Biofuels for Transportation

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Why Biofuels?

• Besides electricity, transport is the biggest CO₂ emitter in South Africa
  – Due to Sasol’s coal processes
  – 40% efficiency = 60% CO₂ production
• Liquid biofuels have a good energy density
  – Energy stored per kilogram biofuel is an order of magnitude greater than electric batteries
• Cheapest option for gaseous fuels is biogas which can be used in petrol or diesel vehicles
  – Significant range limits compared to liquid fuels
Types of Liquid Biofuels

• The most well known:-
  – Biodiesel by transesterification
  – Bioethanol – to blend with petrol
  – Synthetic fuels – from biobased resource

• Less well known:-
  – Upgraded pyrolysis oil
Types of feedstock

- **First Generation (1G)**
  - Edible oils (soybean and canola oil) used for biodiesel
  - Bioethanol produced from sugar cane or starch crops (grain sorghum and triticale)

- **Second Generation (2G)**
  - Waste oils and animal fats used for biodiesel production
  - Lignocellulosic biomass (energy crops, agricultural and forestry residues, industrial waste)
  - used to produce a variety of products including ethanol, synthetic fuel and upgraded pyrolysis oils

- **Third Generation (3G)**
  - Algae can be used to produce fuels and high value pharmaceuticals
Challenges with Manufacturing

- More expensive to process due to feedstocks having:
  - Low energy density
  - High oxygen content
- Financial incentives usually subsidies required
- The need to avoid competition with food – by using or displacing edible feedstocks
- Process energy is often required and this may be sourced from fossil fuels – carbon balance
The carbon cycle - biodiesel

- Energy to plant, cultivate and harvest crops
- Energy to make vegetable oil
- Energy to make biodiesel

Key:
- Red: Energy Flow
- Green: Carbon Flow
- Blue: Material Flow
SA Biofuels subsidy route

- Mandatory blending targets - 1 Oct 2015
- Subsidy to guarantee a 15% ROA
- Calculations by Brian Tait (2014):

![Graph showing incentive (c/l) to achieve 15% ROA]

Averages Jun 10 to Nov 13:
- Sorghum = 301.5 c/l
- Sugarcane = 287.5 c/l
- Soya = 209.2 c/l
Starch crops

Wheat  Triticale  Rye

Endosperm  Bran  Wheat germ
Additional subsidy considerations

- There is a focus on large scale producers
  - Typically 160 million litres / year
- There is a focus on developing new agriculture
  - Job creation
  - Rural upliftment
- Limited to 1G projects
  - Cheaper
  - Dedicated energy crops such as grain sorghum (carbon balance?) – new agriculture
1G Environmental Issues

• 1G ethanol – from sugar cane
  – Brazilian experience shows that social and economic benefits are possible
  – Very positive carbon balance
  – Sugar cane bagasse available for energy
  – BUT a specific climate required to grow sugar cane

• 1G ethanol – from starch e.g. grain sorghum
  – Potential food vs fuel issues
    • Primarily land use
  – Carbon balance issues
    • Energy for conversion may be supplied by fossil fuels such as coal

• 1G biodiesel
  – Also food vs fuel issues
  – Water required for product purification and catalyst removal
BIOFUELS NOT INCLUDED IN SUBSIDY SCHEME
Invasive Plants as a feedstock

120 million tons of invasive alien plants in South Africa

SASOL uses 40 million tons of coal / year
What about industrial waste?

- Approximately 550-1500 dry tons paper sludge/day
- Degraded cellulose fibres $\rightarrow$ ethanol
The 2G Options

- The lignin fraction of lignocellulosic biomass can be burnt for energy
- Includes dedicated crops and associated issues
- Potential to use agricultural waste, forestry residues and alien vegetation
- Pyrolysis can be used to convert lignocellulosic biomass to charcoal which could be gasified by Sasol or PetroSA
The Sasol Perspective

- Replace 10% of Secunda’s coal feed with biomass.
  - 4 million tons/a of **sustainable** agricultural residue
  - Excludes invasive plants
- Relative cost of different feed material to Secunda

