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Cogeneration of Transportation Fuels and Clean Water from Littoral Feedstock

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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The idea

- Climate change and a 1.5 m sea-level rise
- 65,000 sq. miles innundated, 35,000 sq. miles become tidal / estuarine / water-logged / damp
- Highly populated area, ripe for distributed energy production and supply
  - But what feedstock to exploit the inundation?
  - What form of power/energy? Electricity? Ethanol? Hydrogen?
- Can we desalinate and get potable water too, from the vegetation?

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The vegetation

- These are water-logged / damp / brackish / saline regions
  - Corn, soy, and other starch-bearing cereal crops will not thrive
- Typically vegetation : grasses (reeds)
  - Reed canary grass (RCG) : Everywhere except SE
  - Arundo donax : Warm coastal areas
  - Cordgrass (Spartina) : Salt marshes, Atlantic and Gulf coast, SF Bay, Humboldt Bay
    - Note: Spartina has a C_4 photosynthesis mechanism; can produce sugars for ethanol
- Also, weedy softwoods
  - Cottonwood : Eastern US
  - Willow : temperate N. America

Figures from Wikipedia

Questions

- How can we turn this biomass into energy?
- What are the biomass yields?
- What are the energy yields (vis-à-vis coal)? Energy balance?
- What forms of energy can we turn the biomass into?
  - What has already been done?
- With what efficiency can we turn the biomass into various forms of energy?
- It will not be sufficient to displace all petroleum, but will it be economic? At what price of petroleum?
- What are its non-energy advantages/disadvantages?
- What are its prowess at water desalination?

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Water co-generation

- Salt-marsh plants are desalinating at the cellular level.
- Some pollutants are locked in the roots, others in stems, leaves etc.
- Existing water extraction technologies (non-solvent):
- Mechanical
  - E.g. sludge drying, wood waste resizing and drying.
- Thermal
  - Air drying (no water capture, however)
  - Steam/kiln drying.

Deal-breaker

- Desalination using plants seems uneconomic
  - Much water in plants is in capillaries rather than cells: contaminants from the water source.
  - Mechanical:
    - Dissolved salts, organics remain.
  - Thermal:
    - Volatile organic pollutants extract with water product.
- Not as much free filtration work as expected– if you want clean water from littoral water, just clean it directly.

Biomass supply -1

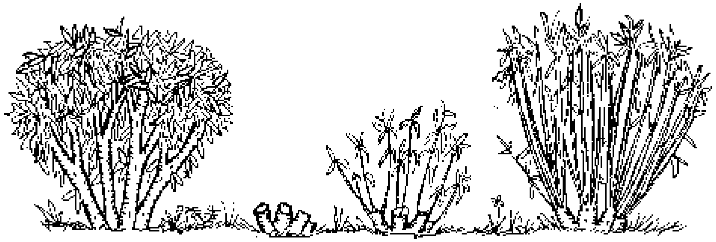
- Grasses/reeds grow well in estuarine / brackish / moderately saline water
  - Florida forage production: 5 Dry Mass ton/acre/yr (= 12.5 DM ton/ha/yr)
  - Yields in colder climates (N. Europe)
    - Reed canary grass: 7-13 DM ton/ha/yr
    - Cordgrass: 15-20 DM ton/ha/yr
    - Arundo donax: 23 DM ton/ha/yr
  - States yields are fertilizer-free yields, else 100 DM ton/ha/yr are possible
  - Yearly harvests, sometime twice
- Grasses grow from rhizomes, so no replanting
- Some (fossil fuel?) energy expended in planting, harvest etc
  - Energy balance later

Figure from National Park Service

Biomass supply - 2

- Weedy softwoods (cottonwoods, willow) grow in damp (riparian) regions
  - Cultivated via Short Rotation Coppice (SRC)
- Coppice:
  - Old forest management technique to keep trees juvenile
  - Frequent harvest
    - Cottonwood, birch : 2-year rotation
    - Willow : 4-year rotation
- Fossil energy expenditure : planting, harvesting
- Yields:
  - Cottonwood: 5-9 DM ton/ha/yr
  - Willow: 15-18 DM ton/ha/yr

Figures from Wikipedia



Tree to be coppiced | Cut close to base in winter | Shoots rapidly regrow from stool the following spring | Coppice ready for harvest between 7-20 years

