Low capital intensive biomass processing leads to increased employment

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Biomass use today and in 2050 world wide

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

* Excluding grass and seafood

Design rules for a sustainable Bio-economy
People, Planet, Profit

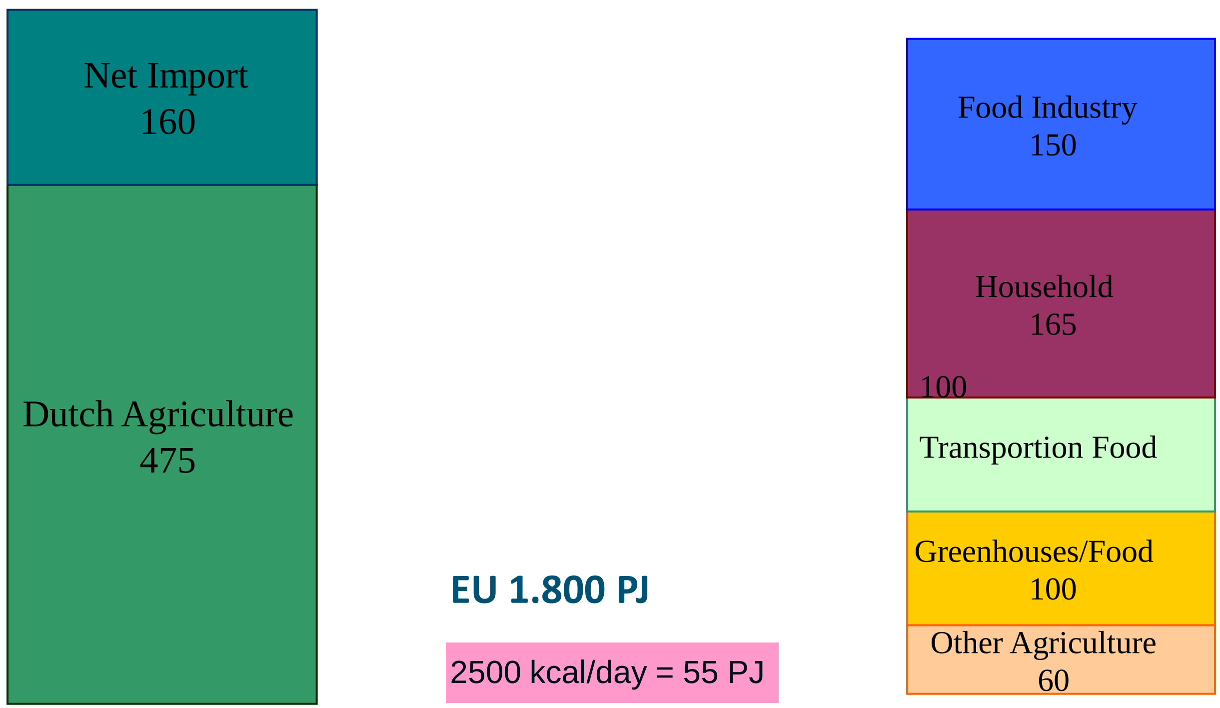
- Improve efficiency of use of raw materials and energy
- Increase field yield but *keep components on the field that are required for soil fertility*
- Use all biomass components and *choose the right raw material*
- Use each component at its highest value:

