Biorefinery, the bridge between agriculture and chemistry

Training Course Biorefinery, International Biomass Valorisation congress, Amsterdam 13 September 2010

Johan Sanders
Professor Valorisation of Plant Production Chains
Wageningen University and Research center

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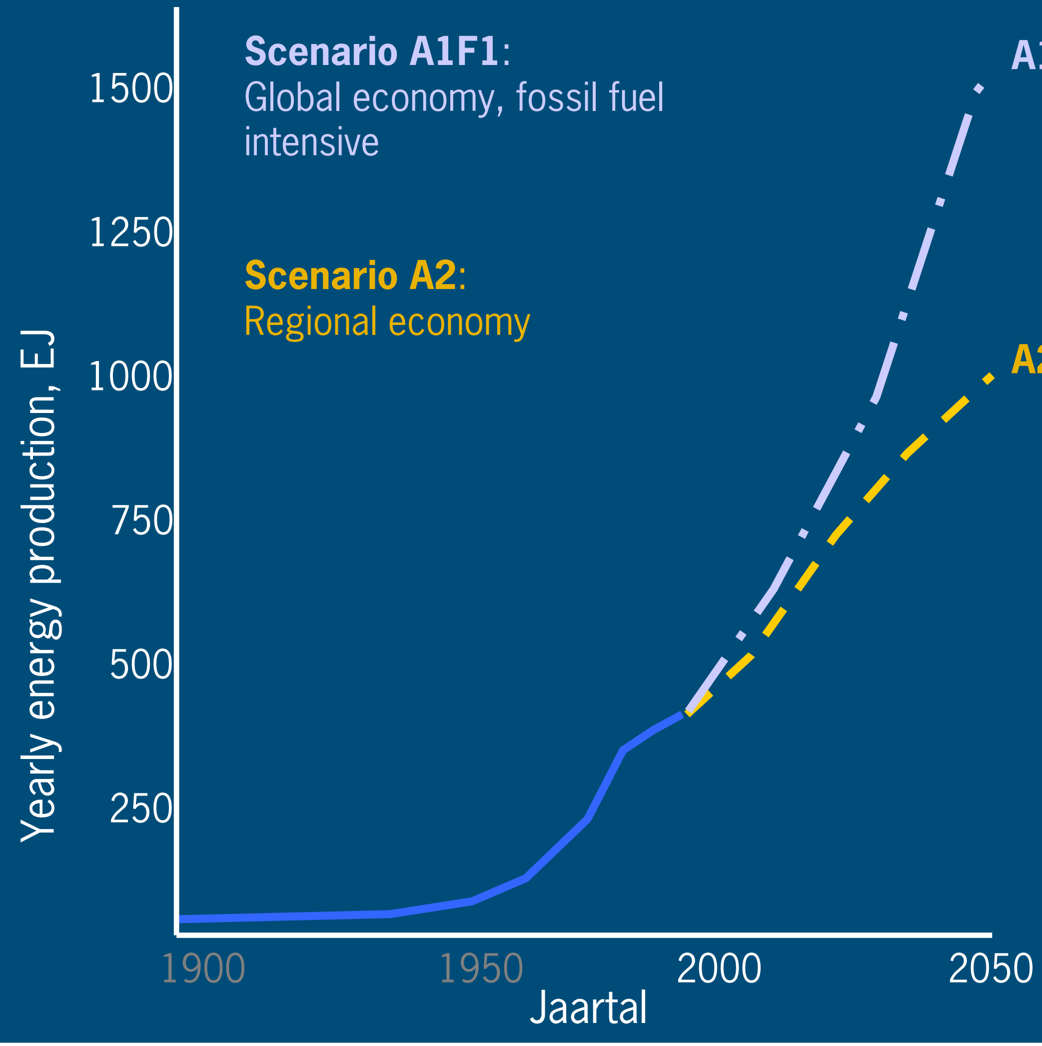
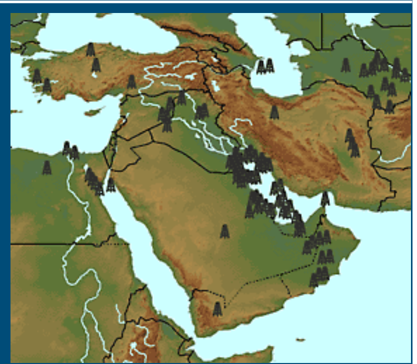
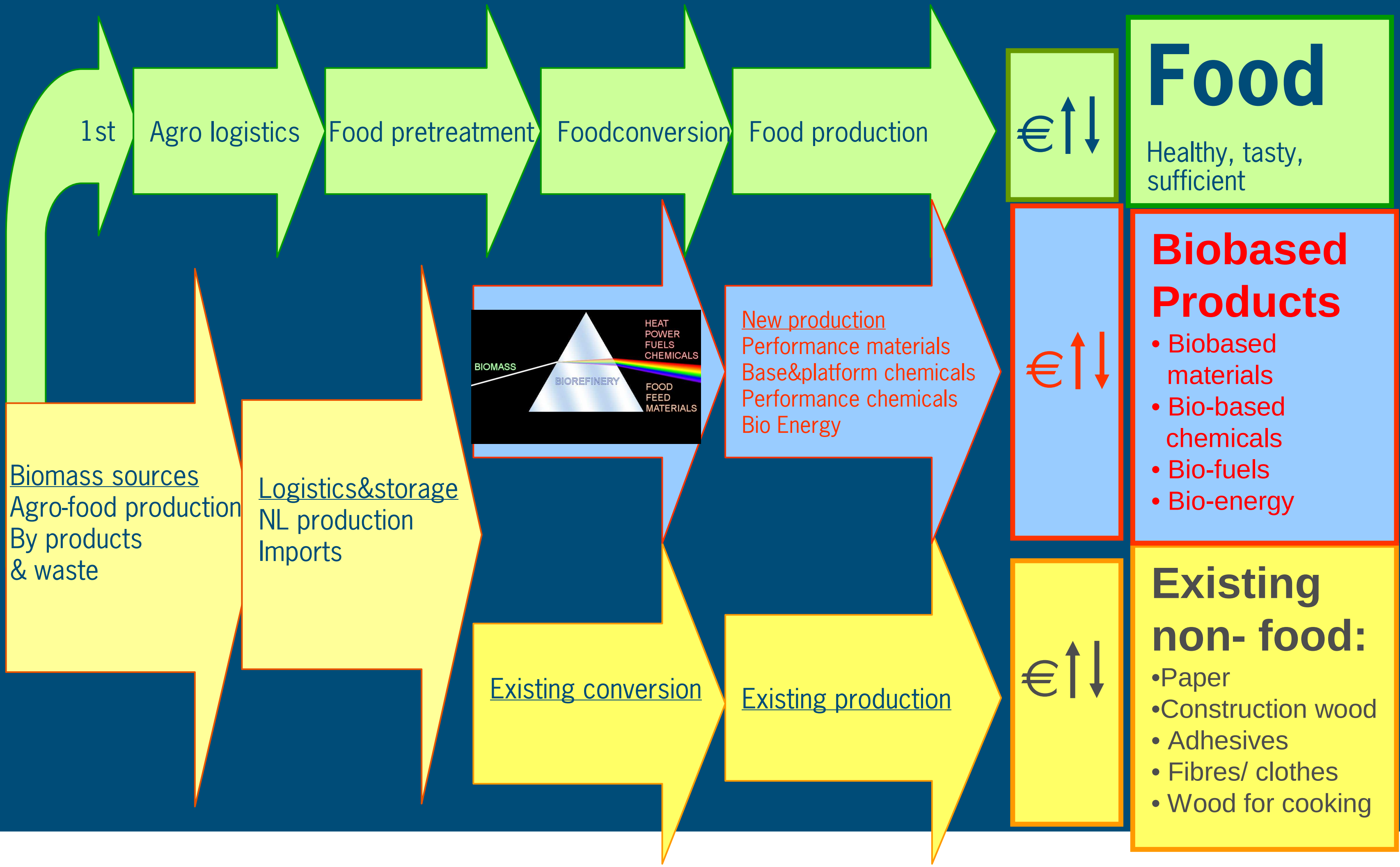
Energy consumption past and future





The New Biomass value chain by biorefinery:



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Many different drivers for a Biobased Economy

- Shortage of cheap oil
- High energy prices
- Security of energy supply
- Climate change by green house gasses
- Rural development
- Developing countries
- Geo-political conditions

Different countries/groups are confident however that a BbE can contribute to their goals.

Platform Renewable Materials

30% substitution of fossil by Biomass in 2030

- 25% chemical resources (140 PJ)
- 60% transportation fuels (324 PJ)
- 17% heat (65 PJ)
- 20% electricity (203 PJ)

By:

- Enhancing efficiency present Biomass (400 PJ)
- Development (new) crops (250 PJ)
- Aquatic cultures (250 PJ)
- Import (250 PJ)

Recommendations from Platform Ren. Resources

- Use the different plant components each at their highest value
- Learn to collaborate with sectors that traditionally were not closeby.
- Optimize the efficient use of biomass, also in the food and feed chains.
- *Governments should develop long term visions in order not to change their direction too often*
- Benefit from the large variety of crops and their genetic improvement potential
- Take care of soil fertility and preferably donot transport what is required on the field
- *Stimulate regional activities and only do large scale operations if required*
- Improve keepability after harvest and thereby trigger agronomic improvements
- Develop a broad variety of technology and products to reduce introduction risks
- Stimulate the standardization of products to enhance market stability
- what are domestic reasons for ILUC? How can we reduce ILUC in the NL
- Develop large scale chemical and energy production in an international setting
- The financial sector is an necessary link in stting up the Biobased Economy

