From vegetable oil to fuel: Biodiesel production – An overview

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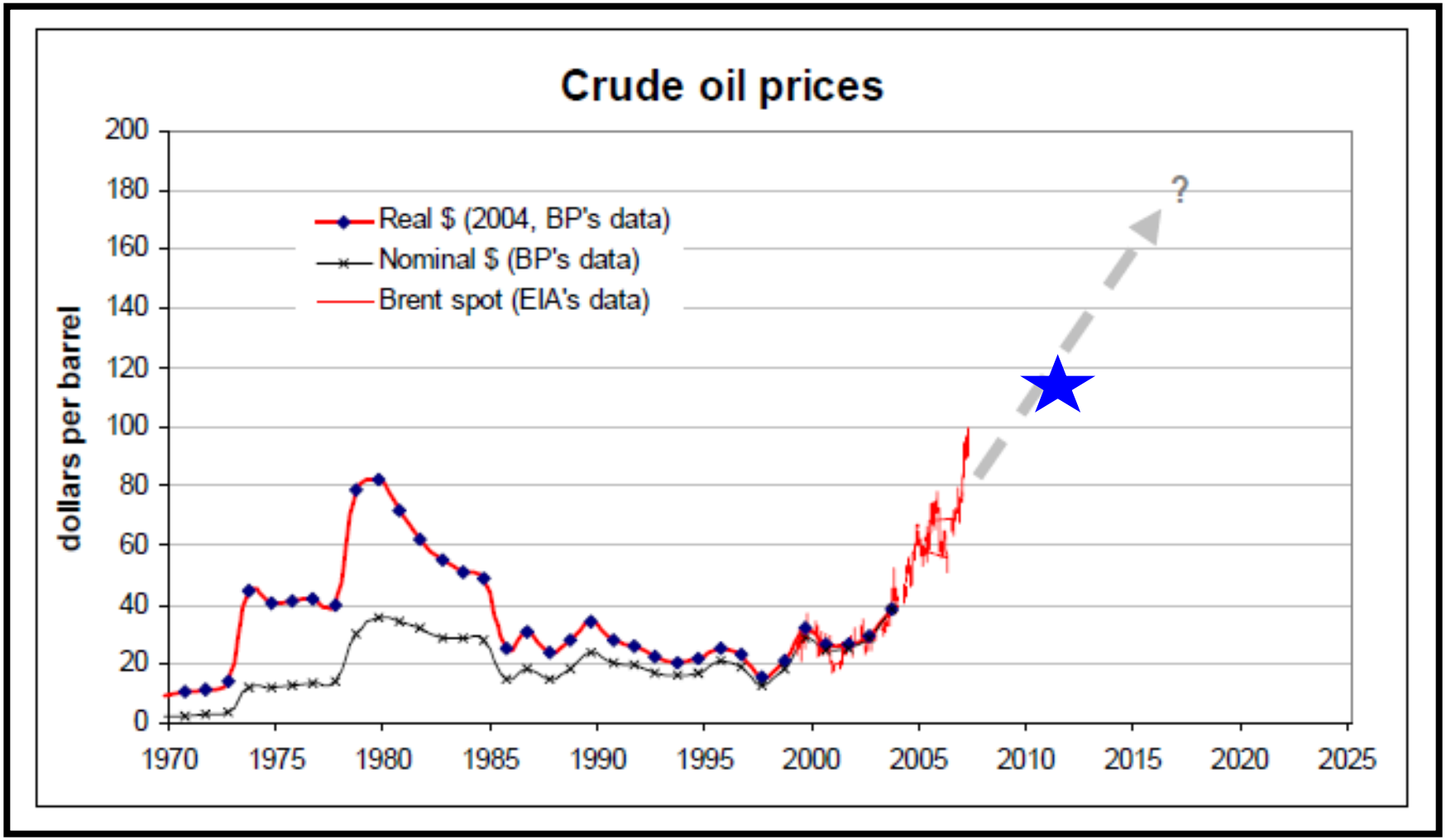
Presentation overview

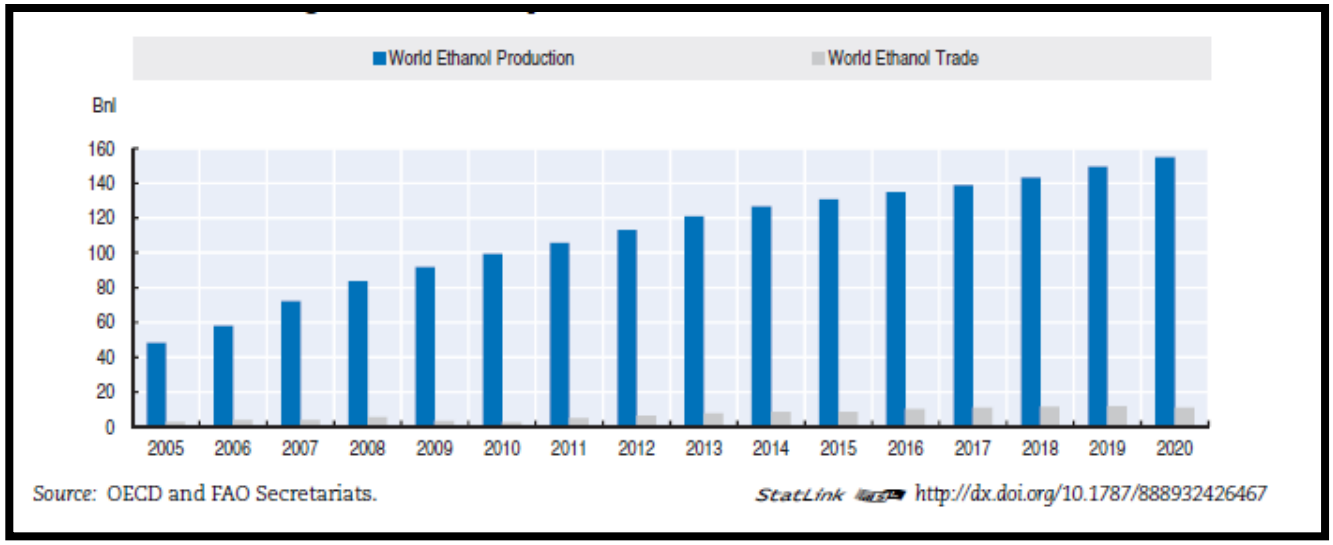
The topics covered will include:

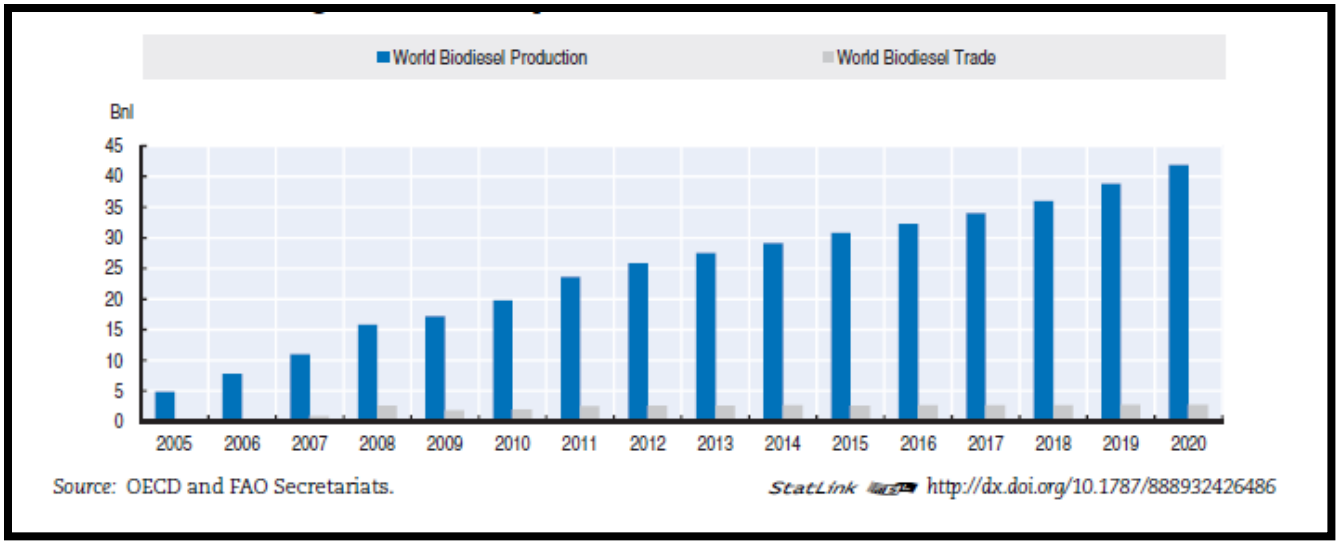
- Forecasted increase in biofuel production
- Biofuel classification
- Diesel engines and how they operate
- Demonstrate how to make transesterified biodiesel
- Case studies of small scale biodiesel production and use
- Presenting a typical home `biodiesel´ processor
- Biodiesel production 2nd and 3rd generation production
- Future biodiesel development



