Biorefinery, the bridge between agriculture and chemistry
Opportunities for the Biobased industry

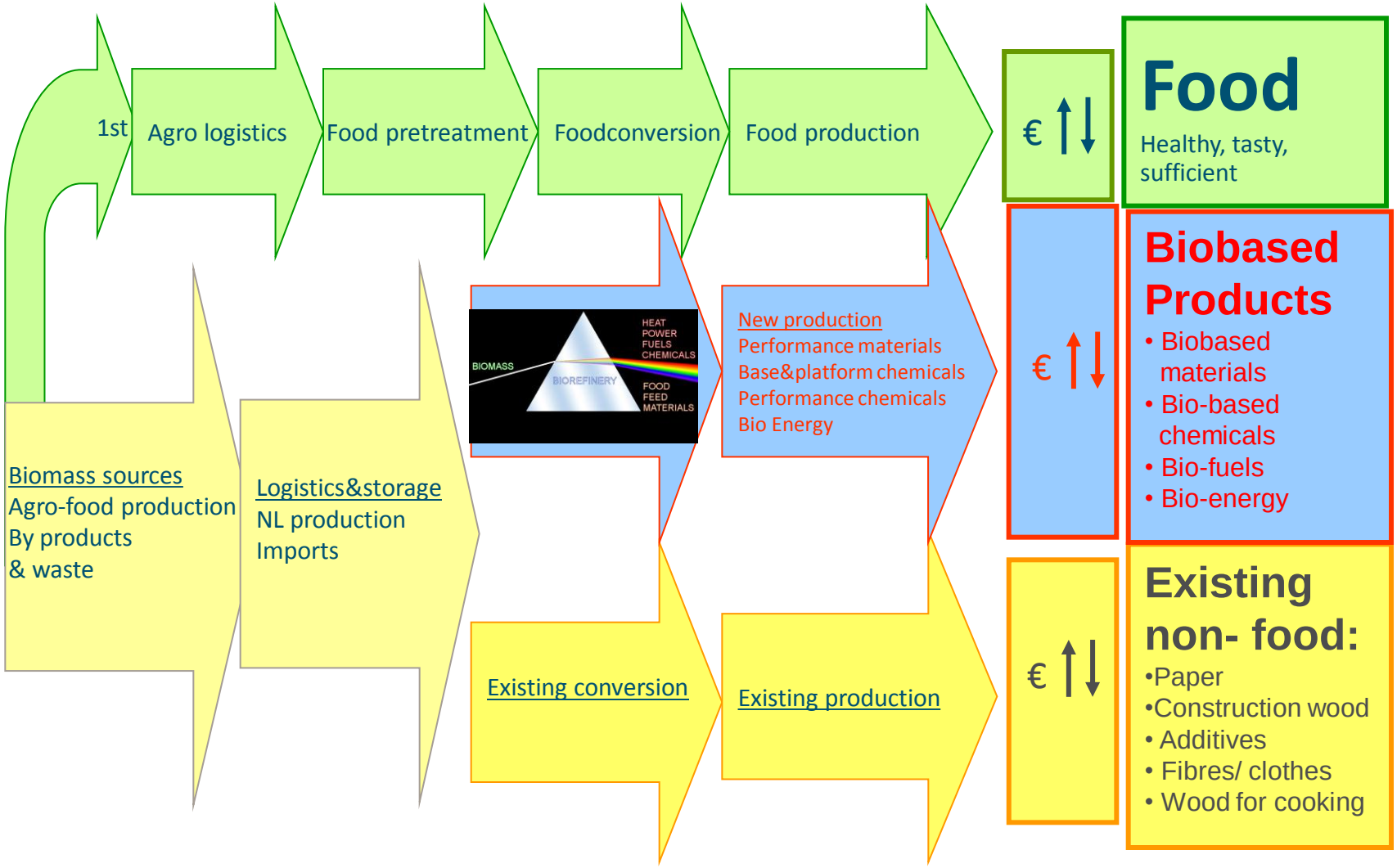
Bioeconomy in Argentina: Present and Future

Buenos Aires, 22 March 2013

Johan Sanders, professor Biobased Commodity Chemicals

WAGENINGEN UNIVERSITY
WAGENINGEN UR

The New Biomass value chain by biorefinery:



WAGENINGEN UNIVERSITY
WAGENINGEN UR

Biomass use today and in 2050

	Mton
▪ Food incl. feed*	4 – 5000
▪ Wood, paper, cotton	2000
▪ Wood for cooking	4000
▪ 30% of 1000EJ in 2050=	20 000
▪ All bulkchemicals in 2050	600(= 2000 input!)

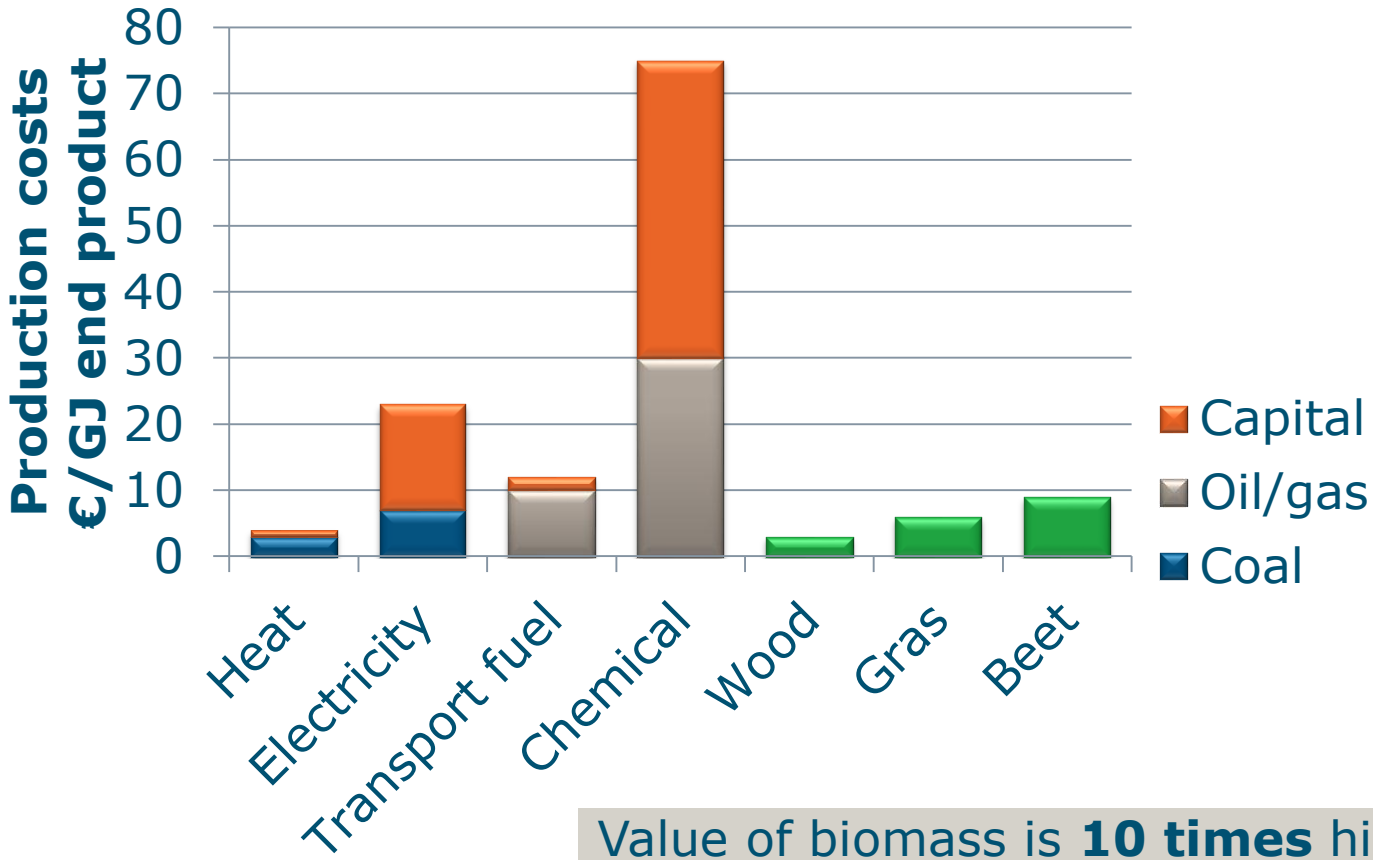
* Excluding grass and seafood

How to compete with fossil under sustainable conditions?

- Increase field yield but *keep components on the field that are required for soil fertility*
- Use all biomass components and *choose the right raw material*
- Use each component at its highest value:

  (molecular) structure is much better than caloric
- Reduce capital cost to speed up innovation and *to benefit from small scale without the disadvantages*
- *Reduce integral costs by integrating process steps*

How biomass can best compete with fossil feedstocks



Value of biomass is **10 times** higher as chemical building block than to use it for biogas or bio-electricity

WAGENINGEN UNIVERSITY
WAGENINGEN UR

F - ladder

How to get the best value from biomass?

	€/ton
Farma	High
Fun	High
Food ingredients	5 - 20000
Food nutritional	100-500
Feed young	100-500
Feed pigs	100-300
Feed cattle	50-250
Functional chemical	500-800
Fibre	500
Fermentation	150-400
Fermentation bulk	100-300
Fuel	100-300
Fertilizer	-/- 200-100
Fire	50-150
Flare	0
Fill	-/- 300

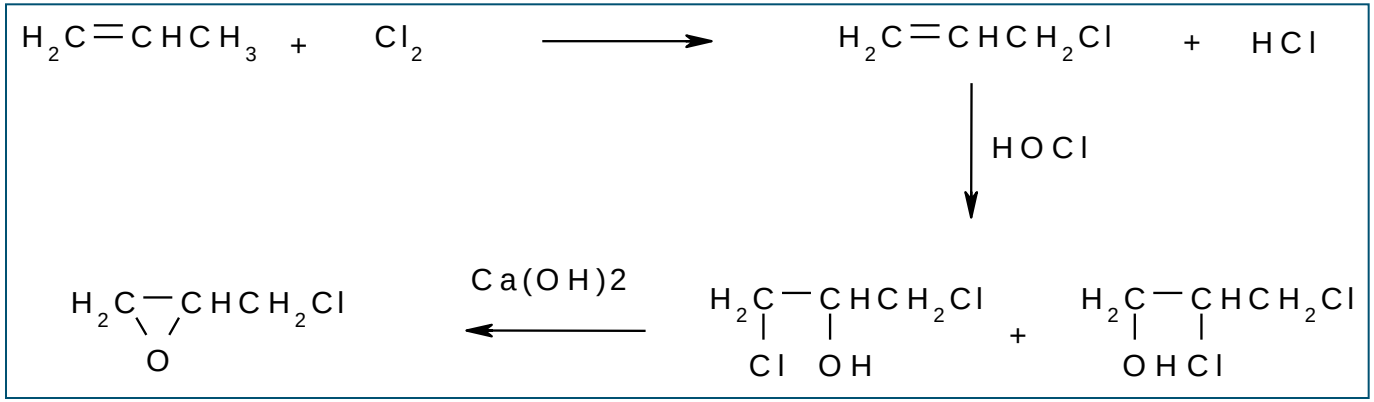
Good use of biomass? **Value of glycerol:**

