Karlsruhe Institute of Technology

Energy from Biomass

- Lecture 3 -

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3. Types and Structure of Biomass

Efficiency of nature

Global radiation ≈ 1,000 kWh/(m² a)*

S-Triticale**	9 t/(ha · a);	H_i = 4.0 kWh/kg
Miscanthus**	10 t/(ha · a);	H_i = 4.5 kWh/kg

efficiency η = (production · heating value)/radiation

assumption: one harvest/a

⇒ **efficiency η:**

S-Triticale:	0.4 %
Miscanthus:	0.5 %

comparison with solar cell:

η_{Ph} < 17 %

* medium value for Karlsruhe 1982 - 1991, solar radiation atlas ; ** “dry“ plant (low water content)

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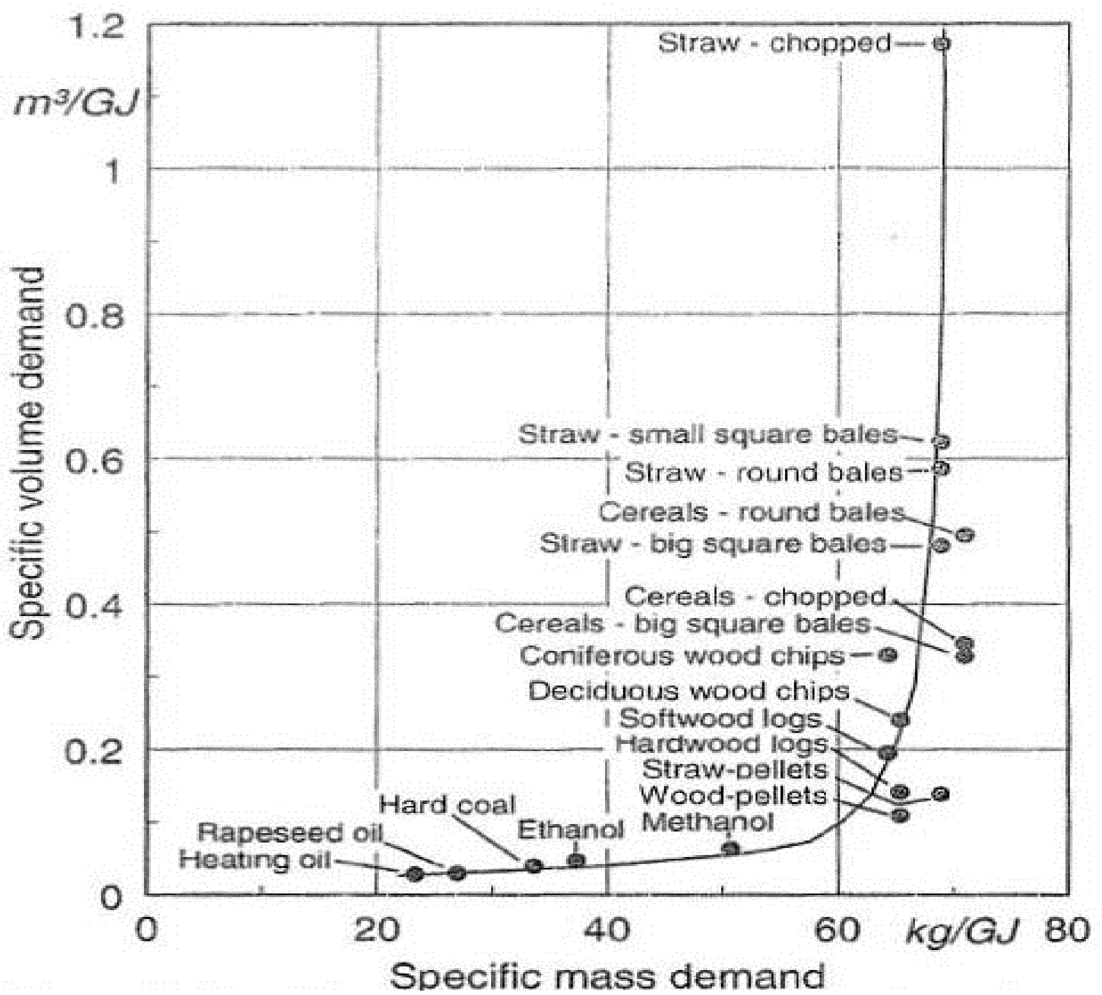
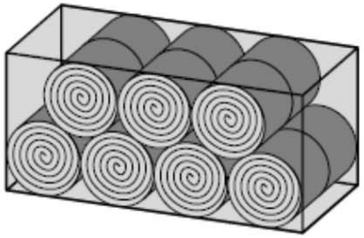
3. Types and Structure of Biomass

