Engineering College Council
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ILR Conference Center

Energy and Sustainability Related Minutes

Members Present: Geoffrey Hedrick, James Becker, Samuel Fleming, William Hudson, Joseph Bonventre, Jay Carter, Evelyn Taylor Pearson, Frank Huband, Robert Shaw, Timothy Costello, Michael Goguen, Sophie Vandebroek, Susan Ying, William Shreve, Kent Fuchs, John Swanson, Roger Strauch, James McCormick, Elizabeth Altman, Venkatesh Narayanamurti, Kenneth Arnold, Christine Mazier, John Neafsey, Sarah Fischell

Emeritus Members Present: Richard Aubrecht

The meeting presentations can be found at http://132.236.67.210/ecac/ecc_ld.cfm.
User Name: spring08
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Energy Curriculum – Teresa Jordan, Chair of the Department of Earth and Atmospheric Sciences (EAS) and Paulette Clancy, Director of the School of Chemical and Biomolecular Engineering (CBE)

Kent Fuchs – I made a personal request to the president to not mention Kent Fuchs or the Dean more than once or twice in his presentation. The department chairs are the academic leaders at Cornell and we are fortunate to have two of our department chairs who are helping lead this initiative: Terry Jordon, Chair of EAS, and Paulette Clancy, Director of CBE. We also have in the audience, Jeff Tester. You will have at your table after lunch the announcement of his appointment at Cornell as the David D. Croll Professor of Sustainable Energy Systems. David Croll is here as well. He funded the professorship that helped us recruit Jeff.

Paulette Clancy – We are at an early stage of determining the energy curriculum and want your input. We are excited that Jeff Tester will be the Croll Chair of Sustainable Energy. Our philosophy is that fossil fuels will continue to dominate for at least the next 50 years. The shift to renewable energy sources will be gradual and Cornell will study both existing and new technologies. Our goals are to:

- Make current technologies cleaner,
- Investigate carbon capture strategies, and
- Develop sustainable renewable sources of energy.

The sustainable energy initiative includes research, education, and outreach. Education is our focus today broken into the undergraduate, Master of Engineering, and PhD curriculums. We are considering what is required for undergraduate energy literacy. We already have a joint MEng/MBA program in sustainable energy and we are considering

whether there should be a PhD level core curriculum, graduate field, or minor in energy. We are organized around a set of questions that have been placed to you.

Cornell is uniquely positioned to lead a sustainable energy initiative. We have a global systems approach to producing benign energy solutions that is enhanced by Cornell's interdisciplinary teamwork and non-traditional, de-balkanizing graduate structure and work that cuts across graduate and undergraduate boundaries.

Our intended impacts of an educational program are to:

- Highlight international interactions as part of a global solution
- Education both specialists in sustainable energy systems and produce well informed generalists.

These goals are important, but we are just starting to make the right connections.

At the undergraduate level, our key goal is to develop and disseminate energy literacy across the college, across the university, and beyond the university. The questions are, "How do we teach it?" Should we have a coherent curriculum? We currently have a buffet of courses. Should there be required a structure with specific courses or areas and levels of courses? If so, what are the key concepts of that core? Should we offer a minor in sustainable energy?

We have more focus in the Master of Engineering program that is largely project based. Our current project is looking at how much energy could be saved by changing the windows in Olin Hall. How can Cornell save 15% energy?

Chemical Engineering has an MEng concentration in Energy Economics and Engineering. We also have a new joint Engineering/JGSM program combining an MEng in sustainable energy with an MBA (the MESE program). At this level our question is, "How best to market existing MEng degree programs in sustainable energy systems?"

At the doctorate level we are questioning, "What should the core set of courses be for a PhD student? How do you take the depth of knowledge in a technical field and be prepared to be environmentally benign?" We plan to develop a core set of courses to provide a systems view of sustainable energy systems:

- Management of Earth-Energy Systems– This is the big picture including the interplay of technology, the environment, economics, politics, sociology etc. Engineering is a bit player in the larger context of the global view of earth and energy systems
- Energy Systems – A systems approach for processes and products from cradle to grave.
- Systems Modeling – Hands on projects regarding sustainable living.

At this point we believe that there should not be a degree in Sustainable Energy. We lack sufficient depth. Should we create a graduate field of Sustainable Energy and offer a grad minor?

In summary we are seeking your input on how to define and spread energy literacy at the undergraduate level, how to expand and market our MEng and MEng/MBA sustainable energy programs, and how to structure PhD level training and pick the appropriate core courses and thesis topics to bring together energy and the earth's concerns from the outset.