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

Glycerol 25.3 GJ/tonne

Per GJ product ca 0.65 GJt input can be saved

Epichlorohydrin

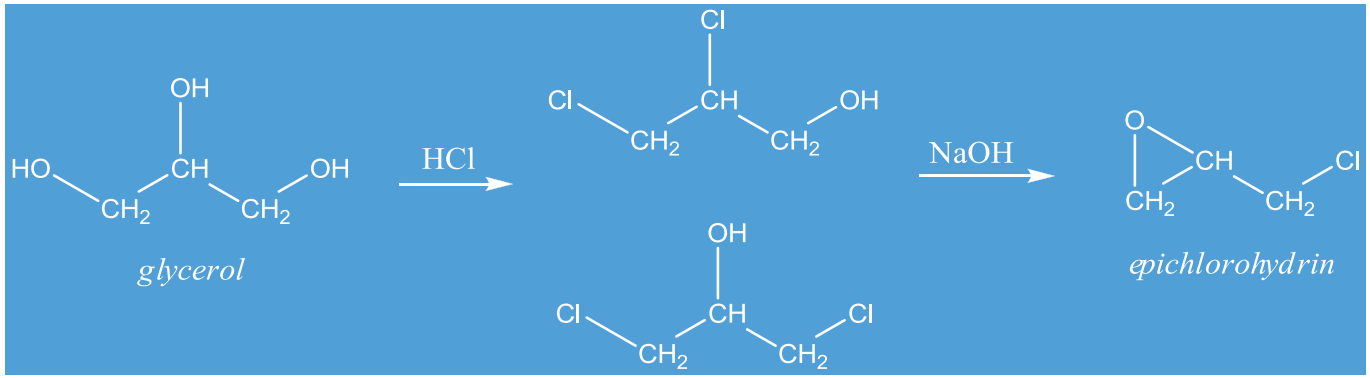


- Price:

  € 1300 - 1500 per tonne

- Volume:

  0.5 mln tonnes per annum

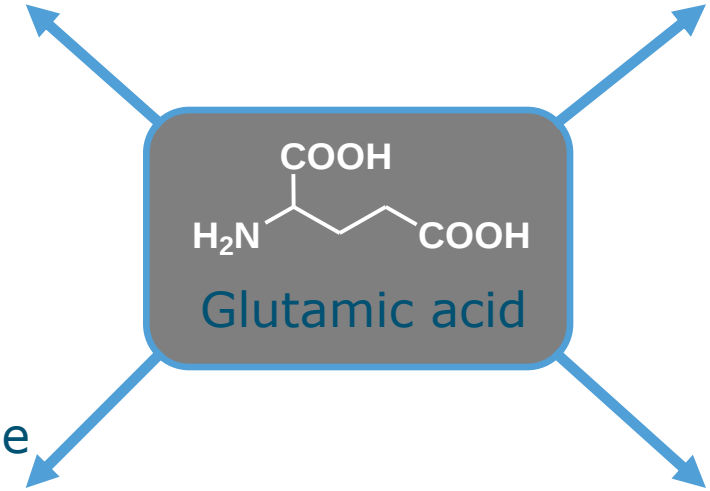


- Solvay ‘Epicerol’ process: glycerol to epichlorohydrin

Use of plant molecular structures

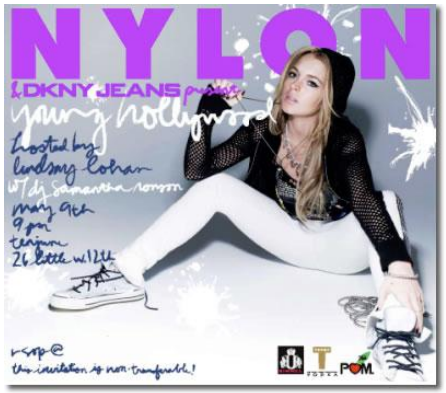
N-Vinylpyrrolidone

Acrylonitrile



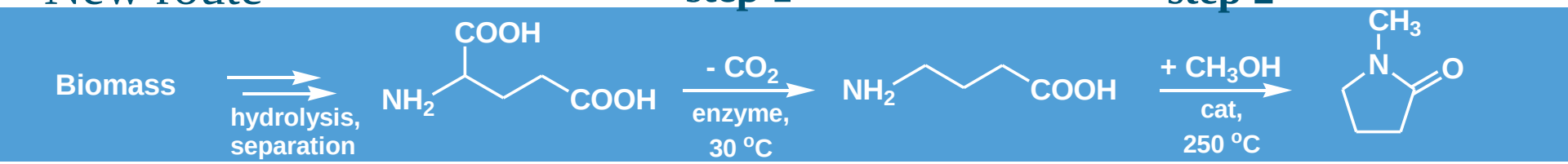
N-Methylpyrrolidone

Diaminobutane

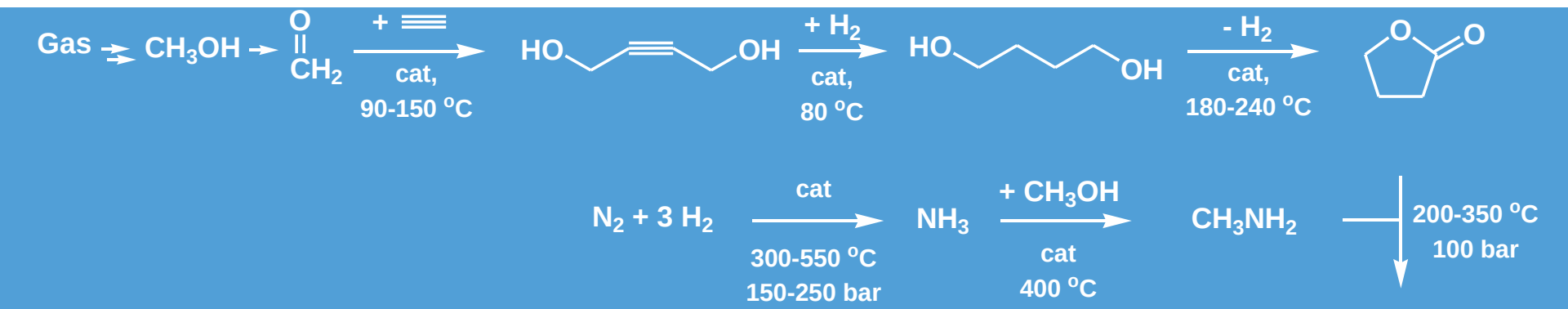


The route to NMP, new vs conventional

New route



Conventional route



Amino acids contain N and O.

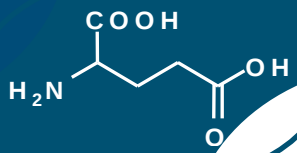
□ Less steps (= factories) & energy for the same product!

Biobased NMP, makes an ethanol plant profitable

500 Million liters bioethanol

(~ 400 kton) =200M€

360 kton DDGS (~130 € / ton) =46M€



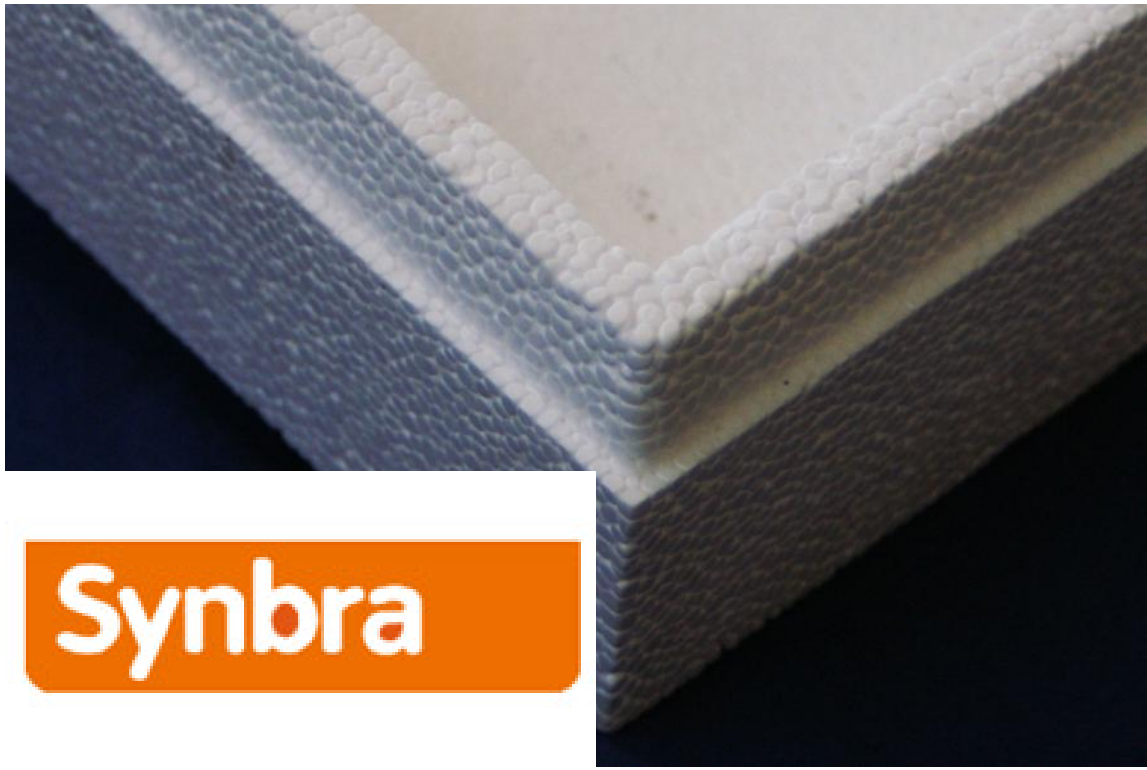
23 kton NMP

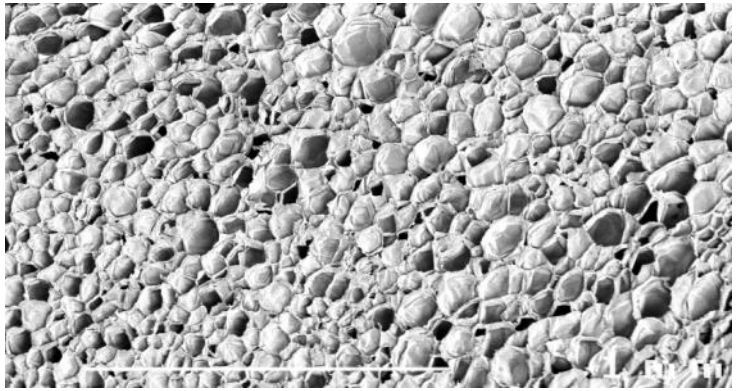
(~2500 € / ton)

=58 M€/y

3D-foamed polylactic structures (Wageningen UR)