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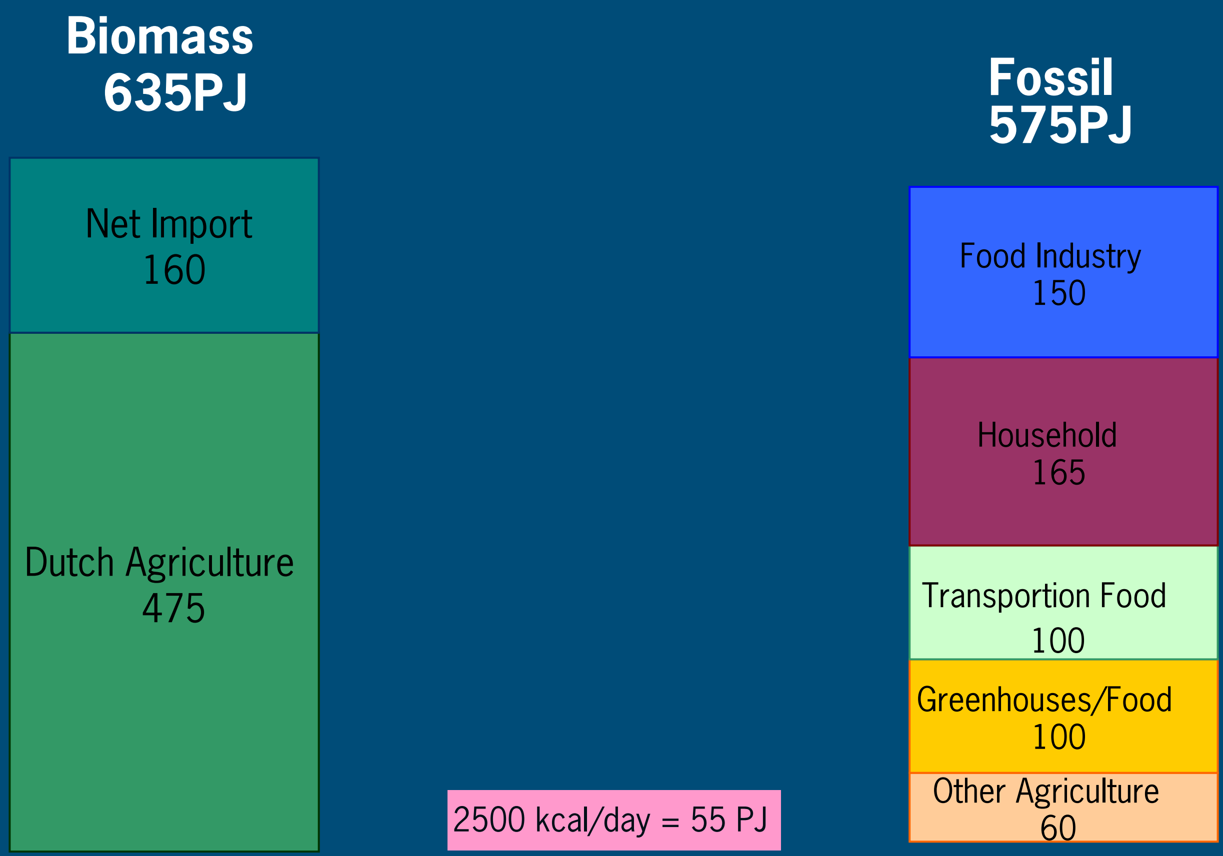
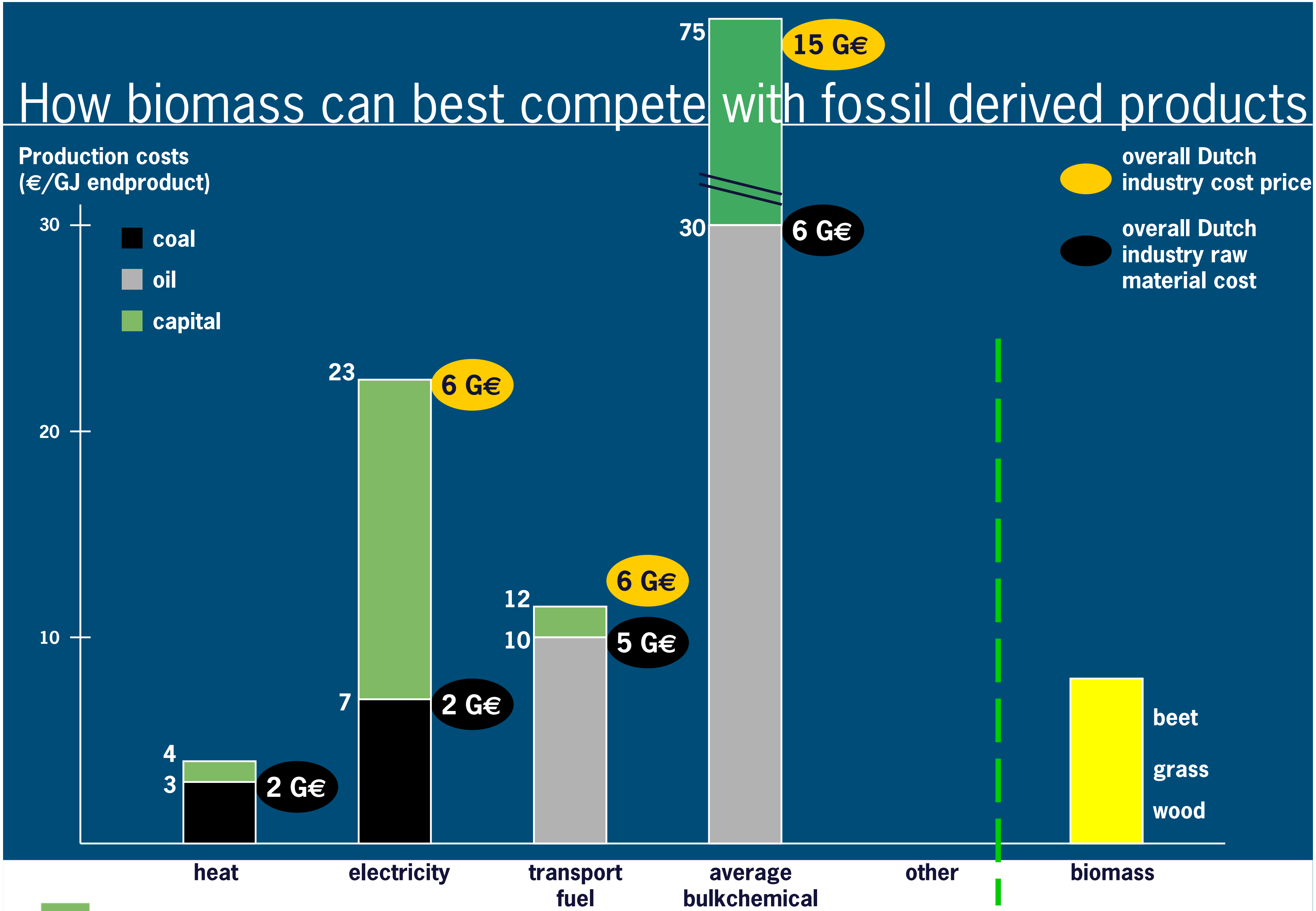
Our daily food needs a twenty fold higher energy input



How biomass can best compete with fossil derived products



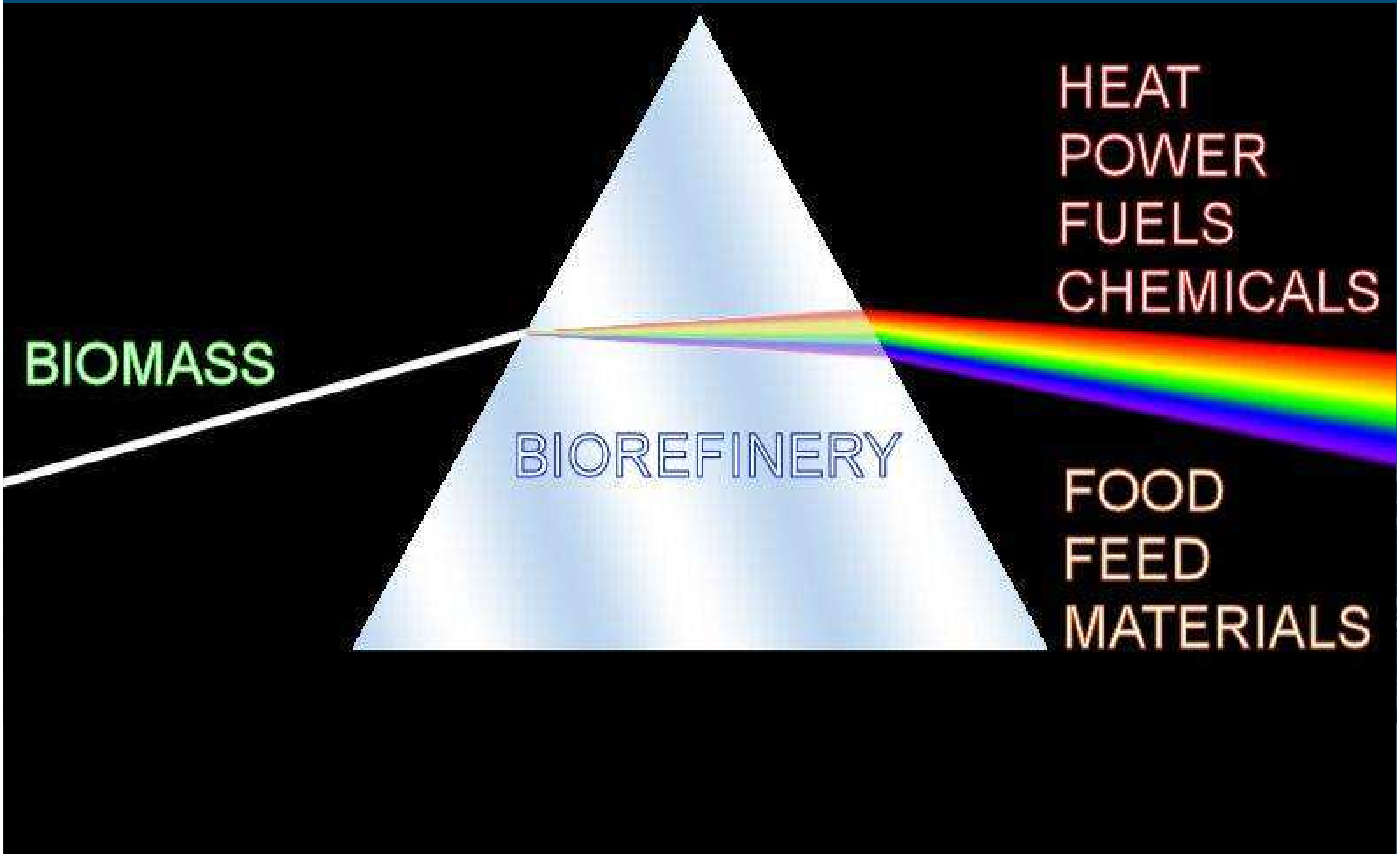
Good use of biomass? **Value of glycerol:**

	€/GJ
• Epichlorohydrin	30 - 40
• Transportfuel	10
• Electricity	3

Glycerol 25.3 GJ/tonne

Per GJ product ca 0.65 GJt input can be saved

Bioraffinage

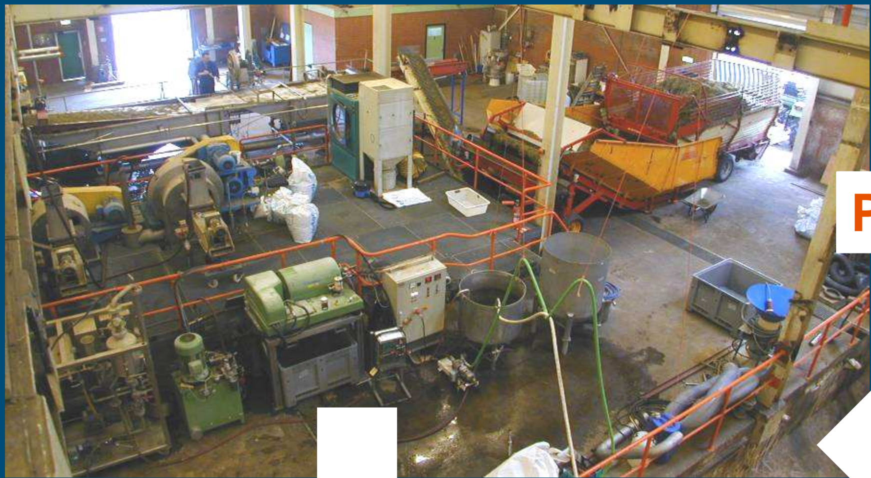


Biomass can bring different contributions to the farmer (€/ha)

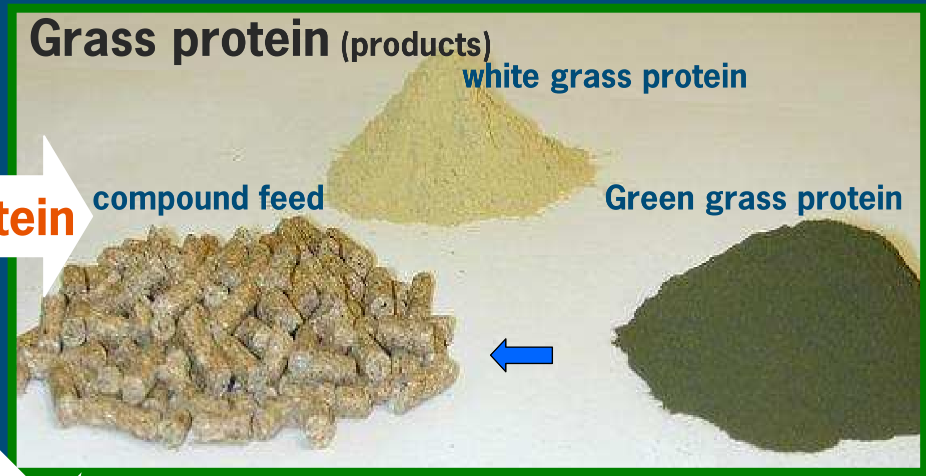
Assuming a yield of 10 tonnes dry weight per hectare, being 160 GJ, using *whole crop* and GAP up to 20 tonnes whole crop yield, 320 GJ/ha

On raw materials substitution only	**€/hectare**
• All Energy at coal value	: 640 –
• All transportfuel	: 1360 –
• All bulkchemical	: 6400 –
• **20% bulkchemical, 80% Energy**	**: 1800 – *3600***
• **20% bulkchemical, 40% fuel, 40% Energy**	**: 2080 - *4160***
Including capital cost substitution	
• **20% bulkchemical, 40% fuel, 40% Energy**	**: 3000 - 6000**

Pilot biorefinery line Foxhol (Groningen) (Prograss Consortium), nu Grassa (Oenkerk)

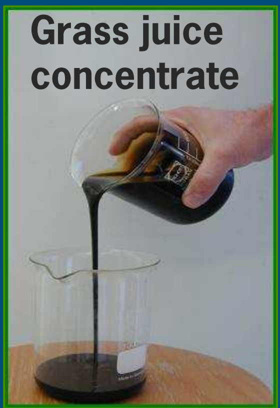


Protein



Grass juice

Fibers



compound feed

+ .....

