December 15, 2011

Current Issues in Clean Energy

The following issues are offered as potential topics for ENMG698 projects. The list is intended to be suggestive as opposed to inclusive

1. **Biomass scenarios** - Given the limitations of low phtosynthetic efficiency, to what extent can biomass displace fossil fuel without disrupting food crop production? What is the magnitude of the opportunity?
   a. Municipal waste burning is one opportunity. What is the technology, the economics, and the magnitude of this resource?
   b. Another direction is synthetic biology, using microbe metabolism to breakdown plant cell walls. What are the potentials and realities of this approach?

2. **Building design** - Most of today's building codes predate the need for clean energy. What are the main features that can improve the energy efficiency of new building design for residential commercial and industrial applications. What is the magnitude of the opportunity and the return on investment.

3. **Carbon sequestration** - One proposed approach for reducing carbon emission to capture the carbon released during fossil fuel burning and either sequester it.or use it.
   a. Geological sequestration - The idea is to store CO_2 in locations such as deep saline aquifers or depleted oil and gas reservoirs. What are the potentials and realities of this approach? What data would be necessary to demonstrate safety? What do the cost numbers look like?
   b. Chemical sequestration- What are the potential and realities transforming CO_2 from combustion into useful products like formic acid, biodiesel fuel using CO_2 and algae, nitrogen fertilizers, salicylic acid and polycarbonate plastics and an industrial solvent.

4. **Climate change, a critical review** - The earth's climate is always changing and man's activity is affecting climate. Advocates say that this is a serious threat. Skeptics say it is overblown. To what extent does the data say that anthropogenic climate change is a serious threat? Look at climate models and limitations; forcings and feedbacks; paleoclimate and recent temperatures and observations an projections.

5. **Energy efficiency** - What is the lowest hanging fruit? What actions, from caulking homes to hybrid automobiles, to plugging leaks in natural gas pipelines, to elecricity generation and transportation provide the highest (unsubsidized) financial return on investment?

6. **Fuel Cell Fundamentals** - There are many different types of fuel cells. In general they are more efficient than combustion engines but the inefficiency of the oxygen reduction reaction make them less efficient than batteries. Are there any opportunities, perhaps with catalysts to change the game?

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7. **Geoengineering,** a critical review - The National Academy of Sciences defined geoengineering as "options that would involve large-scale engineering of our environment in order to combat or counteract the effects of changes in atmospheric chemistry." Broad techniques include carbon dioxide removal, solar radiation management and heat transport. What are the potentials and realities? Are any of the specific proposed techniques effective and practical?

8. **Geothermal**
   a. Heat pumps - Traditional heat pumps exchange heat with ambient air. Geothermal heat pumps exchange heat with the earth. What are the cost/performance tradeoffs. Under what conditions will one or the other me more practical?
   b. Heat engines - Geothermal power (as opposed to heat pumps) has both promise and problems. What are the barriers and opportunities? Where will commercialization begin? Hawaii?

9. **Grid operations**
   a. Main issues - What are design principles for reliable grid operations? Guidelines for recovering from grid failures? To what extent can emissions be reduced with existing generators by simply improving grid operations?
   b. One day in ten years - The generating capacity required for reliable grid operations is determined by the requirement for a maximum of one day loss of load every ten years. The is a heuristic, derived from experience with random failures of generators of equal size. How does this requirement change as a result of large generators or correlated wind farms.
   c. HVDC scenarios What are the potentials and realities of HVDC transmission. Where has it bee used, what are the proposals? What is HVDC transmission likely to be in 2050.
   d. Smart grid - What is the smart grid? What is its real value? People talk about leveling the load, reducing congestion, and recovery from blackout. What is hype and what is real? If the purpose is to level load, what is ROI? How much can the utility afford to pay the use to shift consumption from peak hours to off-peak hours?
   e. High temperature superconductors - Potentials and realities.

10. **High penetration wind systems** - To what extent is wind power compatible with zero (or nearly zero) carbon electric power systems?
    a. Wind peak capacity - Peak capacity is the ability to reliably produce power during peak demand. A single wind turbine has no peak capacity. To what extent can seperated wind farms with reduced correlation provide peak capacity? Consider closed system constant load model. Assume Ralyeligh distributions and measured correlation. An extension of this study could employ real data simulations.
    b. Long distance transmission (LDT) - Closely spaced wind farms have high correlation and function like a single large wind turbine with regard to low frequency wind fluctuations. To what extent can wind penetration be increased by reducing the correlation. What is the theoretical limit with independent wind farms and no curtailment? What are practical

limits with partial correlation and curtailment?

c. Impact of diurnal and seasonal load variations - With constant load, nominal wind penetration (no curtailment) equals average wind capacity. To what extent does load variation reduce wind penetration?
d. Curtailment - Penetration can be increased by curtailing wind during peak production. To what extent can curtailment increase penetration when the system is subject to diurnal and seasonal load fluctuations?
e. Mid Atlantic wind production - An offshore power cable has been proposed to connect wind farms between Norfolk and New York. To what extent can this cable increase wind penetration by reducing correlation?
f. Storage - a key problem with wind is the ability to the system to satisfy load when there is a rapid, unexpected loss of wind. What are the characteristics of a storage system that would enable the system to satisfy load during such an event.

11. **Hydroelectric**
    a. Traditional dams - The Pacific Northwest is blessed with both hydro power and wind and have the potential to provide an integrated wind+hydro base load subsystem. What modifications to traditional hydro plants would necessary to make this work?
    b. Waves and tides - Both waves and tides are confronted with high costs and site specific customization. What are the potentials and realities of this approach for providing reliable cost competitive electric power.