- Expandable bead technique
  - Good cell structure
  - Density <30 g/l



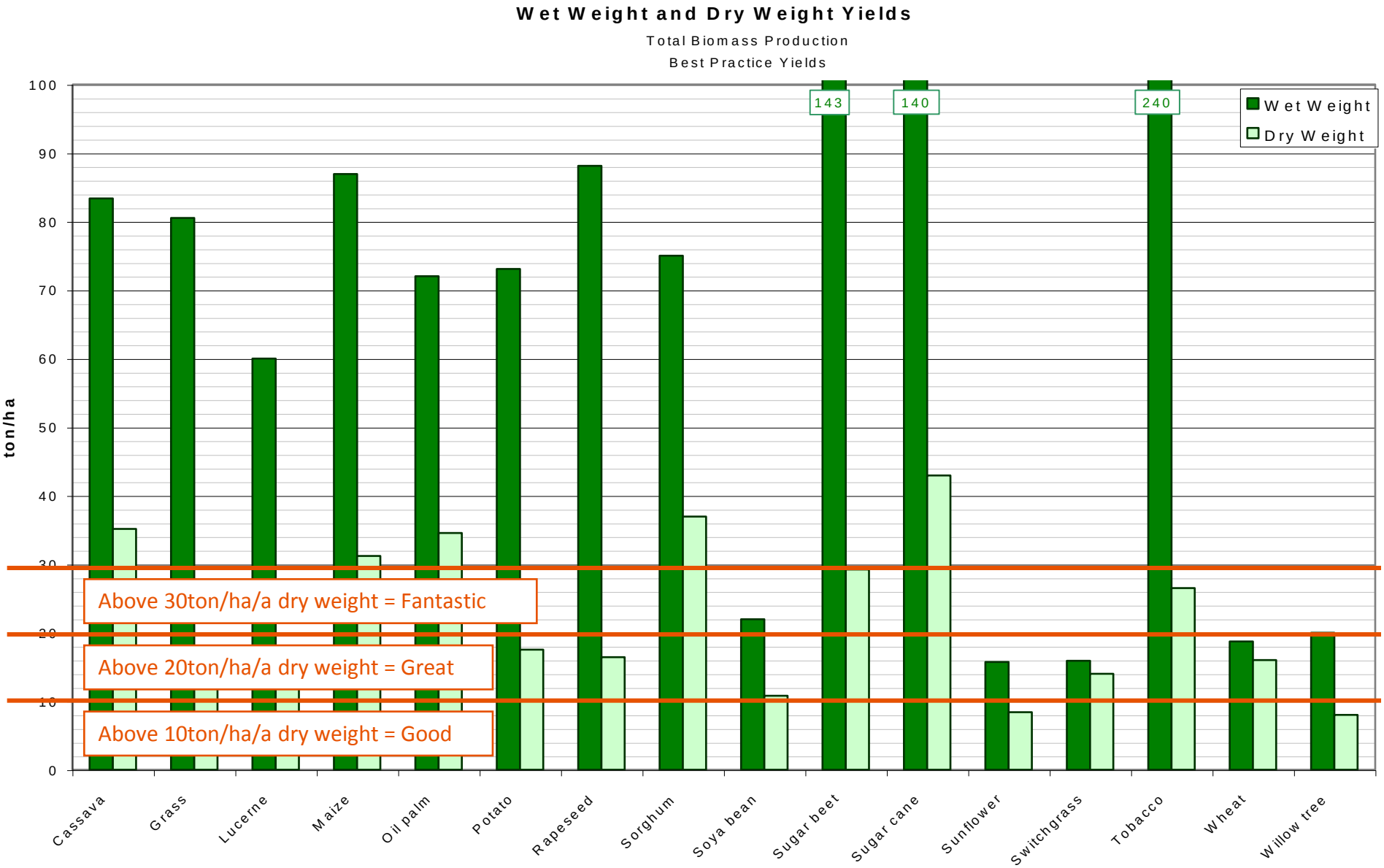


Synbra

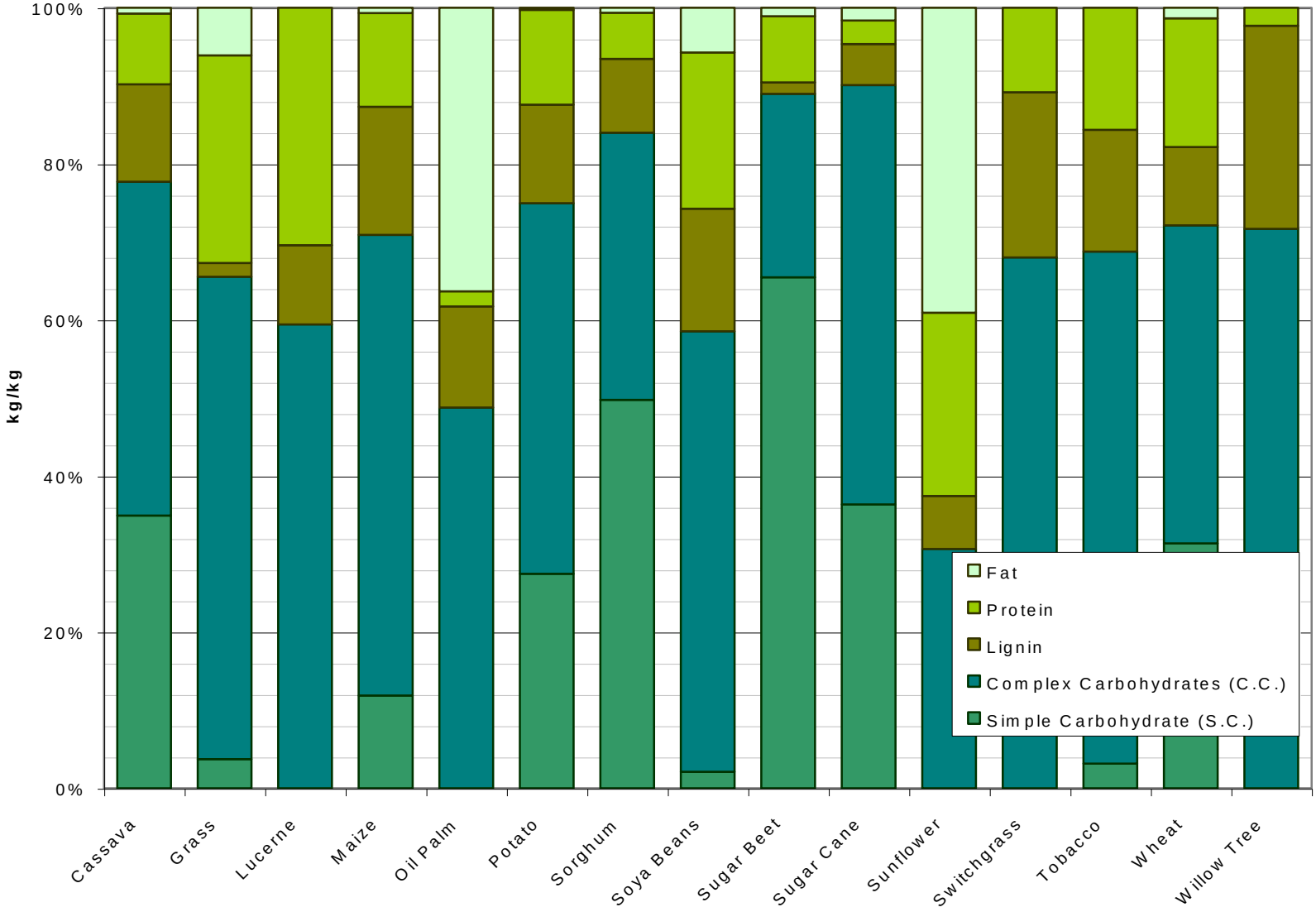
WAGENINGEN UNIVERSITY
WAGENINGEN UR

Sheet: Karin Molenveld

Total crop yields



Proportion of constituents

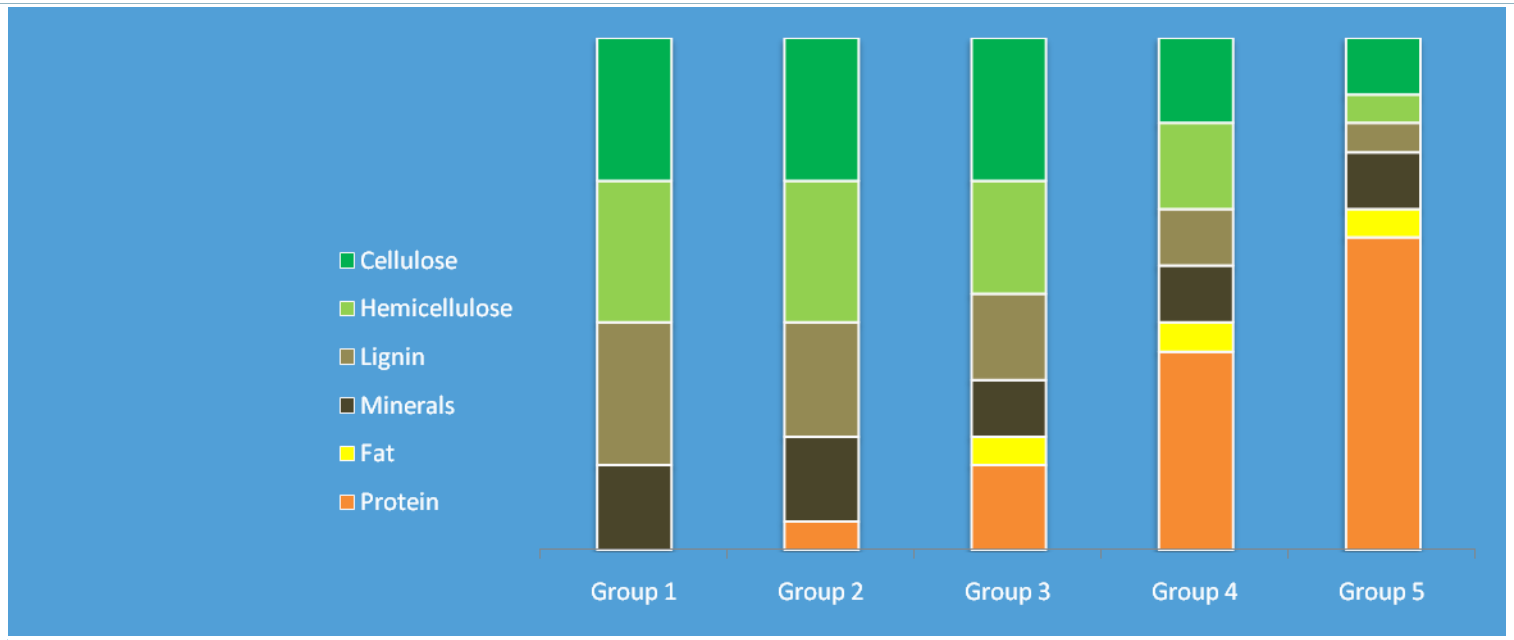


WAGENINGEN UNIVERSITY
WAGENINGEN UR

Lignocellulose hydrolysate, not an ideal substrate yet

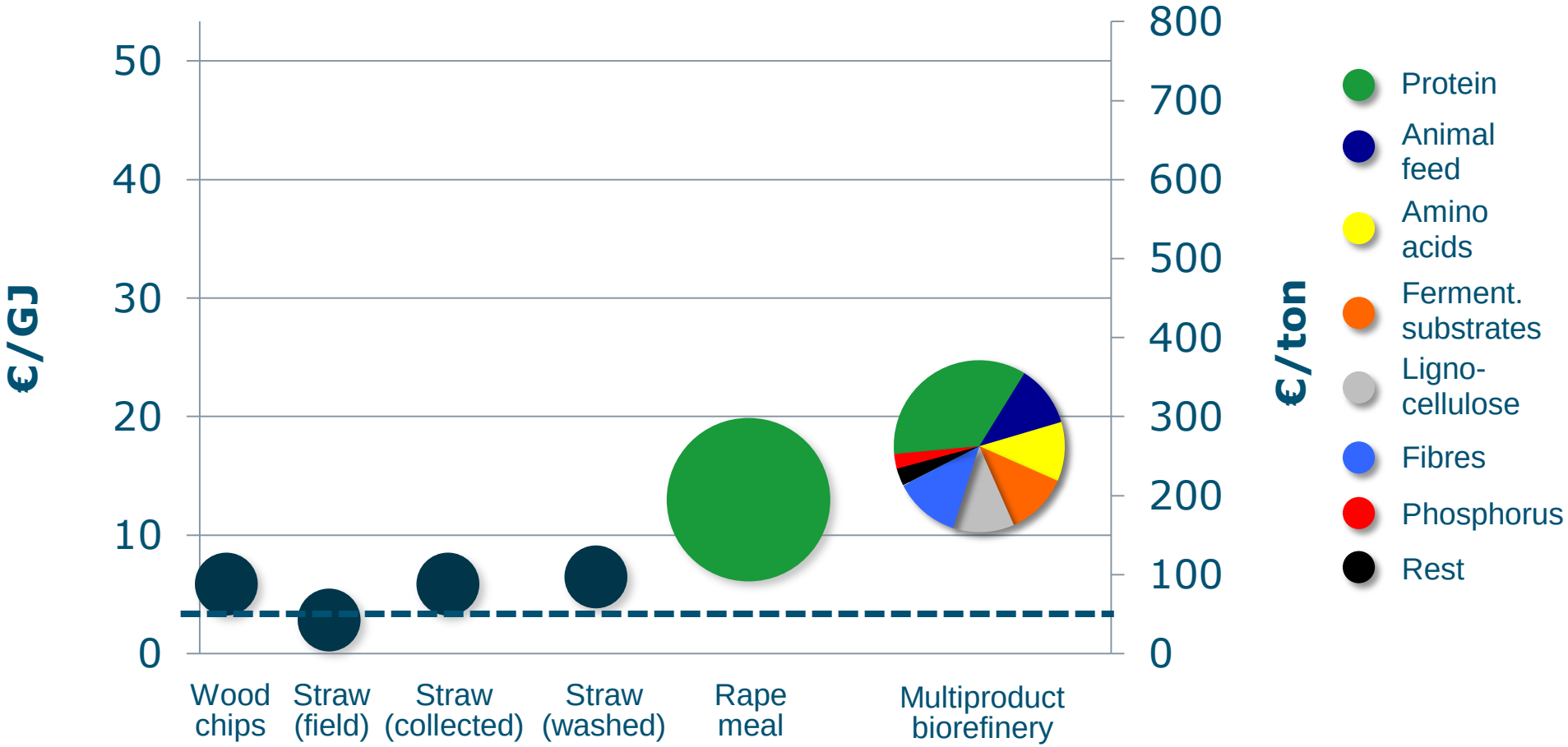
- mixing problems, low oxygen transfer, low substrate concentrations, fermentation inhibitors
- Complex: implications for product recovery

Biorefining of agricultural residues ..