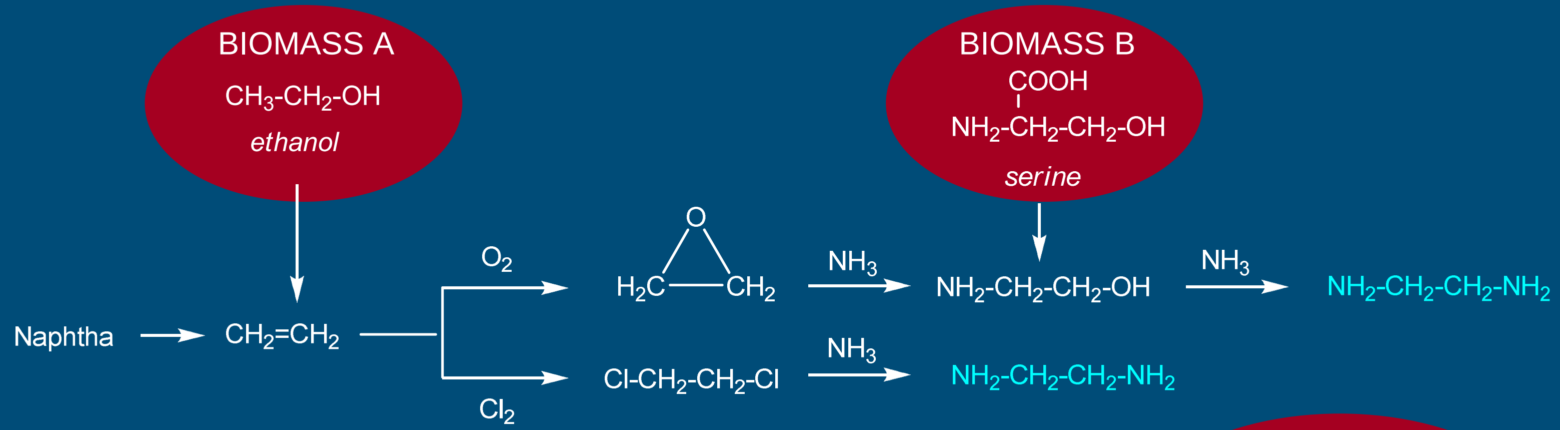
HTU-
Biofuel

Construction material + paper

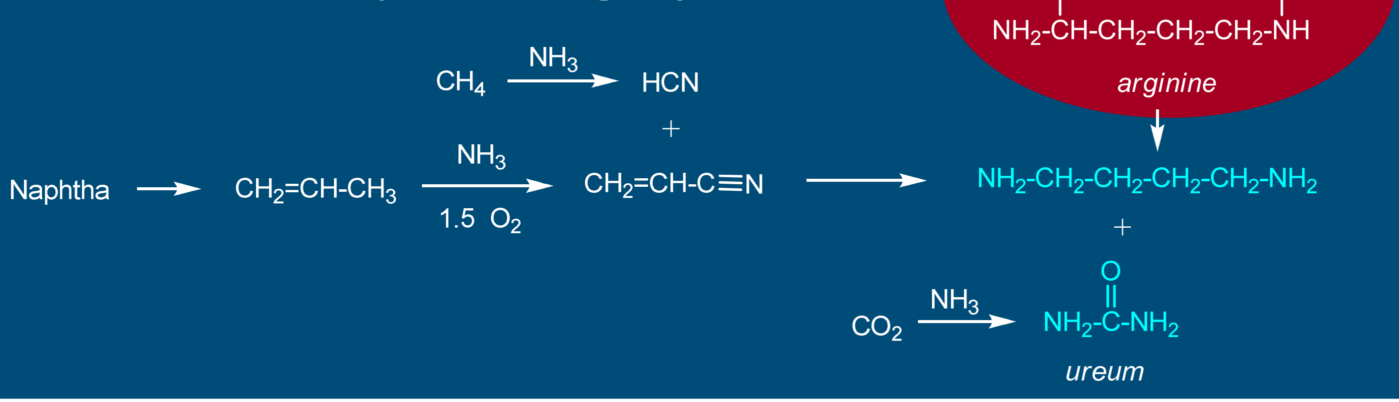
Polymer extrusion products

Savings potential of functionalized biomass

- 1,2-Ethanediamine: rubber chemicals, pharma, lubricants, detergents



- 1,4-Butanediamine: polymers, e.g. nylon-4,6



Costs breakdown of Bulkchemicals (**€/ton**) at 60$/bbl

	non-functionalised	functionalised
Raw materials	300	975
Capital	300-500	400-650
Operational	50	50
Recovery	50-100	50-100
Total	825	1525

Derived from J.P. Lange (Shell)

Ethanol production and Cyanophycin accumulation
(collab. Univ. Münster/Steinbuchel, AVEBE, Cosun, Energy Valley)

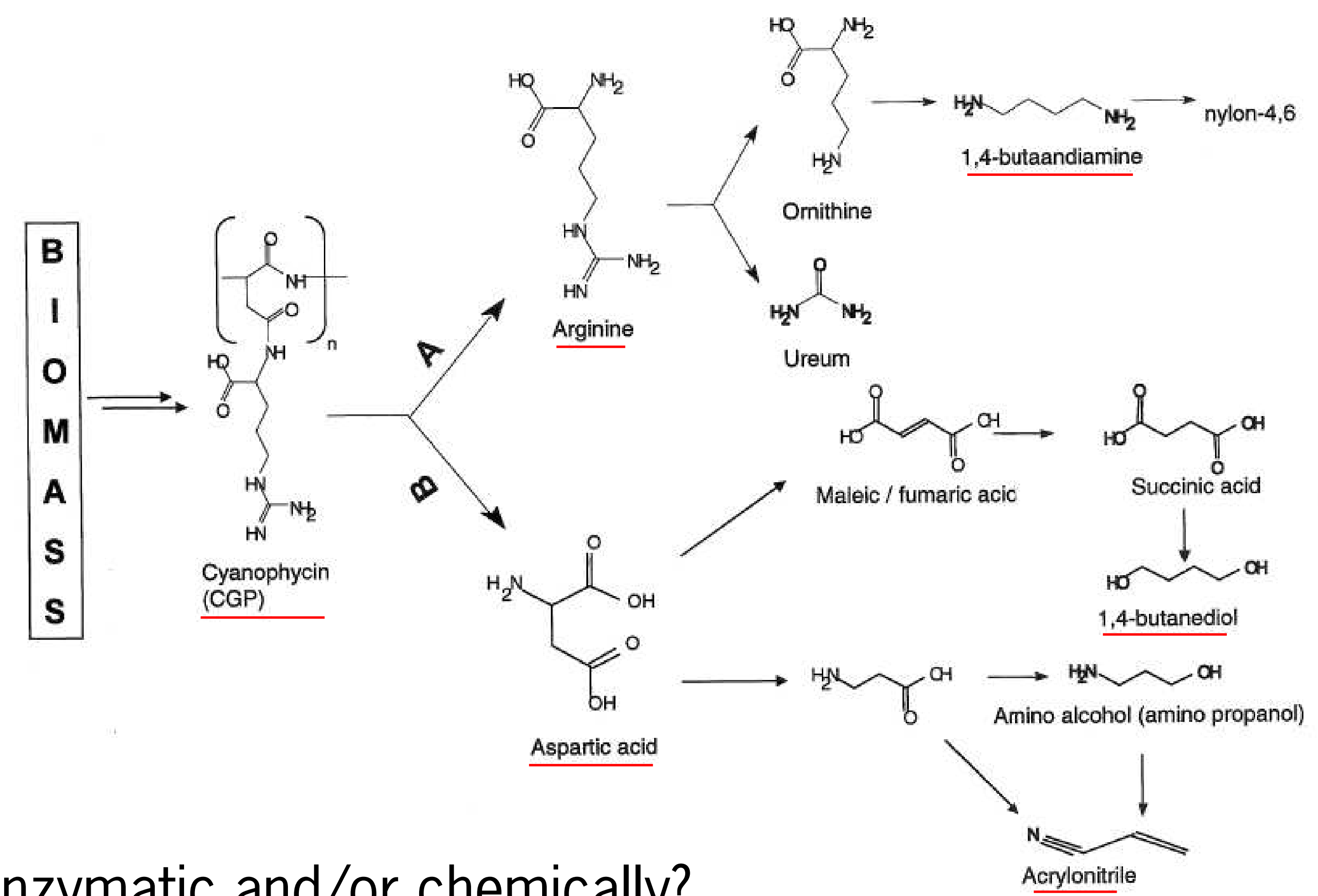
cyanophycin granule peptide, mainly in cyano-bacteria as nitrogen and energy reserve material

= Asp + Arg

Granule
35% (wt/wt) and slow growth

EOS- project
(Economic Affairs)

Cyanophycin as bulk precursor chemical



Enzymatic and/or chemically?

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The Chemical Products of the Harbour of Rotterdam

DuPont Genencor/Tate & Lyle BioProducts :1,3 Propanediol factory, Loudon, USA

50 000 tonnes/y and still competitive!

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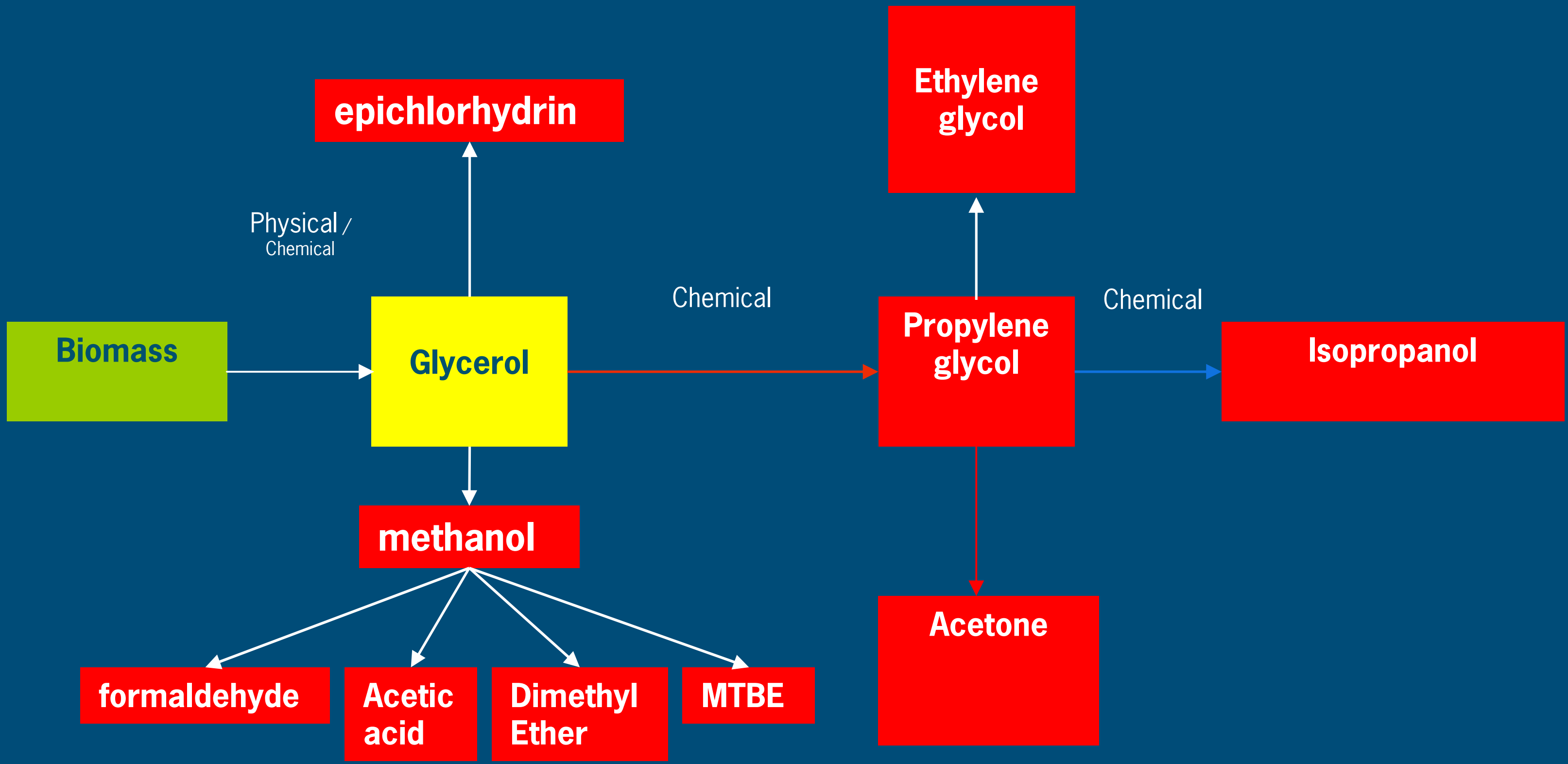
Many 'Rotterdam' chemicals can be produced from Biomass