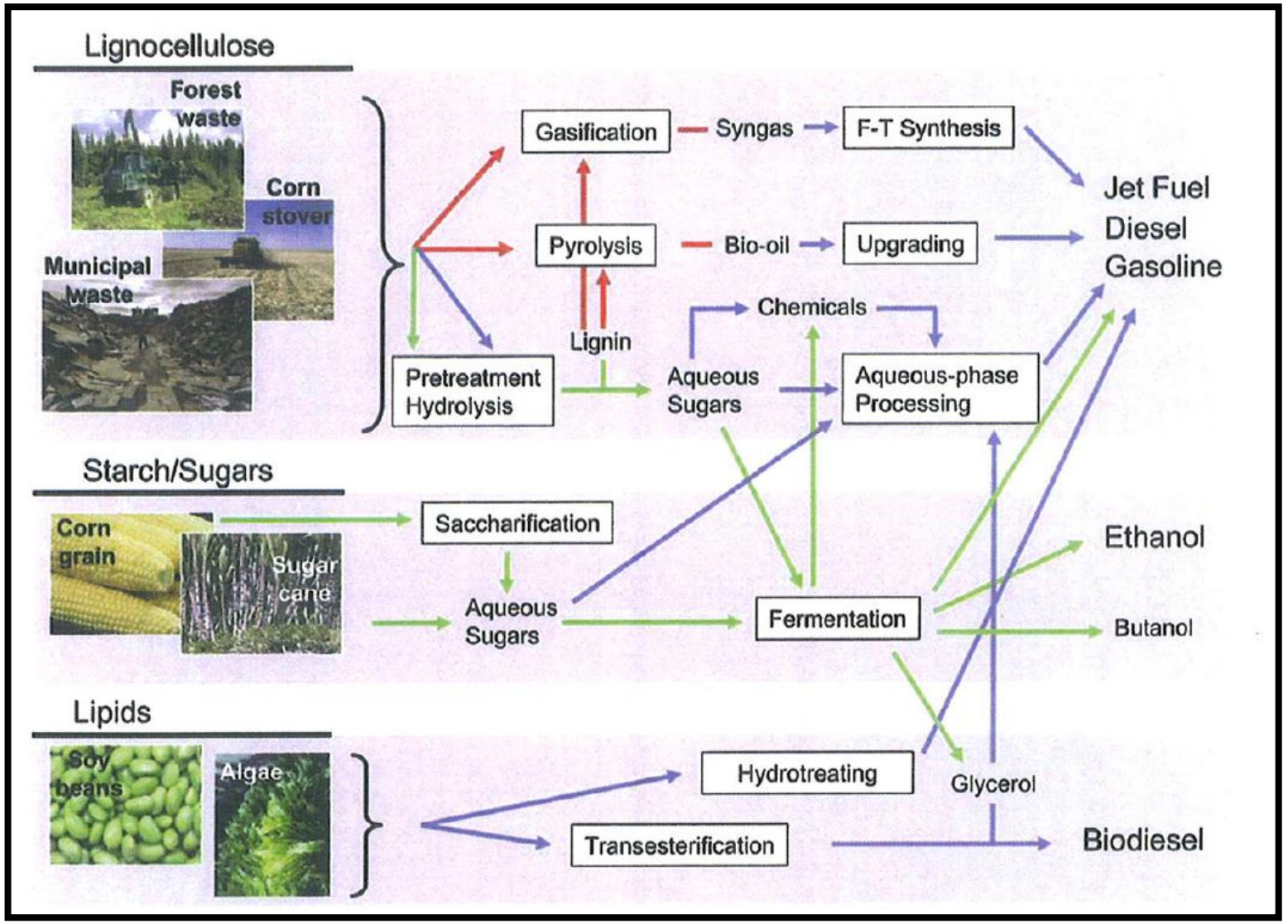
Source: http://ourfiniteworld.com/

Forecast for increase in biofuel production



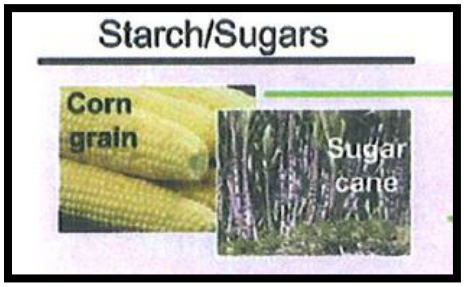


Consider liquid biofuels (complex)……



(Source: Serrano/Ruiz and Dumesic, Energy Environ Sci, 2011)

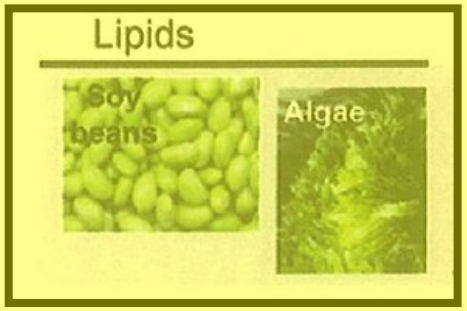
Consider liquid biofuels (simplified)…..



Sources of carbohydrates

Petrol ‘substitute’

(sugars and starches)



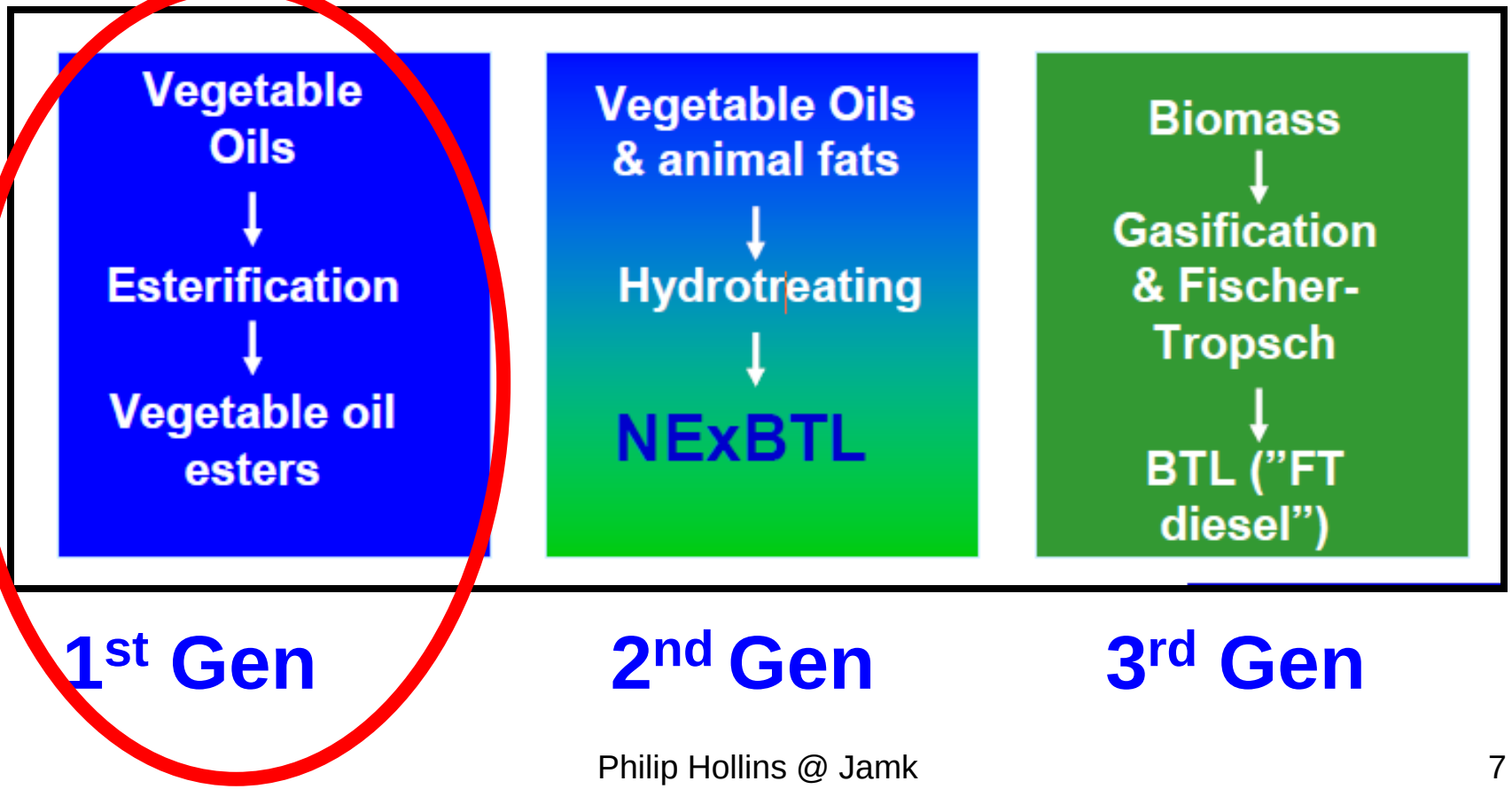
Sources of fats

Diesel ‘substitute’

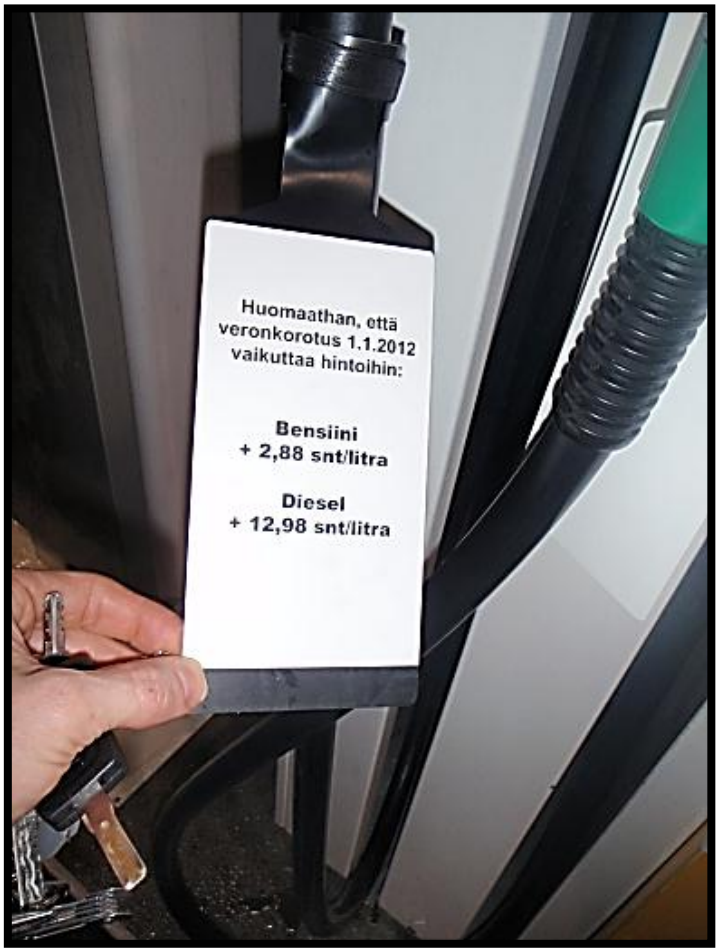
(saturated, mono/polyunsaturated & fatty acids)

Liquid bio-fuel classification
(by conversion)

Neste (and others) define generation …….