Protein content	0	5 %	15 %	35 %	50 %
Examples	Wheatsstraw	cocoahulls 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

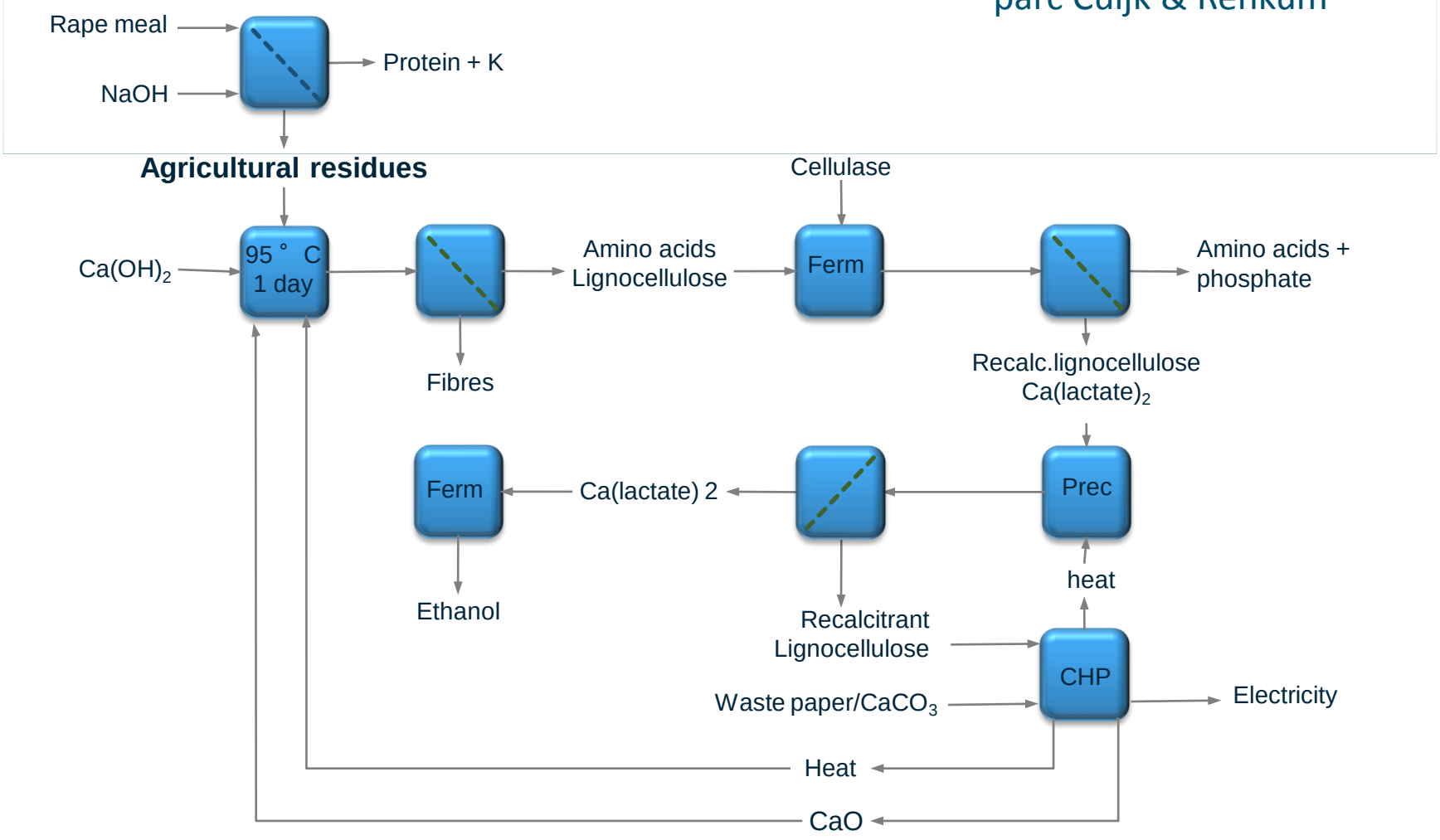
Biorefinery enables power generation at 45€/ton and high quality 2nd generation fermentation raw materials for 200€/ ton



WAGENINGEN UNIVERSITY
WAGENINGEN UR

Integrated production of chemicals & power

parc Cuijk & Renkum



Income per tonne rape meal

Product	Mass	Income €
Protein	300	240
Amino acids	100	30
Animal feed	200	100
Ethanol	(200)	(20)
Fibres	100	20
PO_4	20	10
Lignocellulose	200	10
Total	**920**	**330-410**

Costs rape meal = 180 €/tonne (November 2011)

6 Mtonnes oil seed meal will enable 2.5 TWh

(3 Mtonnes of protein, 1.5 Mton fermentation raw materials and 0.75 Mton fibers)

World production of:

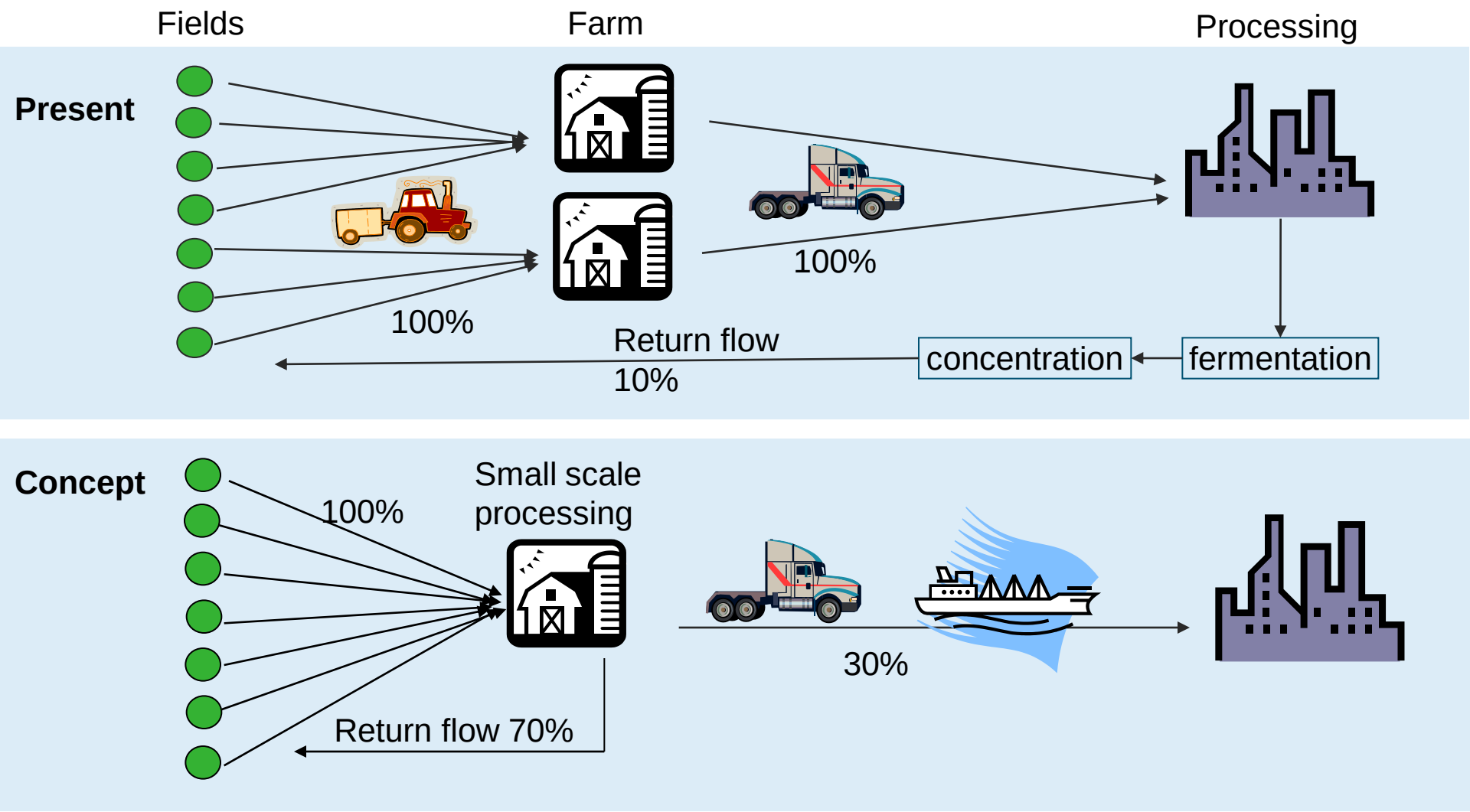
Rape meal	42 Mtonnes/y
Sunflower meal	22 Mtonnes/y
Palm kernel meal	130 Mtonnes/y

Dutch import of seeds and meals is 7.8 Mtonnes/y

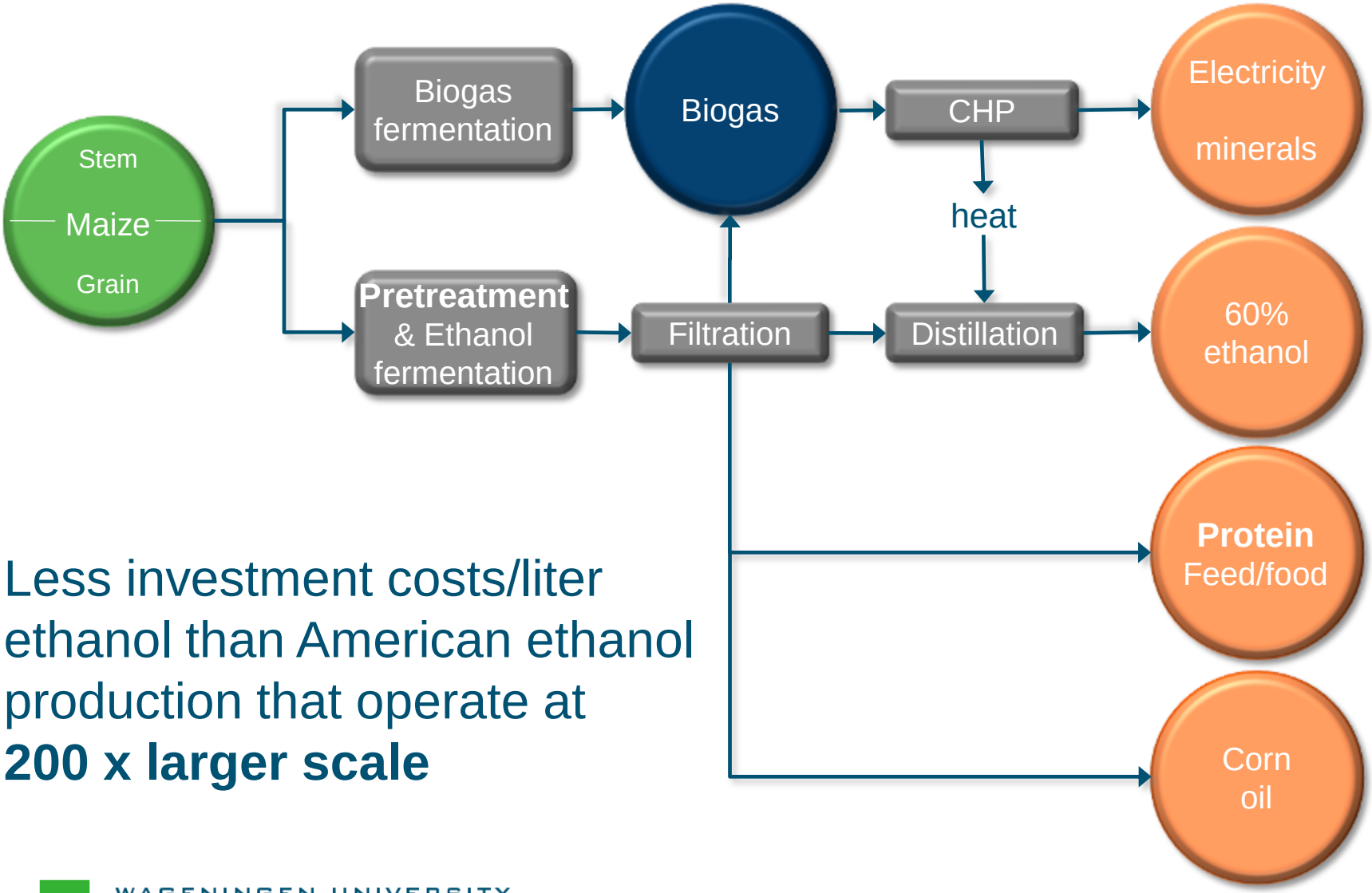
Small scale can be competitive

	Output (kton/y)	Investment (M€)	Turnover (M€/y)	Investment/ ton (€)	Turnover/investment (€/€)
Neste Oil	800	760	480	950	0.63
2nd generation ethanol	175	300	87	1700	0.30
2nd generation multi product	30	15	12	500	0.8

