BIOFUELS FUNDAMENTALS

Dr. Gilles Vaitilingom
BIOFUELS FUNDAMENTALS

• Key World Energy Stats
Total Primary Energy Supply In the World - 2005

2005

- Coal: 25.3%
- Oil: 35.0%
- Natural Gas: 20.7%
- Nuclear: 6.3%
- Hydro: 2.2%
- Combustible Renewables & Waste: 10.0%
- Other**: 0.5%

11 435 Mtoe

**: wind, solar, geothermal, ...

81% from Fossil Resources


Biofuels USP Tuvalu May 2008
ALOFA TUVALU
Total Final Consumption
In the World - 2005

Total Final Consumption
In the World - 2005

Primary supply 11 435 Gtoe
Final Consumption 7 912 Gtoe

Residential, commercial,… 2.61 Gtoe
Industry 2.45 Gtoe
Transport 2.14 Gtoe
Non energetic use 0.71 Gtoe

31% are lost in conversion and process.

INTEREST OF BIOFUELS

Two points:

• Humanity is producing and consuming such quantity of energy only since the industrial era,

• There are 3 primary energy forms:
  • 1. Fossil (81 % of primary supply)
  • 2. Nuclear (6.3 % of primary supply)
  • 3. Renewable** (12.7 % of primary supply)

**: biomass, hydro, wind, solar, geothermal, ...
• 81% of the energy consumed worldwide come from fossil resources
• during the 20th century we have consumed more than 50% of exploitable world reserves
INTEREST OF BIOFUELS

• Each second, nature is (re) generating 100 liters of crude oil, but we are consuming 150 m³.
• If people were consuming as US citizens do exploitable oil reserves would last only 10 years.
• There are 10 millions cars in China, and 100 millions in 10 years.
Before 2050,
it is a duty and a necessity to look for solutions by all means:

- to improve our energetic efficiency
- to stop wasting energy
- to develop renewable resources
We all need Energy

- food
- dress
- heating
- cooling
- health
- entertainment
- work
- ...

Source: R. Olivès
Univ. Perpignan
PROMES-CNRS
We are Energy eaters

Energy Resource → Needs
We need more and more
More and more Power

Source: R. Olivès
Univ. Perpignan
PROMES-CNRS
Annual Average Growing Rate of Energy Consumption

Oil: + 1.3 %
Coal: + 3 %
Natural Gas: + 2 %

Electricity: + 3.2 %  (Tuvalu Funafuti: + 3.8 %)

Total Primary Energy Supply: + 50 % in 2030, + 100 % in 2050

TPES

Outlook for World TPES in 2030

In 2030, transports will consume 3900 Mtoe of oil, EQUIVALENT TO 2007 ENTIRE WORLD OIL PRODUCTION.

Peak Oil coming soon?

La production de pétrole va bientôt entrer dans sa phase de déclin continu

Pic de production : maximum de la production journalière de pétrole

Courbe de Hubbert appliquée à la production mondiale (Laherrère, 2004)

Source : R. OLIVES (PROMES).
Evolution of Oil Prices

April 2008: 120 US$

### Availability: Reserves

<table>
<thead>
<tr>
<th>Resource</th>
<th>Production Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>OIL</td>
<td>40 years</td>
</tr>
<tr>
<td>NAT. GAS</td>
<td>60 years</td>
</tr>
<tr>
<td>COAL</td>
<td>230 years</td>
</tr>
<tr>
<td>uranium</td>
<td>60 ans...</td>
</tr>
<tr>
<td>RENEWABLE</td>
<td>unlimited !!!</td>
</tr>
</tbody>
</table>

Source: R. OLIVES (PROMES).
Global Warming / GHG

Evolution of CO2 (ppm) in the atmosphere

Evolution of temperature in the atmosphere (ref. 1961)

Source: R. OLIVES (PROMES).
Consumption of Energy per inhabitant per year

1000 kWh/y./inhab.

- Amérique du Nord: 95
- Europe Occidentale: 50
- Amérique latine: 15
- Asie: 10
- Afrique: 6

Source: R. Olivès, Univ. Perpignan PROMES-CNRS

(Global Chance)
6 billions inhabitants but 2 billions without electricity
BIOFUELS FUNDAMENTALS

- Fundamentals
NEW AND RENEWABLE ENERGIES

- Solar Stirling engine
- Pelamis (Ocean Power Delivery)
- Energy from waves
- Hydroliennes
- Geothermal
- Fusion: ITER
BIOFUELS ???

BIOFUELS (1)

Fuels from Biomass ?