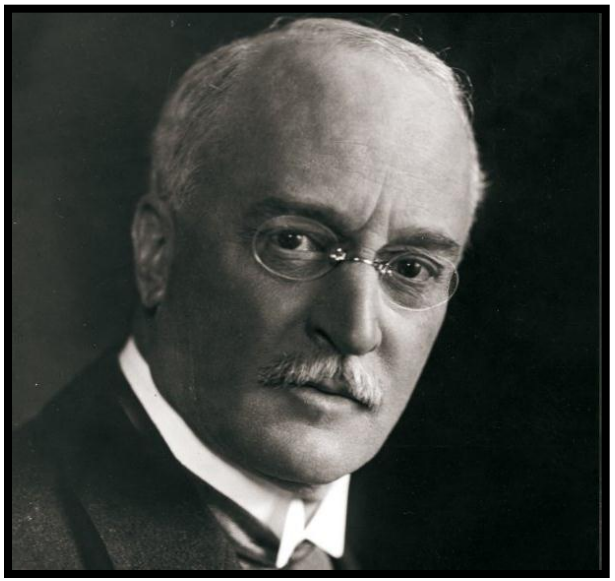
Currently diesel costs → Cost is increasing



How about making it for 0.57cents !*

*** Including tax - assumes free labour and feedstock**

Rudolf Diesel



Born 1858 **Died 1913**

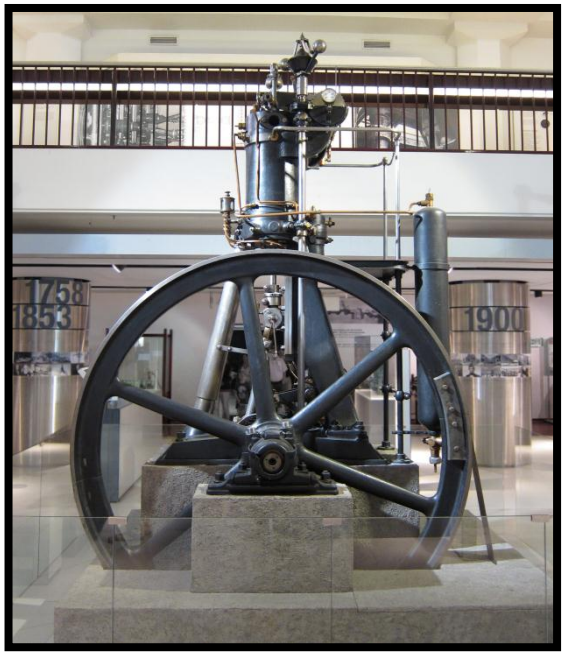
1892: Patent obtained

1897: First prototype developed

1900: Demonstrated World Exhibition in Paris running on **peanut oil**

1912: Presentation to the British Institute of Mechanical Engineers

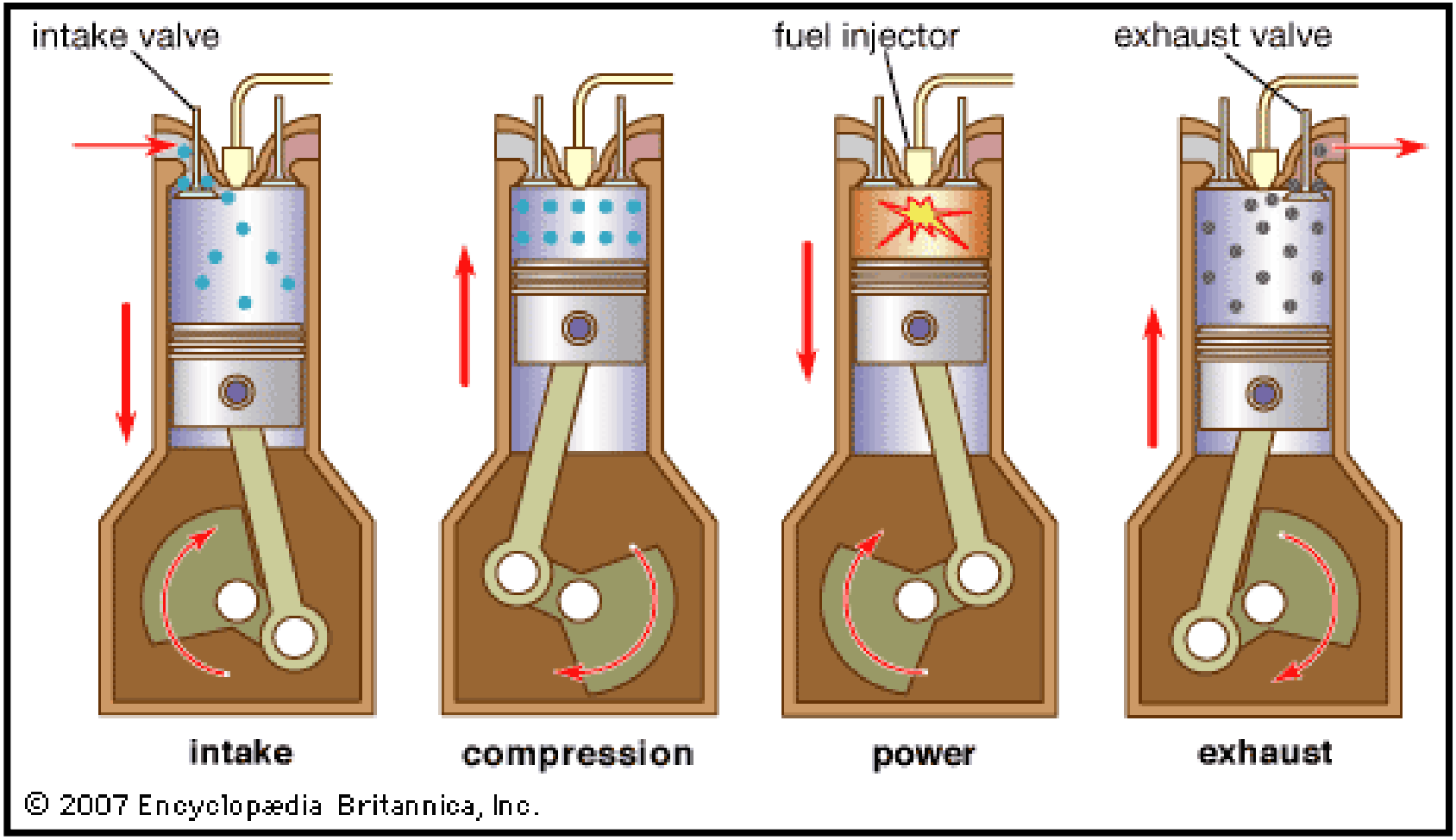
1913: Died in ‘mysterious’ circumstances - found drowned in the English Channel



Deutsches Museum in Munich.

“The fact that fat oils from vegetable sources can be used may seem insignificant today, but such oils may perhaps become in course of time of the same importance as some natural mineral oils and the tar products are now” **(Diesel, 1912)**

How a diesel engine works (CI: Compression ignition)



Hyperlink to video 1……..
Hyperlink to video 2……..
Hyperlink to video 3…….

Diesel ‘substitute’ vegetable oil yields

Crop	Litres oil/ha
Corn (maize)	712
Jatropha	1892
Lupin	232
Oats	217
Opium poppy	1163
Palm oil	5950
Rapeseed	1190
Soybean	446
Sunflower	952

Source: Adapted from www.journeytoforever.org

Fuel'	Viscosity @ 40^0 Celcius
Diesel	**2.50 Cst**
Rapeseed	54.10 Cst
Soyaflower	35.40 Cst
Sunflower	35.20 Cst
Palm oil	47.80 Cst
Peanut oil	42.00 Cst

Source: Adapted from www.Green Team Alternative Fuels.com

Problems with vegetable oil.....

- Originally diesel engines where designed to operate using raw vegetable oil.
- Modern diesel engines **are too specialised** to reliably run on pure vegetable oil
- Vegetable oil is **too viscous** to use directly

Modifying the engine……

Kevin Alford is a final year studying for B.Sc. in Agriculture.

Dual tank system

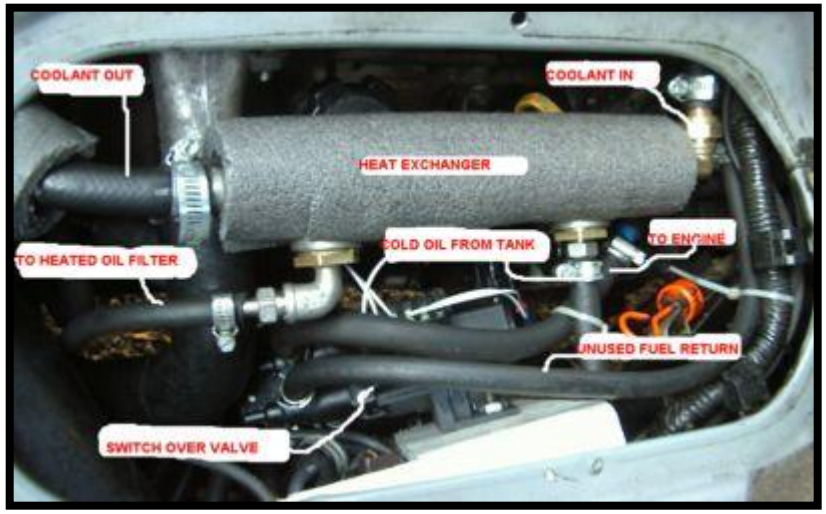
Diesel/(waste) veg' oil

Start on diesel…..