We need to think about the context. Engineering students take 6 liberal arts courses. Poets etc. don't have to take a single course in technology. We want to explain to non-engineers what energy literacy is and spread the idea beyond the walls of Cornell.

From your perspectives and business experience, what are the big holes? How do we balance a broad education in energy-earth systems against deep technical knowledge within existing fields?
Cornell is demonstrating its commitment to sustainability by striving for a Green campus. We generate 16% of our own power and have held our energy use steady over the last decade through our hydroelectric and steam/electricity co-generation plants. We reduced our electricity use for air-conditioning by 85% by using lake source cooling and we have reduced our carbon dioxide emissions by 50K tons per year over the last 20 years. A new heat and power plan will be completed in 2010 which will reduce our coal usage by nearly 50%.

Questions:

William Hudson – I am a believer in letting the free market system determine the direction of the curriculum. What kinds of roles are the students playing when they graduate? Where is the market for these people? There is a lack of knowledge about energy efficiency in the building industry.
Paulette Clancy – Oil and gas industries have come back with a great force. 15-20% of Chemical Engineering graduates are going into these industries and also into green fuel companies.

Frank Huband – I see fossil fuels and renewable energy. In the middle isn't there nuclear? Is there any thought about nuclear? Pragmatically there will be more nuclear plants in the next 5-10 years.
Paulette Clancy – We see that nuclear is part of the equation of education and we have a course in that area. That is one of the reasons we think we need to educate engineers in the social context.

John Neafsey – Do you see delivering this as a spectrum so that your students can evaluate the options? Ethanol is the biggest joke.

Michael Goguen – Sequoia helped create 720 companies. Sustainability has gotten big – the third largest area of development. What is it that would make the Cornell graduates most attractive? A resume from an undergraduate should illustrate that the candidate is a great candidate. It shouldn't be buried -- it should be focused and visible.

Paulette Clancy – We agree. We would like to see a formal minor that is noted on the student's transcript.

Robert Shaw – There have been studies that predict 40 million green jobs in the next decade. Most people don't know anything about the sustainability subject. We are into 3rd-5th generation initiatives. Full systems analysis and understanding how it plays into the entire economy is important.

Susan Ying – One of the important sectors is the transportation industry – automotive and aerospace. We should be building cars that don't adversely impact the environment.

Roger Strauch – I want to reinforce your focus on energy literacy. Tomorrow's citizens won't be able to weigh in without energy literacy. You are on the right track if you think about what it takes to make us all energy literate. Ultimately we will apply that to where we go to work, how we vote, and how we allocate resources in the years ahead. The most important goal is to be leaders in the vocabulary and basic concepts.
Paulette Clancy - We agree. We have a captive paying audience in the freshman at Cornell. Then maybe we can go outside to have an impact.

Timothy Costello - We focus on the discrete application of energy. Network management and power distribution are also going through massive change. How will solar power be financed? We need to consider the network and economic models that will make the systems sustainable.

Paulette Clancy - We couldn't agree more. Our first alliance will be with Applied Economics and Management (AEM). Maybe it is time to hire new people in the power distributions systems areas.

Christine Mazier – It is tough to influence policy makers by introducing freshman courses. If one of the challenges is informing public opinion, one of the ways is to form a minor between public health and journalism as we did. You might have a similar influence on journalism students coming through Cornell.
Terry Jordan– Last year we had a focus on sustainability communications. We also have the advantage of cooperative extension as a ready made agent for outreach beyond the university. We feel compelled to define the few fundamental pieces of knowledge to communicate.

Geoffrey Hedrick – The rest of the university should have a passing understanding of things like efficiency. We drove the nuclear industry out of business through people who got emotional about the situation without an understanding of the technology. The average person should have more than the specifics of their field but a broader education including the ability to write and read and of the understanding of the fundamentals that go into energy production and distribution. Sustainability is going to become a political issue and an uniformed electorate has the potential to make bad decisions.

Sophie Vandebroek - Clean technology also includes water, air, and waste. How does it all fit together and how does it relate to your major in environmental engineering?
Paulette Clancy – That is a big question. Once you start trying to inter-relate energy and economics you have difficulty with people who don't have an education in one of the two areas. We are trying to offer short courses on things like solar cells for architects, and thermodynamics for economists so that students can move on to take something deeper.

There is a link to environmental engineering. Terry Jordan and I focus on systems modeling, the climate, earth systems, and energy. All of the students will think about these issues from day one and will have two advisors: one focused on energy and one focused on the environment. Graduate students are now more knowledgeable than their advisors.

