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Energy Education, Transformative Research and Wicked Problems

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Miami Beach – 1 meter ocean rise – E. Mazria – Architecture 2030

Recent Comments by Ernst von Weizsäcker – UC Santa Barbara

- Lots of Doom and Gloom Statements – CO_2 Capture, F-T development, biofuels damage.
- Some sense in keeping energy costs high and in line with energy productivity. (Energy productivity measures the output and quality of goods and services generated with a given set of inputs. Relationship between energy demand and economic growth)
- Factor Four – Doubling Wealth, Halving Resource Use - Book
- Factor Five – Resource Productivity – New Book

Challenges for the Chemical Sciences – Chemical Transformations (N. Lewis)

- Methane Activation to Methanol: $CH_4 + (1/2)O_2 = CH_3OH$
- Direct Methanol Fuel Cell: $CH_3OH + H_2O = CO_2 + 6H^+ + 6e^-$
- CO_2 (Photo)reduction to Methanol: $CO_2 + 6H^+ + 6e^- = CH_3OH$
- H_2/O_2 Fuel Cell: $H_2 = 2H^+ + 2e^-$; $O_2 + 4H^+ + 4e^- = 2H_2O$
- (Photo)chemical Water Splitting:(Nocera & Kanan – Science, Aug 22, 2008)
  $2H^+ + 2e^- = H_2$; $2H_2O = O_2 + 4H^+ + 4e^-$
- Improved Oxygen Cathode; $O_2 + 4H^+ + 4e^- = 2H_2O$

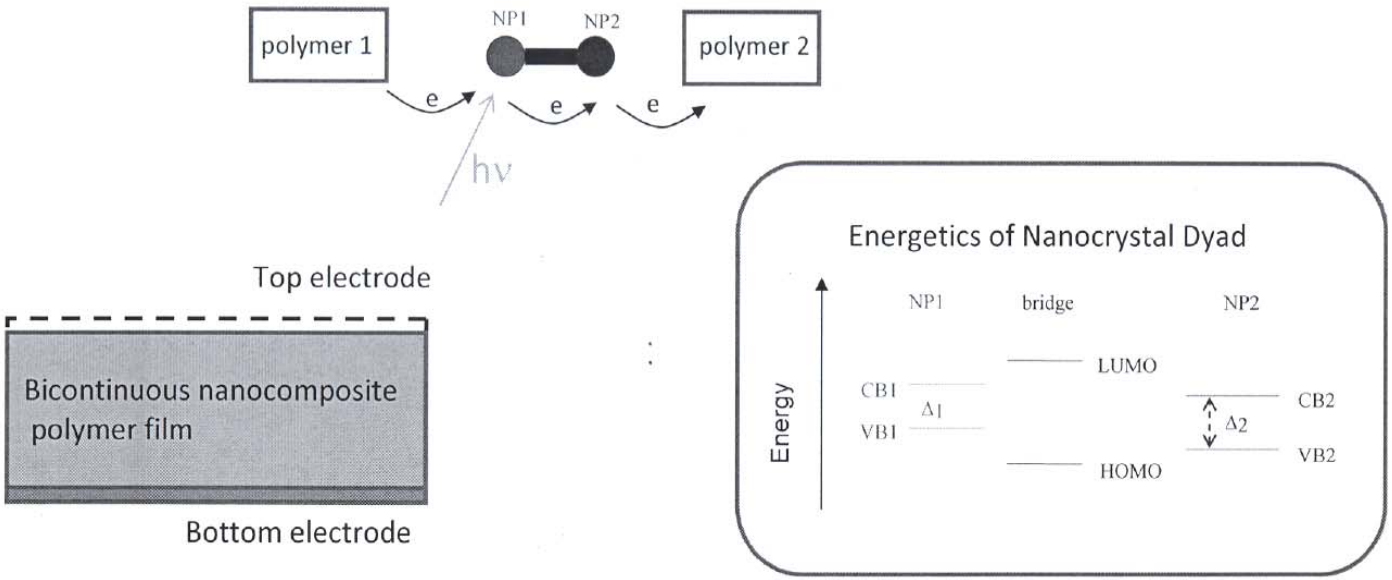
Common Theme

- Multi-electron-multi-proton reactions with sunlight and a catalyst of some sort.

Top – light causes electron flow D.Waldeck

Left – Block Diagram of a Photovoltaic Device

Right – Energetics of Dyad Charge Separation (Conduction/ Valence Bands – lowerest unoccupied and highest occupied molecular orbitals



Ultrafast plasmonics for energy conversion – H. Petek

- Efficient coupling light into and out of **nanometer scale semiconductor nanostructures** is crucial for a variety of energy related phenomena such as **light harvesting in photovoltaic solar cells and solid state lighting**. H. Petek has developed a unique ultrafast coherent microscopic method that is capable of imaging electromagnetic fields with 20 nm spatial and <10 fs temporal resolution. By combining **femtosecond** laser pump-probe excitation of nonlinear two-photon photoemission with photoemission electron microscopy, they are able to record movies at a 300 **attosecond/frame rate** (corresponding to ¼ of an optical cycle) of electromagnetic fields in nanostructured metal or semiconductor devices. Through iterative, fabrication, imaging, and analysis, they developed optimized plasmonic structures for transduction of electromagnetic waves on the nanometer scale.