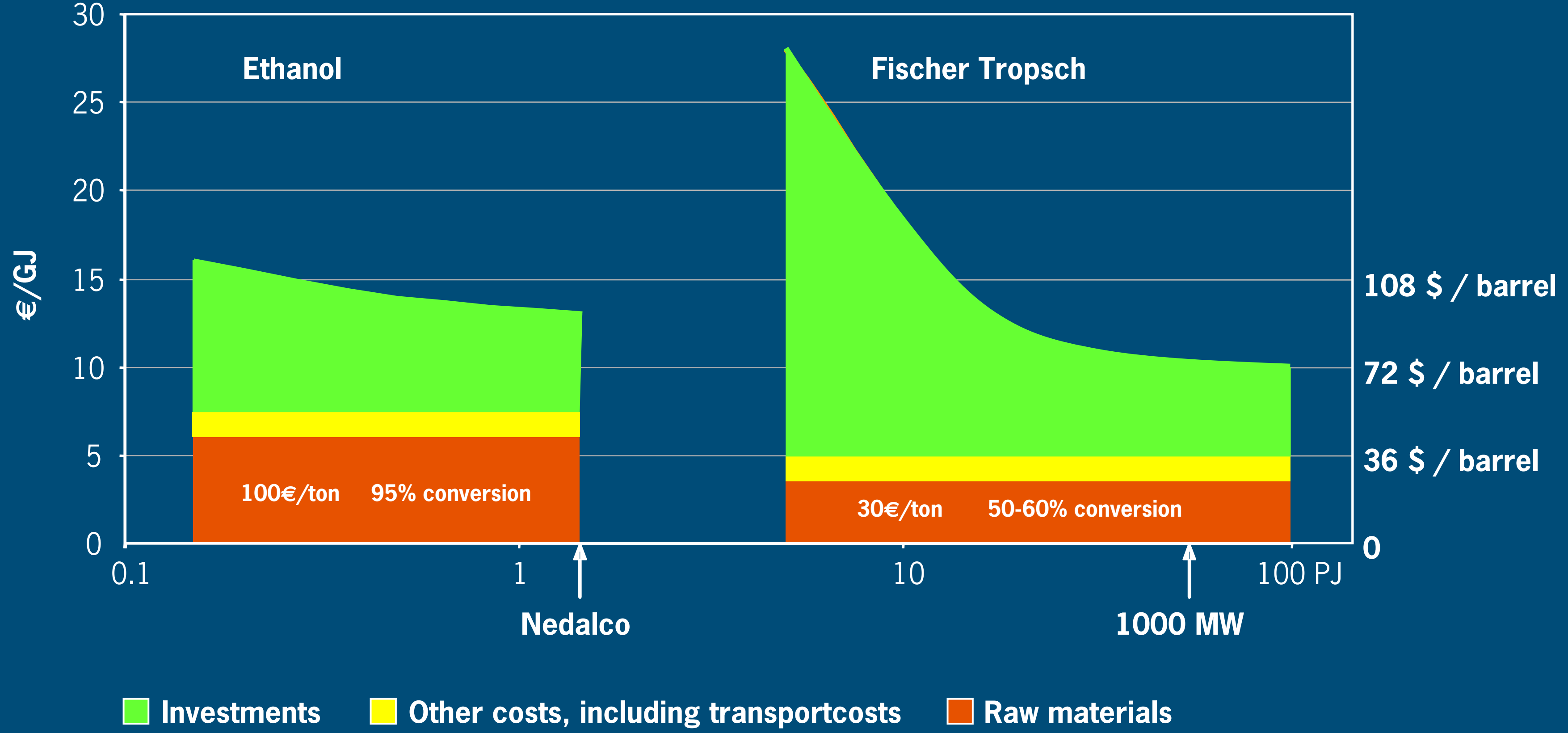
Example of short term substitution potential

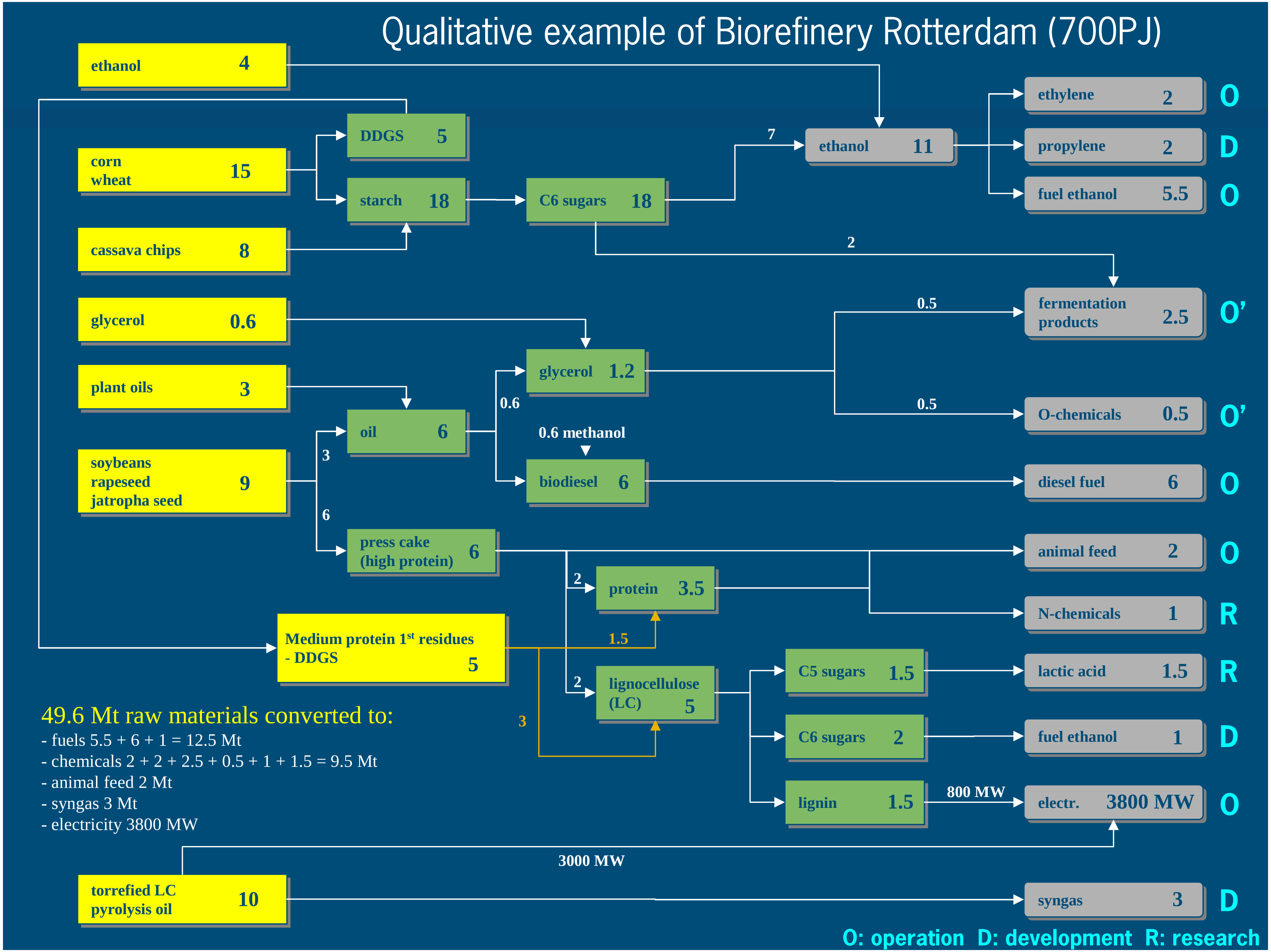


Scheme. *Chemical production in Rotterdam - a bio-based alternative for butadiene and ethylene.*

Current production by Shell Chemical and Lyondell

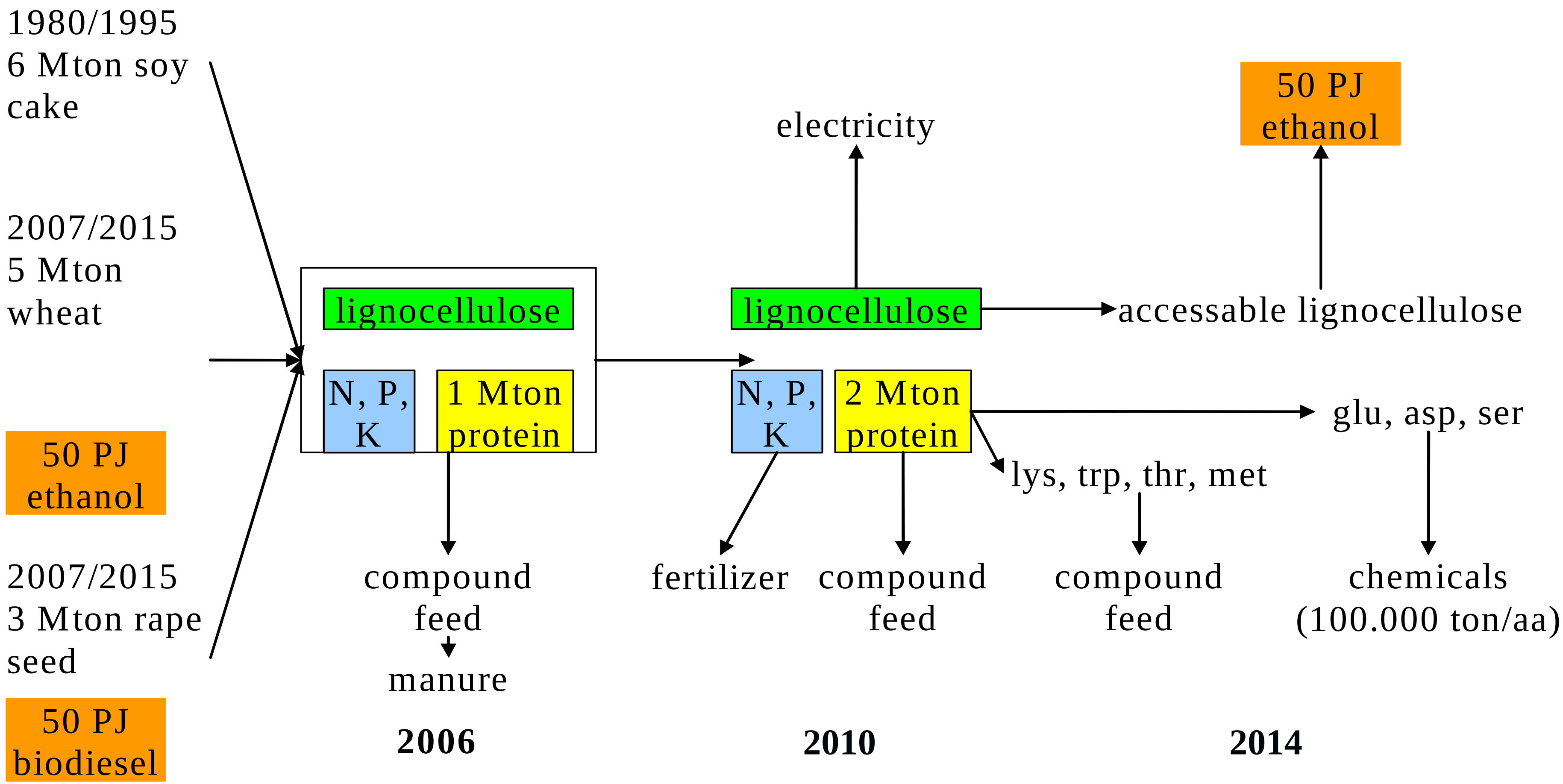
Different Economies of Scale





Qualitative example of Biorefinery Rotterdam (700PJ)
ethanol 4
corn
wheat 15
cassava chips 8
glycerol 0.6
plant oils 3
soybeans
rapeseed
jatropha seed 9
DDGS 5
starch 18
C6 sugars 18
7
ethanol 11
ethylene 2
propylene 2
fuel ethanol 5.5
2
0.5
fermentation
products 2.5
glycerol 1.2
0.6
0.5
O-chemicals 0.5
oil 6
3
0.6 methanol
biodiesel 6
diesel fuel 6
6
press cake
(high protein) 6
animal feed 2
2
protein 3.5
N-chemicals 1
Medium protein 1st residues
- DDGS 5
1.5
2
lignocellulose
(LC) 5
3
C5 sugars 1.5
lactic acid 1.5
C6 sugars 2
fuel ethanol 1
lignin 1.5
800 MW
electr. 3800 MW
3000 MW
torrefied LC
pyrolysis oil 10
syngas 3
O
D
O
O'
O'
O
O
R
R
D
O
D
49.6 Mt raw materials converted to:
- fuels 5.5 + 6 + 1 = 12.5 Mt
- chemicals 2 + 2 + 2.5 + 0.5 + 1 + 1.5 = 9.5 Mt
- animal feed 2 Mt
- syngas 3 Mt
- electricity 3800 MW
O: operation D: development R: research

Development of Dutch BbE can be build on Dutch pilars: Agriculture, Chemistry, Ports.