Teresa Jordan – Environmental Engineering is a well established program in BEE and CEE. Our mission has been to focus on that which was missing. The chairs of BEE and CEE were part of the team that worked together to make energy visible and a strategic goal in the college. We have to take advantage of everything that exists too.

Evelyn Taylor Pearson – I applaud this effort. I wonder how integral it is to the basic engineering programs and the use going out into industry? How will it be integrated into all of the engineering programs?
Paulette Clancy – It is very important to CBE. For the last 15 years our students have been taught to develop benign systems.

In summary I have heard that:

1. A systems engineering approach is necessary,
2. There is a need for broader energy literacy at the undergraduate level,
3. There is a need for deep experts in specific areas at the graduate level,
4. Energy is only one piece of a sustainable future. There are lots of resources that are running out.
5. The university as a whole needs to be aware of all four of these issues.

Handouts provided to the ECC after lunch included:

- The March 25, 2008 Chronicle Online announcement of Jeffrey Testers appointment as the Croll Professor of Sustainable Energy Systems.
- ASEE Public Policy Briefings – (1) Energy and (2) University-Industry Partnerships and Technology Transfer

Cornell Center for a Sustainable Future - Sidney Leibovich, Interim Associate Director of the Energy Institute and Professor of Mechanical and Aerospace Engineering

The mission of the Cornell Center for a Sustainable Future (CCSF) is to create applicable solutions to global sustainability problems by:

- Establishing linkages to enhance research

- Promoting partnerships with government foundations, industry, NGOs
- Educating the leaders of tomorrow

There are three common themes that cut across these initiatives:

1. Connectivity
2. Communication
3. Making things happen

Sustainability issues will dominate society and we need to educate people who will have to deal with these problems. We are well positioned to take on this task at Cornell with a strong Engineering College and strong physical and life sciences and agricultural. All of these are important elements.

We want to establish linkages internally at Cornell. This is surprisingly not in good shape. The CCSF will provide a central point of contact for those outside Cornell and help us connect with industry to define the real problems and set our directions. This wide range of sustainability research will heighten our visibility. The problems of sustainability will dominate this century and we need to educate the people who will have to deal with these problems.

About 20% of the faculty at Cornell are working on sustainability. Here is an example of this sort of challenge. We assembled 18 faculty working in photovoltaics to meet each other. Most didn't know their neighbor was working on a similar problem in a similar discipline. Of the 18 people only 7 knew of each others work. We need to make connections easier and to communicate better. We will lay the groundwork for responses to proposals that call for large interdisciplinary efforts. We are not in as good a position as we might be. Another goal is to strengthen our impact by taking a broad collaborative interdisciplinary approach.

We need to establish partnerships. Often we are unaware of what the real problems are. We don't necessarily know what the people who are dealing with these problems every day know. These partnerships will help us set our directors. The Center will also be a central point of contact and heighten the visibility of our work.

In 2004 there was a report recommending the establishment of the Center and the connection of it to a larger sustainability initiative. President Lehman's call to engagement included Sustainability as one of the three priority areas. The Provost's Task Force on Sustainability followed up this call with a report in March 2006. In June 2007 an Implementation Committee appointed by the Provost also issued a report resulting in the establishment of the CCSF and following the original recommendations of the task force. Initially the CCSF will focus on energy, environment, and economic development. The Energy Institute, which preceded the Center, will be led by the College of Engineering and supported by CCSF.

CCSF will be an umbrella organization. It will include Architecture, JGSM, Human Ecology and Agriculture and Life Sciences. It will not manage research or instruction.

Participants will be from units university wide and the first year of funding ($3M Total and $1.65M for programs) will come from internal Cornell donor and general funds. In the future the CCSF will be funding through the endowment, gifts, and support from external partners. This is not how Centers in the past have operated. This new Cornell model makes the administration a little uncomfortable because they are paying for it.

CCSF plans to work towards its goals by:

- Providing seed grants for research
- Developing new research teams in response to proposals
- Facilitating internal and external communication and offering workshops
- Building partnerships and investment
- Fostering new courses and educational programs
- Outreach to enhance public understanding of sustainability and the work at Cornell
- Engaging academic units in the hiring of faculty who can contribute to sustainable solutions.

The first three items will be accomplished in the first year. The model is different than most venture opportunities. The money goes out to get things started but no money is expected to come back in. The first seed funding will be issued in May and will give a preference to proposals with potential early impact and those that involve cross disciplinary collaboration. Each of these grants will be for 6 months to 2 years. Unsuccessful ones will terminate. Successful ones will receive other funding and continue on their own. Workshops and symposium will be seeded.