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

Our daily food needs a twenty fold higher energy input

Biomass
NL 635 PJ
EU 20.000 PJ

Fossil
NL 575 PJ
EU 20.000 PJ



Total energy NL fossil 3.300 PJ
EU fossil 85.000 PJ

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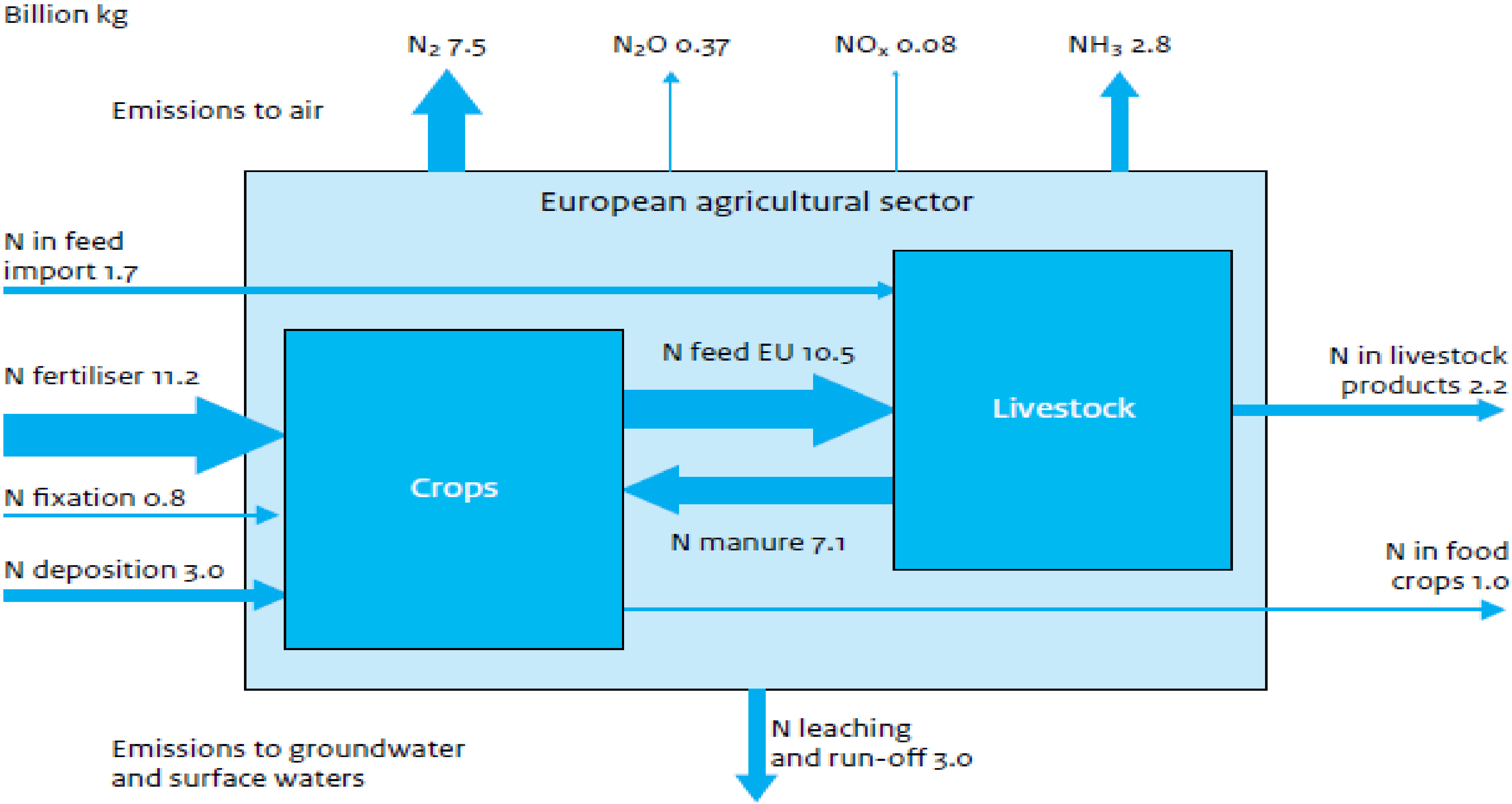
Nitrogen flows in agricultural sector in EU27, 2005



Source: Miterra-Europe

EU agriculture has a nitrogen efficiency of 19%. The livestock sector is one of the main causes of nitrogen losses to the environment. These losses occur in various chemical forms, such as ammonia (NH_3), nitrate (NO_3), nitrous oxide (N_2O) and the harmless N_2.