Volume and mass per unit energy of different fuels



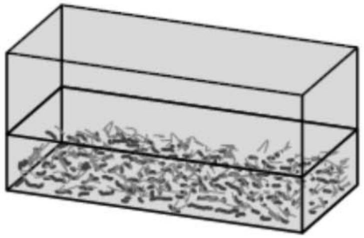
Reference: R. E. H. Sims, D. Culshaw, Biomass for energy and industry conference, Würzburg, 1998

Storage/transportation room necessary for straw bales



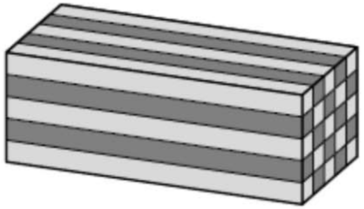
Rundballen

Durchmesser: 1,20 m
Ballendichte : 120 kg/m³
Lagerhöhe : 2,25 m = 100 %



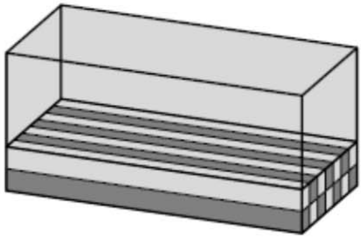
Geschüttete Compactrollen

Durchmesser: 0,35 m x 0,35 m
Ballendichte : 350 kg/m³
Lagerhöhe : 0,90 m = 40 %



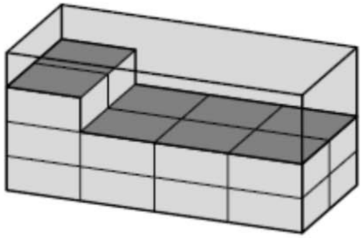
Hochdruckballen

0,46 m x 0,36 m x 0,80 m
Ballendichte : 120 kg/m³
Lagerhöhe : 1,80 m = 80 %



Gespaltete Compactrollen

Durchmesser: 0,35 m x 1,60 m
Ballendichte : 350 kg/m³
Lagerhöhe : 0,70 m = 32 %



Kubische Großballen

1,20 m x 0,60 m x 2,40 m
Ballendichte : 150 kg/m³
Lagerhöhe : 1,35 m = 60 %

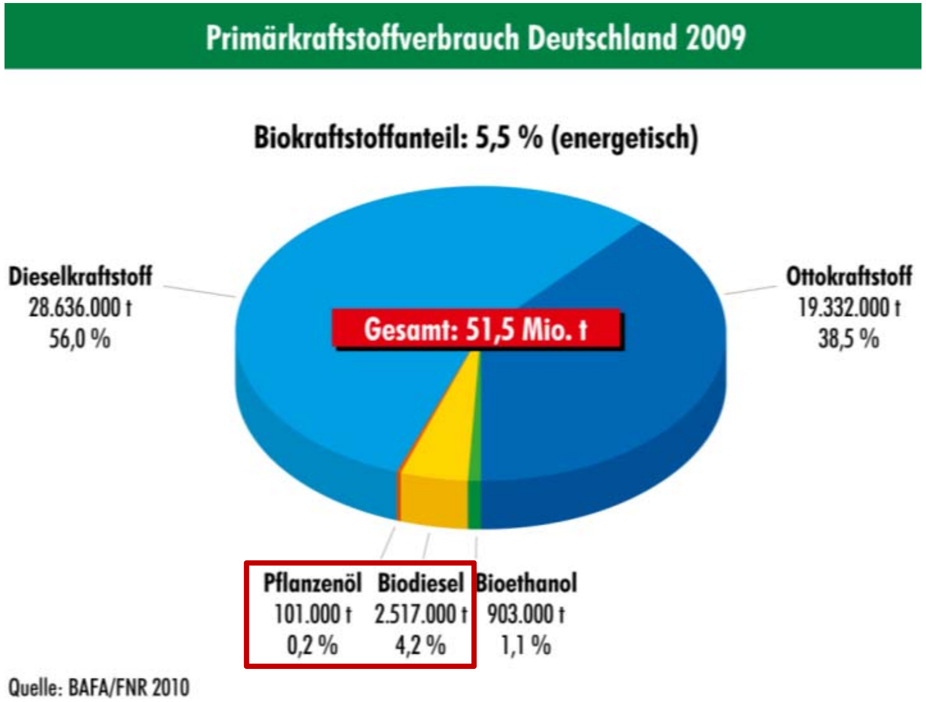
(Strohgewicht 2,3 t,
Wassergehalt = 10 %,
Grundfläche 4,8 x 2,4 m)