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Triticale in the Western Cape

Lots of hectares of marginal lands, no longer economically viable for wheat production => triticale
Technology considered by EnviroServ (1)

- Anaerobic Digestion
  - Well Proven
  - Can be utilised for all 3 types of energy offtakes
  - Requires minimum of 15 tons/day
  - Balance Nitrogen and Carbon
  - High Digestate volume
An Energy Offtake option - EnviroServ

- Transportation Fuel
  - Diesel R 1.18/ kWh
  - Wide Application
  - Upgrading required
  - Compressed Methane
  - Dual Fuel Conversion
  - Diesel & Petrol
Bio-ethanol/Diesel blending

Economic Pre-feasibility study on ethanol diesel blending in South Africa – BP Greyling

Basic idea:
Pioneered by South-African’s in 1980’s as possible alternative agricultural fuel
Blend Bio-Ethanol with diesel 16% (v/v)
Ethanol production – Industrial first generation Tech @ 1, 80 or 160 million l/annum have been shown to be economically viable production volumes

Approach:
Blending of ethanol at fuel Depot level - Safety and Vehicle limitations
Supply to dedicated vehicle fleet i.e. Logistics operators
Localized production of Bio-ethanol allows regional bio-feedstock

South African logistics operations
Blending based at major logistics depot locations.
Current model - up to 513 million l/annum ethanol demand for blending via this approach.
(2.08% of Bio-fuels Target)
Efficient use of biomass
Thank you for Listening
Types of Biofuel

• The most well known:-
  – Biodiesel
  – Bioethanol – blended with petrol
  – Wood chips and pellets

• Less well known:-
  – Upgraded pyrolysis oil
  – Biochar and torrified wood to replace coal
Potential areas of collaboration

- Specifically (thermo)chemical processes (excluding any biotech/bioprocessing) the following would be interesting:
  - David Naron’s project on catalytic pyrolysis of lignins
  - Catalytic pyrolysis will also apply to waste tyres (we are planning a project for 2015) and waste plastics (Evans Chomba).
  - Techno-economic and environmental impact modelling, similar to the Greenfund project. Processes to consider will include:
    - Biological production of organic acids, followed by catalytic upgrading
    - Catalytic conversion of ethanol to high value chemicals
    - Aqueous phase pyrolysis with lignocellulose and/or lignin
    - Fractionation of lignocellulose by chemical solvents, to provide raw materials for further conversion => and possible further chemical conversions.
Strengths - SA

- Sasol industrial scale gasification synthesis
- Coal heavy industry provides opportunity for pyrolysis products
- Good academic biotech
- Western Cape grain production
Stellenbosch

- Good biotech
- International collaborations
- Pilot scale equipment
  - Pre-treatment Hydrolysis fermentation of LCB
  - Pyrolysis equipment with investment in new equipment
- Separation and distillation
Steamgun Pretreatment of Lignocellulose
Leading Investment, Unprecedented Focus on CBP

Technical Focus: Overcoming the biomass recalcitrance barrier and enabling the emergence of a cellulosic biofuels industry via *pioneering CBP technology integrated with advanced pretreatment*

Partners in Mascoma’s CBP Organism Development Effort

- VTT
- Dartmouth College
- University of Stellenbosch
- BioEnergy Science Center
- Department of Energy

Three Platforms

1. *T. saccharolyticum*, thermophilic bacterium able to use non-glucose sugars
2. *C. thermocellum*, thermophilic cellulolytic bacterium
3. Yeast engineered to utilize cellulose and ferment glucose and xylose

*Multiple chances to succeed near-term & long-term*
Challenges

• Limited biomass availability and production
  – Marginal lands e.g. triticale,
  – W2E
Total bioenergy production potential in 2050 based on different agriculture systems [expressed as EJ ($10^{18}$ J). yr$^{-1}$; left to right bars – conventional to highly productive agriculture systems].
Additional data

• Brazilian carbon balance is 8 (green carbons vs fossil carbon) – based on atoms

• The estimated subsidy to feed Sasol is R4/litre