Frank DiSalvo is currently the Director of CCSF. Sid Leibovich is the Associate Director for the Energy Institute. CCSF has an internal Faculty Advisory Committee and an external Advisory Committee. Jeff Tester, once he has arrived at Cornell in the fall, will step up to the Associate Director for the Energy Institute position.

We have already started to assemble teams to respond to proposal requests. The most immediate one is the DoE basic energy sciences one.

Current Energy Research Groups include:

- Biofuels production
- Fuel cells
- PSERC
- Photovoltaics
- Modeling and computation of energy systems and climate
- Combustion processes
- Wind
- Energy economics and policy

Questions:

William Hudson – I downloaded both the reports and looked at the makeup of your committee and linking that to our discussion about building awareness. It is in good

position to help understand how we bring awareness amongst the student body in the area of sustainability (freshman year orientation). You might want to use that committee.
That committee was an interesting one and a good one to work with. The center will follow the general guidelines of the report.

William Shreve – How do you expect continuing funding to come for the Center?
We have a donor David Atkinson who will partially fund the Center by giving $1M each year for 3-5 years. There is a need for additional donors and there will also be an endowment fund. The expectation is to build an endowment to support the Center.

William Shreve – Who are you hoping to partner with and how are you going to build those partnerships?
That is Dave Deitrichs job. He has just been hired and is making contacts with potential corporate partners throughout New York State and beyond. We are hoping that he is going to start to make these connections.

Donald Giddens – There are a lot of stakeholders and a lot of interested parties. I looked at the timeline and about how fast things are going. I urge the college to not be held back by the slowest link in the chain when you are dealing with such a diverse group of people. Be the lead dog and push it as fast as you possibly can. Don't be held back by others. The strategy is to make progress and show results to the donor.
The implementation committee recognized that each of the three Es will develop at their own pace and the energy initiative will develop the fastest. I think that is the case.

Kent Fuchs – Our next speaker is an MIT professor, Jeff Tester. Jeff you should tell us how many Cornell degrees you have in your family.

Sustainable Energy Research and Education – Jeffrey Tester, Professor of Chemical Engineering, MIT, and future Croll Professor of Sustainable Energy Systems and Professor of Chemical and Biomolecular Engineering, Cornell University

I have my degrees from Cornell and my wife also is a graduate of A&S here and went on to get her PhD. My daughter was also in A&S and took up veterinary medicine and is married to a Cornelian. We were destined to come back to Ithaca.

I have been developing a personal relationship with David Croll. It is an honor to have this position. I hope I can share with you some of the reasons why this will be a great and exciting opportunity for me.

I originally went to school at Cornell and now I am back again. There are many opportunities for multiscale, multidisciplinary energy research here. I want to talk about the metrics and dimensions of sustainable energy and the variety of definitions. Cornell is a much bigger challenge that at MIT because you have so many parts here. The lessons learned from pursuing energy education at MIT.

Before I came to Cornell I was working on a diary farm in Connecticut. Because of the comments made this morning about nuclear power, I want to point out that my first engineering project was building a nuclear reactor in my basement. My early introduction, as a freshman at Cornell, to sustainability was water desalination using the Cornell method. It convince me that Chemical Engineering was the way to go. I had many early lessons as an undergrad and Cornell is a premiere institution and my experience at MIT has reinforced the value of my Cornell education. I spent a lot of years drilling deep holes in New Mexico and came back to MIT to reinvigorate an educational program to connect MIT graduate masters students with real engineering Practice.. This might be a good model to follow in the energy and sustainability area here.

I had fun as the director of the MIT energy lab. Some of it was challenging in a time that energy wasn't regarded as it is now. About 10 years ago we started teaching a course in sustainability largely because we wanted the students and other faculty involved to help us to define this area. This eventually led to my writing a text book. Now I am co-chairing the energy institutional task force at MIT.

Engineers love big problems but we don't appreciate how far this set of disciplines has come and the tools available. Looking at impacts at all scales is something engineers didn't used to do. Now we are using quantum mechanics and looking at systems. There is a shift of thinking about providing power in a remote village versus a big city, or providing alternative fuels versus industrial processes. Making students aware of the economic well being, social justice and equity is critical. It is certainly not just about technology. If we expose our students to this early on it will make a big difference. So here are the five-Ds:

1. Discovery
2. Definition with basic research
3. Development of technology
4. Demonstration at commercial scale
5. Deployment in the field

Students can appreciate this in some depth in their early years. We try to expose them to a rich base with a lot of uncertainty and risk in it and many different optima on a complex surface. This is the dimensionality of this problem.