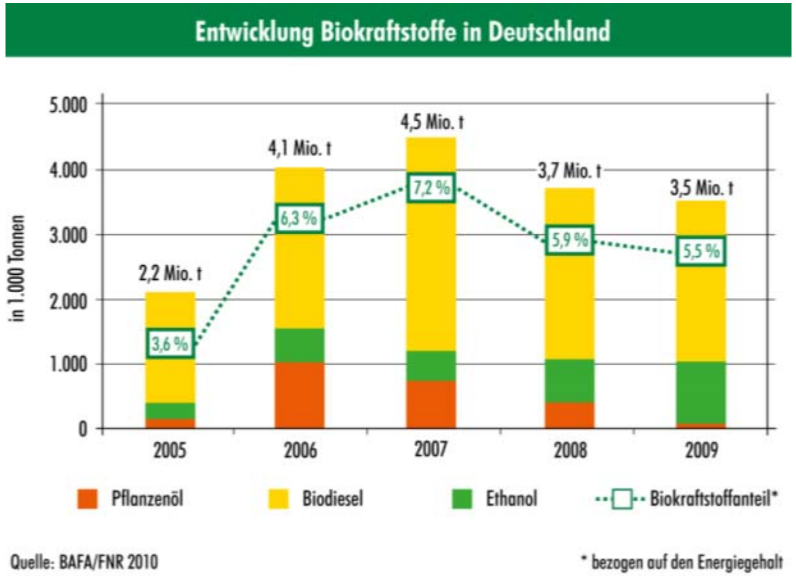
Reference: Energie aus Nachwachsenden Rohstoffen, FNR (2002)

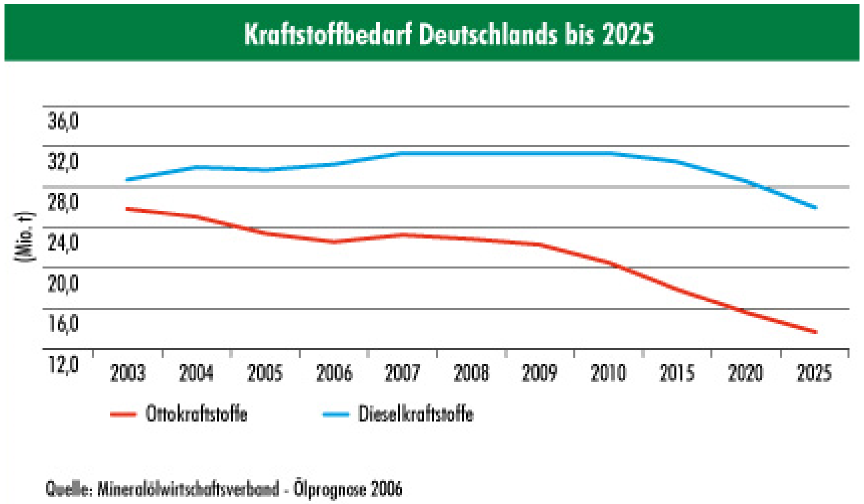
Contents

4. Fuels from Oil Seeds

Demand of liquid (bio) fuels (in Germany)