Engine heat exchanger
→ lower viscosity

Switch to vegetable oil

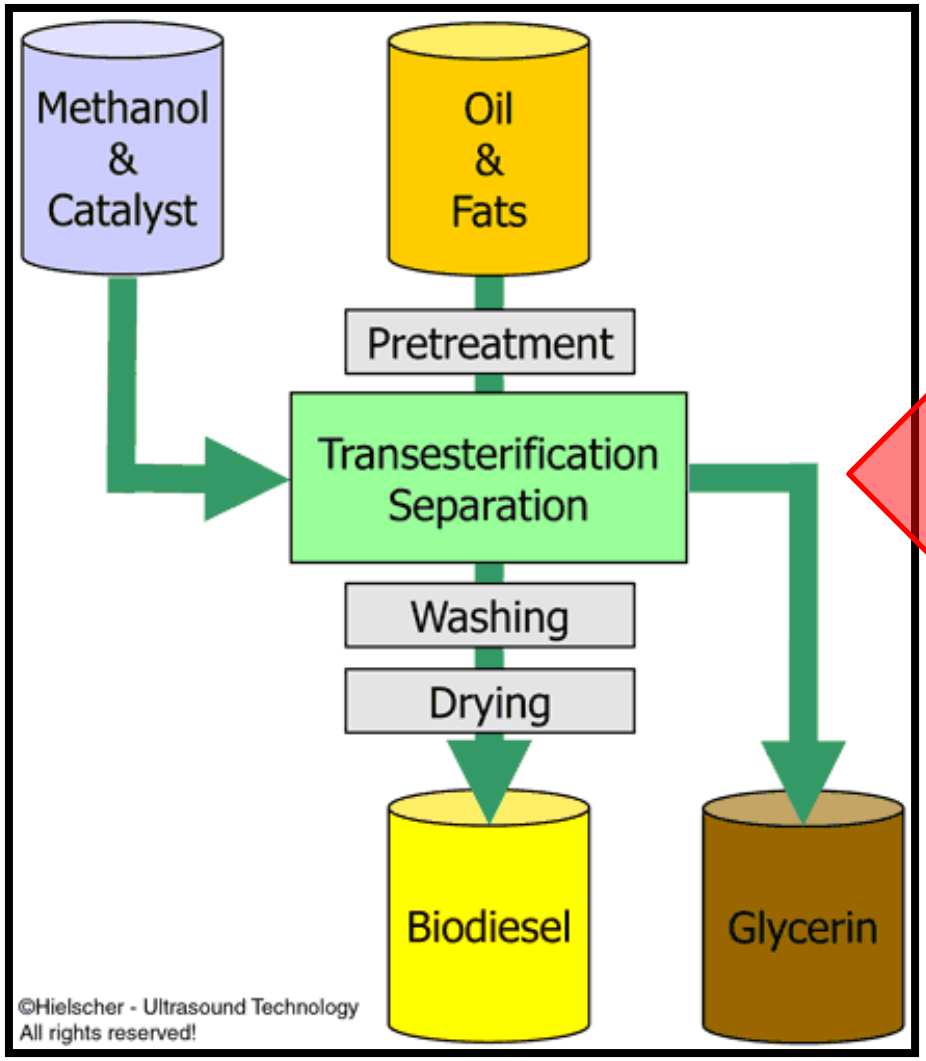
Cost of system
→fitted ~ €1600



Example manufacturer: Elsbett

Home made system taken from : www.reuk.co.uk

Modifying the vegetable oil……



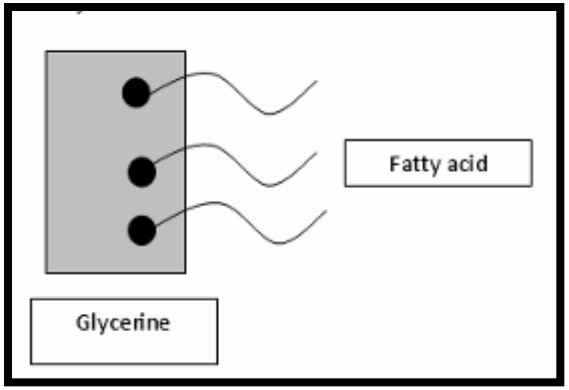
Transesterification process

→ remove glycerine molecule

→ reduces viscosity (x3)

Modifying the fuel (FAME)……..

Convert vegetable oil to bio-diesel

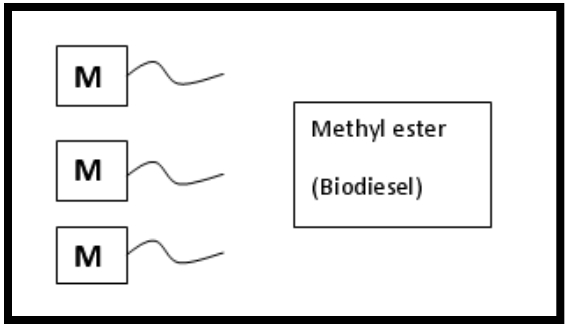


Vegetable oil → Triglycerine ester

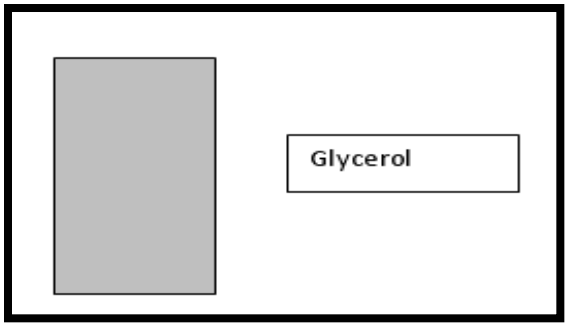
Large molecule → viscous

Transesterification process

→ reducing viscosity → remove glycerine molecule



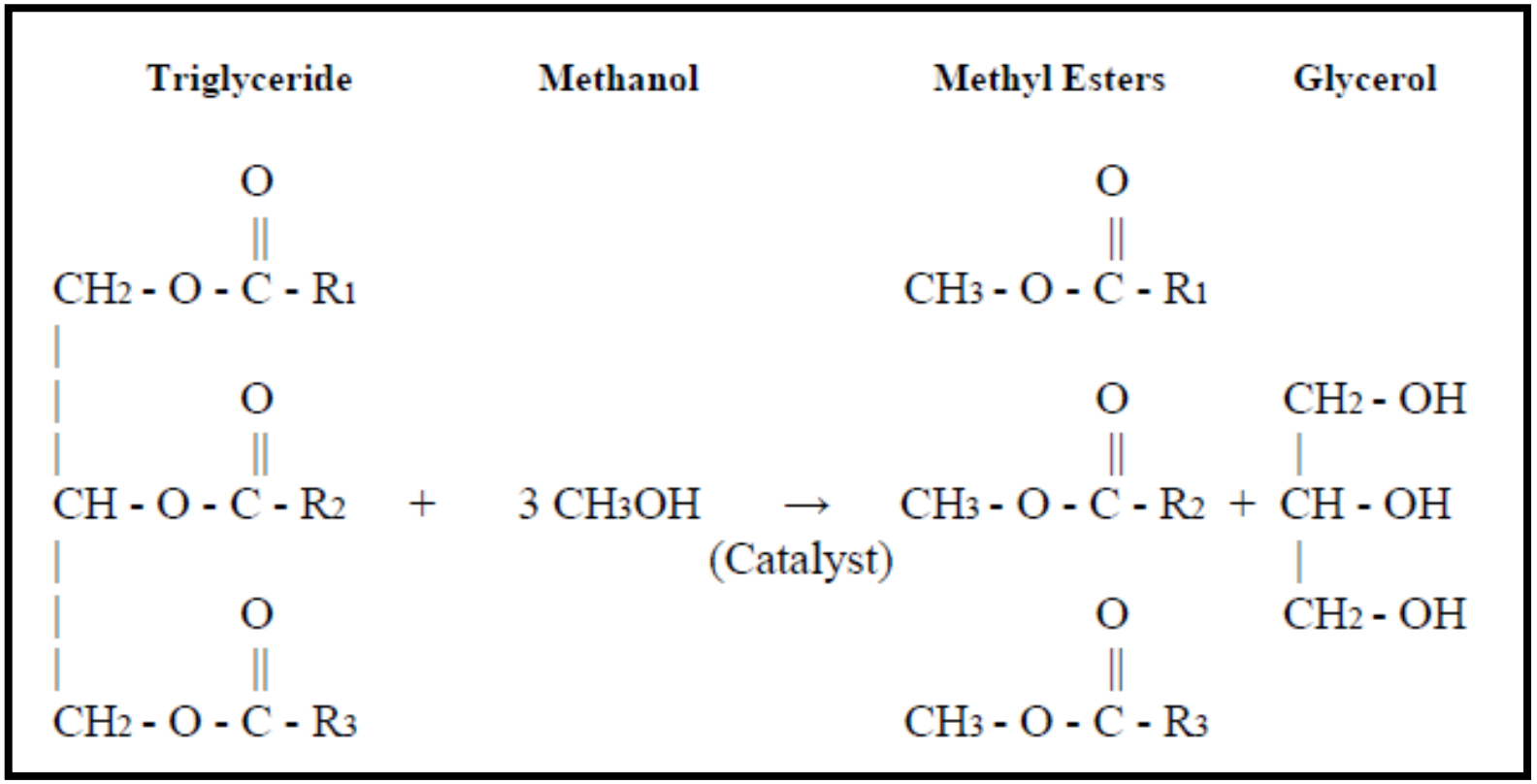
methanol
and
catalyst



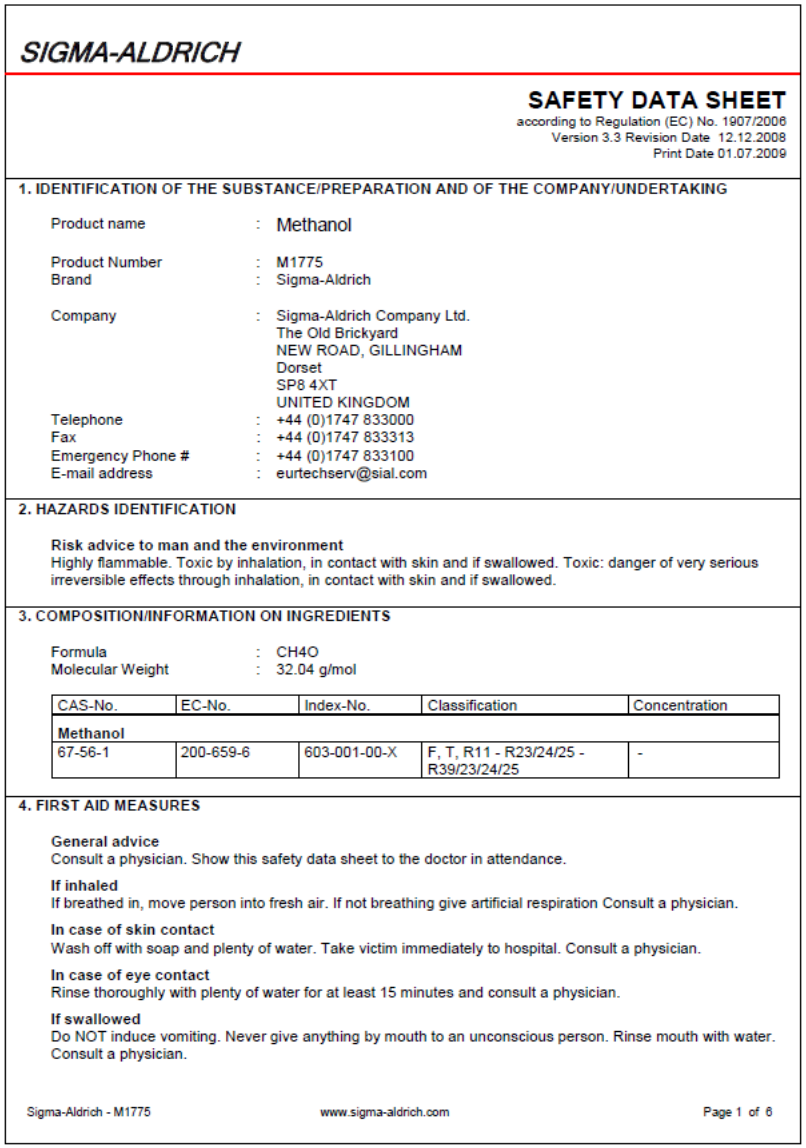
Viscosity decrease x 3

Waste product → with uses

The chemisty ……



Methanol



SIGMA-ALDRICH

SAFETY DATA SHEET
according to Regulation (EC) No. 1907/2006
Version 3.3 Revision Date 12.12.2008
Print Date 01.07.2009

