The Industrial Physics Forum 2007: The Energy Challenge

Room: 602/603 - Session IPF-TuM

Energy for Low Carbon Input

Moderator: J. Hobbs, American Institute of Physics

8:00am **IPF-TuM1 The Prospects for Low-Cost Photovoltaic Electricity**, ***D.E. Carlson***, BP Solar **INVITED**

In the last decade the photovoltaic (PV) industry has grown at an annual rate of about 35%. While PV modules made in the 1960s sold for hundreds of dollars per Watt, prices are now in the range of $3-$4 per Watt, and this corresponds to levelized electricity costs of about 20-25 cents/kWh for large commercial systems. Silicon technology has dominated the industry since its inception and about 91% of all solar cells sold in 2006 were based on crystalline silicon. However, there are a number of other technologies under development involving materials such as amorphous silicon, microcrystalline silicon, cadmium telluride, copper-indium-gallium-diselenide, gallium arsenide (and related compounds), dye-sensitized titanium oxide, nanocomposite materials and organic molecules and polymers. The U.S. Department of Energy has set a goal of attaining levelized electricity costs of 6 to 8 cents/kWh for commercial PV systems as part of the Solar America Initiative, and this will require not only a reduction in the cost of the PV modules, but also in the cost of inverters, support structures, wiring and installation. Continued improvements in solar cell conversion efficiency will help to reduce costs. While the efficiency of crystalline silicon PV modules is generally in the range of 12 to 15% today, the module conversion efficiency should increase to about 17 to 20% by 2015. In the laboratory efficiencies as high as 24.7% have been demonstrated for single crystal silicon solar cells. The efficiencies associated with other PV technologies also continues to improve, and thin film copper-indium-gallium-diselenide solar cells have been fabricated with conversion efficiencies as high as 19.5% in the laboratory. Efficiencies as high as 40.7% have been demonstrated for a triple-junction cell operating under concentrated sunlight. There are also a number of new potentially disruptive PV technologies that could lead to significantly higher efficiencies in the next few decades, and new types of solar cells may be developed using novel multijunction structures, intermediate-band semiconductors, multiple-carrier generation, collection of hot carriers, etc. that could lead to conversion efficiencies in excess of 50%. If the growth rate of the last several years continues, then PV module prices could fall below $1 per Watt by 2030, and PV could be supply about 10% of the world's electricity in the 2030-2035 timeframe.

8:40am **IPF-TuM3 Constraining Carbon to Confront Climate Change**, ***R. Bierbaum***, University of Michigan **INVITED**

Article 2 of the Framework Convention on Climate Change calls for stabilizing concentrations of greenhouse gases in the atmosphere at levels that prevent *dangerous anthropogenic interference with the climate system* and in a time frame to *allow ecosystems to adapt naturally to climate change*. Increasingly, expert assessments are calling for limiting the global average temperature increase to 2-2.5oC above pre-industrial levels and atmospheric concentrations below 550 ppm CO2-equivalent to meet these goals. Given that the earth is already committed to 1.4oC today and emissions are growing rapidly, domestic and international policy responses must be immediate, significant and sustained. The size of this task and the potential roles of various technologies and policies to achieve these goals will be described. A roadmap to confront climate change will need to include the following elements: accelerating the implementation of win-win solutions; developing a new global framework for mitigation; identifying strategies to adapt to ongoing and future changes in climate; creating and rebuilding cities to be climate resilient; increasing investments and cooperation in energy technology innovation; and forging partnerships across governments, corporations, the financial community and private organizations.

9:20am **IPF-TuM5 Offshore Sustainable Electricity Supply Systems: The POSEIDON Vision**, ***D. de Jager***, Econcern B.V., The Netherlands **INVITED**