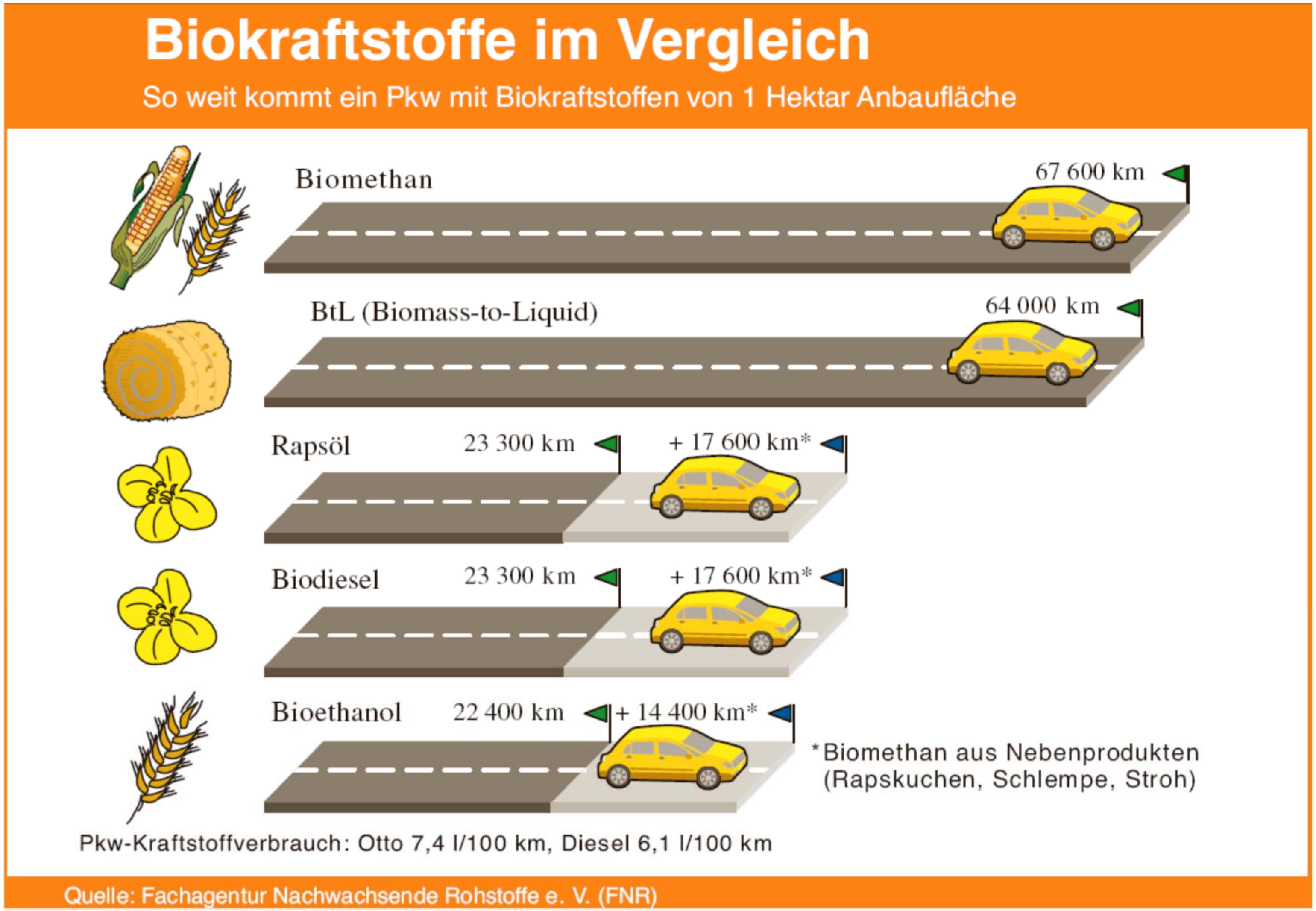




currently: about 5 % Bio Fuel in Germany

4. Fuels from Oil Seeds

Comparison of liquid (bio) fuels



4. Fuels from Oil Seeds

Types of Biomass

Conversion Paths

extraction

esterification

Products

HVO

Vegetable Oil

FAME /RME

4. Fuels from Oil Seeds

Bio oil and bio diesel

Oil yields per area

1 dt/ha = 100 kg/hectare = 1 kg/100 m^2

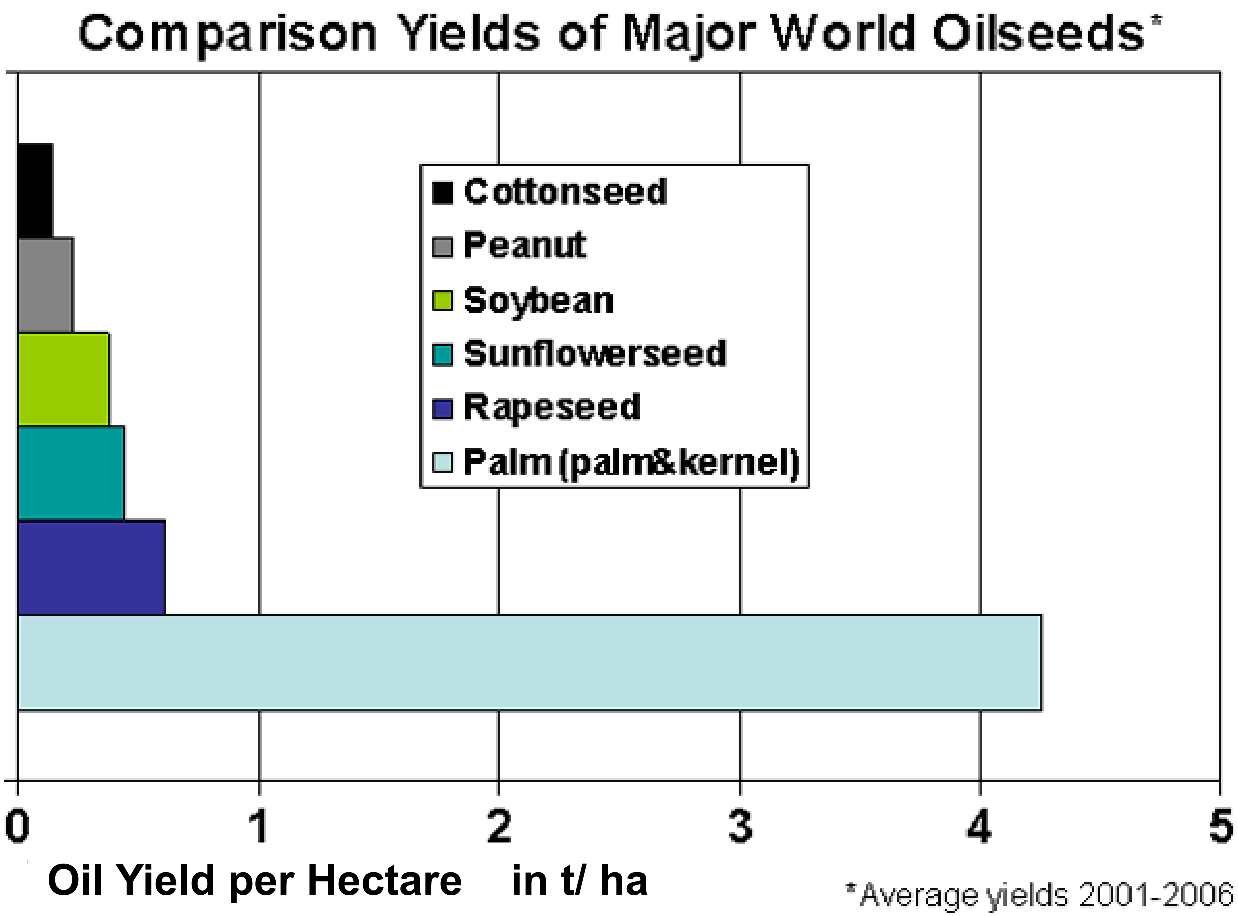
Plant	average yield of seed in dt/ha	average oil content in %
Winterraps	30	45
Sommerraps	22	40
Winterrübsen	20	40
Sommerrübsen	14	38
Weißer Senf	14	34
Schwarzer Senf	14	32
Ölrettich	16	44
Krambe	18	38
Ölrauke	14	34
Sonnenblume	30	45
Öllein	22	40
Leindotter	10	30
Mohn	14	48