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Product name : Methanol

Product Number : M1775
Brand : Sigma-Aldrich

Company : Sigma-Aldrich Company Ltd.
The Old Brickyard
NEW ROAD, GILLINGHAM
Dorset
SP8 4XT
UNITED KINGDOM
Telephone : +44 (0)1747 833000
Fax : +44 (0)1747 833313
Emergency Phone # : +44 (0)1747 833100
E-mail address : eurtechserv@sial.com

2. HAZARDS IDENTIFICATION

Risk advice to man and the environment
Highly flammable. Toxic by inhalation, in contact with skin and if swallowed. Toxic: danger of very serious irreversible effects through inhalation, in contact with skin and if swallowed.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Formula : CH4O
Molecular Weight : 32.04 g/mol

CAS-No.	EC-No.	Index-No.	Classification	Concentration
Methanol				
67-56-1	200-659-6	603-001-00-X	F, T, R11 - R23/24/25 - R39/23/24/25	-

4. FIRST AID MEASURES

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled
If breathed in, move person into fresh air. If not breathing give artificial respiration Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

Sigma-Aldrich - M1775 www.sigma-aldrich.com Page 1 of 6

- Clear, colorless liquid odour like alcohol.
- Four millliliters can cause blindness and 80 to 150 milliliters can be fatal
- Inhalation of methanol vapor is the most common route of occupational exposure.
- Poisoning also possible from absorption through the skin

You will be using 100ml

Potassium Hydroxide (KOH)

SIGMA-ALDRICH

SAFETY DATA SHEET
according to Regulation (EC) No. 1907/2006
Version 3.1 Revision Date 12.12.2008
Print Date 01.07.2009

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Product name : Potassium hydroxide

Product Number : 484016
Brand : Sigma-Aldrich

Company : Sigma-Aldrich Company Ltd.
The Old Brickyard
NEW ROAD, GILLINGHAM
Dorset
SP8 4XT
UNITED KINGDOM
Telephone : +44 (0)1747 833000
Fax : +44 (0)1747 833313
Emergency Phone # : +44 (0)1747 833100
E-mail address : eurtechserv@sial.com

2. HAZARDS IDENTIFICATION

Risk advice to man and the environment
Harmful if swallowed. Causes severe burns.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Synonyms : Caustic potash

Formula
Molecular Weight

CAS-No.	EC-No.
Potassium hydroxide	
1310-58-3	215-181

4. FIRST AID MEASURES

General advice
Consult a physician. Show

If inhaled
If breathed in, move perso

In case of skin contact
Take off contaminated clot
physician.

In case of eye contact
Rinse thoroughly with plen

If swallowed
Do NOT induce vomiting. N
Consult a physician.

Sigma-Aldrich - 484016

pH 13 - drain cleaner

Exposure Routes
inhalation, ingestion, skin and/or eye contact

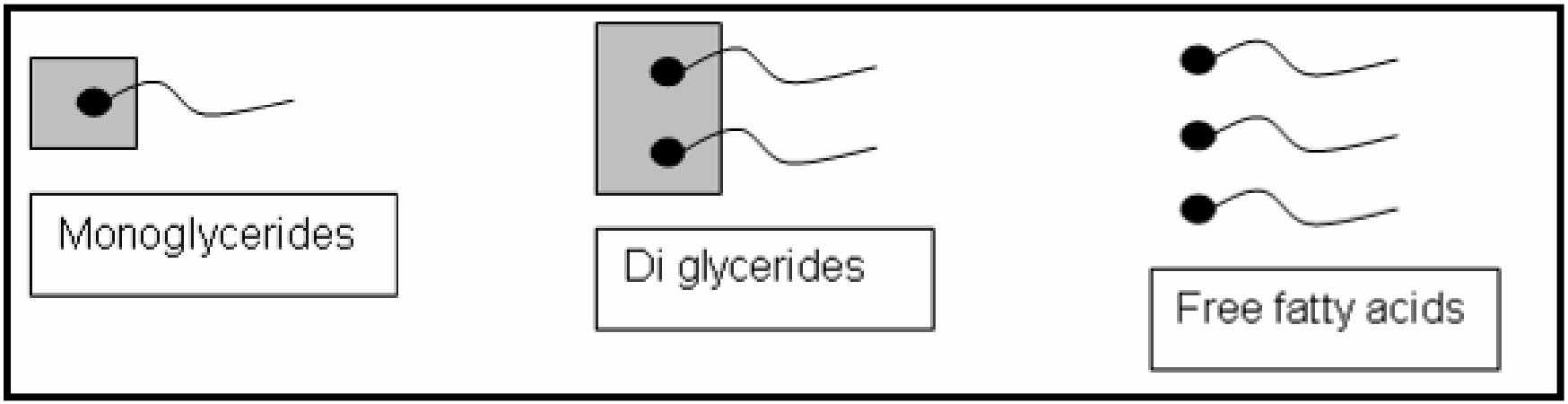
Symptoms
irritation eyes, skin, respiratory system; cough, sneezing; eye, skin burns; vomiting, diarrhoea

Target Organs
Eyes, skin, respiratory system

You will be using 14g max

Convert (waste) vegetable oil to bio-diesel

Waste vegetable oil contains:



Mono and Di–glycerides → no problem
Free fatty acids → problem

Neutralised by the addition of potassium hydroxide
Determined by pH test titration

Potassium hydroxide also acts as catalyst
Potassium hydroxide & methanol → methoxide

Sourcing the waste oil……..

The processing unit……

Testing the pH → titration……

Determining the amount of ‘neutraliser to add……..

NEW Oil (No Titration Needed)	
Methanol (L)	Amount of KOH required (grams)
24	1080

WASTE Oil (W.V.O.) Titration Chart		
Methanol (L)	Oil Titration reading (ml/s)	Amount of KOH required (grams)
24	1	1200
24	2	1320
24	3	1440
24	4	1560
24	5	1680
24	6	1800
24	7	1920
24	8	2040
24	9	2160
24	10	2280

Preparing and adding the methoxide……..

Removing the glycerol…..

Hyperlink to video……..

…….and testing batch quality

‘Washing’ the bio-diesel…….

‘Drying’ and filtering the bio-diesel...

Distributing the finished bio-diesel……

K. Kapilakarn, A.Peugtong / International Energy Journal 8 (2007) 1-6

Purity 1

A Comparison of Costs of Biodiesel Production from Transesterication

www.serd.ait.ac.th/reric

Kulchanat Kapilakarn*[1] and Ampol Peugtong*

Abstract - Nowada
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were reaction times
Moreover the work
found that the optir
wt.), the reaction te
the process with do
reactors, it is found
the equivalent size.

Keywords - Biodiesel

Conversion

Int. J. Environ. Sci. Tech., 5 (1), 75-82, Winter 2008
ISSN: 1735-1472

Production optimization and quality assessment of biodiesel from waste vegetable oil

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[1]Department of Chemical Engineering, Faculty of Engineering, Cairo University, Egypt
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Received 6 November 2007; revised 26 November 2007; accepted 3 December 2007; available online 26 December 2007

ABSTRACT: Biodiesel production is worthy of continued study and optimization of production procedures because of its environmentally beneficial attributes and its renewable nature. In Egypt, millions L. of oil used for frying foods are discarded each year into sewage systems. Thus, it adds to the cost of treating effluent or pollutes waterways. This study is intended to consider aspects related to the feasibility of the production of biodiesel from waste/recycled oils in an attempt to help reduce the cost of biodiesel and reduce waste and pollution coming from waste oils. The variables affecting the yield and characteristics of the biodiesel produced from used frying oil were studied, the achieved results were analyzed and a set of recommendations was proposed. From the obtained results, the best yield percentage was obtained using a methanol/oil molar ratio of 6:1, potassium hydroxide as catalyst (1%) and 65 °C temperature for one hour. The yield percentage obtained from waste vegetable oil was comparable to that obtained from neat vegetable oil which reached 96.15% under optimum conditions. From the results it was clear that the produced biodiesel fuel, whether from neat vegetable oil or waste vegetable oil, was within the recommended standards of biodiesel fuel.

Key words: *Biodiesel, waste vegetable oil, transesterification, optimization*

Homebrew Tests Listed

Written by Rickdatech

Best of the Tests

Tests for Finished Biodiesel

- ASTM Laboratory Testing
- The pHLip Test
- Clarity Test for Water
- Cloud Point Testing
- Gel Point Testing
- The Methanol Test from JTF
- The Dr Pepper Viscosity Test
- The Dr Pepper Reprocess Test

Initial Feedstock Testing

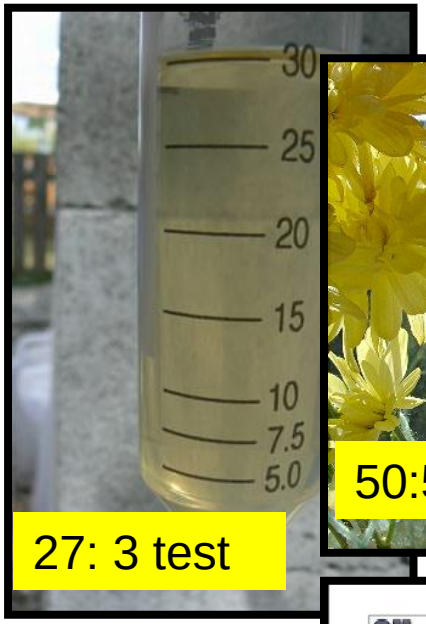
- Titration Test for WVO
- The Frying Pan Test
- The Hot Pan Test
- Quantitative test for water
- Specific Gravity of Methanol