Seas and oceans cover over 70% of the earth's surface. They already play a crucial role in the global energy supply: a considerable part of our oil and natural gas is extracted off shore, and will be in the future. But at sea, also large potentials of renewable energy sources can be harvested, like wind, wave, tidal and osmotic energy. By offering space, abundant energy resources, and the opportunity for geological sequestration of carbon dioxide, the seas offer a huge opportunity to meet the world's growing energy demand in a sustainable way. The POSEIDON vision is a seaway to harvest these energy resources and to create a sustainable electricity supply system. The heart of the concept is the construction of an off shore electricity transmission grid. This grid connects major onshore demand regions with each other, and with off shore fossil and renewable electricity production and storage technologies. In combination with geological sequestration of carbon dioxide (including enhanced oil or gas recovery), a carbon free electricity supply could be attained. The POSEIDON vision emphasizes the importance of an integrated system approach. Production, conversion and transformation, transmission and distribution, storage and final energy demand are not separate elements, but must be considered from a system perspective. Also changes over time should be taken into account. POSEDION builds on current infrastructure, ensures access to sources, balances load and demand, and enables the incorporation of new emerging off shore technologies. By combining these technologies and marine resources, the seas offer the opportunities to build a truly sustainable energy system: cheap, reliable and sustainable. POSEIDON is an initiative of Econcern, the sustainable energy solution provider. Europe is seen as an excellent region to prove the concept. The North Sea region will be discussed as an example, as well as the key technologies that are expected to form the basis of this concept: off shore wind and wave energy, high-voltage electricity transmission technologies, and zero emission power plants. Developing POSEIDON-like systems asks for venturous project developers and other companies, inventive policy and decision makers, and creative researchers. They all can contribute to building this new, truly sustainable perspective.

10:40am **IPF-TuM9 Science & Technology Barriers to Economic Ethanol Biorefineries**, ***M. Himmel***, NREL **INVITED**

Lignocellulosic biomass has long been recognized as a potential low-cost source of mixed sugars for fermentation to fuel ethanol. Several technologies have been developed over the past 80 years that allow this conversion process to occur, often in wartime context, yet the clear objective now is to make this process cost competitive in today's markets. Replacing 30% of U.S. 2004 finished motor gasoline demand (or about 60 billion gallons) with ethanol by 2030 will require a significant increase in ethanol production over today's corn starch-based industry. This process is technically feasible for corn stover and wheat straw today using biochemical conversion technology that includes pretreatment, enzymatic hydrolysis, and fermentation. However, the process remains fundamentally inefficient and is therefore risky to commercialize. Cellulosic ethanol production via biochemical conversion can provide fuel at prices commensurate with historical gasoline prices (<$1.00/gallon) only by taking full advantage of critical scientific breakthroughs in feedstock production and biomass conversion science. Indeed, in order to ensure a successful transition from existing to 2030 technologies, investing in knowledge-based solutions to critical barriers is essential.

11:20am **IPF-TuM11 Carbon Sequestration to Mitigate Climate Change - A Geological Perspective**, ***R.C. Burruss***, US Geological Survey **INVITED**

The fraction of global carbon emissions that must be eliminated to impact climate change is huge, about 70% of present emissions over many years (100's to 1000's of gigatonnes of CO_2) to stabilize atmospheric CO_2 at about 500 ppm. Such reductions require all means of carbon management, including geological and biological sequestration; shift from fossil fuel to renewable biomass; electricity from solar, wind, and nuclear power; and improved efficiency of generation and use. The IPCC Special Report on Carbon Capture and Storage (2005) estimates that storage of CO_2 in geological formations (geological sequestration) could eliminate about 50% of emissions. The potential role of enhanced carbon storage in biomass and soils (biological sequestration) is difficult to evaluate due to the complex dynamics of greenhouse gases in the global biosphere. Geological sequestration involves injection of supercritical CO_2 into porous and permeable rock formations at depths of 1 to 3 km beneath low permeability seals. Storage formations include oil and gas reservoirs, saline aquifers, coal beds, and organic-rich shale. Over 30 years of experience with CO_2 injection in oil fields for enhanced oil recovery demonstrate that injection and storage of CO_2 is possible with existing technology. Geological sequestration projects currently deployed in Norway, Canada, and Algeria, collectively store 3 megatonnes (MT) CO_2/year. For perspective, a 1000 MW coal-fired power plant emits about 4 MT CO_2/yr and the largest CO_2 separation plant captures 4 MT CO_2/yr. Clearly, CO_2 capture and storage to eliminate a significant fraction of atmospheric emissions will require deployment of new energy systems at an enormous scale. Although the basic principles of geological sequestration are well known and reservoir engineering for CO_2 injection is understood, significant research remains. A particular concern is identification of storage sites with adequate capacity for commercial projects (CO_2 storage from a 1000 MW power plant for 50 years requires a volume equivalent to a 2-3 billion barrel oil field). Other concerns include detailed knowledge of the integrity of sealing formations, and the rates of reaction of CO_2 with dissolved components in formation water, host rocks, and organic matter. This information is needed to assess the permanence of CO_2 storage and the potential environmental impacts of leakage.

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