12. **Hydrogen**
    a. Transportation and distribution - One scenario views molecular hydrogen generated in central station and distributed much like natural gas is today. Is this practical. Can this be done cheaply and safely? How serious are hydrogen safey issues?
    b. Hydrogen storage - Hydrogen can be stored as a compressed gas, a cryogenic liquid, various hydrates and ammonia. What are the potentials and realities of hydrogen storage? What are the most promising technologies and research direction.
    c. Hydrogen generation - Hydrogen can be generated many was. Today the main process is steam reformation from natural gas and coal; it can also generated by high temperature dissociation, electrolysis and, and proton exchange membranes. What are the most promising technologies and research directions?
    d. Hydrogen automotive fuel scenarios - Hydrogen can power motor vehicles by either internal combustion engines or through generation of electricity by fuel cells. Hydrogen fueled automobiles have been researched for decades. So where are they? What is the problem?
    e. Hydrogen forecourt system - A novel system approach is to use electricity to electrolyze hydrogen at local filling stations for distribution to motor vehicles. What are the potentials and realities of this approach? Is any research being done? What about generating hydrogen from PV and use tanks for overnight storage for a base load PV system?

13. **Nanotechnology ultracapacitors** - Conventional ultracapacitors have lost out to batteries for

hybrid automobiles and plug in electric vehicles. One suggestion has been to store electricity using nanotechnology engineered molecules, perhaps with a sis-trans state. Explore the research and patent literature to identify the potentials and realities of this approach.

14. **Natural gas**
    a. Shale gas - The development of hydraulic fracking unleashed a large amount of unexpected natural gas. How large is the opportunity compared with other fossil fuels? Is there an international component?
    b. Transportation fuel - Natural gas is being developed to replace diesel fuel in trucks. What do the systems and technologies look like? How long will it take for the infrastructure to evolve? What is the outlook for automotive fuels?

15. **Nuclear fission**
    a. Sustainable nuclear fuel cycle scenario - The Advanced Fuel Cycle Initiative Options study looks at a variety of established nuclear fuel cycles and concludes that continuous recycle is the only option that can significantly impact high level waste. What are the various ways to implement continuous recycling? Can we really build fuel cycles with little long lived waste.
    b. Molten salt reactors - Most conventional nuclear reactors employ solid uranium oxide as a fuel. What are the potenaitls and realities of liquid fuel and molten salt reactors?
    c. Traveling wave reactors - In a traveling-wave reactor, or TWR, fission does not happen in the entire TWR core, but takes place in a fairly localized zone that advances through the core over time. TWRs reach a state where they can achieve very high fuel utilization while using no enriched uranium and no reprocessing. What are the potentials and realities of TWRs?.
    d. High Level nuclear waste disposal - Evaluate cost and performance of sustainable approaches to disposal of transuranic waste with long half lifetimes. Include mined geologic disposal and non-retrievable disposal including deep borehole, seabed/sub-seabed, subduction zone, rock melt, ocean dilution and outer space.
    e. Nuclear waste irradiation requirements - Considering natural ambient levels of nuclear radiation, what is a reasonable requirement for safe human exposure to decayed nuclear waste? How does this compare with Yucca Mountain, EPA and other requirements?
    f. Non-proliferation systems - A primary argument against the separation and recycling of nuclear fuels is the risk of weapons grade fuel being removed for weapons. How real is this risk and what are the system that are or could be developed to minimize that risk?

16. **Nuclear Fusion**
    a. Critical review of nuclear fusion - Nuclear fusion for commercial power has been researched for over 50 years. What are the successes and failures, the potentials and realities of this approach? What are the potential advantages over fission? Is there anything close to commercialization?
    b. Novel nuclear processes - In 1989 Martin Fleischmann and Stanley Pons announced that they had produced anomalous heat ("excess heat") of a magnitude they asserted would defy explanation except in terms of nuclear processes. DOE cold fusion reviews in 1989

and 2004 found that evidence of new nuclear processes was not persuasive. Is there any evidence for cold fusion or new nuclear processes.

17. **Ocean Thermal Energy Conversion** (OTEC) - OTEC technology takes advantage of the temperature difference between shallow and deep ocean water to produce electricity. The scientific principles behind OTEC have been demonstrated in prototypes, but the technology is not widely used.. What ar ethe potentials and realities of OTEC?

18. **Photovoltaics**
    a. System limits - Using typical diurnal load curves, and a closed system model, how much PV can a system accept before PV disrupts operations. Check Hawaii.
    b. Costs - While PV panel costs have bee dropping rapidly, PV system costs less so. What are the cost prospects for residential systems, both new and retrofit.
    c. PV+storage subsystems - Overnight storage can make PV a base load system with much broader applications. Explore the costs and efficiencies of ice air conditioners for shifitn A/C load. Explore the PV driven hydrogen forecourt system.
    d. Technology directions - At the panel level, cost per watt has been minimized by shifting from higher efficiency silicon crystal based PV to lower efficiency films. But lower efficiency *systems* require more area to produce the same power as higher efficiency systems. Where is the technology headed and what are the prospects of system costs competitive with fossil fuel without subsidy.

19. **Policy** - Policies to encourage clean energy include EPA regulations, renewable portfolio standards, clean energy standards and carbon tax.
    a. What are the most effective incentives to reduce carbon emissions, greenhouse gasses, and other harmful emissions (RPS, Clean Energy Standards, regulations)?
    b. What are the most effective state and local policies for stimulating clean energy? Many policies are being criticised as ineffective. What really works??

20. **Transportation infrastructure** - Infrastructure offers high return opportunities including improved public transit, congestion pricing, dedicated high-occupancy vehicle lanes, improving electric train efficiencies and urban planning that encourages walking and biking.