• Firewood  
  >10 % of world energy consumption (# hydro & nuclear)  
  In many countries: 80 % of total energy sector

• Biogas  
  Fermentation biodigester ➔ CH₄

  Gasification of wood, agro-residues ➔ CO, H₂
BIOGAS

BIODIGESTOR – Natural gas for domestic purpose or small rural electrification (Wad Medani, SUDAN)
BIOGAS

BIODIGESTOR – Natural gas for domestic purpose or small rural electrification (Amatuku – TUVALU)
BIOGAS

Rice husk Gasifier (Indonesia)

Electricity from crops residues
BioFuels: Liquid Substitutes of Petroleum products

- **ALCOHOLS**
  - Ethanol from sugar cane
  - sugar beat
  - mais (corn)
  - Substitute of gasoline
  - HIGH GRADE FUEL
  - BRASIL, USA, EUROPE

- **Derivatives: ETBE**
  - octane enhancer
Bio-Fuels: Liquid Substitutes of Petroleum products

- **VEGETABLE OILS**: PALM, COPRA
  - COTTONSEED, PEANUT,
  - RAPESEED, SUNFLOWER, SOJA,...
  
  Substitute of Diesel oil

  EUROPE, South Pacific (New Caled., Fiji, Vanuatu,…),
  Africa, Latin America,…

- **Derivatives: Methyl and Ethyl Esters of Veg. Oils**

  EUROPE (France: 4000 millions of liters rape&sunf/ year)
Biofuels are environmentally friendly:

- Biofuels coming from agriculture don’t increase CO2 rate in the atmosphere.
  1000 litres of sunflower oil = 3.2 tonnes CO2 saved.
- Pollutants at the exhaust:
  - Are respecting the legal limits in force prescribed for diesel and gasoline.
  - Are benefiting of depolluting exhaust systems development.
Energy Production

CO2 balance

Oil mill

Engine biofuel

sunflower

Energy Production

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BIOFUELS

Make power available

PRODUCTION
BIOFUELS FROM BIOMASS

- Ethanol
- Methanol
- Acetone butanol (ABE) – additive for blends of alcohol/gasoline
- Vegetable oils natural or esterified – diesel engines
BIOCHEMICAL CONVERSIONS
ethanol production (1)

Fermentation of organic, ligno-cellulosic or glucidic materials

→ Ethanol or similar products

Fermentescible
‘ juice ’

Fermentation

Distillation
certification
BIOCHEMICAL CONVERSIONS
ethanol production (2)

Fermentation of organic, Ligno-cellulosic and glucidic materials.

œ saccharide materials (fruits,...)
BIOCHEMICAL CONVERSIONS
ethanol production (3)

Fermentation of organic; Ligno-cellulosic and glucidic materials.

- saccharide materials (fruits,...)

<table>
<thead>
<tr>
<th>Ethanol</th>
<th>Sugar Beat</th>
<th>Corn</th>
<th>Mais</th>
<th>Potatoes</th>
<th>cassava</th>
<th>Sugar Cane</th>
<th>Topinam-bour</th>
</tr>
</thead>
<tbody>
<tr>
<td>yield hl/tonne</td>
<td>0.905</td>
<td>3.9</td>
<td>4</td>
<td>1</td>
<td>1.78</td>
<td>0.75</td>
<td>0.85</td>
</tr>
<tr>
<td>Productivity Tonne/ha</td>
<td>45</td>
<td>4.5</td>
<td>5</td>
<td>30</td>
<td>40</td>
<td>70</td>
<td>55</td>
</tr>
<tr>
<td>Productivity M$^3$ ethanol/ha</td>
<td>4.07</td>
<td>1.75</td>
<td>2</td>
<td>3</td>
<td>7.1</td>
<td>5.3</td>
<td>4.7</td>
</tr>
</tbody>
</table>
BIOCHEMICAL CONVERSIONS
ethanol production (4)

Fermentation of organic; Ligno-cellulosic and glucidic materials.

Ligno-Cellulosic materials (wood, straw,...)

- Fermentescible ‘juice’
- Enzymatic Hydrolisys
- Rectification
- Destruction of the cristaline structure surrounding the cellulose (mechanical, acid, thermochem., steam explosion)
- Distillation rectification
- Dehydratation
THERMOCHEMICAL CONVERSION
synthetic fuels production (1)

Hydrocracking

Hydrocracking (wood, straws,...)

Example:
1 tonne of wood =>
112 kg gas
240 kg light fraction
310 kg heavy fraction
355 kg aqueous fraction
**THERMOCHEMICAL CONVERSION**  
**synthetic fuels production (2)**

Gasification

Investigations are towards the substitution of coal by charcoal or raw biomass

At high temperature (350°C), Fisher-Tropsch synthesis produces gasoline and light olefins.