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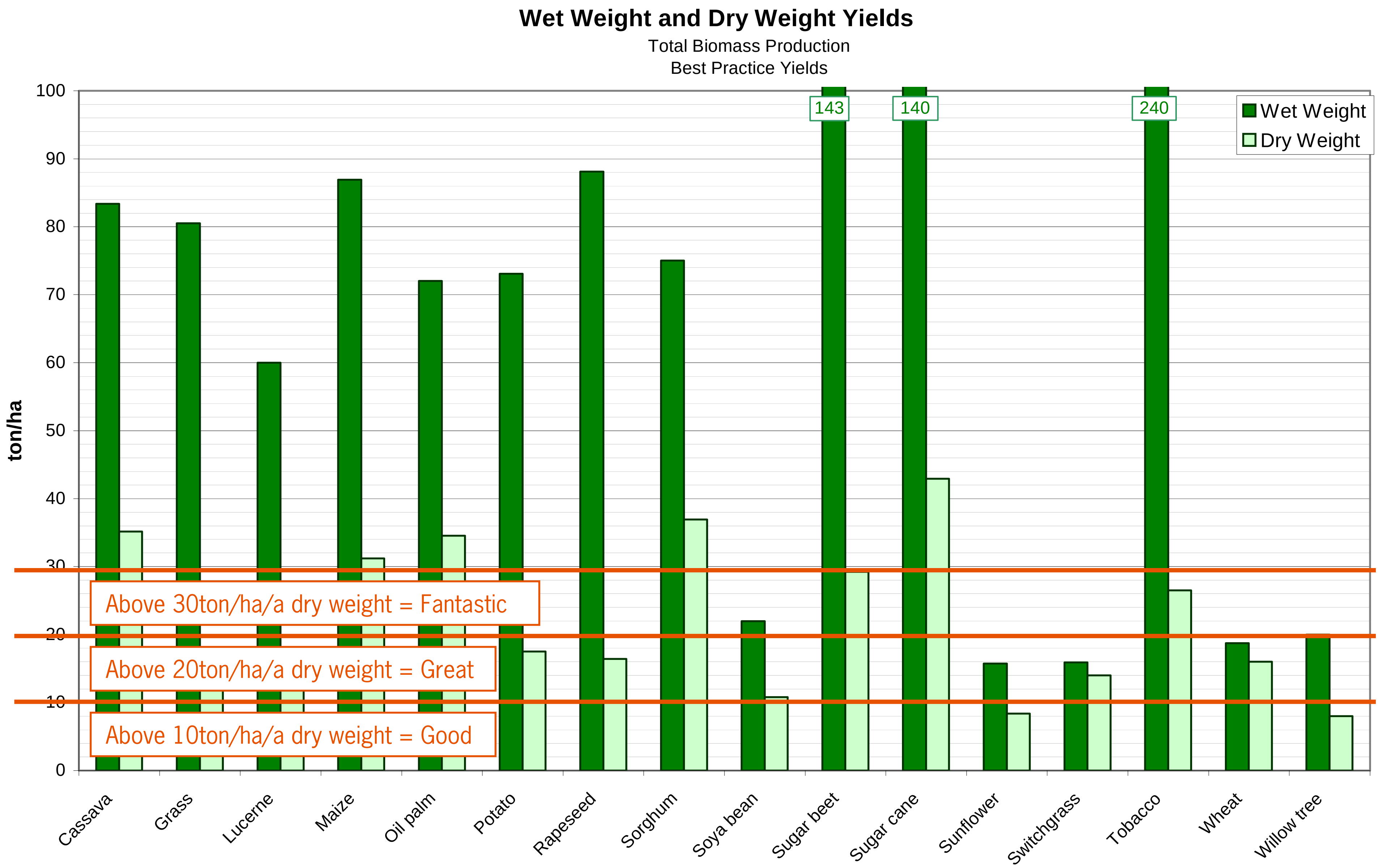
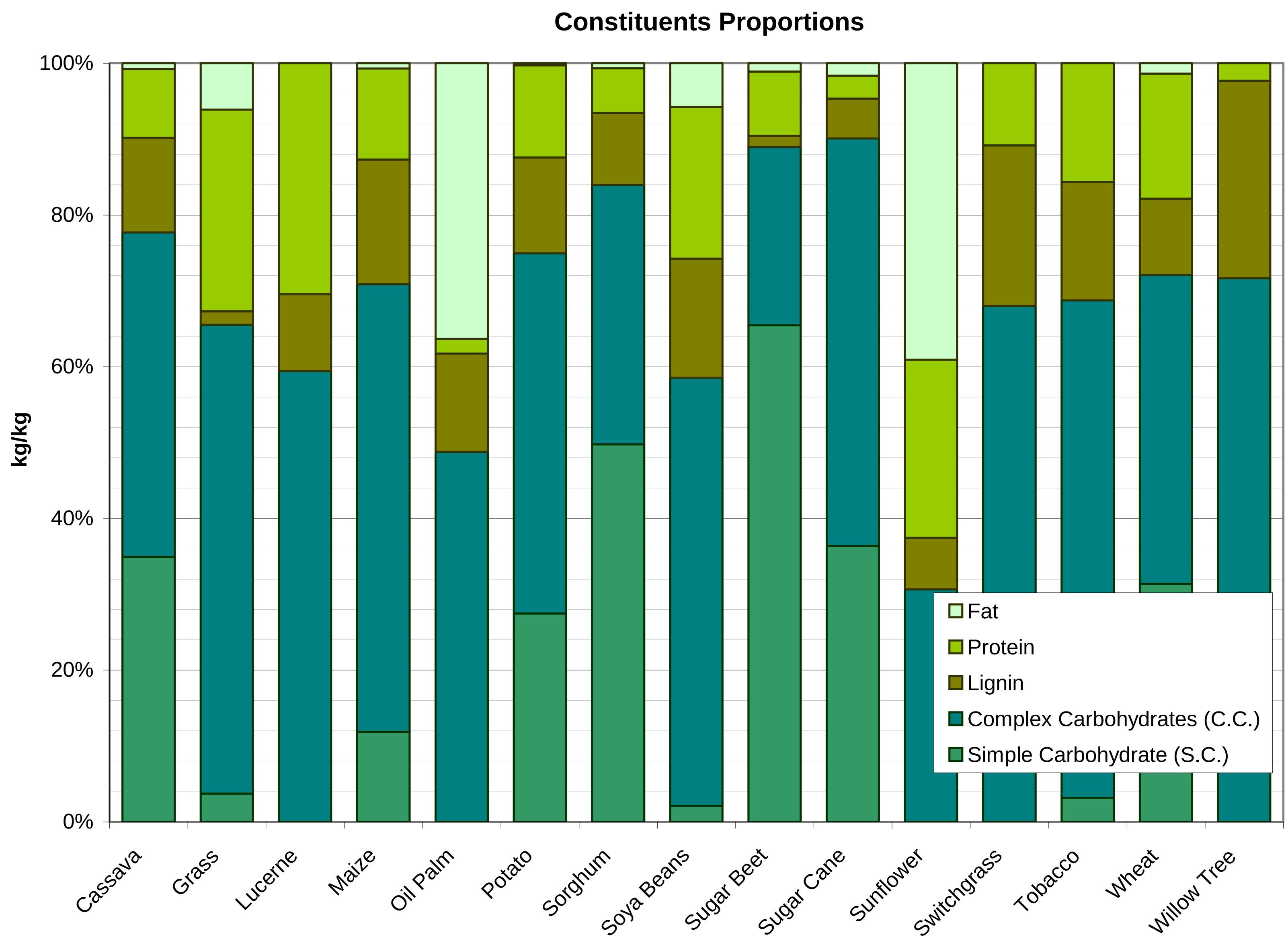
Other co-products as a consequence of biofuel production

- if 10% of the WW transportation fuels are produced from corn, wheat, rape, palm, sunflower, cane this will supply **100 million tonnes of proteins**

- Several bulkchemicals might be produced from different amino acids: Succinic acid, Acrylonitril, Aniline, Acrylate, Metacrylate, (hydroxy) Styrene, Caprolactam, Butandiamine, urea, 1,4 butandiol, 2,3 butandiol, 1,2 propanediol, (hydroxy) Phenethylamine

Total Crop Yields





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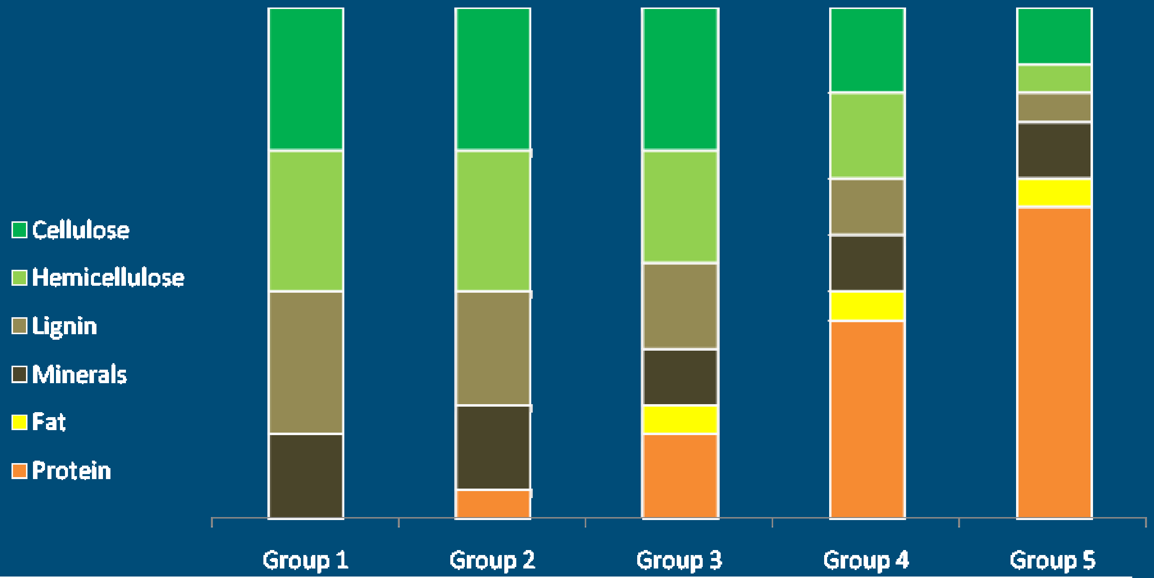
Processing of agricultural residues



Protein content	0	5 %	15 %	35 %	50 %
Examples	Wheatsstraw	cacaohulls Corncobs Sugarcane leaf	Coffee pulp Rape straw Beet leaf	Rape meal	Soy meal
Cost (€/ton)	50-80	50-110	100-140	150-180	300-350
Value (€/ton) as feedstock for: *					
Electricity	85	80	80	75	75
ethanol	25-50	25-50	25-50	15-30	10-20
ethanol + protein	25-50	45-70	105-130	175-190	250-260
idem + hemicell.+ lignine	70	100	145	195	260
idem + hemicell.+ minerals	75	110	155	205	265

* No processing costs included

Ta

Table 21.1 *Potential energy savings from biorefining of crops*

Crop	*Location Region*	*Fossil fuel savings* (Top 5)		
		GJ/tonne of chemical	*GJ/tonne of biomass*	*GJ/ha*
Cassava	Nigeria	37.1	12.5	438
Grass	Netherlands	50.8	17.6	249
Lucerne	South Dakota	29.2	12.4	186
Maize	Iowa	45.4	15.4	382
Oil palm	Malaysia	37.0	20.9	721
Potato	Holland	34.5	11.4	200
Rapeseed	Belgium	41.9	21.5	353
Sorghum	Kenya	39.0	12.3	455
Soya bean	Illinois	40.3	18.1	196
Sugar beet	Germany	32.3	10.0	292
Sugar cane	Brazil	42.0	11.3	490
Sunflower	France	22.2	15.3	128
Switchgrass	Iowa	38.5	14.8	208
Tobacco	Australia	35.5	13.1	346
Wheat	France	49.6	18.5	343
Willow tree	Sweden	44.0	15.6	125

Source: Brehmer et al (2009)

Water use efficiency increases by biorefinery

same data from previous slide combined with Brehmer, maximal fossil feedstock replacement potential; Chem Eng Res Des (2009) doi:10.1016

Crop	Av yield	Water use efficiency	Biorefinery substitution	Water use efficiency
unit	GJ/ha	M3/GJ	GJ/ha	M3/GJ
Maize	60	20-60	382	3-10
Wheat	36	31-40	343	3.5-4.5
Sugar cane	280	11-16	490	6-9
Sugar beet	150	17-26	292	8-13
Rape seed	20	7-10	353	0.5-0.7