Energy balance

	Biomass yield, DM ton/ha/yr	Energy input GJ / ton DM	Energy output GJ / ton DM
Reed canary grass	7-13	0.8	16.2
Cordgrass	15-20	0.8	17
Arundo donax	23 (100 with fertilizer)	1	17
Cottonwood	5-9	0.5	19
Willow	15-18	0.67	19

- To date, biomass has only been burnt, usually with coal
  - Coal energy output: 30 GJ/ton

Converting biomass to other fuels

- Lignocellulosic ethanol
  - Lots of research, still experimental
- Direct fired turbines
- Biomass gasification to syngas
  - Syngas then reformed to H_2, CH_4, MeOH, EtOH

Lignocellulosic Biomass to Ethanol

- Necessary in order to expand ethanol production past 6-8 billion gallons a year
- Feedstock (lignocellulosic biomass) includes waste paper, wood waste, pulp sludge and grass straw.
- Process:
  - mechanical preparation steps include cleaning, drying and reducing the size of biomass feedstock.
  - Cellulose-to-ethanol technology converts lignocellulosic feedstock (LCF) into component sugars, which are then fermented to ethanol.
  - Efficiency: 8% (considering only fossil energy inputs) to 39% if by-products are used in the conversion process
  - Technology is currently in an early stage of commercial development.

Biomass Gasification

- Two-stage process
  - 1st stage: pyrolysis→heat vaporizes the volatile components of biomass in the absence of air. Pyrolysis vapor consists of CO, H2, CH4, volatile tars, CO2 and water and about 10-25% charcoal residue.
  - 2nd stage: char conversion→charcoal residue from the pyrolysis stage reacts with oxygen producing CO
- Systems :
  - Large scale gasification
    - staged steam reformation with a fluidized-bed reactor
    - staged steam reformation with a screw auger gasifier
    - entrained flow steam reformation
  - Small scale biomass systems – via partial oxidation
    - promising technology to supply electricity and heat to rural areas, businesses
  - Technologies are in the development stage

Direct-fired gas turbine

- Convert biomass to electricity.
- Process
  - fuel pretreatment reduces biomass to a particle size of less than 2 millimeters and a moisture content of less than 25 percent.
  - then the fuel is burned with compressed air.
  - cleanup of the combustion gas to reduce particulate matter before the gas expands through the turbine stage.

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Synthetic Gas Assesement

- Possible products from biomass via synthetic gas
  - Hydrogen
    - mainly consumed for ammonia production
  - Methanol
    - one of the top ten chemicals produced globally
  - Mixed higher alcohols
    - more attractive gasoline blending stock for octane enhancement compared to methanol
  - Ethanol
    - obtained from syngas via fermentation

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Energy Yields and Efficiency

Conversion process	Energy yield / ton of feed (GJ/ton)	Energy (product) / Energy input (fossil + biomass)	Energy (product) / Energy input (fossil fuel)
Biomass - syngas - H_2	6 – 13	0.36 – 0.73	14 - 29
Biomass - syngas - MeOH	5 – 11	0.29 – 0.65	12 - 26
Biomass - syngas - Mixed Alcohol	135 – 223	0.18 – 0.3	8 - 13
Biomas - syngas - EtOH	228	0.35	16

Values based on LHV (lower heating value)

Data extracted from NREL report TP-510-34929 (Dec 2003)

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Syngas Yields and Economics

- Ethanol via syngas fermentation: wet gas cleaning, fermentation, distillation, EtOH dehydration

Fuel	$/GJ (LHV)	$/gallon
Gasoline	10.4	1.25
Diesel	9.13	1.24
Ethanol (via syngas fermentation)	13-35	1.0-1.40

- Gasoline and diesel prices exclude distribution, marketing and taxes (about 50%); gasoline price as of 2005, diesel as of 2006
- Ethanol price as of 2000
- Data based on NREL report TP-510-34929 (Dec 2003)
- Energy Information Administration (http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html)

Other features

- The good :
  - Good at fixing Nitrogen, can be used with wastewater
  - Flood and soil erosion control
  - Wildlife habitat
  - Can be mixed and matched for biodiversity, pest and disease resistance (cut down on herbicide and pesticide)
- The bad :
  - Droughts affect production of SRC
  - Fires will require replanting and a long wait (4 yrs for willow)
  - Biomass storage required (for drying)
- The ugly : What new area should Sandia invest in ?
  - Lignocellulosic EtOH research is widespread
  - NREL owns syngas and process / manufacturing research

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