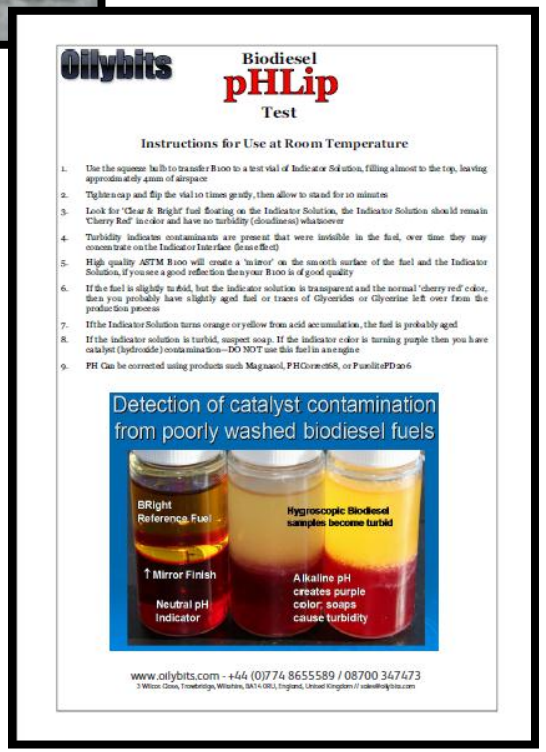
Mid Process Tests

- Soap Test Titration
- The Drying Test

The Rest of the Tests

- pH Testing
- Reprocess Test from JTF
- Specific Gravity of Biodiesel
- The Wash Test from JTF
- The Shakem Up Test
- Wash Water Clarity Test
- pH Testing the Wash Water
- Smelling for Methanol





Oilybits

Biodiesel **pHLip** Test

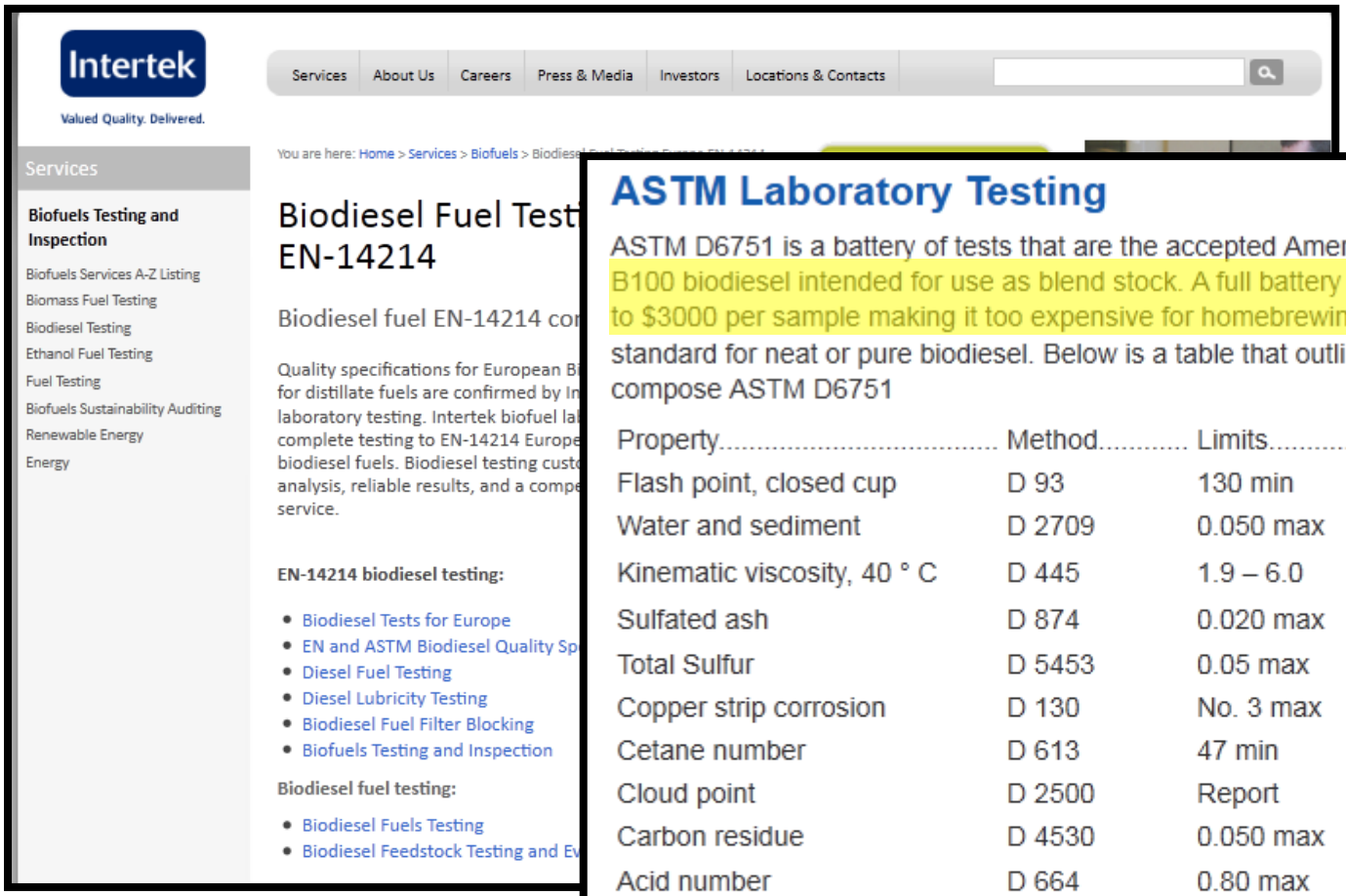
Instructions for Use at Room Temperature

1. Use the squeeze bulb to transfer B100 to a test vial of Indicator Solution, filling almost to the top, leaving approximately 4mm of airspace
2. Tighten cap and flip the vial 10 times gently, then allow to stand for 10 minutes
3. Look for 'Clear & Bright' fuel floating on the Indicator Solution, the Indicator Solution should remain 'Cherry Red' in color and have no turbidity (cloudiness) whatsoever
4. Turbidity indicates contaminants are present that were invisible in the fuel, over time they may concentrate on the Indicator Interface (lens effect)
5. High quality ASTM B100 will create a 'mirror' on the smooth surface of the fuel and the Indicator Solution, if you see a good reflection then your B100 is of good quality
6. If the fuel is slightly turbid, but the indicator solution is transparent and the normal 'cherry red' color, then you probably have slightly aged fuel or traces of Glycerides or Glycerine left over from the production process
7. If the Indicator Solution turns orange or yellow from acid accumulation, the fuel is probably aged
8. If the indicator solution is turbid, suspect soap. If the indicator color is turning purple then you have catalyst (hydroxide) contamination—DO NOT use this fuel in an engine
9. PH Can be corrected using products such Magnasol, PHCorrect68, or PurolitePD2a16

Detection of catalyst contamination from poorly washed biodiesel fuels

www.oilybits.com - +44 (0)774 8655589 / 08700 347473

Source: http://www.make-biodiesel.org/



ASTM Laboratory Testing

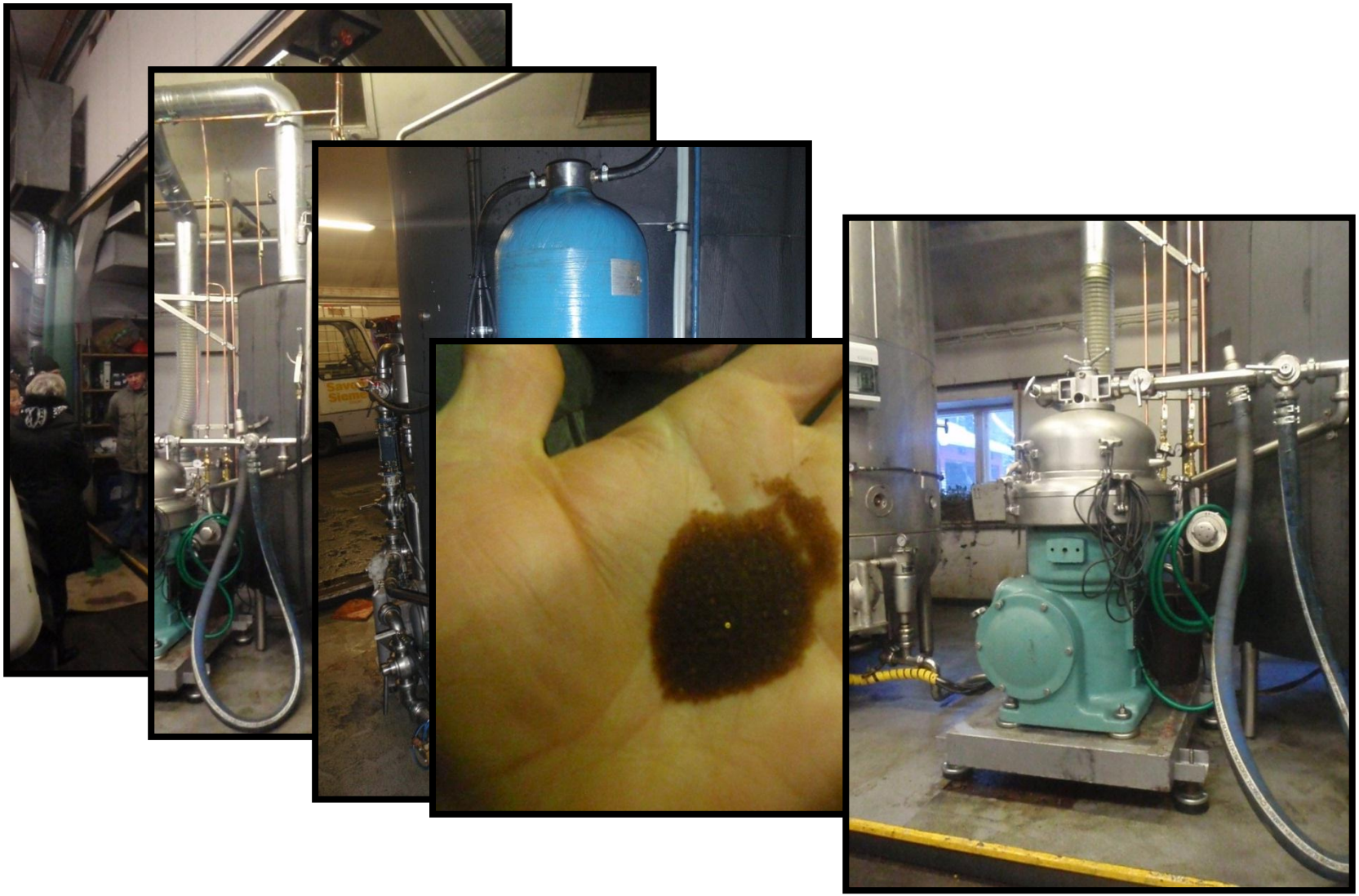
ASTM D6751 is a battery of tests that are the accepted American Standard for testing B100 biodiesel intended for use as blend stock. A full battery of tests cost from $1000 to $3000 per sample making it too expensive for homebrewing. It is not an accepted standard for neat or pure biodiesel. Below is a table that outlines the tests that compose ASTM D6751

Property.....	Method.....	Limits.....	Units.....
Flash point, closed cup	D 93	130 min	° C
Water and sediment	D 2709	0.050 max	% volume
Kinematic viscosity, 40 ° C	D 445	1.9 – 6.0	mm^2/s
Sulfated ash	D 874	0.020 max	wt. %
Total Sulfur	D 5453	0.05 max	wt. %
Copper strip corrosion	D 130	No. 3 max	
Cetane number	D 613	47 min	
Cloud point	D 2500	Report	° C
Carbon residue	D 4530	0.050 max	wt. %
Acid number	D 664	0.80 max	mg KOH/g
Free glycerin	D 6584	0.020	wt. %
Total glycerin	D 6584	0.240	wt. %
Phosphorus	D 4951	0.0010	wt. %
Vacuum distillation end point	D 1160	360 °C max, at T-90	% distilled

For more information on ASTM 6751 see Biodiesel Analytical Methods by the NREL. The actualt test procedures are available from ASTM.com with the purchase of a membership or from Techstreet.com without membership.