After you have worked in the area for a while the attributes are easy to identify:

- Non-depletable energy
- Low impact
- Accessible and well distributed
- Emissions free
- Scalable and efficient
- Dispatchable Robust
- Flexible
- Economically competitive

Qualitatively this is easy but when you try to quantify it is extremely complex. This is not a list of singular solutions. There are a lot of uncertainties in the potential impacts and damages that might result from that.

We try to think how a research university can put together an educational program that will work. Research and education are synergistic but research across disciplinary boundaries occurs naturally in many situations but not in all situations. It is not natural for economists to interact with engineers. I think that Cornell will have to face that obstacle as we move forward. Only a few institutions are really capable of providing a comprehensive multidisciplinary energy education.

The assets of Cornell are so strong across the board it really makes sense to focus on education. How you do it is tricky. I call this the people we need. We are facing a shortage of graduate students and faculty to carry out the transformational change that we need to do. They need to understand the sustainability language to make good energy choices. It requires both depth and openness to think about the area across the broader context of social science and humanities. Cornell is embracing this in what they do to their buildings and how they carry on their daily activities.

We also feel that getting students involved in deployment to address societal needs and to get the institution itself, the deans, the president and the provost to really buy into this not just by creating it but also by allowing the task force to have the resources for implementation. Coherency and depth across disciplines is not widely practiced. There is a lot of shallow work that goes on and that is not going to solve this problem. The undergraduate curriculums are constrained and somewhat inflexible and students may not have enough time to complete this education without taking a double major or staying another year. Often teaching these subjects is seen as being softer. Getting rid of this misperception is important to tenure decisions and to attracting you faculty. The sustainability major may not be the appropriate vehicle to get the kind of exposure to sustainability ideas. It may have to be a minor or a secondary master's degree. There are limited number of faculty to teach this and the funding for multidisciplinary education is constrained by the disciplinary structure of universities.

The approach we have taken is to develop set of core energy subjects as electives that could be listed across the schools of science and engineering. Some are focused in particular areas. To make the general student aware of the importance of this we are integrating this content into existing departmental programs and the general institute requirements. Project based courses and capstone courses in energy are part of this and may be more appropriate for seniors and graduate students than freshmen. We are also in the process of developing a university-wide minor for undergraduates and graduate students. The courses are cross listed so they can get credit for them wherever they take them.

After four or five years we started writing a textbook that tries to teach students how to do analysis. It doesn't propose a particular set of solutions but tries to teach system analysis in the context of many uncertainties.

We developed a roadmap of outputs for undergraduates: perspectives, foundations, integration and advanced knowledge. We try to place subjects in the structure to show what we would like to see. This helps us think through it as a faculty.

The last slide is a concept thinking about creating an institute wide undergraduate minor. There are only double majors now – which take a special person. A minor should be digestible and should allow a student to count some of their requirements towards a minor as well as to take special subjects to develop knowledge and understanding within each domain: science domain, technology domain and the policy/business domain. Supporting this kind of effort with teaching assistants and faculty time is not easy. That is the end of my remarks. Thank you.

Questions:

Robert Shaw – Why not make the energy program a test case for partnerships with industry to produce things that could be turned into a commercial application? From a venture point of view it is not feasible: (1) faculty are not interested in leaving and (2) there is no infrastructure. Select a set of venture players to look at technologies coming out of energy research. Have faculty come to Boston once or twice a year to meet with the investors and see where it goes. If it works in energy, maybe it would work in other places and increase IP.

Richard Aubrecht – Missing in your course descriptions is an analysis if what is proposed is a long term successful possibility or not. Analyze energy ideas on the basis of BTUs in versus BTUs out. Fundamentally in the long term the technology will win out. Why am I not hearing that in any of the discussion about education? It will drive the economics.
It is something we believe in and make that point in daily discussions in class and in looking at life cycle costs and the analysis of many options. People need to understand the dimensions of making assumptions about energy input versus energy output. They are not as simple as you think. When we do the biomass case, for example, we talk about Pimenthal's and DoEs analysis at the two ends of the spectrum. Students don't have to be experts, but they have to be skeptical.

Richard Aubrecht— I am suggesting taking it beyond that in terms of the analysis you ought to start with the BTUs – BTUs in versus BTUs out - then do the analysis – not the other way around.
Let me share an example. We have students from Harvard in our MIT course. Most are out of the government school and they don't appreciate what we are talking about. We spend a lot of time teaching them the laws of thermodynamics. They then help us with the other side of the domain: economic analysis, thinking about policy, thinking about poverty etc. It is a good, but hard, balance. You are right on.