Quelle: nach Holger Flaig, Hans Mohr (Hrsg.): „Energie aus Biomasse – eine Chance für die Landwirtschaft", 1993, Springer-Verlag

4. Fuels from Oil Seeds

Bio oil and bio diesel

Yield comparison of selcted oil seeds



Source: United States Department of Agriculture
http://www.pecad.fas.usda.gov/highlights/2007/12/Indonesia_palmoil/

4. Fuels from Oil Seeds

Bio oil and bio diesel

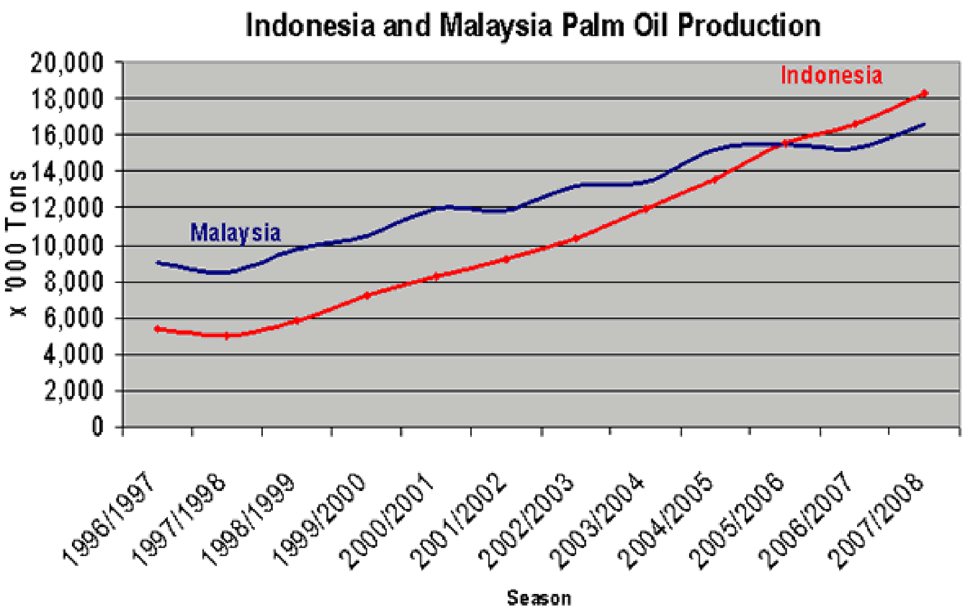
Problems: Mono cultures and destruction of rain forest