At high temperature (350°C), Fisher-Tropsch synthesis produces gasoline and light olefins.
Synthetic fuels production

Coal to Liquids: example of SASOL (RSA)

...applicable to biomass?
THERMOCHEMICAL CONVERSION
synthetic fuels production (3)

Pyrolysis

Biomass
300,000 t

- Char
  52,000 t

- Bio-oil
  218,000 t
  - oil
    102,000 t
  - liquid
    102,000 t
  - gas
    13,000 t

- Pyrolysis gas
  30,000 t

- SCW gas
  29,000 t

- Clean Water
  73,000 t

- Char
  52,000 t
ESTERIFICATION OF VEGETABLE OILS

Biodiesel production

Vege oil + Alcohol → Reaction → Decantation → Distill. Alcohol + Crude glycerol

Decantation → Ester + Biodiesel

1 tonne Veg oil + 0.1 tonne alcohol → 1 tonne Ester + 0.1 tonne glycerol + catalyst
METHANOL OR ETHANOL?

Methanol:
- Highly toxic not « renewable » at present
- Low solubility in oil, high solubilization glycerol → easy decantation

Ethanol:
- Can be « renewable »
- Higher boiling point (78.3 / 64.7 atm pres) but lower heat of vaporization (204 / 270 cal.g\(^{-1}\))
- Hydratable (appropriate storage), increases soap formation…
- Acts as co solvent to both ester and glycerol → difficult phase separation

Additional solvent:
- can be expensive and difficult to remove (boiling range of alcohol) → diesel fuel itself
- May helps phase separation during work out
- But traces left in glycerol are troublesome

→ Ethanolysis workable (linked to an optimized excess)

Requires careful study, phase diagram, complicated because dependant on the process (neoformed surfactant: soap and monoglycerides)
BIOFUELS FUNDAMENTALS

- Ethanol as Fuel in Petrol Engines
ETHANOL FUEL HISTORY

Everything started in 1931

Brasil
ALCOHOL BIOFUEL

- 1975: first ethanol cars

- In 1994 Brazil had more than 4.6 million alcohol cars;

- When the international oil price was reduced in the late 80s years, the government draw back the subsidy,

Conclusion: in 1999 sales of alcohol based cars represented only 1%
ALCOHOL BIOFUEL

- Nowadays, all Brazilian gasoline has 25% of alcohol – so, all engine cars are moved by alcohol pure or in blends.

- In Brazil spark ignition engines are adapted to:

  * one fuel = gasoline + alcohol
  * “Flex two fuels” = gasoline + alcohol or only alcohol,
  * “Flex three fuels” = gasoline + alcohol or only alcohol or only natural gas (VNG).
1. ALCOHOL BIOFUEL

It is a fuel for gasoline engines!

<table>
<thead>
<tr>
<th></th>
<th>Diesel</th>
<th>Gasoline</th>
<th>Bioethanol (95)</th>
<th>Rapeseed oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/dm³)</td>
<td>0.83</td>
<td>0.75</td>
<td>0.79</td>
<td>0.92</td>
</tr>
<tr>
<td>Lower Heating Value (kJ/kg)</td>
<td>43800</td>
<td>44000</td>
<td>26900</td>
<td>39500</td>
</tr>
<tr>
<td>Air Fuel Ratio (g air/g fuel)</td>
<td>15.00</td>
<td>14.60</td>
<td>8.9</td>
<td>14.50</td>
</tr>
<tr>
<td>Octane number (IOR)</td>
<td>20</td>
<td>98</td>
<td>106</td>
<td>12</td>
</tr>
<tr>
<td>Cetane number</td>
<td>50</td>
<td>15</td>
<td>5</td>
<td>37</td>
</tr>
</tbody>
</table>
ALCOHOL BIOFUEL

It is a fuel for gasoline engines!

Constraints?

**Blends with less than 10%**
- Stability, content of water
- Volatility (cold starting)
- Corrosion of materials

**Blends with more than 30%**
- New engine settings or design
- Corrosion of materials
- Performance: Eff. + 10% power + 15%
- Pollutant: aldehydes
- lubrication
**ALCOHOL BIOFUEL**

Vulnerability of materials

<table>
<thead>
<tr>
<th>Vulnerable</th>
<th>Compatible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg and Zn alloy. Carburator .... lead: Fuel tanks</td>
<td>Others metal or alloy</td>
</tr>
<tr>
<td>Polyurethane, PVC, polyamides polymethacrylates, rubber nitrile rubber acrylic</td>
<td>Polyethylene Silicones Polyacetates Teflon Polyesters</td>
</tr>
</tbody>
</table>
ALCOHOL BIOFUEL

