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Techno-economic challenges associated with biomass energy utilization and CCS

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Biomass Energy and CCS (BECCS)

- Biomass Energy with CCS has been proposed by the IEA and others as a means of bringing the CO_2 concentration in the earth's atmosphere back down to some acceptable level after a likely overshoot in the middle of this century.
- Regardless of one's viewpoint on what level is acceptable, it is fairly certain that we cannot allow CO_2 levels to increase indefinitely.
- In addition, CCS, in its current state of the art is considered to be fairly expensive.
  - Post combustion capture systems and oxy fired systems nearly double the capital cost of a power plant and add a 20% energy penalty as well.
  - IGCC has thus far been demonstrated to be quite expensive.

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- Direct separation of CO_2 from air has been proposed, but the concentration of CO_2 in the atmosphere is so dilute, that such processes are unlikely to be less expensive than CCS, as we know it today. In addition, the captured CO_2 has to be stored in either case.
- The potential advantage of BECCS is the capture of the CO_2 as well as the use of biofuel to get, in effect, "negative emissions".
- Studies by Williams at Princeton and others have estimated that by co-gasification of a mixture of about 40% biomass and 60% coal, a carbon neutral product can be generated.

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- So, What’s the Problem?
- As with any energy application, the problem comes down to cost, both capital cost and operating cost.
- Cost arises from process complexity and operational issues.
  - “Too many pots and pans”
  - Too many products
  - Too much integration

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- Issues with IGCC
  - Integrated Gasification Combined Cycle technology was intended to provide for the use of coal at a higher efficiency than was possible with conventional steam power plants, with potentially lower emissions.
  - In order to achieve the higher efficiency, integration between the gasification system, the steam generation system, and the power system was required.
  - This led to a very complex plant.
  - The complexity, in turn, led to higher capital cost and lower availability of the plant.
  - Performance turned out to be about the same as a conventional steam plant, but costs were higher and availability was lower.

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- Now the proposal is to add biomass to the mix and CCS.
- The basic question will be, “How can this approach reduce the cost?”
  - If CCS is successful, then CO2 can be captured and stored without the necessity of adding biomass gasification to the system.
  - Although biomass can be converted to a gas more readily than most coals, there are issues such as tar formation, degradation during storage, handling issues, etc. that still have to be addressed for biomass systems.
  - If using wood as a fuel were so easy and cheap, why did we ever go to fossil fuels in the first place?

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- What is needed is process simplification.
- Electricity may not be the right product.
- Polygeneration rarely works out to be economical.
- Product focus will be critical.
- The “normal” trade offs need to be revisited.

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- The Coffeyville model
  - Gasification plants that make chemicals tend to run at steady state and have much greater availability (Eastman Chemical, Coffeyville, Great Plains).
  - The Coffeyville plant makes one product…..ammonia
    - There is no power plant
    - There is no substation with high voltage lines, etc.
    - The plant does not have to follow load.
    - The plant does not rely on the sale of byproducts to be economical.
      - A low cost fuel (pet coke) is gasified using oxygen to make a syngas, which is then run through a shift reactor to make hydrogen, and then acid gas clean up. The clean hydrogen is reacted with the nitrogen from the air separation plant to make ammonia.

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- The Coffeyville model
  - To be fair, Coffeyville is a rather unique situation,
    - The plant is located near a refinery, so that pet coke can be readily obtained at very reasonable cost.
    - There is a cement plant and a sulfuric acid plant nearby. The cement plant takes away the slagged ash and uses it in the production of cement clinker. The sulfuric acid plant takes the raw acid gas and uses it to make sulfuric acid. The Coffeyville plant does not have to process the acid gas into a product and incur the costs of production, sales, marketing, promotion, accounting, etc. for any of these materials.
    - In choosing ammonia, there is a ready market for this single product.
    - Further, by choosing ammonia, the nitrogen from the air separation plant (needed to provide oxygen for the gasification step) can be used.
    - Finally, the plant was able to purchase the gasifier cheaply from the Coolwater IGCC Demonstration plant when it was torn down.