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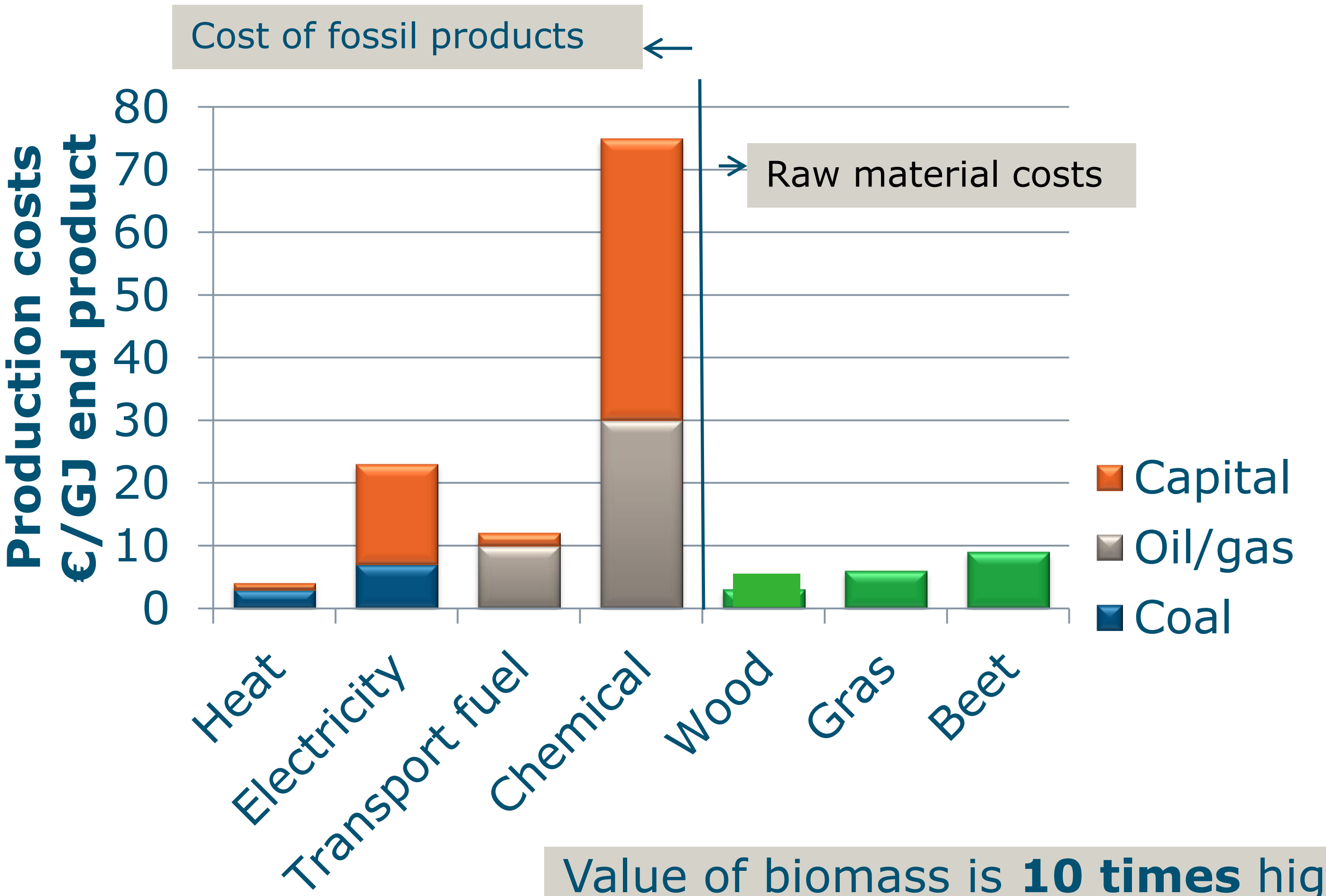
From: PBL, the Protein Puzzle, 2011

F - ladder

How to get the best value from biomass?