Small scale biorefinery reduces transport cost and seasonality



protein/oil/ethanol/biogas from small scale corn-biorefinery



Less investment costs/liter ethanol than American ethanol production that operate at **200 x larger scale**

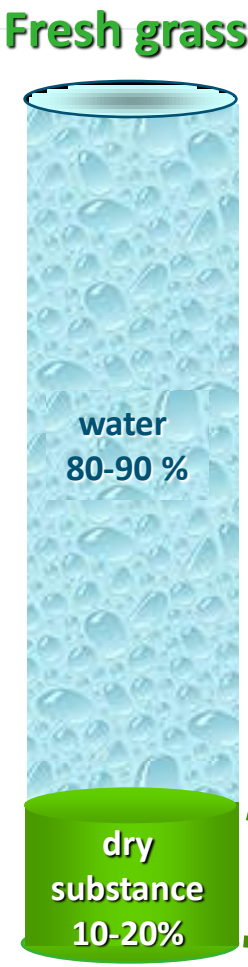
WAGENINGEN UNIVERSITY
WAGENINGEN UR

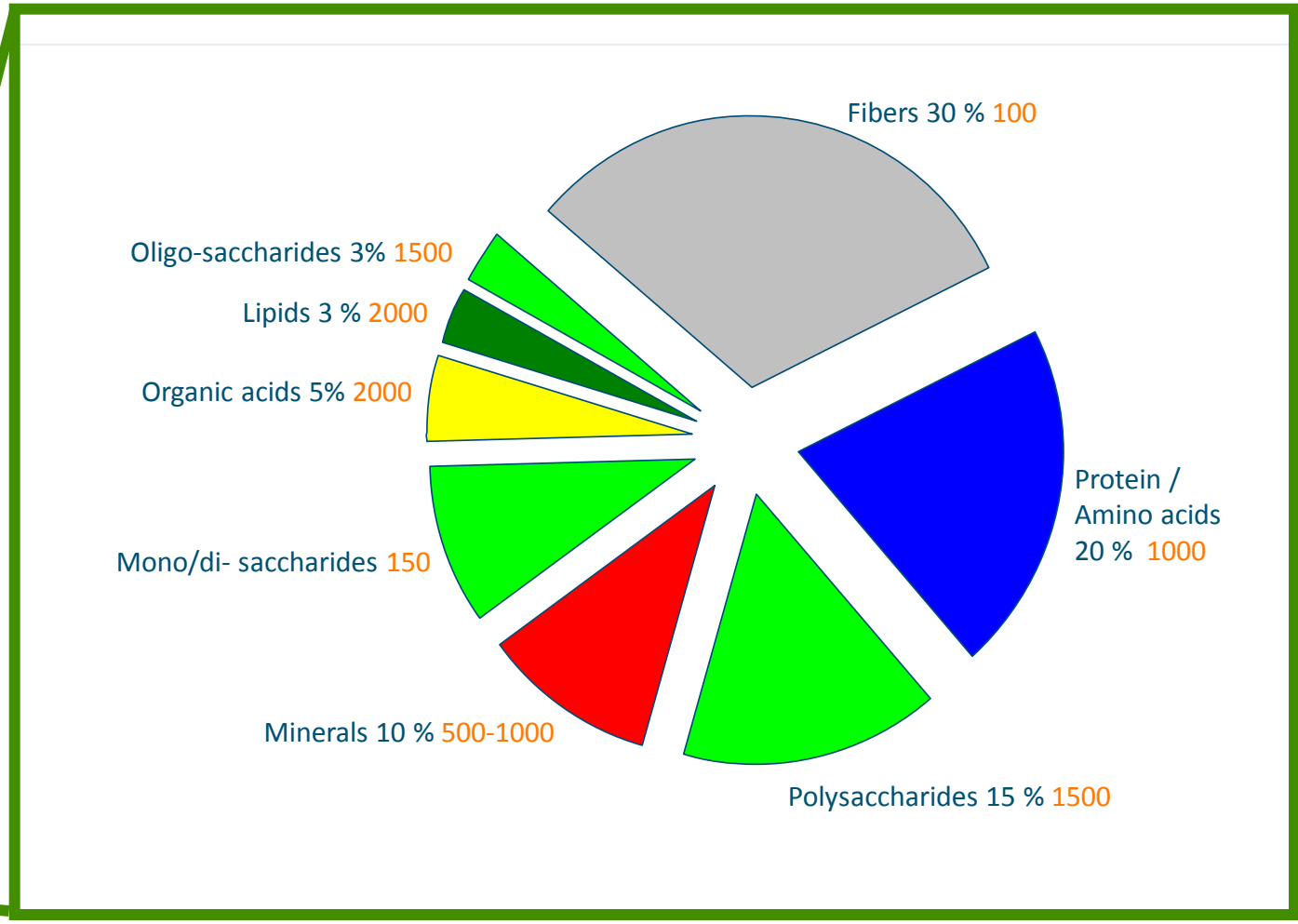
Byosis/Zeafuels (Lelystad, Netherlands)





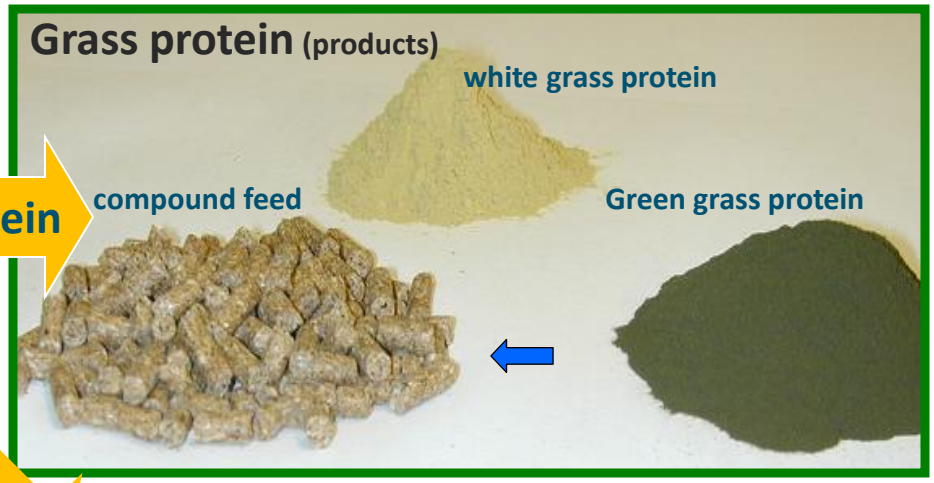

The separated components of grass value 700 – 800 €/ton as compared to 50 – 70 €/ton raw materials





Mobile grass refinery unit Grassa (the Netherlands)

Protein



Grass juice

compound feed

+ .....

Fibers

HTU-Biofuel

Construction material + paper

Polymer extrusion products

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Mobile Cassava starch refinery in Africa

Bio-commodities is a necessity for the industry to start!

- Pyrolysis oil
- Torrefaction pellets
- HTU biocrude
- Non purified syngas
- (hydrous) ethanol
- lactate
- Biodiesel
- Pure plant oil
- Rape seed
- Soy beans
- Cereal grains
- Crude protein (hydrolysates)