Mauritius & Island of La Réunion: 100% sugar cane alcohol applied in diesel engines
ALCOHOL BIOFUEL

PERFORMANCE

![Power Output kW Graph]

- **DIESEL**
- **ETHANOL**

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ALCOHOL BIOFUEL

PERFORMANCE

CONSUMPTION L/H

DIESEL
ETHANOL
ALCOHOL BIOFUEL

Example of BioEthanol production

Ethanol produced from todi. TUVALU
BIOFUELS FUNDAMENTALS

- Vegetable oils as Fuel in Diesel Engines
HISTORY OF VEGETABLE OILS AS FUEL

SINCE NEOLITHIC PERIOD: 9000 before J.C.

BUT: APARITION OF PETROL LAMPS IN 1853
HISTORY OF VEGETABLE OILS AS FUEL

Rudolf DIESEL (1858 – 1913)

1900: test of some vegetable oils in his engine
VEGETABLE OILS AS FUEL

• Characteristics close to diesel oil
  LCV coconut oil: 41 MJ/kg
  LCV Diesel oil: 44 MJ/kg
  Density coconut oil: 0.92
  Density Diesel oil: 0.83

• History:
  - Mr. Diesel himself in 1900
  - World War II
  - Banned from research in the 50’
  - interest renewed at the end of 70’
VEGETABLE OILS AS FUEL
Why so few applications?

• higher cost than diesel ➤ case of most renewable
  But new position with USD 120/barrel

• too different to respect fuel standards
  New standards on the way: Germany, and soon Fiji

• considered as high income agri-products
  Only for some “niche”

• “Food versus energy”
  New concept of Sustainable development

• Coconut Oil! Not to be compared to a cheap, common and
  stinking product
  New consideration → USD120 for 159 liters
VEGETABLE OILS AS FUEL
Two ways =>

• Methyl or Ethyl Esters any Diesel engine
called “Biodiesel Fuels”

• Natural or “crude” only in adapted Diesel engines
BUT IT IS POSSIBLE !!!

EXAMPLE OF PURE VEGETABLE OILS USES

DIESEL INJECTION INDIRECTE

DIESEL INJECTION DIRECTE

Exemple : FIAT 80 ch.

Principe de la modification

Exemple : FIAT 80 ch.
Tractor Biocombustible Yumz D-65 M, Sunflower or soja

IVORY COAST

Genset 320 KVA – crude Palm Oil (2006)
MIXTURES OF COCONUT OIL in DIRECT INJECTION ENGINES

BUT RUNNING AT LOAD > 50 % => > 200 KVA

Cummins genset, 400 KVA, 10-20 % CNO in DIESEL FUEL

Savai’i EPC Power station, Samoa (2005)
COCONUT OIL IN AN ADAPTED DIESEL ENGINE

2004 GENSET. 300KVA
Power Station of ENERCAL (Utility)

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ALOFA TUVALU
CRUDE COCONUT OIL AS FUEL

RURAL ELECTRIFICATION:
Fiji: Vanuabalavu 80 KVA* & Welagi 45 KVA
Coconut Oil as fuel (10 nuts = 1 litre equivalent Diesel Fuel)

* First place in the World to produce grid electricity with its own vegetable oil (April 2000).
COCONUT OIL IN AN IDI ADAPTED DIESEL ENGINE

*DoE staff at the very starting of Welagi genset with coconut oil (July 2001)*
SYSTEM OF DOUBLE CIRCUIT