	€/ton
Farma	High
Fun	High
Food ingredients	5 - 20000
Food nutritional	100-500
Feed/ Food **nutritional protein**	600-1000
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

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

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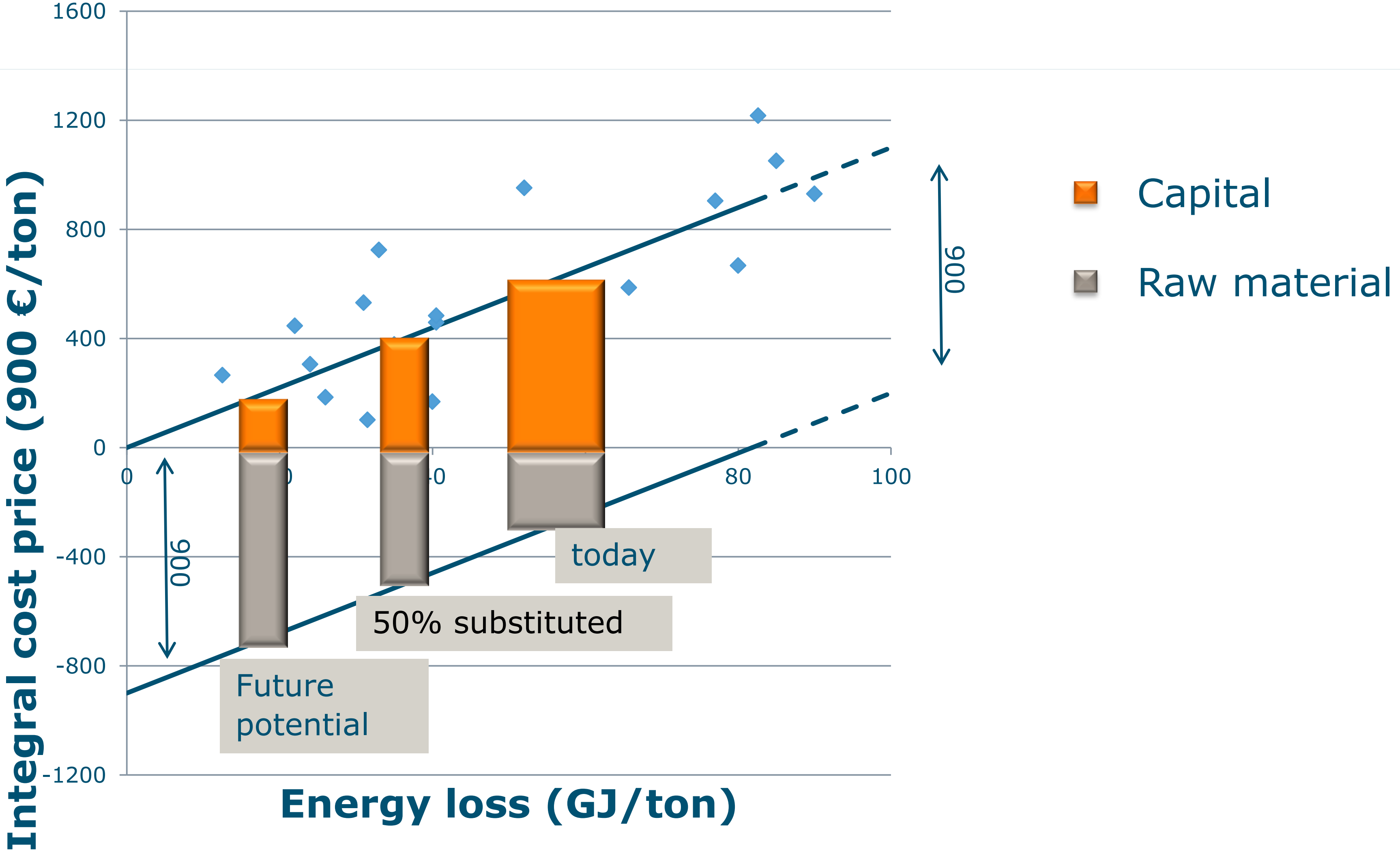
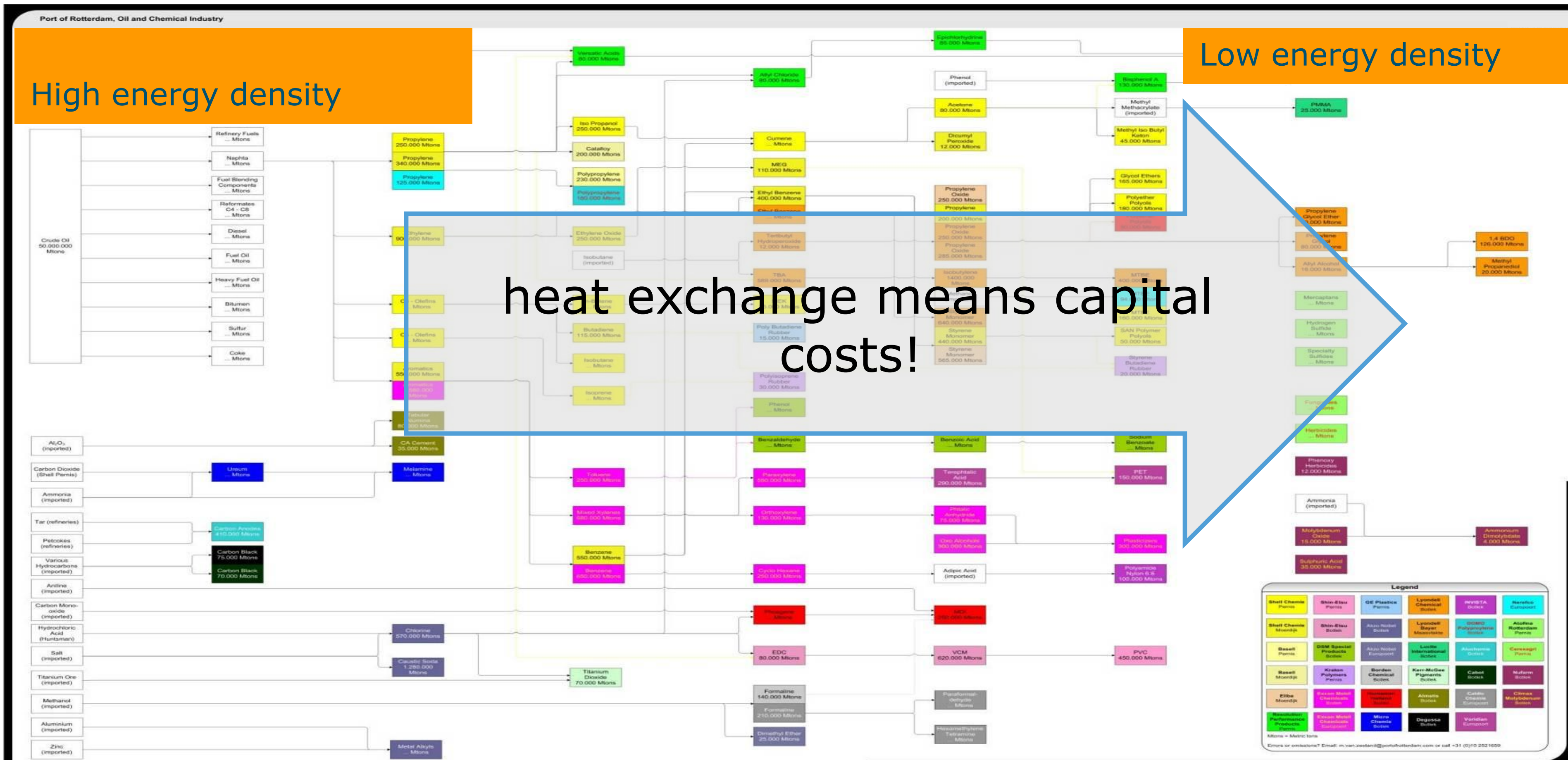
Processes with lower need for heat exchange, have lower capital costs per ton of product and can be economical at smaller scale.