Brazil from feed to doubled feed + biobased

Soy

Protein 24 Mton
Biodiesel 12 Mm3
Cattle feed 24 Mton

400 km
600 km

	Mton	€/ton	M€	PJ
Protein	24	300	7200	
Biodiesel	12	400	4800	420
Cattle feed	24	25	600	
Total			12.240	420
€/ha = 510			4% of GNP	

Soy

Protein 18 Mton
Biodiesel 9 Mm3
Cattle feed 18 Mton

Grass

Protein 24 Mton
Bioethanol 36 Mm3
Cattle feed 24 Mton
Pigfeed 24 Mton

	Mton	€/ton	M€	PJ
Protein	42	300	12600	
Bioethanol	36	200	7200	790
Biodiesel	9	400	3600	315
Cattle feed	42	25	1050	
Pig feed	24	100	2400	
Total			29250	1105
€/ha = 1219			10% of GNP	

Soy

Protein 12 Mton
Biodiesel 6 Mm3
Cattle feed 12 Mton

Grass

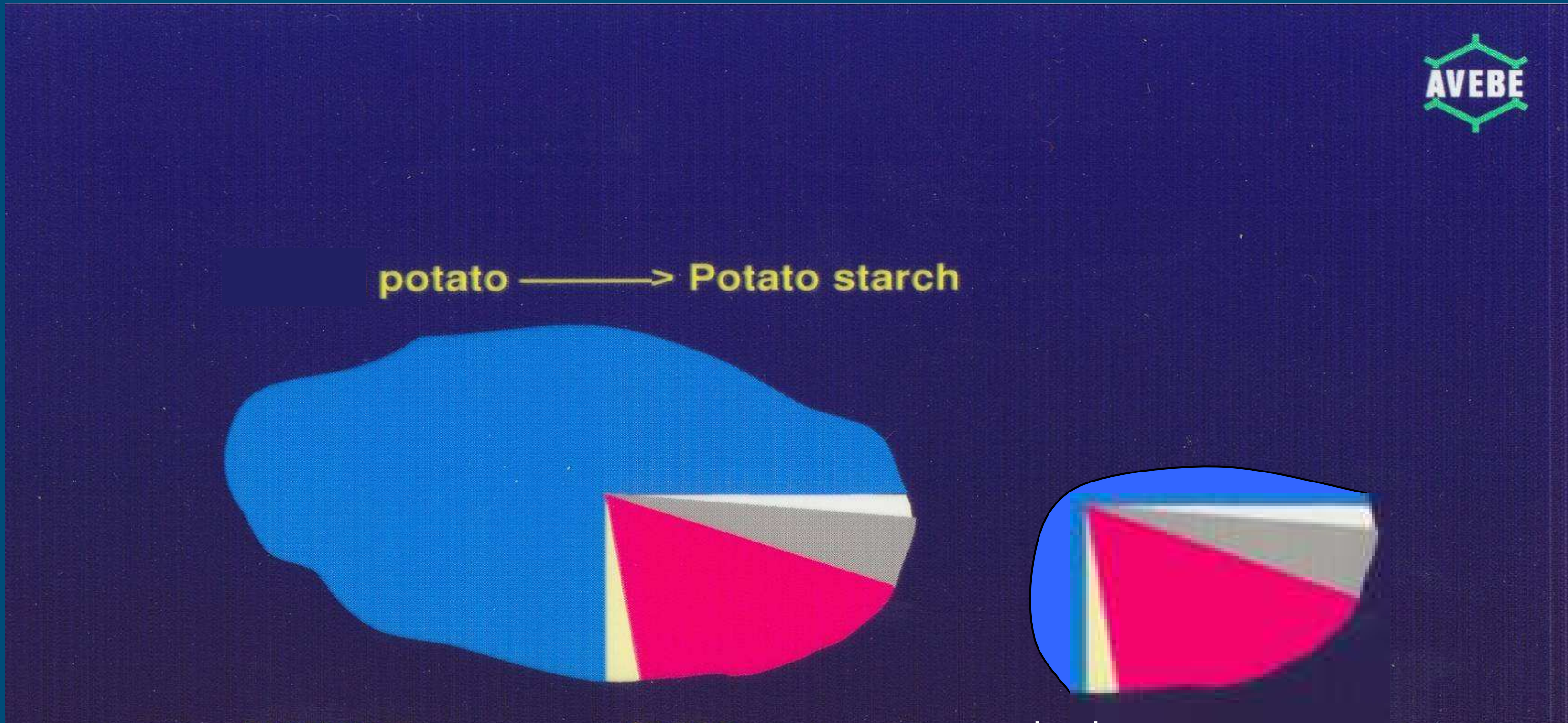
Protein 24 Mton
Bioethanol 36 Mm3
Cattle feed 24 Mton
Pigfeed 24 Mton

Cane

Bioethanol 36 Mm3
Chemicals 12 Mton
Protein 4 Mton

	Mton	€/ton	M€	PJ
Protein	40	300	12000	
Biodiesel	6	400	2400	210
Bioethanol	72	200	14400	790
Cattle feed	36	25	900	
Pig feed	24	100	2400	
Chemicals	12	500	6000	600
Total			38100	1600
€/ha = 1588			13% of GNP	

GMO: improving the potential components of Potato



Lysine

50 → 750 kg/ha = **800 €/ha**

Voorst, Van der Meer, de Vetten EU patent 99204502

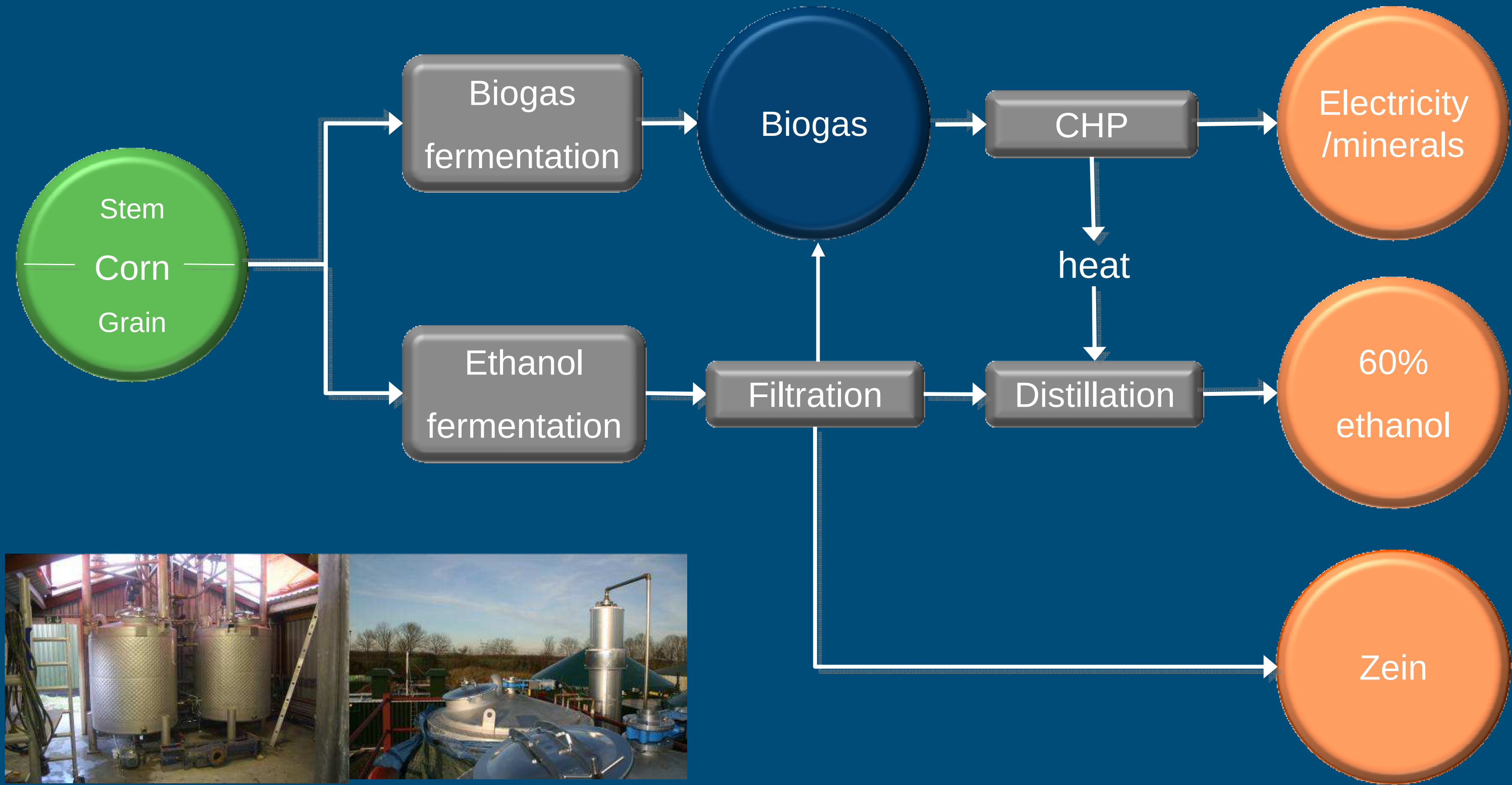
Lysine

1→ 40 kg/ha = **45 €/ha**

Houmard et al. Plant Biot. 5(2007) 605

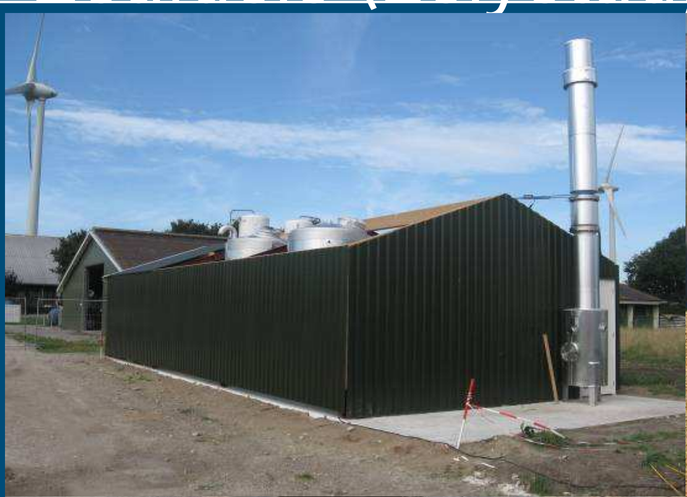
Itaconic acid (2009)

Zeafuels



Less investment costs/liter ethanol than large scale US ethanol production from corn

Zeafuels (Lelystad, Netherlands)






Mobile Cassava starch refinery in Africa (Dadtco)

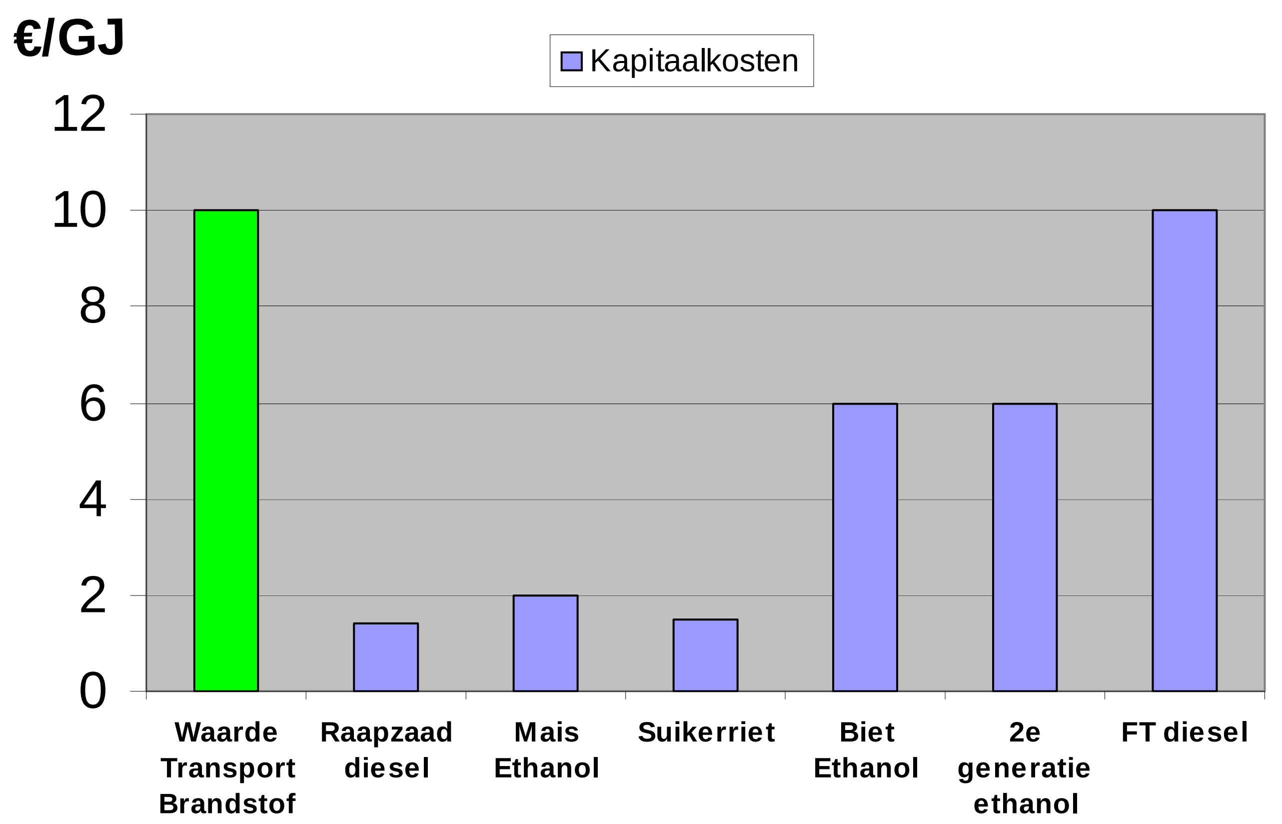
Source: Duteso

Biobased Economy: lessons learnt

1. There is not one single driver for the Biobased Economy
2. Introduction of a Biobased Economy requires a transition
3. Economy of Scale is loosing competitivety
4. Biorefining increases Economic and Sustainability potential

Thank you for your attention!