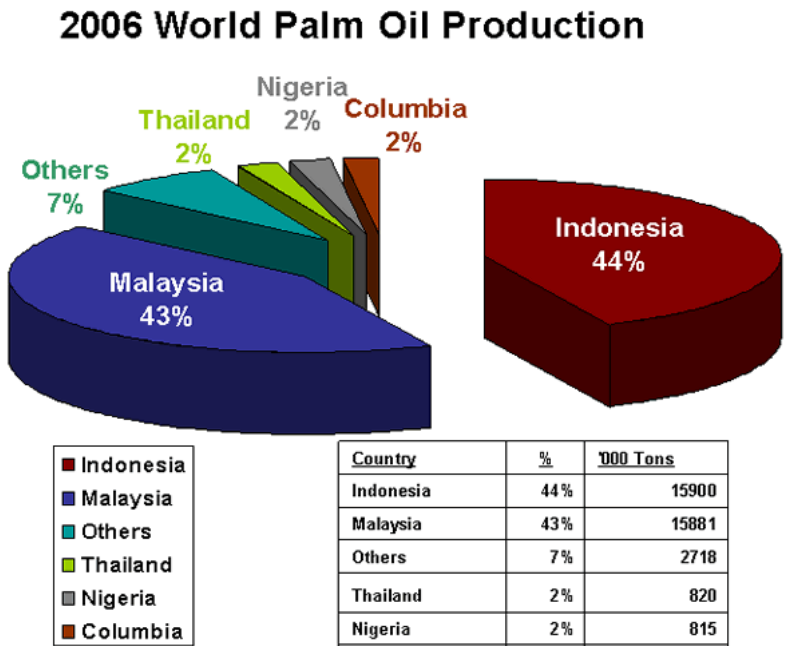
New plantations 1990 – 2005:

Malaysia: ap. 1,9 Mio. ha

Indonesia: ap. 3 Mio. ha

→ Probably more than half by rainforest clearance





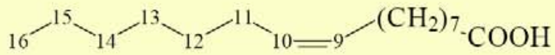
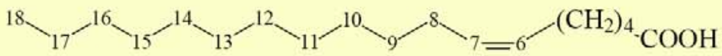
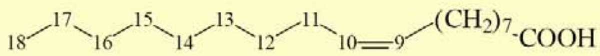
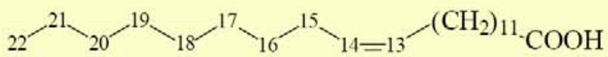
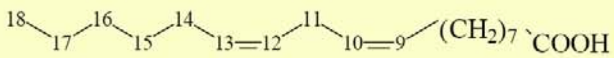
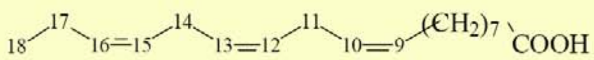
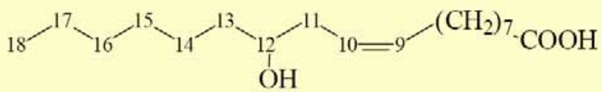
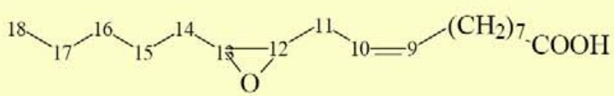
Country	%	'000 Tons
Indonesia	44%	15900
Malaysia	43%	15881
Others	7%	2718
Thailand	2%	820
Nigeria	2%	815
Columbia	2%	711
Source Data: Oil World, GAPKI		

Source: United States Department of Agriculture
http://www.pecad.fas.usda.gov/highlights/2007/12/Indonesia_palmoil/

4. Fuels from Oil Seeds

Bio oil and bio diesel

Some important fatty acids

Name	*C-Zahl*	*Funkt.*	*Formel*	*Vorkommen*
Palmitoleinsäure	16	1		Oliven
Petroselinsäure	18	1		Koriander, Fenchel
Ölsäure	18	1		Oliven-, Palm-, Sonnenblumen-, Soja-, Erdnußöl
Erucasäure	22	1		Rapssamen
Linolsäure	18	2		Palmöl, Soja, Sonnenblume, Raps, Erdnuß
Linolensäure	18	3		Soja, Sonnenblume
Ricinolsäure	18	1+OH		Ricinus
Vernolsäure	18	1+EP		Euphorbia

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4. Fuels from Oil Seeds

(fuel) properties of selected **bio oils**

Pflanzenöl	Dichte (15° C) [kg/dm³]	Heizwert MJ/kg	kin. Viskosität (20° C) [mm²/s]	Cetanzahl	Stockpunkt [°C]	Flammpunkt [°C]	Jodzahl
Rapsöl	0,92	37,6	72,3	40	0 bis -15	317	94 bis 113
Sonnenblumenöl	0,93	37,1	68,9	36	-16 bis -18	316	118 bis 144
Sojaöl	0,93	37,1	63,5	39	-8 bis -18	350	114 bis 138
Leinöl	0,93	37,0	51,0	52	-18 bis -27	-	169 bis 192
Olivenöl	0,92	37,8	83,8	37	-5 bis -9	-	76 bis 90
Baumwollsaatöl	0,93	36,8	89,4	41	-6 bis -14	320	90 bis 117
Jatrophaöl	0,91	40,7	71,0	51	2 bis -3	240	103
Kokosöl	0,87	35,3	21,7*	-	14 bis 25	-	7 bis 10
Palmöl	0,92	37,0	29,4*	42	27 bis 43	267	34 bis 61
Palmkernöl	-	35,5	21,5*	-	20 bis 24	-	14 bis 22