Carbohydrates as the building blocks

Why do aerobic fermentations have low Y_s

Lysine: 0.45 g/g

Glutamic acid: 0.48 g/g

While anaerobic fermentations have high yields

Lactate: 0.95 g/g

Ethanol: 0.95 J/J

Anaerobic fermentations

Productivity: up to 5 times higher as compared to aerobic

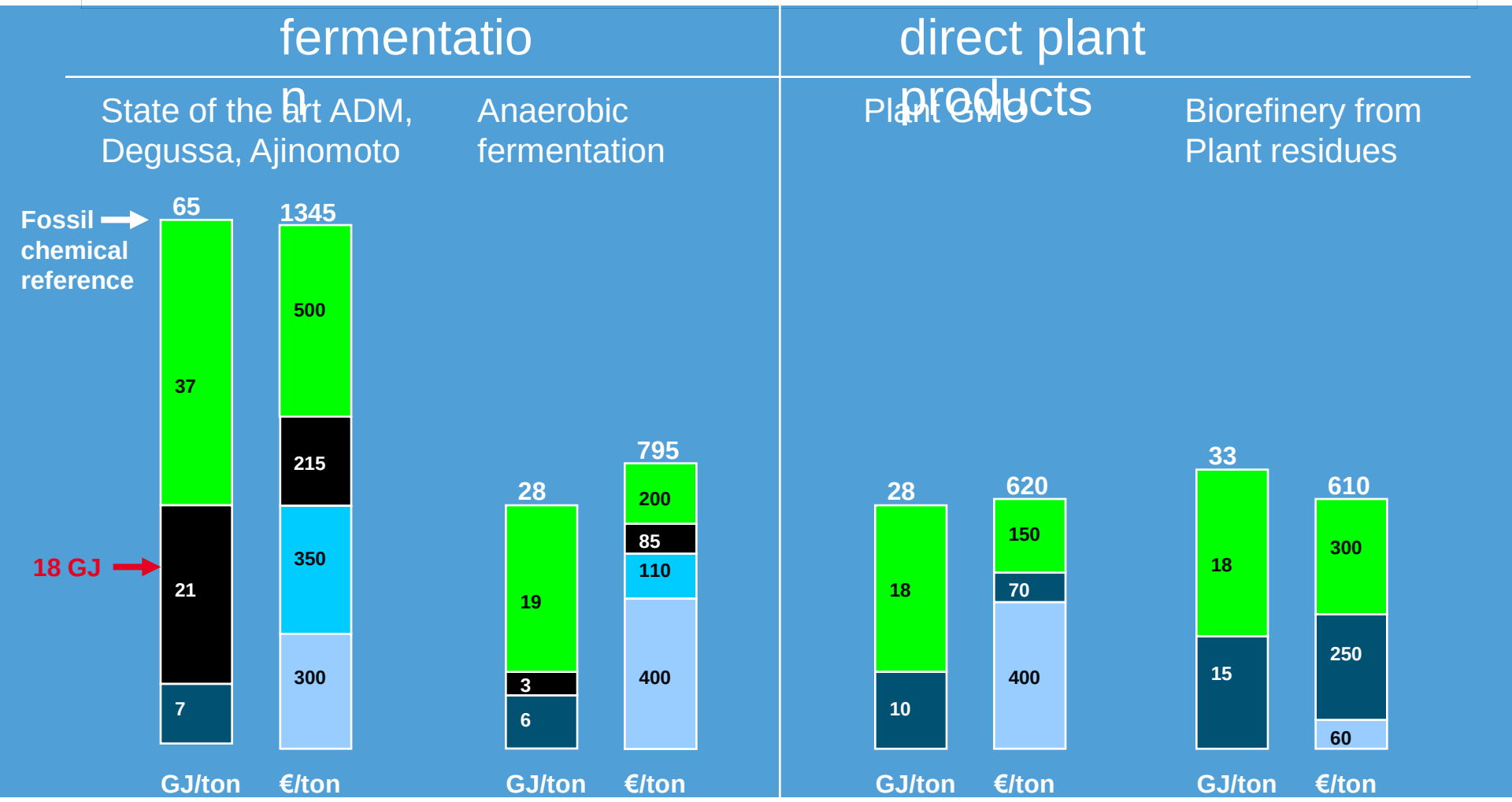
Less cooling equipment

No compressor

Much less stirring

Leading to much lower capital costs per ton of product

Bulk chemicals from Biomass: e.g. lysine

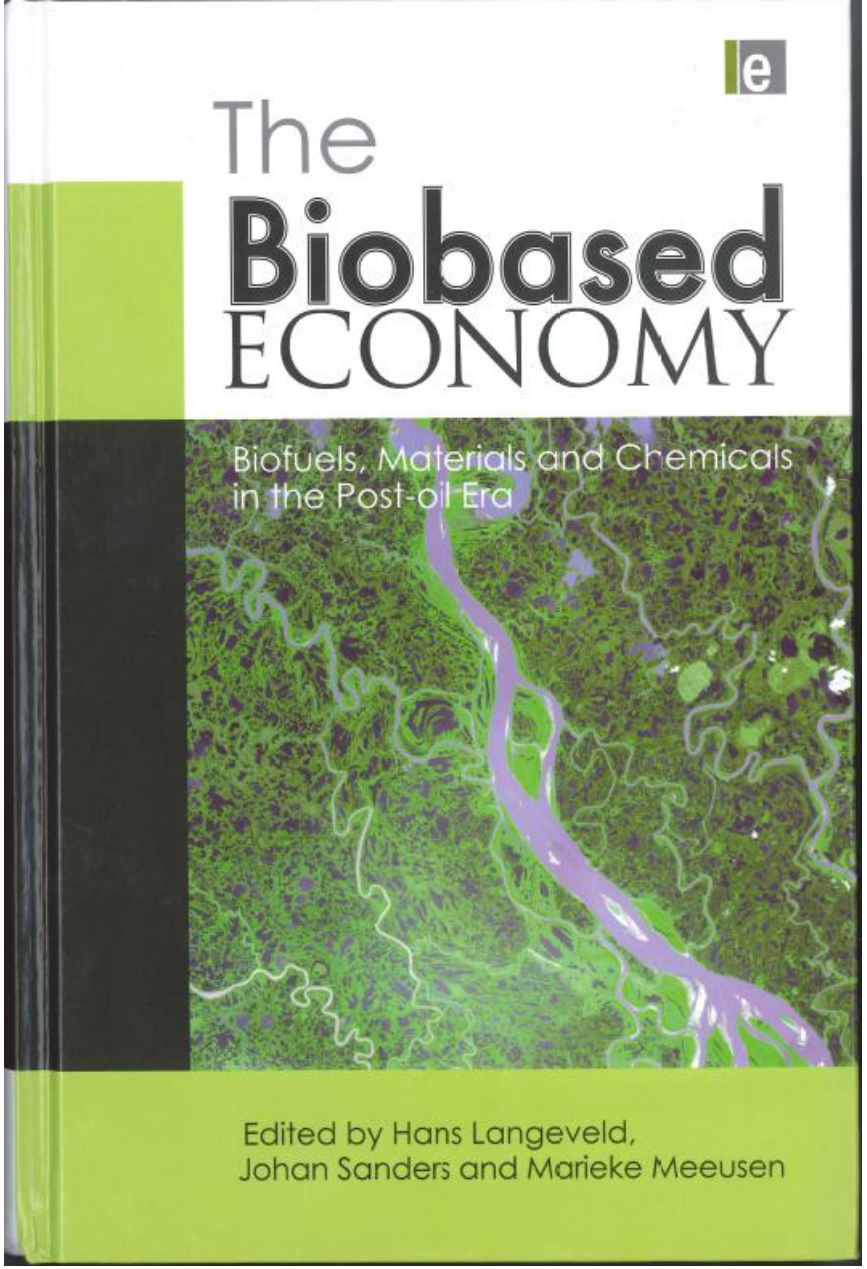


Fossil raw materials (fermentation)
Fossil raw materials (recovery)
Biomass raw materials
Capital (fermentation)
Capital (recovery)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

conclusions

- Use of all biomass components at their highest value enables even to compete with coal and natural gas
- Use of molecular structures needs much less capital and energy
- Anaerobic fermentation gives high substrate yield and low capital costs
- Economy of scale is loosing its competitiveness



WAGENINGEN UNIVERSITY
WAGENINGEN UR

Earthscan, ISBN 978-1-84407-770-0

Why soy?

- Important food crop – can we use it also for non-food? Biorefinery is the key: co-production of food/feed/other products
- Soy is a good binder of Nitrogen from air
- Crops available both natural and genetically modified
- Substantial crop: 91 mio ha globally, 2,2 ton/ha soy seeds
- *AND*
- 6 ton soy-hay and soy rests per ha: valuable components!
- 1,7-3,4 ton soy/ha normal conditions; 4 ton/ha optimal conditions

Soy biorefinery

- Soy: food and feed
- Decentral (on spot) pressing of waste, selling the protein juices
- Sugars: more centralised production of ethanol through fermentation
- Ligno cellulose: second generation bioethanol
- Biorefinery gives access to chemical industry and higher outputs in terms of money.

Soy for example

- Soy contains:

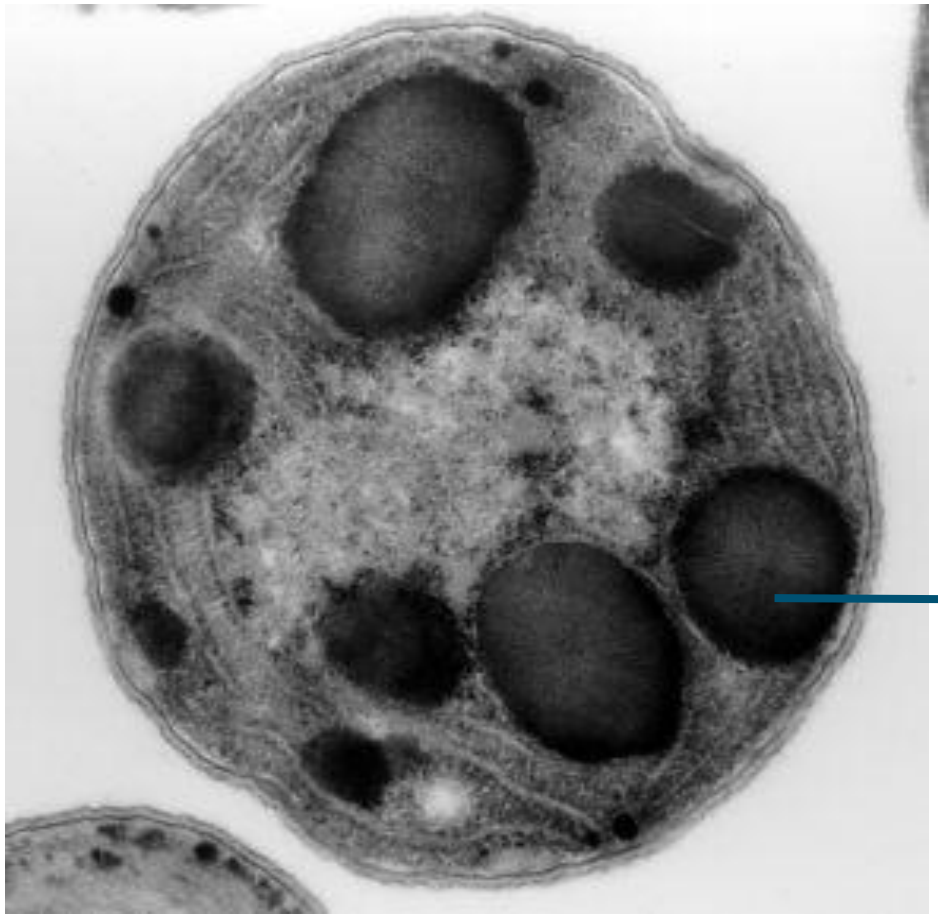
• celluloses	17%
• hemi celluloses	4%
• sugars	7%
• proteins	41%
• oil	18%

- Soy seeds: only 1/3 of total dry plant mass =>
- plant adds enormous quantities of valuable products

Summary

- Use of ag residues (soyleaf/stems, cane-leaf, etc) for the production of protein, animal feed and bulkchemicals
- Protein hydrolysates and the crystallization of pure aminoacids for feed, chemicals and pharma
- Yeast Coproduction of chemicals and ethanol
- Small scale biorefining of rapeseed/ Jatropha/ oil crops in rural areas for the production of biodiesel, protein and minerals
- Small scale production of ethanol and protein from starchy crops
- Low capital and operational cost anaerobic sugar fermentations to bulkchemicals
- In planta (Cane/ Soy/..) production of bulkchemicals by GMO

Ethanol and Cyanophycin building blocks from yeast: two products for the price of one