My Opinion - What can I say.... This is the only official standard we have and it's too expensive for homebrewers to use as a standard.

Finland example 1 (Iisalmi, near Kuopio)



Finland example 2 (Leppävesi, near Jyväskylä)

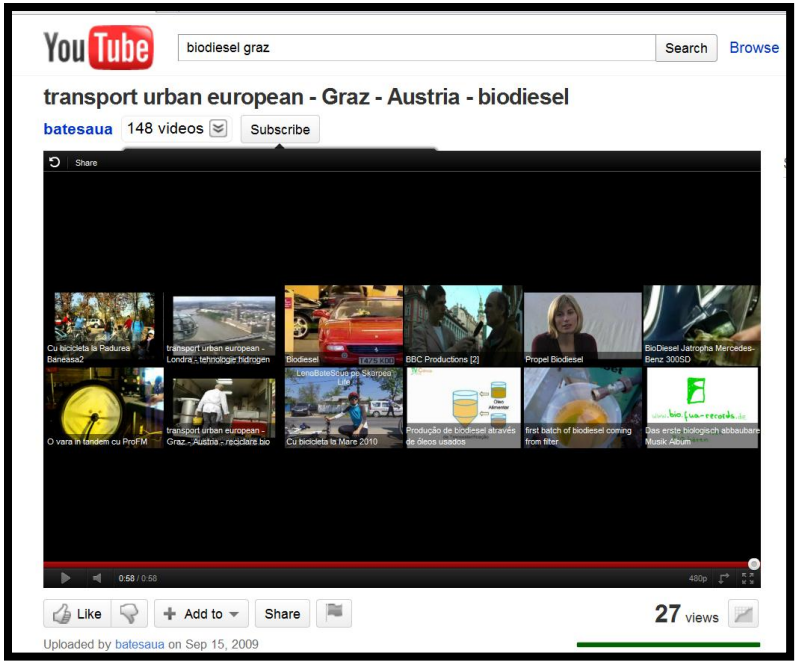
……uses for the waste glycerol

(Leppävesi, near Jyväskylä)

Types of waste used in anaerobic digester

Feed	m^3 CH_4 per tonne dry matter
Pig Slurry	240
Dairy Slurry	180
Poultry Manure	250
Sewage Sludge	270
Maize	370
	500

Case study – Graz in Austria



´From the pan into the tank`

Operational in Graz, Austria (since 1999)

Approx' 56 buses (50% of public transport)

Hyperlink

A typical industrial scale processing unit

green fuels

The Green Fuels FuelMaker up to **8000 litres per day**

Made in batches of 600 litres

Cost £280,000 ~ € 336,600

``*For a fully installed biodiesel factory based on this model, you need to approximately double the cost ´´*

Greenfuel representative

However, not all biodiesel is the same…

NESTE OIL

Generations of renewable diesel components

Gene-ration	Com-mercial scale	Production process *Product*	Availability of feedstocks	Quality of product	Invest-ment costs
1st	≈ 1995...	Esterification *Ester FAME*	-	-	+
2nd					
3rd					

+ Benefit - Disadvantage

C_nH_{2n+2} = Paraffinic hydrocarbon

11 JSAE, July 23, 2007 Seppo Mikkonen, Neste Oil

Neste and UPM are competitors…..

Alternative Fuel Options

Mineral Oil

Refining

Hydrocarbons:
Gasoline
Jet
Diesel

Commercial

NESTE OIL

UPM BIOFUELS

UPM develops biofuels of the future

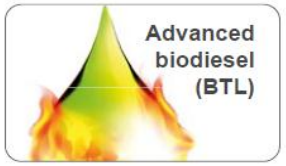
The Biofore Company UPM

Conventional biodiesel

Advanced biofuels

Biodiesel

Hydrogenated Vegetable oils



UPM's development areas

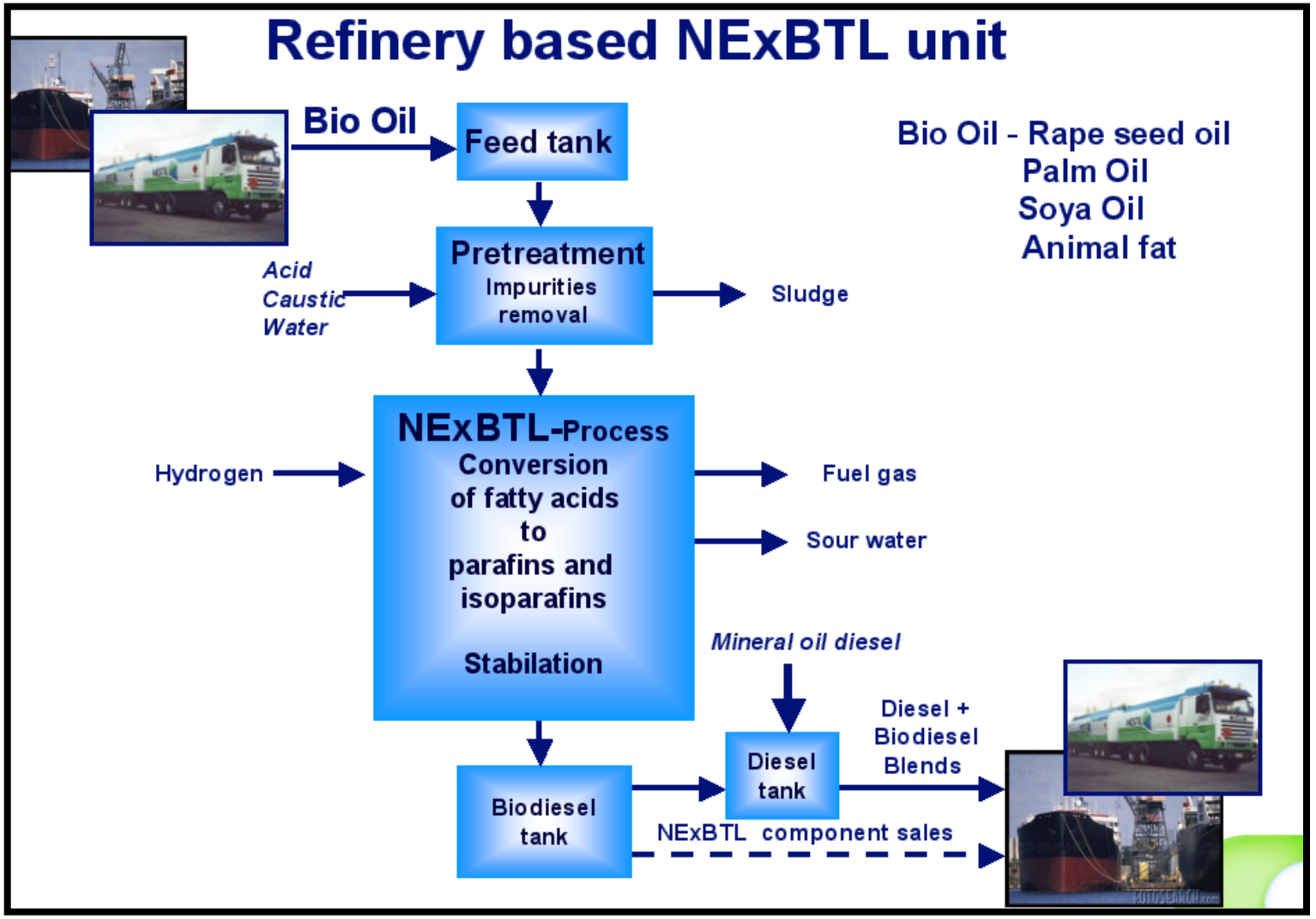
2005		UPM 2011	UPM 2012
Raw materials & processes			
Rapeseed oil Palm oil Soy oil	Rapeseed oil Palm oil Soy oil Fats	Forest industry residues Waste fats Pyrolysis oil	Energy wood
Esterification	Hydrogenation	Hydrogenation	Gasification + Fischer Tropsch

5 | © UPM

September 14, 2011

Neste

Hydrotreated vegetable oil: HVO



Hyperlink (Neste)

Hyperlink (Neste)

Neste NExBTL 100 Green Biodiesel

ISCC
International Sustainability & Carbon Certification

Despite……..

Neste Oil's targets for procurement of renewable raw materials in 2011:

Raw material	Planned share (%) in 2011
Crude palm oil	< 50%
Waste and side streams (waste animal fat, PFAD, stearin)	~ 40%
Others (e.g. rapeseed, jatropha, and camelina)	~ 10%

However, negative publicity……..

19 JAN 2009: **REPORT**

The Cost of the Biofuel Boom: Destroying

The clearing of Indonesia
profound effects – threate
indigenous people, and re
the atmosphere.

BY TOM KNUDSON

Hyperlink 1

HOME | BIOFUELS | BIODIESEL | UPM TO BUILD THE WORLD'S FIRST BIOREFINERY PRODUCING WOOD-BASED BIODIESEL

UPM to build the world's first biorefinery producing wood-based biodiesel

pangea 01/02/2012 12:45:00

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Second generation biodiesel

UPM is to invest in a biorefinery producing biofuels from crude tall oil in Lappeenranta, Finland.