Renault dci 270 Ch (2006)
BIOFUELS FUNDAMENTALS

• BioDiesel in Diesel Engines
ESTERIFIED VEGETABLE OILS
OR BIODIESEL AS FUEL

EXAMPLE OF
ESTERIFIED
VEGETABLE OIL

PHILIPPINE COCONUT AUTHORITY

COCONUT METHYL ESTER (CME) AS
PETRODIESEL QUALITY ENHANCER
# ESTERIFIED VEGETABLE OILS OR BIODIESEL AS FUEL

## CME (Coconut Oil Methyl Ester)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CME</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cetane number</td>
<td>70</td>
<td>Better ignition &amp; acceleration</td>
</tr>
<tr>
<td>Flash point</td>
<td>106°C</td>
<td>Enhanced safety in storage</td>
</tr>
<tr>
<td>Sulfur content</td>
<td>0 %</td>
<td>No sulfur emission</td>
</tr>
<tr>
<td>Oxygen content</td>
<td>11 %</td>
<td>Clean burning, less smoke (but less energy content)</td>
</tr>
<tr>
<td>Viscosity</td>
<td>2-3</td>
<td>Good atomization</td>
</tr>
<tr>
<td>Lubricity (gms)</td>
<td>&gt; 7000</td>
<td>Enhances efficiency of fuel pump &amp; injector unit</td>
</tr>
<tr>
<td>Solvency &amp; detergency</td>
<td>high</td>
<td>Declogs/restores fuel nozzle spray efficiency</td>
</tr>
<tr>
<td>Water &amp; sediments</td>
<td>0.0</td>
<td>Durability of injection systems (if respected)</td>
</tr>
<tr>
<td>Total glycerine</td>
<td>0.145</td>
<td>Must not be &gt; 0.24</td>
</tr>
</tbody>
</table>

ESTERIFIED VEGETABLE OILS OR BIODIESEL AS FUEL

PERFORMANCE:

Efficiency: + 3%
Consumption: + 5%
ESTER OF VEGETABLE OIL

50 % Diesel - 50 % Methyl Ester (rapeseed oil)

Reims - France
METHYL ESTER OF VEGETABLE OIL

Biodiesel Plant
ESTER OF VEGETABLE OILS

Small scale Unit  40 l./day
(doc. Green Fuels UK)

2 tonnes/day Biodiesel Unit
(Ageratec Sweden)
ESTER OF VEGETABLE OILS

Example:
Demo of Coconut Oil Methyl Ester processing (doc. Alofa Tuvalu)
DO VEGETABLE OIL AND ETHANOL CAN REPLACE DIESEL AND PETROL AT THE WORLD LEVEL?

DO BIOFUELS PRESENT A RISK TO FOOD PRODUCTION?
FUELS - WORLD CONSUMPTION

- World consumption of oil: 80 millions of barrels/day (2/3 for transports)

- 12,720 millions litres or 10,176 millions kg = 10,17 millions of toe/day

- transports = 6.78 millions toe/day, or: 2475 millions toe/year)
### VEGETABLE OILS WORLDWIDE PRODUCTION 2007

<table>
<thead>
<tr>
<th>Production Millions tonnes</th>
<th>Production (M de tonnes)</th>
<th>2006-2007 (estim.)</th>
<th>2005-2006 (prév.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Palm</strong></td>
<td>Palme</td>
<td>38,44 30%</td>
<td>35,81</td>
</tr>
<tr>
<td><strong>Soya</strong></td>
<td>Soja</td>
<td>36,66 28%</td>
<td>34,94</td>
</tr>
<tr>
<td><strong>Rapeseed</strong></td>
<td>Colza</td>
<td>18,47 14%</td>
<td>18,07</td>
</tr>
<tr>
<td><strong>Sunflower</strong></td>
<td>Tournesol</td>
<td>11,25 9%</td>
<td>10,95</td>
</tr>
<tr>
<td><strong>Cottonseed</strong></td>
<td>Coton</td>
<td>4,94 4%</td>
<td>4,91</td>
</tr>
<tr>
<td><strong>Palm kernel</strong></td>
<td>Palmiste</td>
<td>4,46 4%</td>
<td>4,20</td>
</tr>
<tr>
<td><strong>Peanut</strong></td>
<td>Arachide</td>
<td>4,31 3%</td>
<td>4,61</td>
</tr>
<tr>
<td><strong>Coconut</strong></td>
<td>Coco</td>
<td>3,27 3%</td>
<td>3,28</td>
</tr>
<tr>
<td><strong>others</strong></td>
<td>Autres</td>
<td>6,90</td>
<td>6,13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>128,70 100%</td>
<td>122,9</td>
</tr>
</tbody>
</table>

**EQUIVALENT TO:** 116 millions toe
LES GRANDES MASSES

ALCOOL ETHYLIQUE

Ethanol global market – 40,9 Billions Litres

North and Central America 34%
South America 38%
Europe 9,8%
Asia 16,2%

Brazil 37%

Potential Market for Ethanol as Fuel:
1,5 Bi de Litros (2005) → 7,0 Bi de Litros (2010)

EQUIVALENT TO: 20 millions toe
• Whole Palm oil production can run world transport for less than 6 days !!! (1 tonne oil = .92 toe)

• World coconut oil production: half a day.
• All vegetable oils can run it during 17 days.

• Brazilian Ethanol can run it 1 day and 9 hours.
• All World Ethanol can run it during 3 days and 18 hours!

We are not at the same level!

Coconut trees Biofuels from Pacific Islands will not be used in the World market.

But they are well adapted and opportune solutions at local level for welfare and sustainable development.
THANK YOU FOR ATTENTION!
MERCI POUR VOTRE ATTENTION !