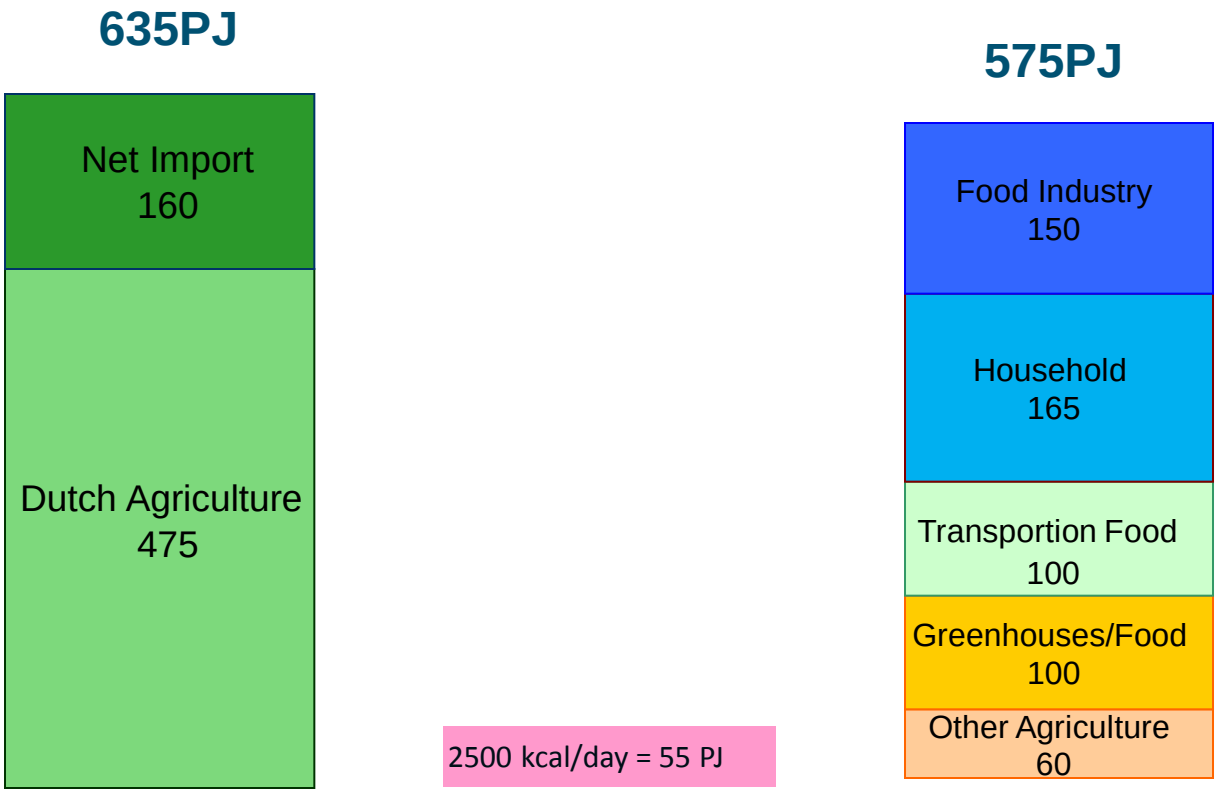


Cyanophycin mainly in cyanobacteria as nitrogen and energy reserve material

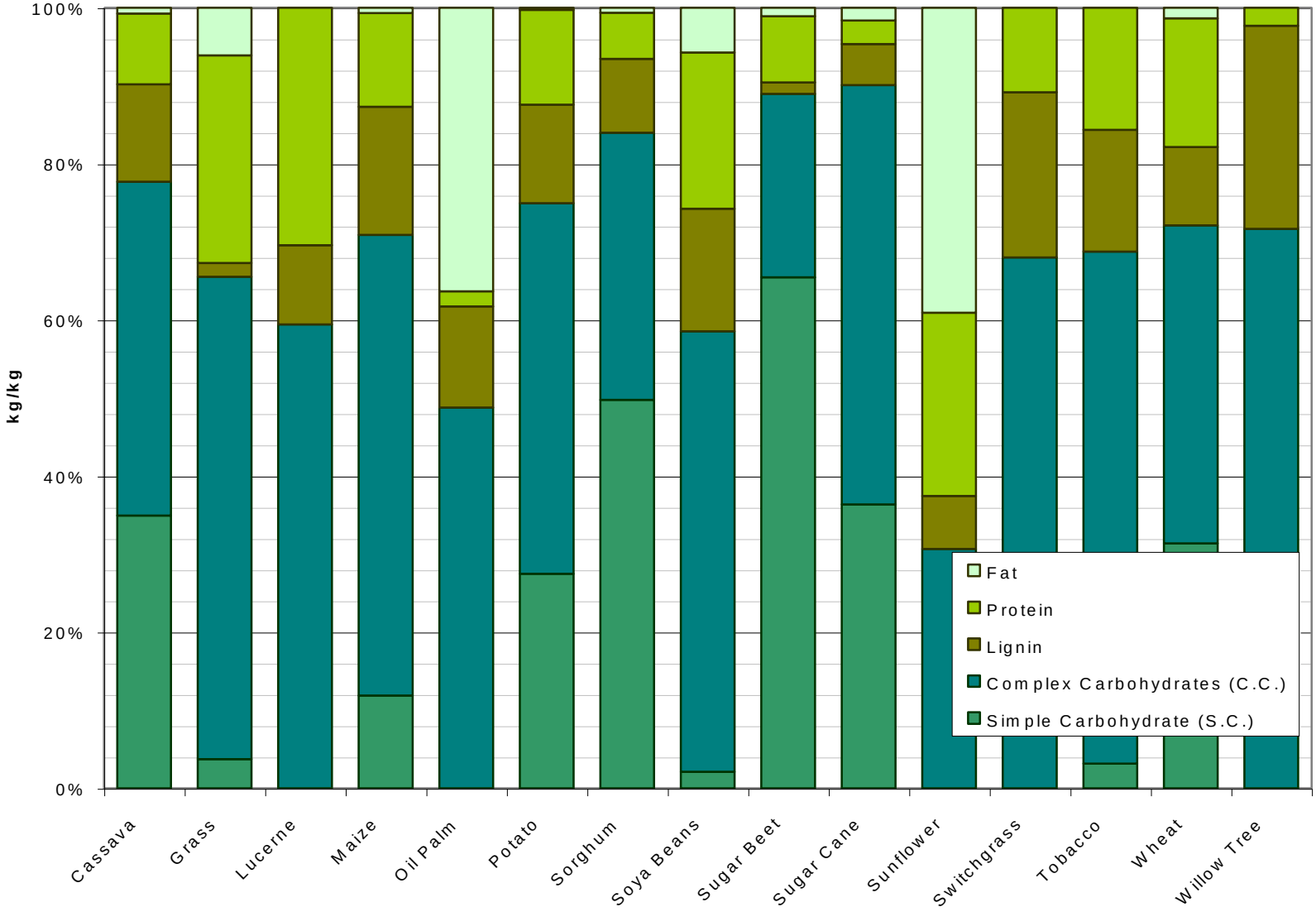
= Asp + Arg

Granule
35% (wt/wt) and slow growth

Our daily food needs a twenty fold higher energy input

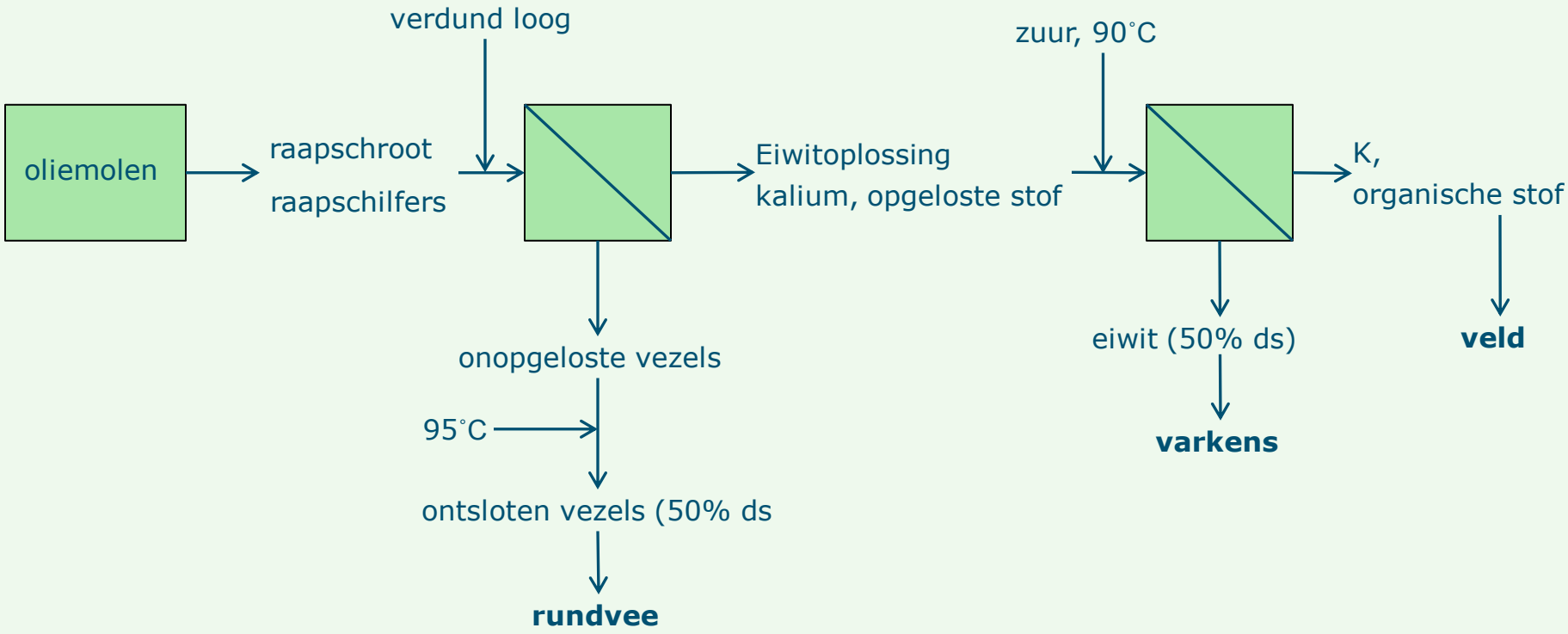


Proportion of constituents

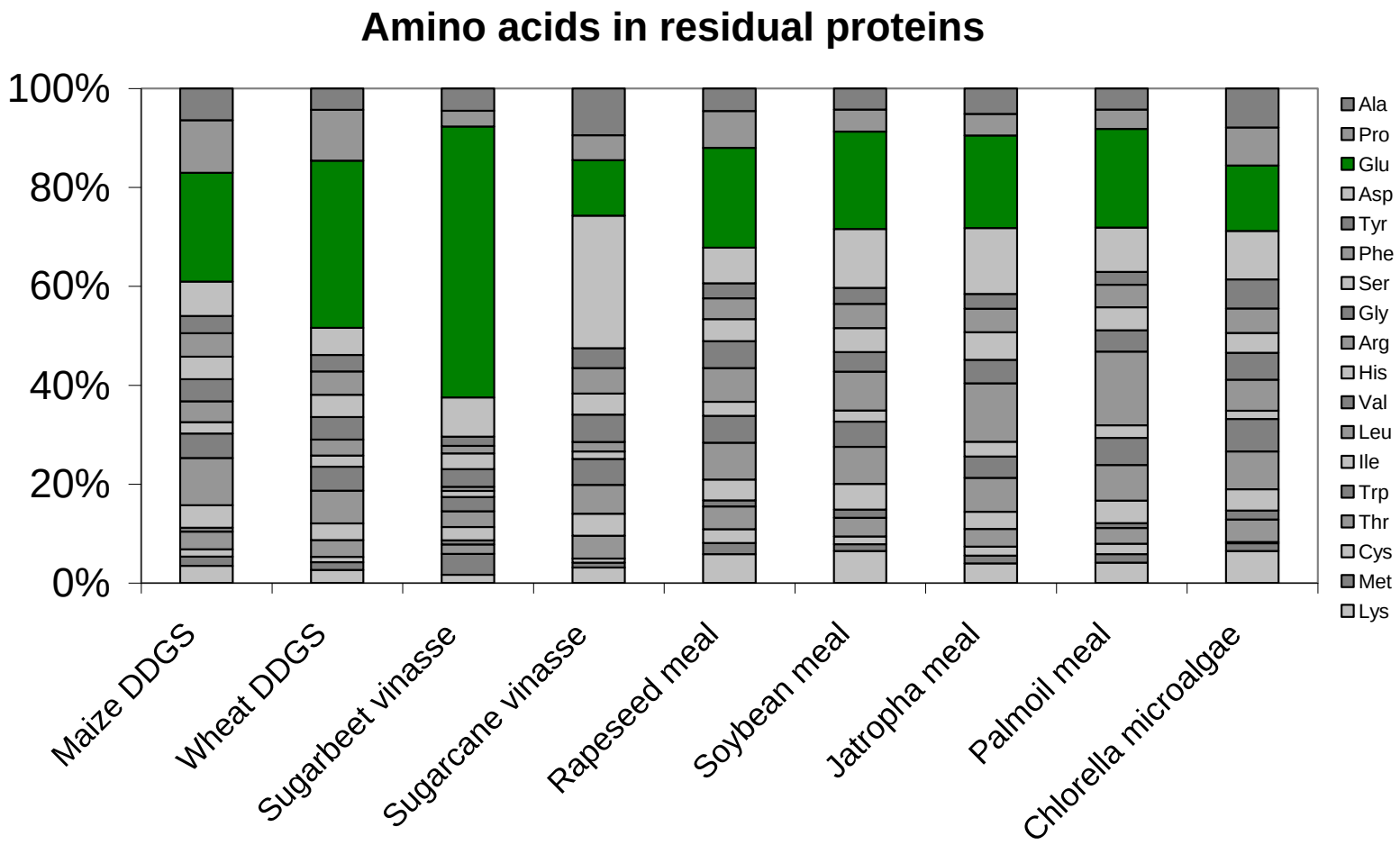


WAGENINGEN UNIVERSITY
WAGENINGEN UR

Decentrale optimalisatie van raapschilfers



Example: Glutamic acid and other aminoacids in byproduct streams

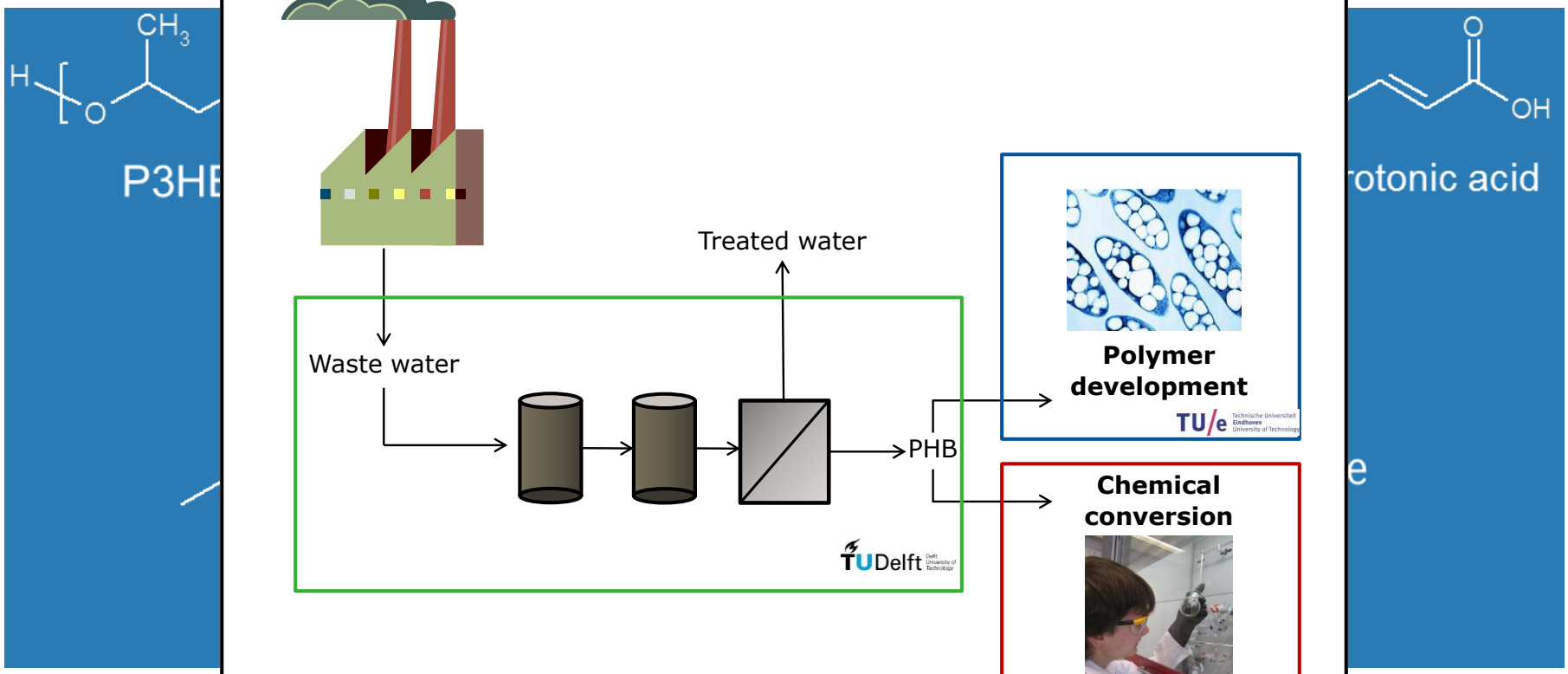


The Chemical Products of the Port of Rotterdam

WAGENINGEN UNIVERSITY
WAGENINGEN UR

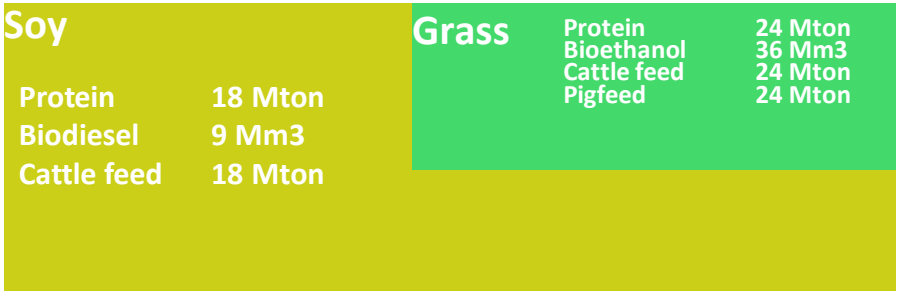
Bulkchemicals from Waste 2 Resource:

Upstream integration, downstream benefits