Joseph Bonventre – Cornell has an unfair advantage having the Agriculture School and space. The students made it clear at lunch that the some of the most powerful experiences are the projects and we heard this morning that Cornell is producing 15% of its own energy. I wonder if this could be laid out in a creative way as a testing ground to build some things, create some things – physical things here - getting people together and excited by that to learn by doing to help realize the campus idea.
That is a great idea that has been discussed in regards to teaching labs linked to the Center on energy or sustainability. I was talking to Susan Henry this morning about that. It would be a terrific opportunity for Cornell. Maybe that is a way in the short term to put this together. You need teaching space, discussion space, space for visitors, and a working laboratory that shows there are multidisciplinary parts to this. Think about how students would react when they come here and this is one of the first things that they see.
William Shreve – What about the basic level of knowledge versus learning the subject in depth?
We had this discussion with a group of faculty and found it wasn't very productive (scientists, engineers, and social scientists). We separated them, put the engineers in one box and the science people in another, and the social science faculty in another, and let them define energy literacy key elements for an undergrad or grad student and it is slowly coming together. Once people believe that this is not just another program that will marginalize their discipline, they will find their way through this. I think it has a probability of working here in a much larger context.

Joseph Bonventre – Maybe you said it before, but what department are you in?
I am in Chemical Engineering at MIT. I will be in Chemical and Biomolecular Engineering at Cornell, but the Center is a multidisciplinary initiative across the college. I will have to wear two hats but that's not necessarily a conflict of interest – it makes it interesting.

Kent Fuchs– Let me share the context for Jeff's position. We decided as a college to push ahead with the energy part of the Cornell sustainability initiative. We got resources from David Croll to do this and conducted a search across the college. The position could have been in any department. We had four finalists and Jeff was our top choice and each candidate was in a different department. Jeff will wear three hats: One in the Sustainability Center, one in the energy initiative within the college, and one as a faculty member in CBE.

With your permission we will email out all of the ECC comments to department directors and chairs.

We have asked three members of the Council to talk about the role of higher education and specifically the role of Cornell and the College of Engineering and energy opportunities for research and teaching. Then we would like to hear a response from the entire Council. You have in your packets the questions that we gave to them to provide context for the panel discussion.

Energy Panel: Michael Goguen, Sequoia Capital; Evelyn Taylor Pearson, BP; Robert Shaw Jr., Aretê Corporation

Michael Goguen – Sequoia Capital is into broad sustainability issues including water technology, green and clean, and brown tech – cleaning up or improving existing technology. The timing is better than you think to do something at Cornell. Economic forces like oil resources and global security coupled with environmental concerns and public awareness (Gore's movie) equal the perfect storm. That translates into things we should care about in this environment:

- Heightened corporate interest – higher and more hungry for innovation
- Student interest – this has caught a lot of people's interest who ordinarily wouldn't have been interested in CS or CE.

The timing is perfect. Cornell needs to move aggressively.

The challenge is that the area is similar to the challenge we had when we started investing across this area because it is incredibly broad. This is a tactical challenge because the area stretches across so many disciplines and schools.

There are areas the school should focus on from a faculty point of view and when directing students. I suggest that the university not be completely purest in terms of the completely green technologies – the ones that fit every bullet on the criteria list. You can make a dramatic impact with technologies that improve things some - a bit. For example if you had a technology that made combustion engines twice as efficient it would have a massive impact. Would they still be spewing greenhouse gases? Yes, but it would still have a huge impact. The industry, venture capitalists and corporations, is extremely eager, including oil and gas companies, for any innovation that can make a dramatic impact. I hope the definition and scope is broad enough at Cornell that you won't frown on those things that look too dirty. Specific areas of interest include:

- Energy efficiency – a near term area - getting more out of what we have
- Energy storage – there is a need for breakthroughs
- Electrification of transportation – is on the verge of being viable - better batteries
- Fuel conversion/gasification technologies – those are near term as well. Companies are currently turning municipal waste into something - garbage in – jet fuel out

The core area of nanomaterials has brought near term applications for clean, green technologies. Specific problems to be solved involve surface areas and nanomaterials dramatically increase surface area whether it is a membrane in a fuel cell or a solar cell, or solar thermal using photonic focusing properties of nanoparticles.

Be sensitive to what industry is very hungry for. A global big picture philosophical concept is important but don't forget the pragmatic innovations that could make a big difference.