(fuel) properties of selected **bio fuels**

	Dichte [kg/l]	Heizwert [MJ/kg]	Heizwert [MJ/l]	Viskosität bei 20°C [mm²/s]	Cetan-zahl	Oktan-zahl (ROZ)	Flamm-punkt [°C]	Kraftstoff-äquivalenz [l]
Dieselkraftstoff	0,83	43,1	35,87	5,0	50	-	80	1
Rapsöl	0,92	37,6	34,59	74,0	40	-	317	0,96
Biodiesel	0,88	37,1	32,65	7,5	56	-	120	0,91
Biomass-to-Liquid (BtL) [1]	0,76	43,9	33,45	4,0	> 70	-	88	0,97
Ottokraftstoff	0,74	43,9	32,48	0,6	-	92	< 21	1
Bioethanol	0,79	26,7	21,06	1,5	8	> 100	< 21	0,65
Etyl-Tertiär-Butyl-Ether (ETBE)	0,74	36,4	26,93	1,5	-	102	< 22	0,83
Biomethanol	0,79	19,7	15,56	-	3	> 110	-	0,48
Methyl-Tertiär-Butyl-Ether (MTBE)	0,74	35,0	25,90	0,7	-	102	- 28	0,80
Dimetylether (DME)	0,67 [2]	28,4	19,03	-	60	-	-	0,59
Biomethan	0,72 [5]	50,0	36,00 [3]	-	-	130	-	1,4 [4]
Wasserstoff GH2	0,016	120,0	1,92	-	-	< 88	-	2,8

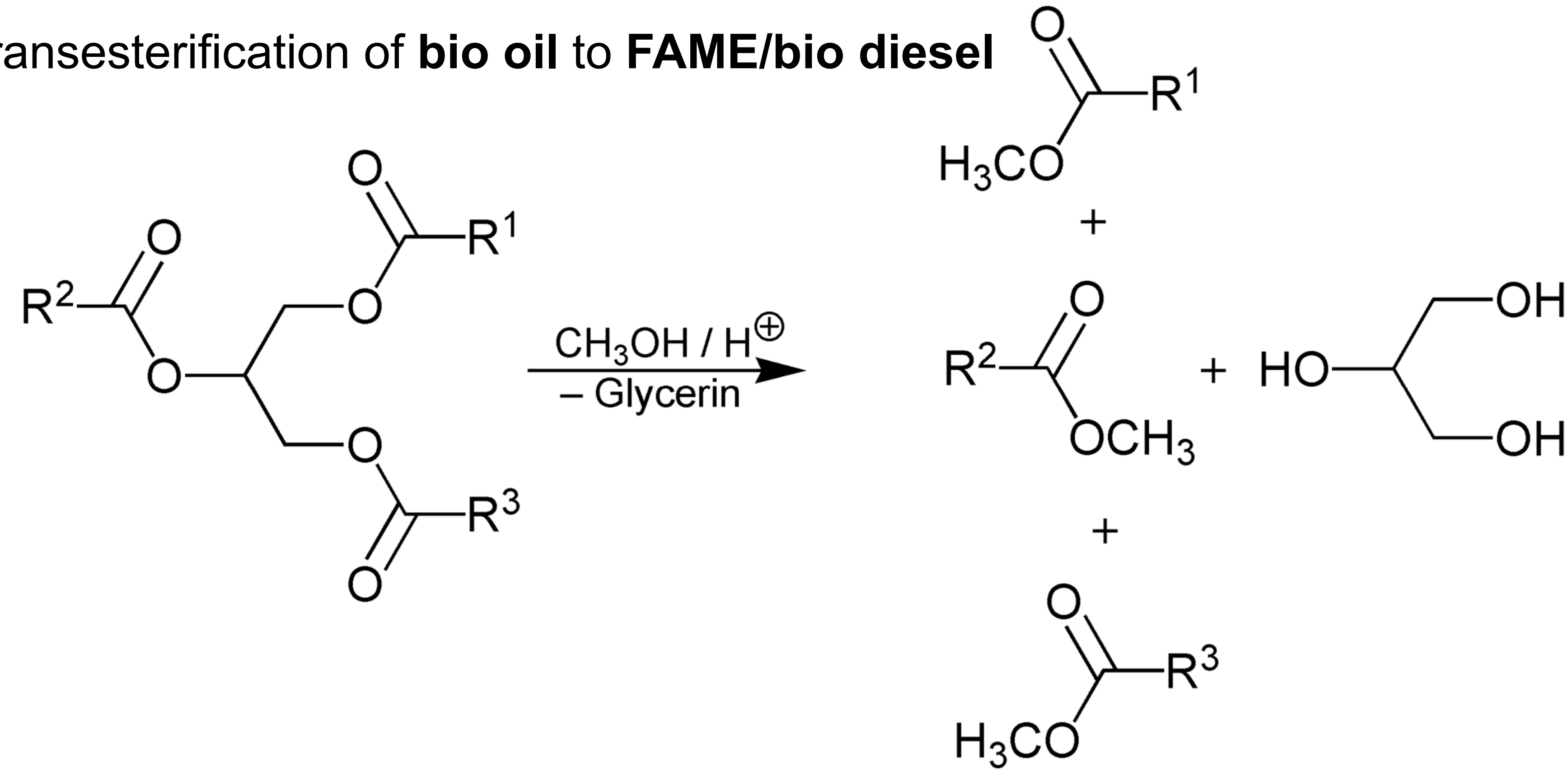
[1] Werte auf Grundlage von FT-Kraftstoffen, [2] bei 20°C, [3] [MJ/m³], [4] Biomethan in [kg], [5] [kg/m³]