1e Generatie transportbrandstoffen leidt mogelijk tot verlaging van honger; 2e generatie wellicht niet



Schatting werkgelegenheid	4%					0.1% van gehele bevolking
CO_2 reductie %	matig	matig		matig		
Incl. verbranden stro	goed	goed	goed	goed	goed	goed

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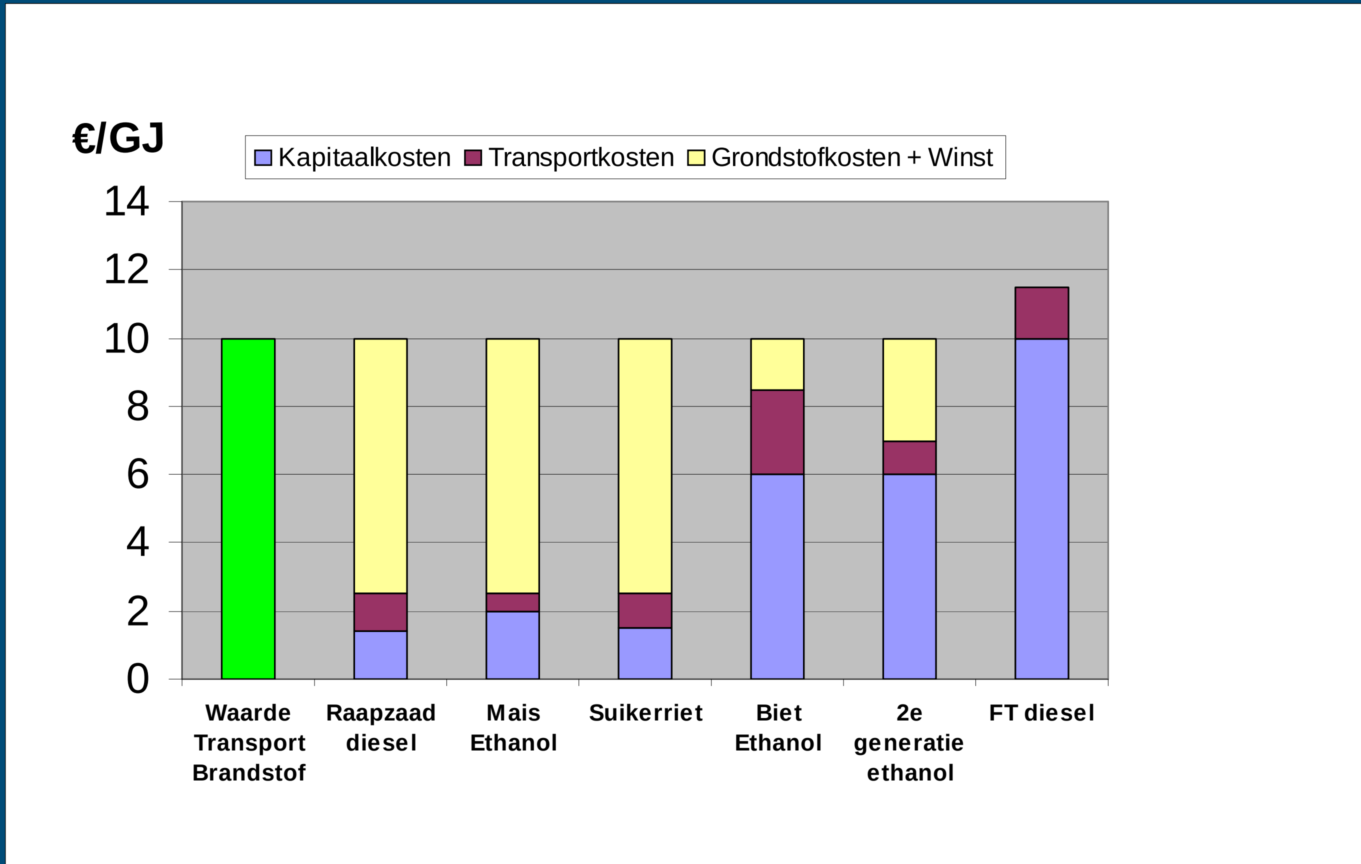

Schatting werkgelegenheid	4%					0.1% van gehele bevolking
CO_2 reductie %	matig	matig		matig		
Incl. verbranden stro	goed	goed	goed	goed	goed	goed

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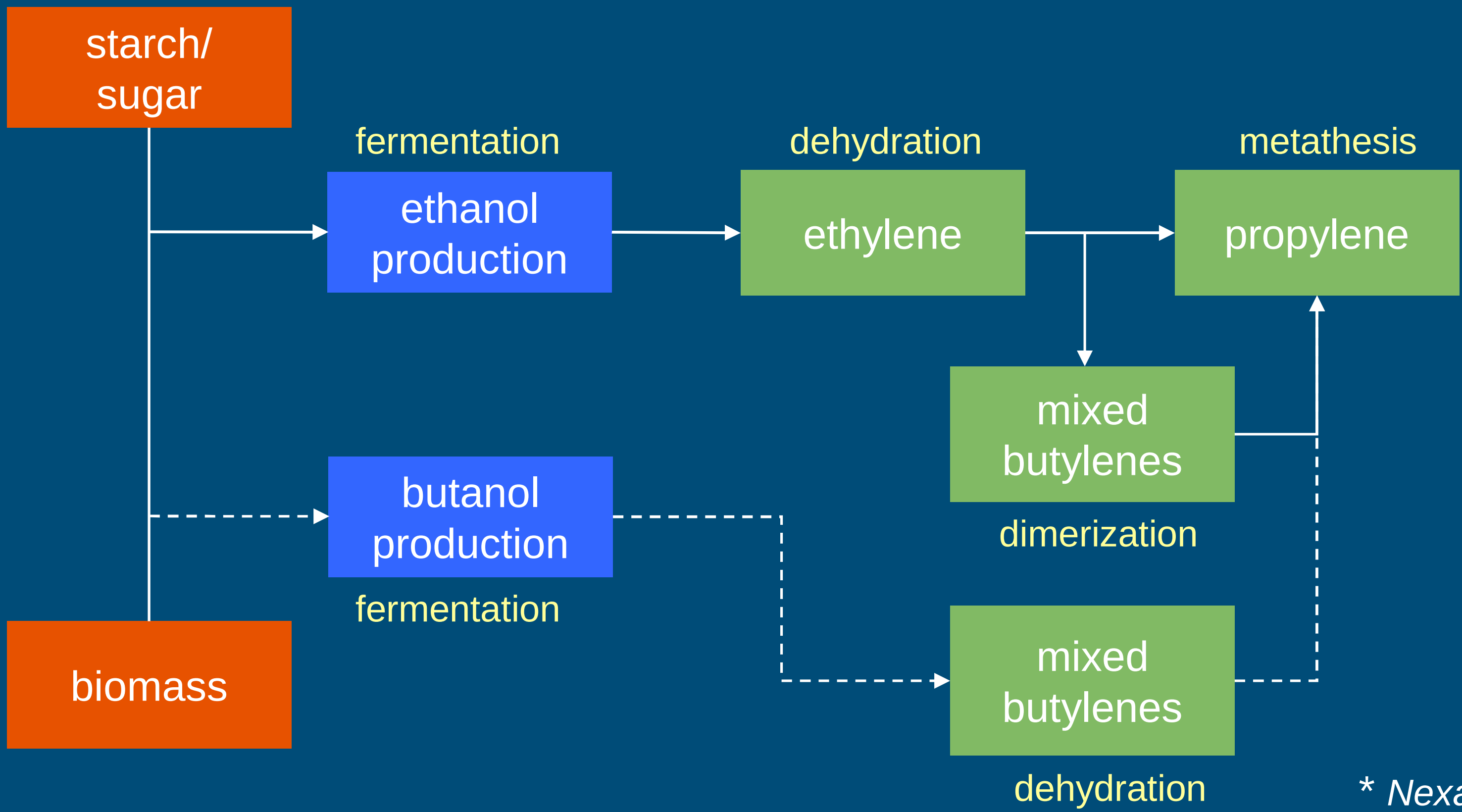
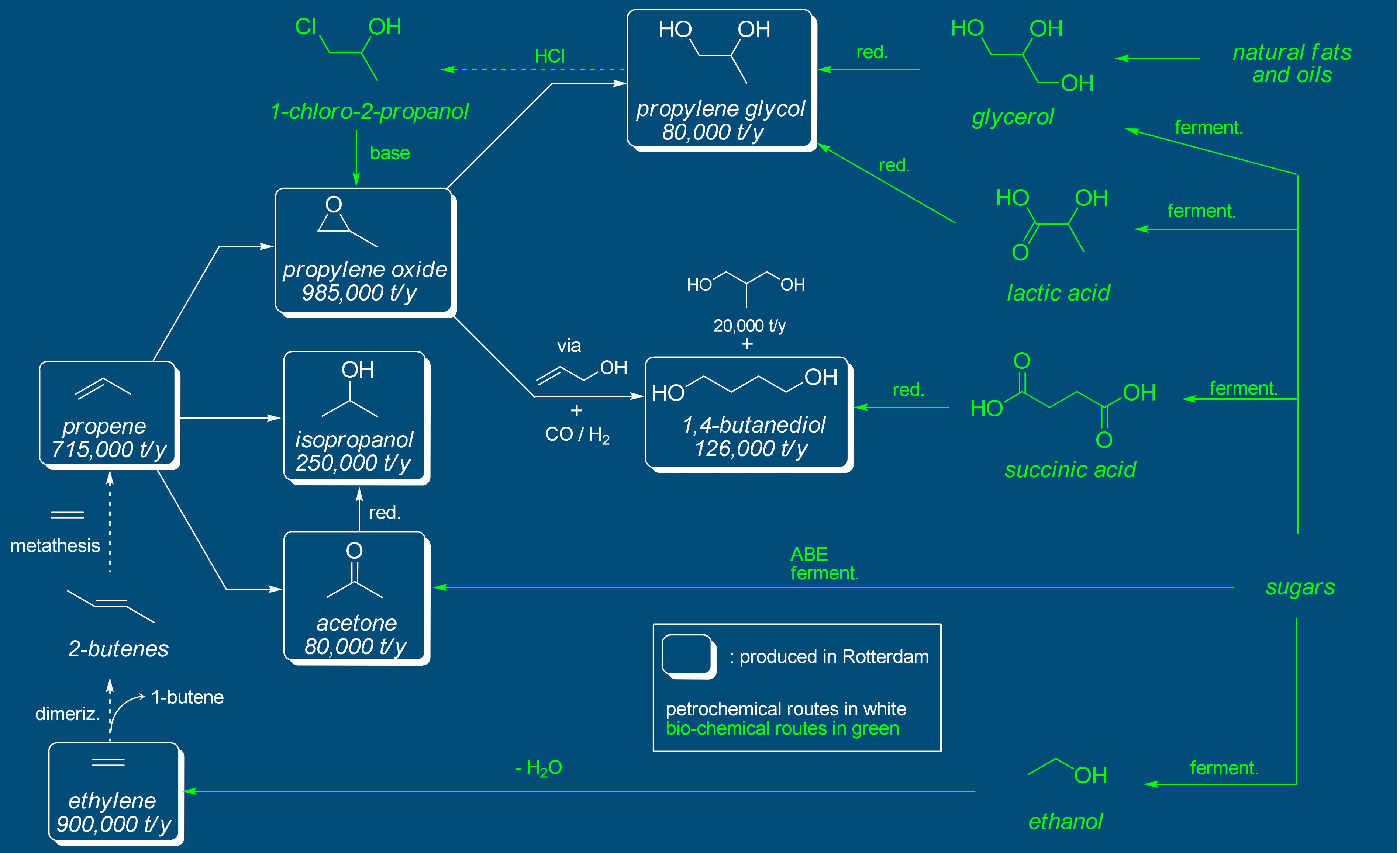
Green propylene production