Robert Shaw - Research to Enable a Sustainable Energy Future

In my family we have at least nine degrees from Cornell. Until 6-8 years ago the notion of the carbon problem was not high on my screen. Since then I have spent a lot of time on the issue. Now carbon is the biggest problem and it breaks down into two issues. One of them is the existing fleet. Very few people focus very much on the fleet. That is what got us in trouble and it is not going away soon. For example, a typical turnover time for a vehicle is 14 years, and for a house many decades. These things don't change quickly.

The far more important issue in my mind is the 17 TW Green Energy Gap by 2050. That one terrifies me.

There are twin challenges:

- Enhanced energy efficiency to deal with the existing fleet
  New sources to fill the Gap

- Student overlay – Cradle to Cradle – design is a statement of intent so in a process, product, or system design you are reflecting what you actually intend. If the product or process is highly polluting, it means that in effect that is what you intended. That is not what people normally think. They think lets just do it the cheapest way and not necessarily design for the good of the planet. The notion that design is a statement of intent should be core and overlay everything that you do.

The nuclear industry is dealing the 17 TW problem. The 17 TW problem is the new resources that will be needed to be added to the system in order to avoid going over 550 parts per million of carbon. The total amount of energy worldwide is in the order of about 11-12 TW. We are at 380 and approaching 400 ppm of carbon quickly. It was at 250 ppm for the last 150,000 years and in the last tiny piece of time it has shot up like a rocket.

The numbers on the chart are not Argonne's but rather Nate Louis's numbers from Cal Tech. They appear in a National Academy report. The basic point is that there are really only two options.

The 17 TW problem equals 17,000 1-GW reactors when today the world's entire fleet is only 400. Think about Iran are we going to deny them nuclear power or let everybody have it? The other interesting option is the solar option at 600 TW. My view is that the ultimate solution has got to the solar/hydrogen approach. It may not happen quickly and most observers say that time is not on our side. We have at best a decade before we go over that magic number of 550. We can do things very quickly but we have to choose. Should we invest in retooling industry or the space program? My view is that we need to refine, improve, and find cost efficiencies of these two technologies. Hydrogen is substitutable everywhere you can now burn a fossil fuel. It substitutes easily for natural gas and petroleum in virtually any application.

We need to work on new ways to enhance efficiency, increase lifetime, and provide storage. At the end of the day my view is that the solution is materials, materials,

materials. Systems have to be put in place too but you can't do anything if you don't have the stuff that makes it work. In that regard, I think a few things that are very interesting include:

- Nanosilicon wires – for producing pv
- Quantum dots – increase efficiency – we can do photovoltaic efficiencies approaching 50% conversion (average today <20%)
- Carbon nanotubes for hydrogen storage
- Chemical and metal hydrides
- Membranes for improving the lifetime and cost effectiveness of fuel cells

Those are a few illustrations of the kind of things that I think are really exciting.

It turns out as I was thinking about this, up pops on my screen an example of the perfect study of a paper published in January out of Prof.Wiesner's group with Frank DiSalvo and others. They came up with a way to produce a couple of important materials, one of which is porous films of crystalline metal oxides, in a single step instead of multiple steps. That is an interesting step towards cheaper production of materials towards fuels for the future. If I were to pick a prize for the day that would be the kind of thing that I would be interested in.

There will always be skeptics as there were in 1875. The Congressional Record of 1875 documents the menace cost challenges of automobiles and gasoline. This is symptomatic of what worries me about the energy people in general is that we are so stuck in our past place and we need to break away to solve our carbon problem. I sure hope that Cornell and other universities can really do something like that.

Evelyn Taylor Pearson – BP has an effort in alternative energy. The expectation is that fossil fuels will be important for decades to come. There are a lot of changes in the world. The rise of international oil companies and the amount of reserves they hold. Reserves to production rates world wide are around 40 – in Saudi Arabia the rate is about 80. In North America over the next 20 years our proven reserves could be depleted. They can change and increase but may cost a different amount of money to explore and produce. We could be increasingly dependent on external sources for these fuels. With the U.S. and China both being major users and a limited amount of reserves, security of supply and security of economic prosperity will be great concerns. They are driving the search for diverse supplies.

Greenhouse gases our increasing along with increasing concern about their effect. How can we minimize the impact on the earth and on human populations? We will see a mix of energy resources with an emphasis on a zero or near zero carbon footprint. CU is well positioned with its broad influence to have an impact. Understand the causes and effects of climate change. There is still some misunderstanding regarding what will happen to the gases and earth temperature.