(UPM, Helsinki, 1 February 2012 at 10.00 EET)

The industrial scale investment is the first of its kind globally. The biorefinery will produce annually a

Construction of the biorefinery will begin in the sum
investment will amount to approximately EUR 150 r

"The biofuels business has excellent growth potenti
significant interest among a wide range of customer
becoming a significant producer of advanced secon
strategy", says UPM President and CEO Jussi Pes

UPM 's advanced biodiesel, UPM BioVerno, is an ir
comparison to fossil fuels. The product's characteris
today's vehicles and fuel distribution systems.

"Our biorefinery in Lappeenranta is the first signific
ongoing transformation of forest industry", says Pes

The construction of the biorefinery will offer work fo
biorefinery will directly employ nearly 50 people and
the project.

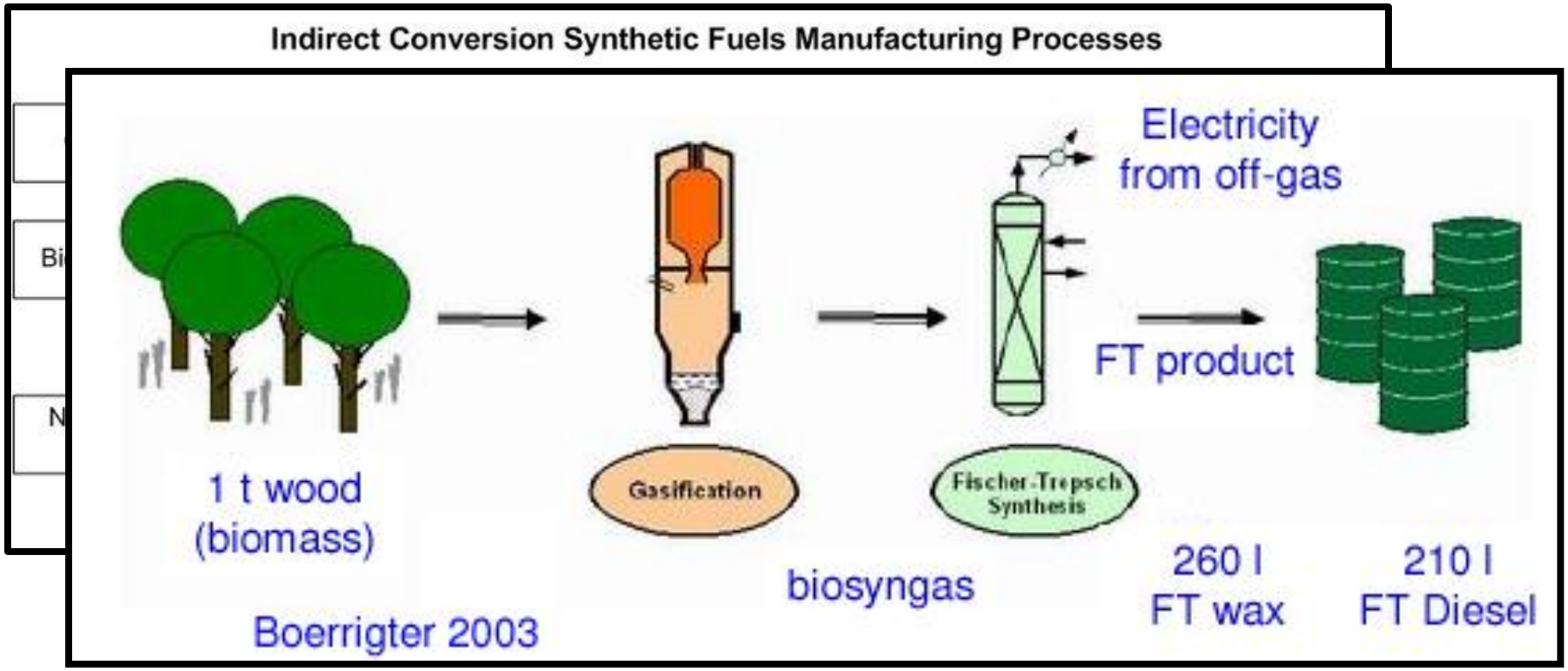
EU 2020 targets create demand for sustainable

The demand for biofuels is expected to grow by app
biofuels in transport fuels to 10% by the year 2020. In Finland, the corresponding target is even more challenging with an increase of

UPM announced the beginning of 2012, that the company will invests (€ 150 million) in the world's first advanced wood based biodiesel production in South Eastern Finland, Lappeenranta. Process is using hydrotreatment technology and raw material will be sustainably produced crude tall oil.

Construction of biorefinery will start in the summer of 2012 and production (100 000 tonnes/year) of advanced second generation biodiesel will start in 2014. The production will cover about 25 percent of Finland's 20 percent biofuels target in 2020.

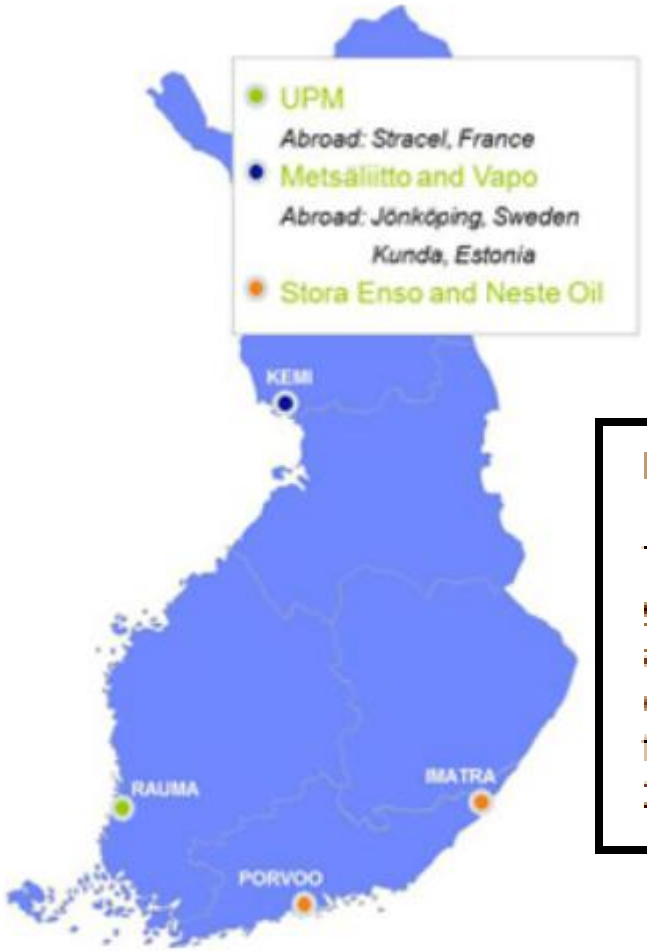
Fischer-Tropsch (FT) biodiesel*



- **Also known as BTL,CTL AND GTL**

Hyperlink –UPM (Fisher Tropsch)

Hyperlink – Neste & Stora Enso



Plans for several biorefineries in Finland.

Biorefineries planned for Finland

Three consortiums are presently planning to establish second generation biorefineries in Finland. Stora Enso/Neste Oil, UPM and Metsäliitto/Vapo are basing their designs on the gasification of biomass and the Fischer-Tropsch synthesis. The planned facilities would each have the capacity to produce 100,000 – 200,000 tonnes of biodiesel annually.

Source: www.forestindustries.fi

Neither of these processes are new.....

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Thanks for the Cheap Gas, Mr. Hitler!

How Nazi Germany and apartheid South Africa perfected one of the world's most exciting new fuel sources.

By Daniel Gross | Posted Monday, Oct. 23, 2006, at 3:30 PM ET

When it comes to racial policies, it may be somewhat hyperbolic to say that the apartheid regime that came into power in South Africa in 1948 picked up where the Nazis left off. It's not at all hyperbolic to observe that the apartheid regime picked up where the Nazis left off when it came to producing gasoline from coal. Nazism, apartheid, and international sanctions created a fuel source that might never have existed in a better world.

The circuitous travels of the Fischer-Tropsch process, a chemical technique to convert natural gas and coal into liquid fuels, provide an object lesson in historical irony. Used by the Nazis to make oil from coal during World War II, it was commercialized by the century's second-most-odious racial supremacist regime in the 1950s through South Africa's state energy company. Now, that privatized company, Sasol, may help liberate Western democracies (and non-Western ones, like India) from the grip of crude oil produced largely by loathsome authoritarian regimes.

Sasol is the ExxonMobil of South Africa, though its annual sales of about $10 billion are around what Exxon Mobil does in about 10 days. With 30,000 employees, including the largest number of Ph.D.s of any company in the Southern Hemisphere, Sasol is one of South Africa's largest employers. It produces about 38 percent of South Africa's fuel needs and accounts for about 4.4 percent of the country's GDP.

MORE SLATE **STORIES**

Mitt Romney's Astonishingly Liberal Answers During the GOP Debate

Remembering Frank Kameny, the Man Who Did More To Make Life Better for Gay Americans Than Anyone

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See All the Visual Inspirations for Beyonce's "Countdown" Music Video

Ruins of the Nazi synthetic petrol plant (Hydrierwerke Pölitz – Aktiengesellschaft), in Poland

What is <u>new,</u> is the use of a <u>sustainable</u> feedstock

Sasol Ltd. (Afrikaans: *Suid Afrikaanse Steenkool en Olie*, English: *South African Coal and Oil*)

The largest producer of motor fuels from **coal** (Bloomberg,2011)

Future biodiesel developments……?

Hyperlink 2

Source: www.thebioenergysite.com

Bio-based diesel - summary

- **FAME (Transesterification)**
  - Production: Oil + alcohol = Fatty acid ester (+ glycerol)
  - ☺ Simple production, low emissions
  - ☹ Quality, food vs fuel, enough feedstocks
- **HVO (Neste)**
  - Oils/fats +hydrotreatment => parrafin HC
  - ☺ Quality, emissions low, production at refinery level
  - ☹ Food vs fuel, enough feedstocks ?, deforestation, price?
- **Fischer-Tropsch (BTL)**
  - Biomass =>gasification=>syngas ($CO+H_2O$) => (Fisher–Tropsch synthesis)=>paraffin HC
  - ☺ Quality, emissions low, any biomass
  - ☹ Price,development stage, diffucult process, small production so far

Source: Adapted from, Larmi and Tilli – Aalto University 2011

Thank you for listening

Any questions ?