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- The Coffeyville model
  - During an EPRI visit to the plant, the plant manager was asked about generating electricity. His reply was that he couldn’t make any money making electricity. This was in spite of the reduced cost of the plant and the favorable location. The additional equipment and complexity needed to generate electricity adds costs and operational issues to the plant, not the least of which is the need to follow load.
  - The CO_2 is typically vented. However, it could be used to produce urea from ammonia and CO_2. Again, the plant manager indicated that the price for urea would have to be very favorable in order to justify the additional complexity of the equipment and plant operation.
  - It should also be noted that the Shell gasification pilot plant in the Netherlands had fairly good availability when run under steady state conditions, but lost about 10 points of availability when run in load following mode.

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- Why Process Simplification?
  - Process simplification reduces the amount of equipment needed to produce the product. Less equipment translates directly into lower capital cost.
    - For example, by not generating electricity, the plant does not need any generating equipment (no combined cycle, no boiler, no turbines, no generator sets, etc.). The plant does not need any substation equipment (no busbar, no big transformers, no high voltage lines, etc.). Finally, the plant doesn't have to sell to the grid with all of the NERC requirements.
    - Further, by not generating electricity, the plant is not designated as an Electric Generating Unit (EGU) by the EPA. Hence the emissions regulations are somewhat less stringent than for EGUs. In the case of Coffeeville, there is no flue gas. Rather than burning the fuel to produce heat to drive turbines and exhausting the products of combustion to the atmosphere, the "fuel" is reacted with nitrogen to produce a product….ammonia. Since there is no flue gas, there are no emissions other than the currently vented CO2, which could easily be sequestered if a characterized field was available.

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- Infrastructure Issues
  - The infrastructure for the transportation and sequestration of CO_2 on a grand scale does not yet exist. This is a problem for all forms of CCS, whether it is post combustion scrubbing, oxygen firing, IGCC, Air Capture, or BECCS. There is no point in capturing CO_2 if there is no place to put it.
  - Further, the financial and legal mechanisms are not really in place to facilitate the routine handling, transportation, ownership, and potential liability issues associated with moving large quantities of CO_2 around and storing it for long periods of time.
    - Ideally, the generator wants to hand off the captured CO_2 to someone else (much like trash pickup from your home). The intricacies of transportation, injection, monitoring, sealing, etc. are not something that the ammonia producer or the electric generator wants to be involved with.
    - The means for monetizing this process has not been clearly articulated, with the possible exception of Enhanced Oil Recovery (EOR)

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- Land Use Issues
  - It will take a lot of biomass to make a serious dent in the gigaton level of CO_2 capture that will eventually be required. China uses over 3 billion tons/yr of coal. The US still uses nearly 1 billion tons/yr of coal. If that were all to be cogasified with biomass, nearly 4 billion tons/yr of biomass would be required. The total worldwide production of wood products for all uses (fuel, pulp and paper, wood pellets, furniture, tools, etc.) is 4 billion tons/yr. Yes, there are other forms of biomass, but not all of these are suitable for mass production, transportation, storage, and utilization for BECCS. Of course, this problem does not have to solved all at once, but it certainly needs to be considered.
  - Faster growing trees will likely be needed if this technology is to make the kind of contribution to CO_2 reduction that is envisioned. Currently, in the northern latitudes, it takes 15 years to grow a tree. One can imagine a circle divided into 15 sectors, so that each year, 1 sector is harvested and replanted (ie sustainable use). For a 100 Mw plant, the circle needs to be 75 miles in diameter.

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- Technology Issues
  - The basic technology for building a BECCS plant exists.
  - In order to get an industry going, demonstration plants will be needed. There are too many moving parts in the system for one entity to take all of the risk on a large commercial plant. A means will have to be found to get smaller plants into operation, but still be commercially and economically viable.
  - Again, process simplification will have an important role to play in this part of the development. A simpler, smaller plant will be easier to finance, build, and modify (if necessary) so as to get the overall BECCS concept up and running.

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- Summary
  - BECCS can make an important contribution to the overall reduction of CO2 in the atmosphere.
  - In order to do so, major process simplifications will be needed.
  - Product focus will be needed. Electric generation may not be the right focus.
  - CCS infrastructure may be the rate limiting step.
  - Land use issues will eventually need to be considered.
  - Demonstration plants will be needed to provide the necessary “learning by doing” and learning curve cost benefits.