Provide advice on technology recommendations and provide technical solutions to alternate energy sources. Integrate this work with energy companies. Potential sources

will include bio-fuels, bio-mass fuels, and energy crops. Processes for fuel production such as microbes releasing energy to produce energy will also have potential.
BP is looking at bio-fuels, solar energy, wind, geothermal, fuel cells, and hydrogen power. We are building two hydrogen power plants enabled by carbon capture and sequestration. We don't see hydrogen used for transportation.

Enablements to cleaner energy include:

- Carbon sequestration
- Limitations on transporting energies – alternate transportation and distribution
- Enhanced oil recovery
- Identification of oil and gas, natural gas, clean coal technology – we have a lot of coal reserves
- Increase efficiency of energy use
- Waste energy use and energy conservation
- Efficient power systems – distribution, vehicle technology, improved batteries that are stronger and have a longer life, improved vehicles and vehicle production
- Mass transit systems – we missed an opportunity for efficient designs as the population shifts to a more urban setting
- Consumer education

The College of Engineering can provide:

- Advocacy
- Understanding of cause and effect
- Advice regarding technology
- Expertise

A lot of the impact in 20 years will be driven by decisions today. Every week 1 GW of coal fired plants are being built without abatement. Fuel efficient vehicles have not been improved enough. Urban/Suburban design has not helped enough.

Discussion:

Michael Goguen – At Stanford two graduate students combined effort and formed companies with a market value of greater than $200B. Market sizes in this area will be at least an order of magnitude bigger. If Cornell had innovations with a massive impact you are talking about at least as big an opportunity.

Susan Ying – Did I hear right that BP doesn't think Hydrogen will be used for transport?
Evelyn Taylor Pearson – Yes – We don't think efficiency and infrastructure issues will make it feasible.

Robert Shaw – That question always comes up. NSF is doing an analysis. Infrastructure cost runs less than 10%. Total cost is measured in a few months of the Iraq war – 10s of billions. Honda, GM, and Toyota don't think that infrastructure is the issue, but the cost of vehicles is. As a societal cost it is not large and infrastructure should not cause concern. With economy of scale eventually it will be cost efficient.

David Croll – Why did you pick a $50M/year for 10 years with a small group as a research structure instead of spreading the money more broadly?

Evelyn Taylor Pearson - BP started an energy biosciences institute with Berkeley, Illinois-UC, Lawrence Livermore Lab, and over 150 researchers from BP. We are working on some public research and some proprietary research and specifically looking at problems in area of getting energy from bioscience. The approach provides an ability to have more direction over the research and to be able to manage what research will be done. It is very early in the process and we don't have results yet.

William Shreve – It is a perfect storm and these problems won't go away quickly. It will take investment over a decade. How patient will the venture community be as we start looking at longer term solutions?

Michael Goguen – There is instant gratification now. There are dramatic markets for things that could help. The solar market, for example, is a rising tide. If you make good solar panels, you can sell more than you can make but that doesn't last –it is a temporary cycle. Many of the areas that I defined as needs are short term. Take the battery -- there is a good coverage across the spectrum and there are people paying real dollars right now.

William Shreve– Improvements in new materials will take a while before they translate into a product or solution.

Robert Shaw – The time scale on lithium ion batteries wasn't as long as you might think. It took less than five years to develop and market and the market went from nothing to over a billion in that period.

William Shreve – That usually happens when you are replacing a technology. If you are creating something new it takes longer.

Robert Shaw – Everything in energy is substitution. (Tim Costello concurred.)

William Shreve – Look at energy from florescent bulbs. It is taking a long time to get it started.

Sophie Vandebroek– What are the key problems not yet being addressed sufficiently?

Michael Goguen - We are talking about a spectrum of problems to be solved and some research topics could have immediate gratification. Other important problems have a much longer time period and require societal change.

William Hudson –I don't see the disruptive change on how energy is delivered. China for example leap frogged over wired to wireless. The energy distribution is being developed in the same way. I don't yet see the disruptive technology to replace what we have and public policy is not driving significant change. There is a lot of criticism of the oil

industry right now to invest in fuels other than oil. Biomass has totally disrupted our food source economy and is not scratching the demand for gasoline. We are not getting a lot of help from public opinion or our government.

Mike Goguen– Electric cars went from golf carts to the Tesla (100% electric with 135 mpg equivalent) in the last five years. Some are practical and get 100 miles on a charge.

Geoffrey Hedrick – It might be easier than distributing hydrogen.

Michael Goguen- If there was a fairly dramatic shift from fuel to electrons it would make a big difference. Solar is also hopeful and the cost is coming down. People forget that parity compares cost against a baseline and that baseline, electricity, is going to skyrocket.