Research Strategies

- Incorporate more transformational approaches and topics. (Extend research to areas that have high risk but big payoffs.)
- Take these risks.
- Fund more exploratory options in energy research.
- Explore basic physics and chemistry on the nano scale and in electron transfer processes. Solar triggers electron transfers.

Research Strategies (contd)

- Do more multidisciplinary research.
- Learn to talk each others language.
- Become better at marketing novel energy ideas.

Multidisciplinary Teams

- Look to multidisciplinary teams across the engineering, science and social science community.
  - The multidisciplinary teams should include the various stakeholders from
    - Academia
    - Industry
    - Government

Ray Orbach's Initiative – DOE Office of Science – Transformational Science

- Efficiency -
- Wind -
- Bioenergy - Termite pathway of lignin to sugars
- Nuclear -
- Fusion -

Simulation and Modeling Tools

- Parallel Processing
- Supercomputers/Clusters
- Grid Computing

Education Issues

- Focus more on projects in energy of all types from coal to solar. Short to full term design projects.
- Encourage students to explore more basic physics, chemistry and biological principles. New concepts comes from concentrating on the basic and trying to apply them.
- Include more efficiency analysis and sustainability in the curriculum.

Education Issues (contd)

- Relook at nuclear. (Bring in the retired engineers to help with the planning and teaching.)
- Explore the mining option.
- Concentrate on Power Engineering.
- Insert renewables incorporated into the mix.
- Insert wind applications into the curriculum.
- Run continuing education programs on energy from efficiency to technology.

Energy Challenges – Is this a Wicked Problem?

- Wicked problems have solutions that can have degrees of good and bad.
- Wicked problems can be tamed rather than solved.

10 Properties of Wicked Problems – J. Camillus – Harvard Business Review

1. There is no definitive formulation of a **wicked problem.**

It's not possible to write a well-defined statement of the problem, as can be done with an ordinary problem. This is certainly true for our energy challenges. **The problem is multi-faceted and involves many contributing and intertwining effects.**

Wicked Problem (contd)

2. Wicked problems have no stopping rule.

While we would like to think of the energy challenges as having an end, it appears that that may not come for years as new technologies are developed and incorporated into the energy mix. One must cope with the issues at hand.

Wicked Problem (contd)

3. Solutions to wicked problems are not true or false, but good or bad.

The true and false issue is definitely a property of the energy challenge. Good and bad is definitely a measure but often times the degree of good and bad may not be immediately obvious and may change from day to day. One effect here that must be intimately tied into this is the environmental consequences of the choices we make.

Wicked Problem (contd)

4. There is no immediate and no ultimate test of a solution to a wicked problem.

As we know, we may embark on a strategy to have a certain energy mix only to find out that a few years later this is not correct and should have be modified the solution along the way or stopped it as a strategy.

Wicked Problem (contd)

5. Every solution to a wicked problem is a "one-shot" operation; because there is no opportunity to learn by trial and error, every attempt counts significantly.

The process of doing something and monitor its progress certainly would seem like a good strategy for the energy challenges. The experiment attempted can yield information which is certainly a opportunity for trial and error.

Wicked Problem (contd)

6. Wicked problems do not have an exhaustively describable set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.

   Describable solutions certainly are limited at first and will hopefully yield more as additional experiments are carried out or strategies followed. The existence of a well-describable set of operations is not in the energy challenge either.

Wicked Problem (contd)

7. Every wicked problem is essentially unique.

Are the energy challenges similar to other problems we have had. I think not. The energy problem is unique. If we had a model we could apply from former difficult problems we probably would have been used this and resolve things by now.

Wicked Problem (contd)

8. Every wicked problem can be considered to be a symptom of another problem.

Energy is a symptom of other problems such as rapid economic development, an every increasing wealth cycle and again intertwined with the environmental issues.

Wicked Problem (contd)

9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways.

A wicked problem involves many stakeholders, who all will have different ideas about what the problem really is and what its causes are. Everyone no matter at what economic level is affected by energy and each has their own way of looking at this and dealing with the issues from the politician, to the engineers to the consumer at-large.

Wicked Problem (contd)

10. The planner has no right to be wrong. Problem solvers dealing with a wicked issue are held liable for the consequences of any actions they take, because those actions will have such a large impact and are hard to justify.

Being held liable for the consequences of any action is also profoundly involved in the energy challenges. Satisfying a wide spectrum of energy users and provide a clean, safe environment may in and of themselves be impossible to achieve. There are many examples here.

Strategies for Taming Wicked Problems

- Involve stakeholders, document opinions, **communicate.**
- Organize brainstorming sessions to identify all aspects.
- Run focus groups to better understand stakeholders in developing future scenarios.
- Create a shared understanding and a commitment to solve.

Strategies (contd)

- Use the Pareto approach to assessing development and risk.
- Take robust action.
- Explore and monitor assumptions often.
- Incorporate efficiencies.
- Many stakeholders make the process complex but opens the door for creativity. Have patience.

Strategies (contd)

- Use feed forward approaches. Imagine the future.
- Food functions are useful to get the team together to communicate.
- **Communicate and take robust action!**

Summary

- Enhance and Broaden our Energy Education.
- Do Transformative Research.
- Start to Tame the Energy Problem with Lessons from Wicked Problems.