Chemical production in the Port of Rotterdam

crude oil 8€/GJ (60$/bbl); LC= 9€/GJ; veg oil = 20€/GJ; Sugar= 20€/GJ



mass loss and/or energy loss <--0→ energy loss and heat exchange

-4 -3 -2 -1 0 +1 +2 +3 +4

methane ethene MEG **sugar** citric acid CO2

ethanol BDO succinate

ethane **butanol** **Terephthalic acid**

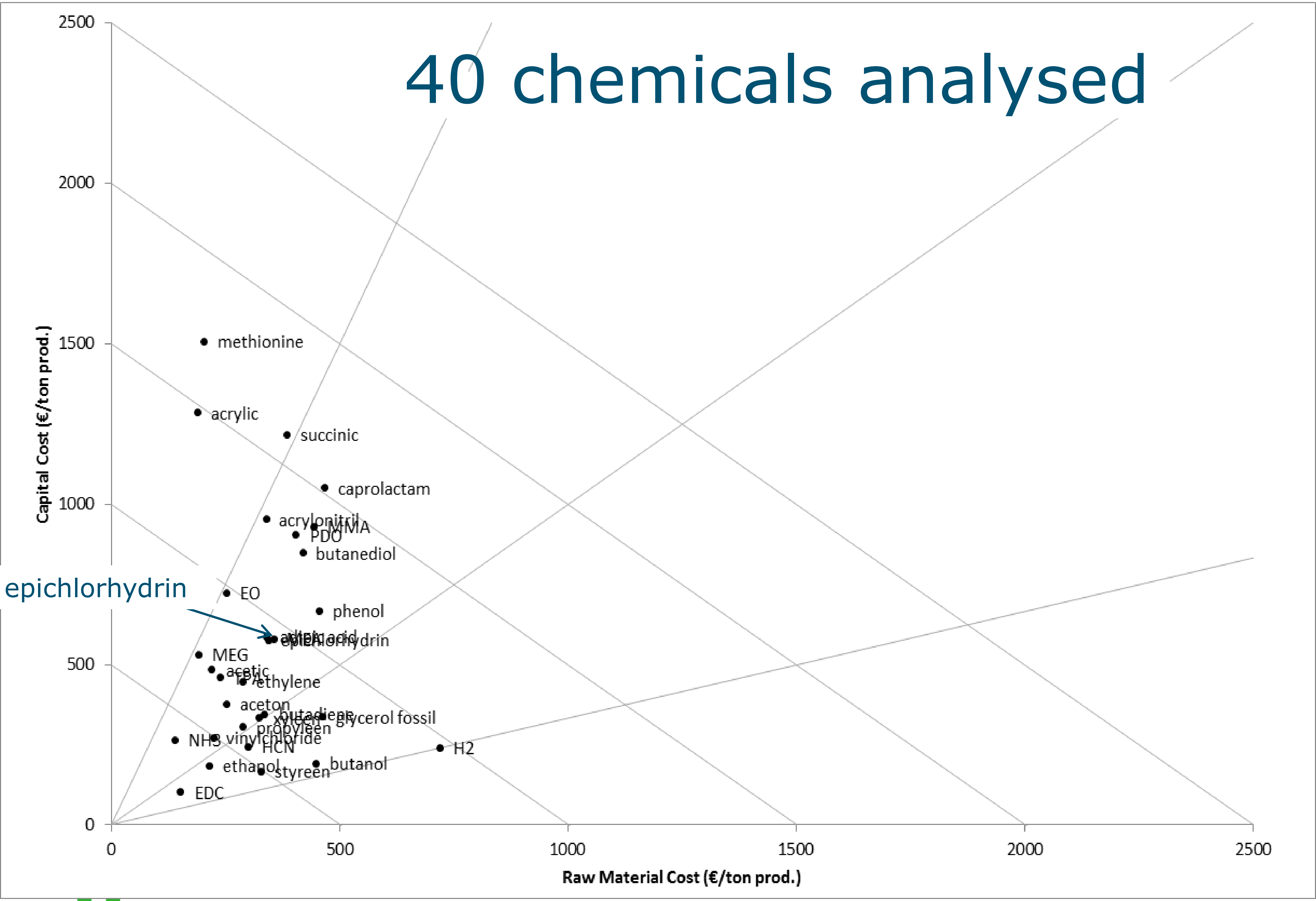
xylene

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)