- Based on fermentation, combined with commercialized petrochemical processes*

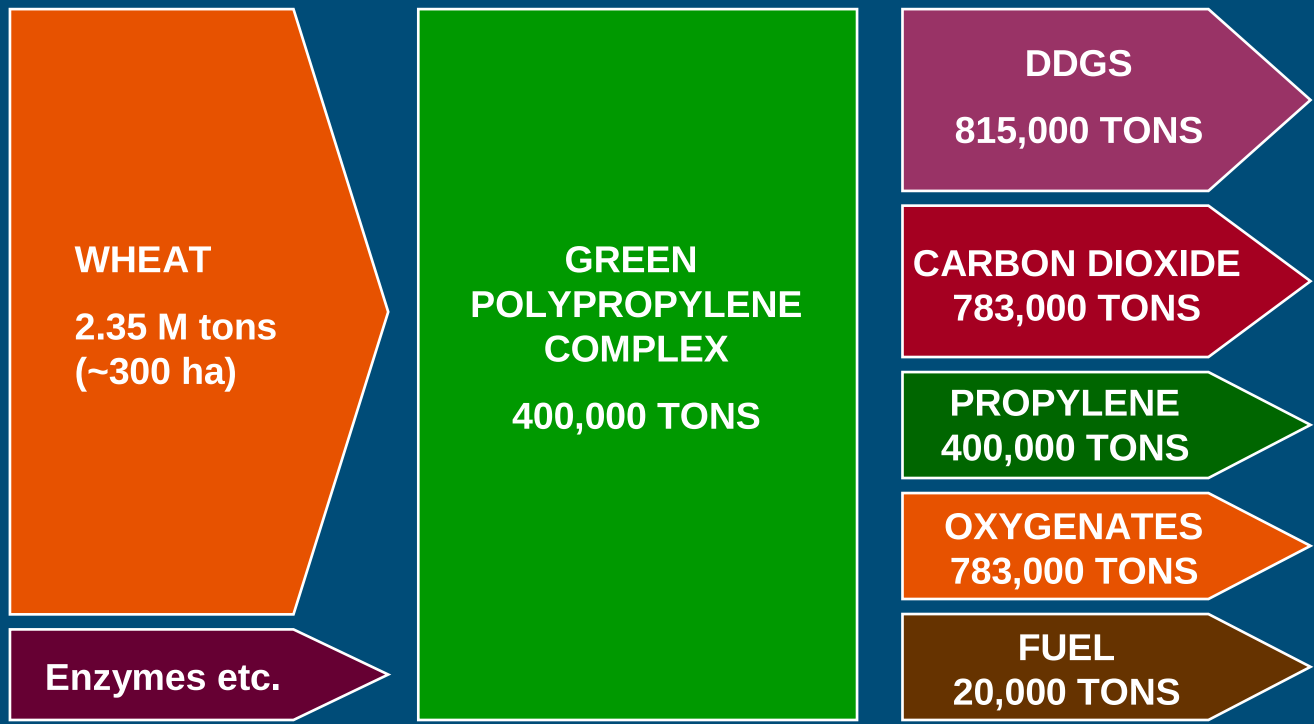


* *Nexant, 2009*

An overview of bio-chemical routes to ethylene, propylene and related oxygenated bulk chemicals produced in Rotterdam



Simplified overall mass balance for the green polypropylene complex*

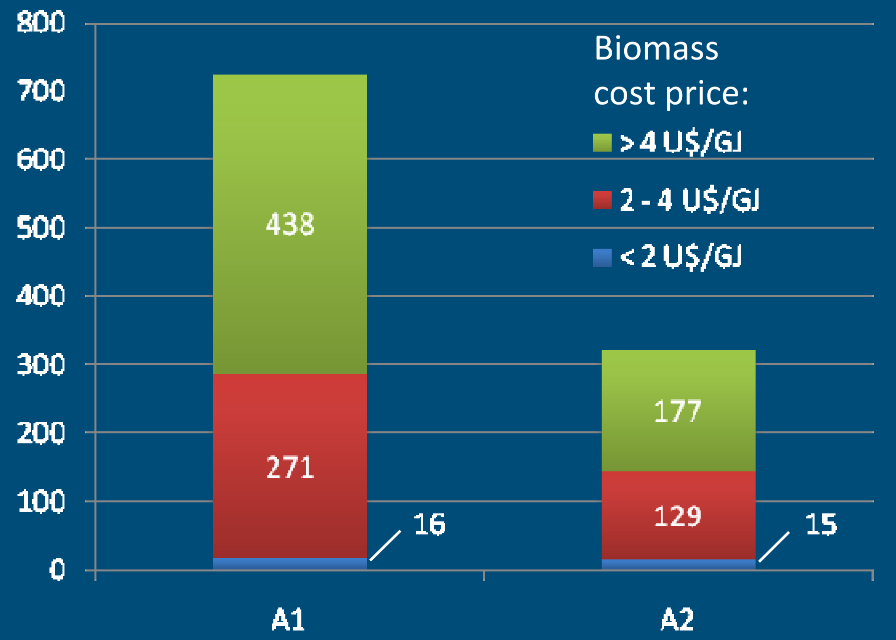


** Nexant, 2009*

Biomass can substitute significant amounts of fossil feedstock

Anticipated energy consumption in 2050: 1000 ExaJoules (EJ = 10^{18}J)/year

Energy crop potential
in 2050 (EJ/year):
two scenarios*



- Extreme scenario A1: global market, no regional protection
- Extreme scenario A2: regional market, protected

** Hoogwijk et al., Utrecht University; RIVM 2004*

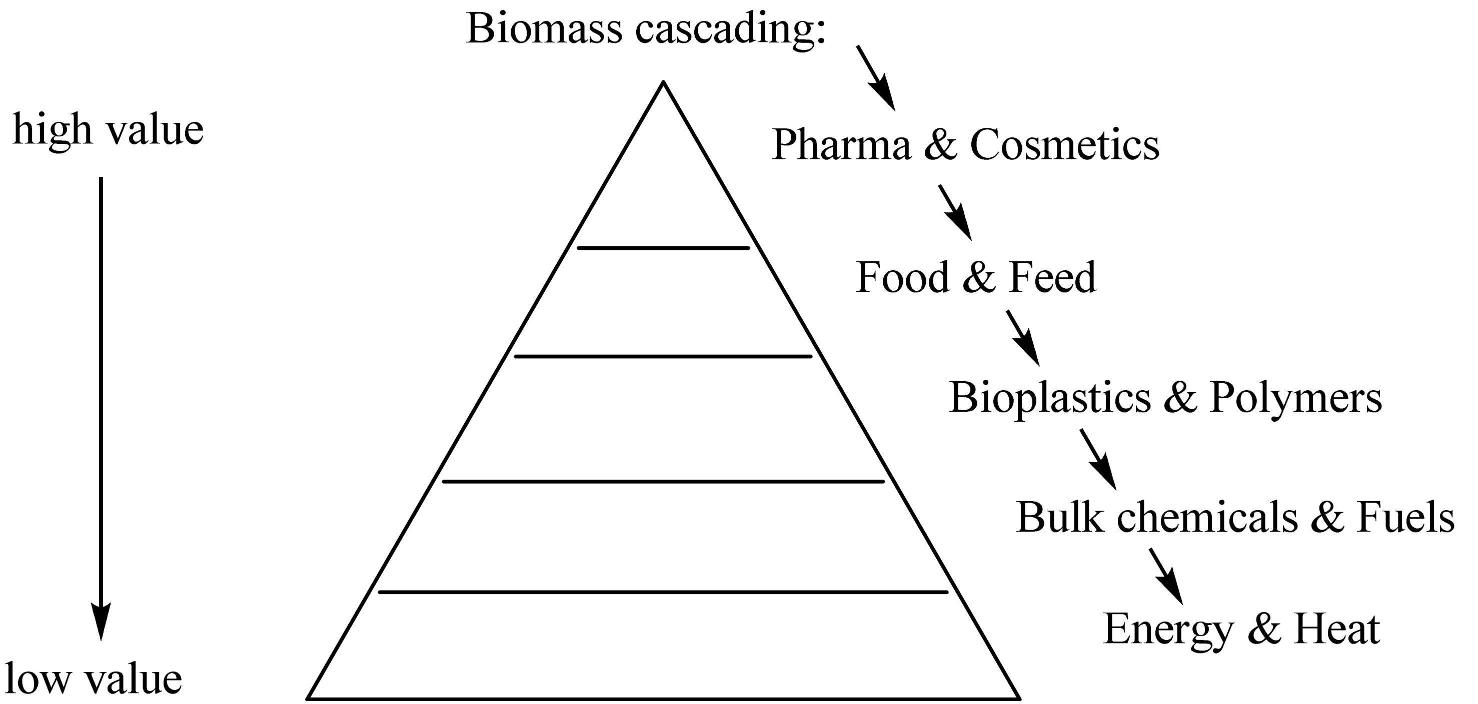
Import large-scale bio-commodities

- Pyrolysis oil
- Torrefaction pellets
- HTU biocrude
- Non purified syngas
- (Hydrous) ethanol
- Biodiesel

- Pure plant oil
- Rapeseed
- Soybeans
- Cereal grains
- Crude protein (hydrolysates)

Eco-pyramid for biomass utilization

You cannot have your cake and eat it



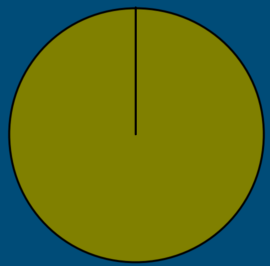
Farma
Fun
Food
Feed
Functional chemical
Fibre
Fermentation
Fuel
Fertilizer
Fire
Flare
fill

Biorefining will give Mitigation under Economic conditions

(125 M (62) hectare = 0,8 % (0.4%) world land area at 10 ton/ha (20 ton/ha))

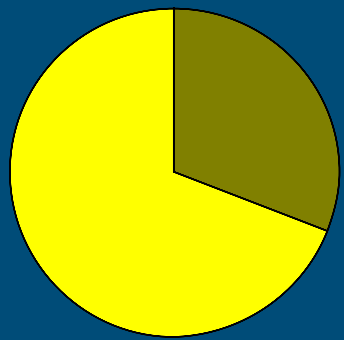
= 4% agricultural land (excl. grassland)

75 billion €
60 €/ton biomass
minus 1200 Mton CO_2



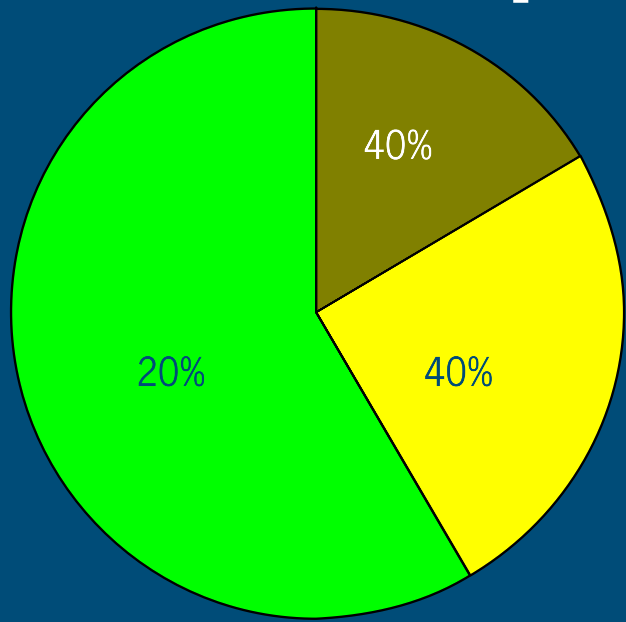
- electricity (3 x 10^6 MW) (40%)

97 billion €
80 €/ton biomass
minus 1200 Mton CO_2



- fuels (375 Mton) (15%)
- electricity (750000 MW) (10%)

225 billion €
180 €/ton biomass
minus 1500 Mton CO_2



- platformchemicals (250 Mton) (100%)
- electricity (750000 MW) (10%)
- fuels (250 Mton) (10%)