Brazil from feed to doubled feed + biobased

	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	



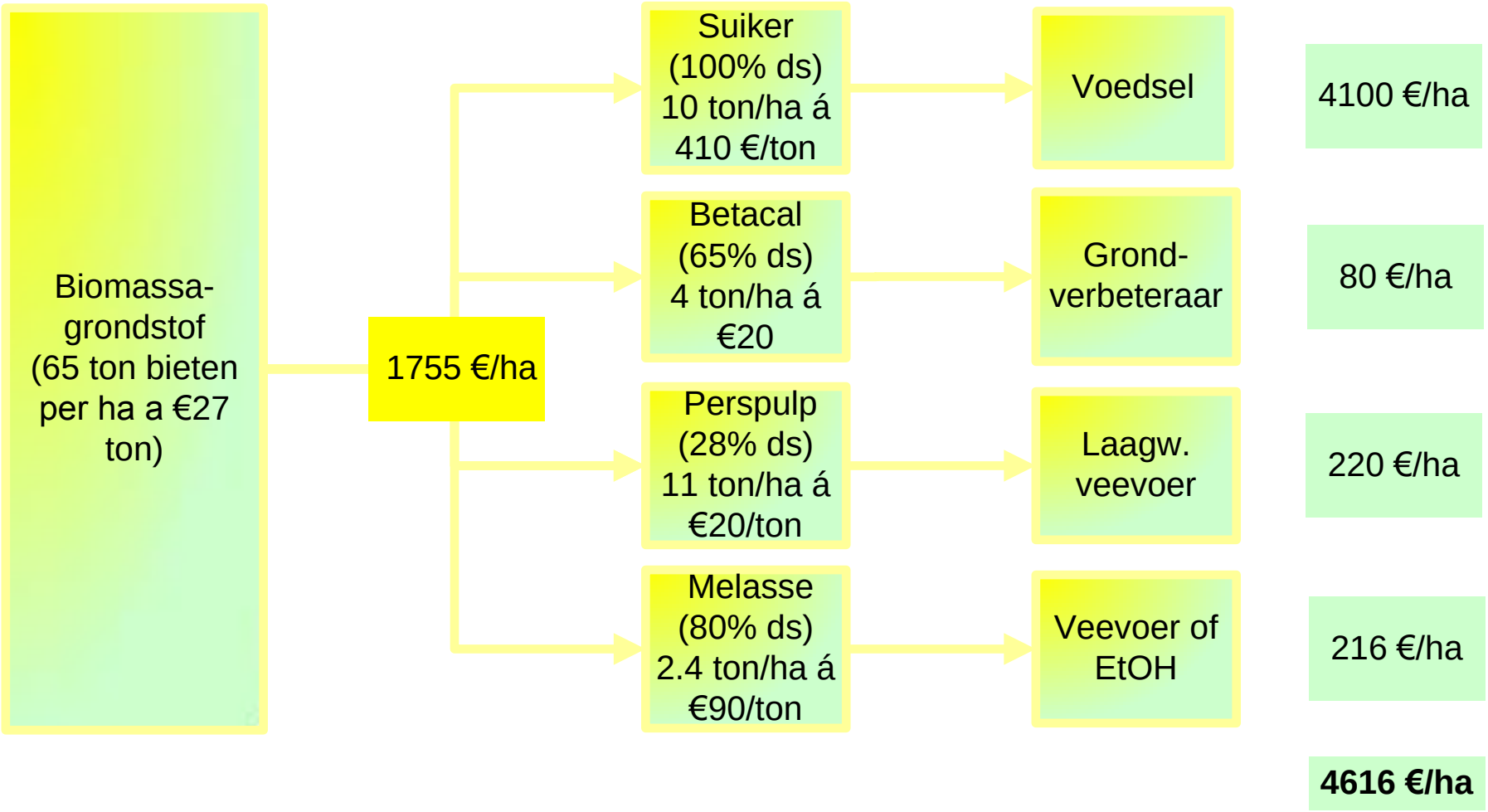
	Mton	€/ton	M€	PJ
Protein	42	300	12600	
Bioethanol	36	200	7200	790
Biodiesel	9	400	3600	315
Cattle feed	42	25	1050	
Pig feed	24	100	2400	
Total			29250	1105
€/ha = 1219		10% of GNP		

	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		

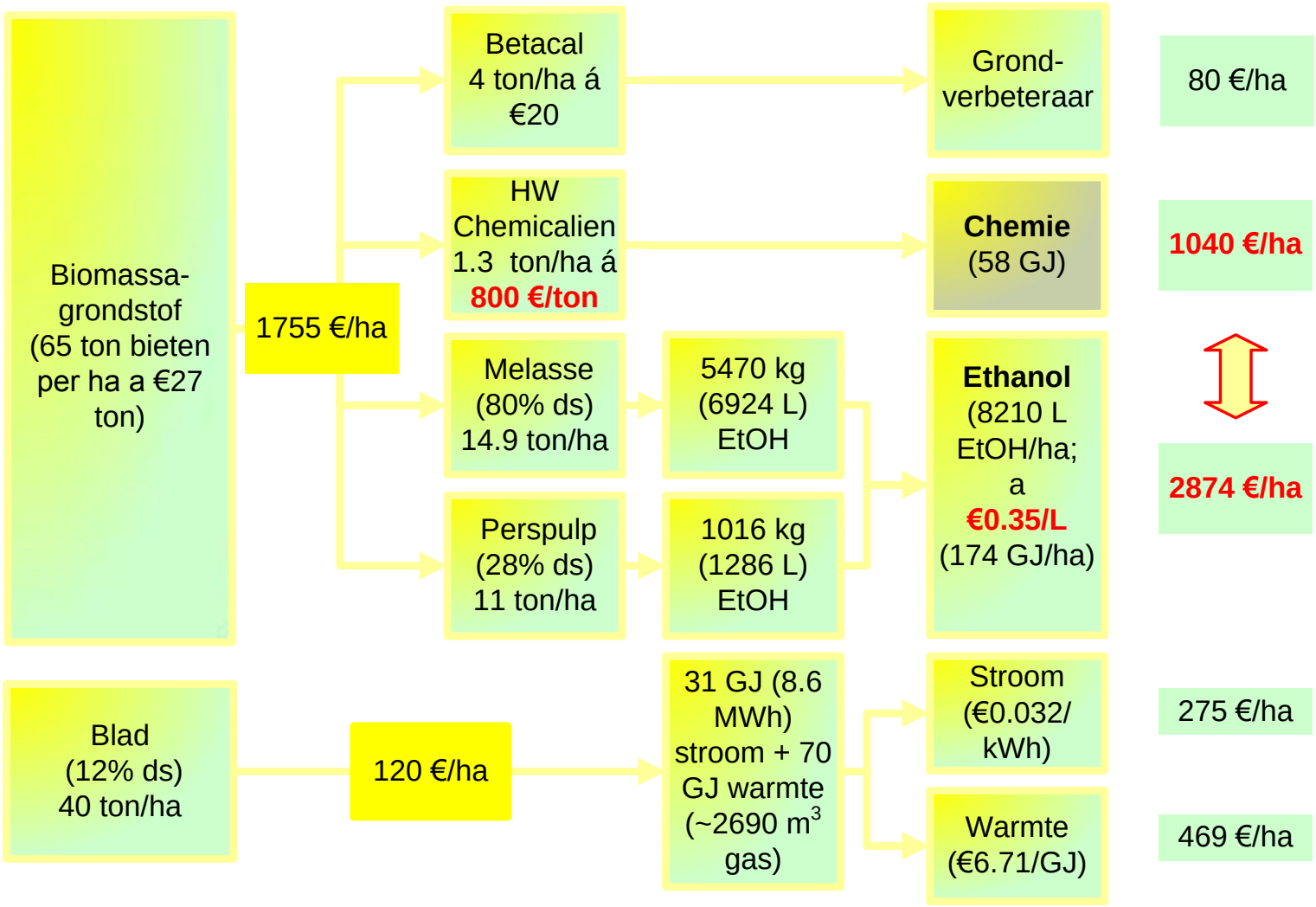
WAGENINGEN UNIVERSITY
WAGENINGEN UR

J.W.A.Langeveld and J.P.M. Sanders in Langeveld et al, The Biobased economy, Earthscan, 2010; chapter 21

Economics food chain (sugar beet)



Economics biobased chain (Sugar beet)



4738 €/ha

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Mobile Cassava starch refinery in Africa