Quelle: FNR

4. Fuels from Oil Seeds

Bio oil and bio diesel

Transesterification of **bio oil** to **FAME/bio diesel**



Oil + Methanol = RME (Rape Methyl Ester) + Glycerin

FAME (Fatty Acid Methyl Ester)

Source: http://de.wikipedia.org/wiki/Rapsmethylester; 18.05.2011

„R“ = fatty acid residues

4. Fuels from Oil Seeds

HVO (= Alternative to FAME)

Alternative route to use bio oils as diesel fuel component

HVO (**H**ydrogenated **V**egetable **O**il)

Processes:

- **Hydrogenation** of the oil in a fixed bed catalyti reactor
  (CoMo- or NiMo-cat. at 350 – 450 °C, p_{H2} = 50 – 150 bar)
  => product can be blended to (fossil) diesel fuel

- **Blending** to fossil vacuum gas oil (up to 30 ma.-%),
  afterwards **Hydrotreating** („desulfurization“ = hydrogenation step)
  => product is a ready to use diesel fuel

By products: H_2O, C_3H_8, (H_2S, NH_3,…)

4. Fuels from Oil Seeds

HVO (= Alternative to FAME)

Established Technology

⇨ in 2007 first commercial plant (170 000 t/a)

HVO ($C_{14\text{-}20}$)

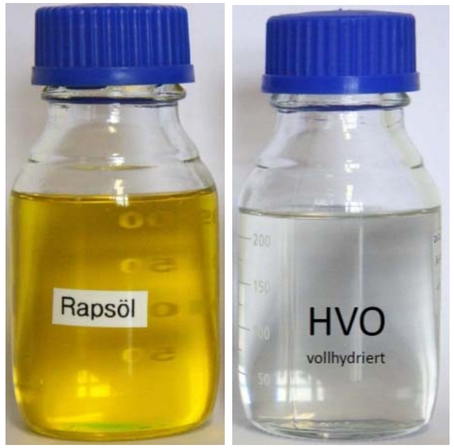
- yield: > 85 ma.-%
- free of oxygen, aromatic components and sulfur
- chemical stable stabil (storage!)

but:

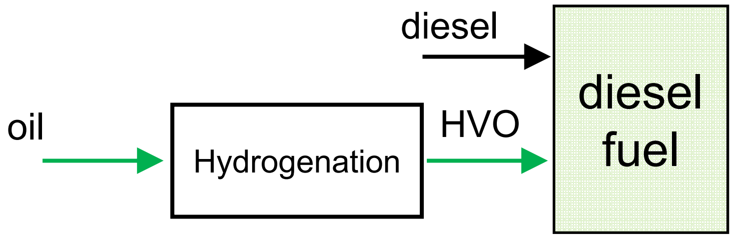
- stability under low temperatures is poor
- high hydrogen consumption

Up to 15 % can be blended to diesel fuel

- better ignition behaviour
- reduction of pollutants in flue gas



$C_{57}H_{104}O_6$



T = 350 – 450°C
p_{H2}= 50 –150 bar
τ = 0,2 – 2 h
cat: CoMo, NiMo

Source: Aatola, 2008; Kuchling, 2010; Huber, 2007; Edzang, 2012