universities in Minnesota
- Community Engagement through governmental/city organizations, civic and senior-citizen groups, faith-based and health organizations concerned about the environment

Tentative Agenda: Saturday April 16, 2016

8:00-10:00 Welcome Remarks and Importance of this Mission:

- Welcome Remarks: Prof. Randall Victora (Dept Head of ECE, UMN)
- Workshop Mission and Agenda: Prof. Ned Mohan (ECE, UMN)
- "College in the Schools" Program – Julie Williams (CIS Coordinator, UMN)
- Greenhouse Effect and Climate Change: Dr. Jessica Hellman (Director – Institute on the Environment, UMN)
- Energy Systems Integration: Thinking Beyond the Grid: Dr. Bryan Hannegan (Assoc. Director – National Renewable Energy Lab)
- View from the National Science Foundation: Dr. Pramod Khargonekar (Head of the Engineering Directorate at NSF)
- Renewable Energy Plans of Xcel Energy – Amy Fredregill (Resource Planning and Strategy Manager at Xcel Energy)

10:00-10:30 Networking; coffee break

10:30-12:00 Energy from Sun and Wind:

- Utility-Scale Photovoltaic Power Plants – Dr. Mahesh Morjaria (VP - First Solar)
- Residential PV systems – Dr. Patrick Chapman (Sun Power)
- Siting and Forecasting of Wind and Solar – Mark Ahlstrom (VP, Renewable Energy Policy, NextEra Energy Resources, WindLogics)
- Grid integration of Wind and Solar – Matt Schuerger (Energy Systems Consulting)

12:00-1:15 Lunch (provided)
Luncheon Presentation:
Driving Electric in Minnesota - Jukka Kukkonen (PlugInConnect)

1:15-2:30 Storage, Transportation
- Batteries: TBD
- Fuel Cells: Brad Palmer (Cummins)
- Electrifying Transportation - TBD

2:30-2:45 Networking; coffee break

2:45-3:30 Conservation
- Lighting through LEDs – Dr. Chris Henze (Analog Power Devices, Inc.)
- Vegetable Production in Greenhouses – Prof. John Erwin (Horticulture Science)
- Lessons on Sustainability from Norway – Prof. Tore Undeland (NTNU/Norway)

3:30-4:00 Discussion, Feedback and Adjournment: Prof. Ned Mohan (ECE, UMN)

Registration Fee: Everyone must register. The procedure to register and the exact location will be announced soon.