40 chemicals analysed



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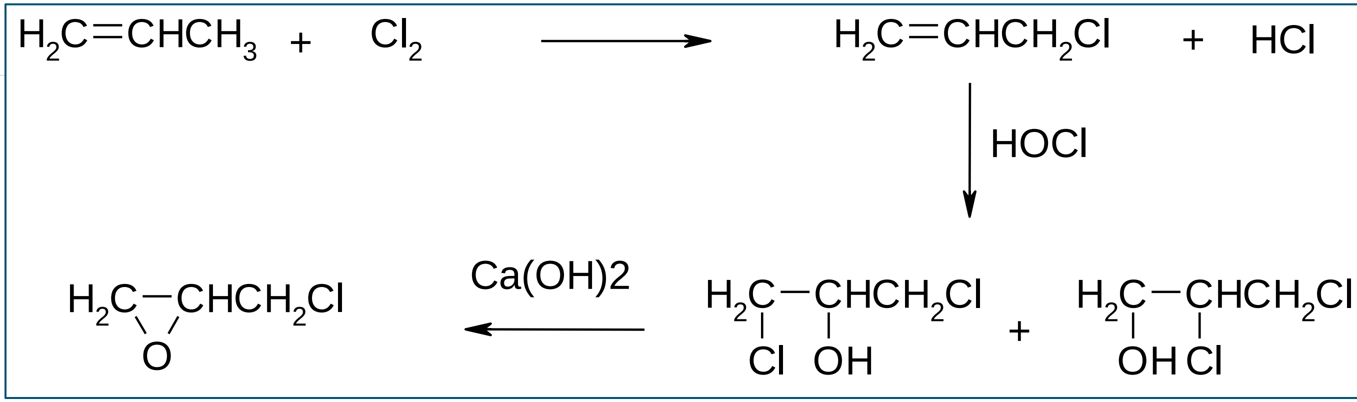
Epichlorohydrin from glycerol leads to *little heat exchange and valuable product*

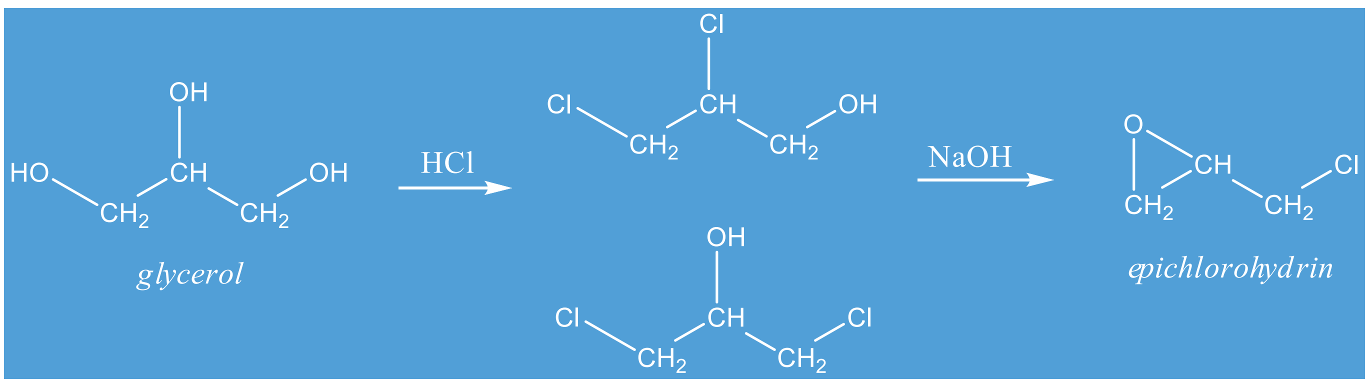


- Price:

  € 1300 - 1500 per tonne

- Volume:

  0.5 mln tonnes per annum



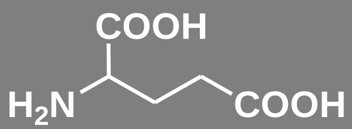
- Solvay 'Epicerol' process: glycerol to epichlorohydrin

At glycerol prices of 350€/ ton the margins are 40- 50%

Use of plant molecular structures leads to *little heat exchange and valuable product*

N-Vinylpyrrolidone

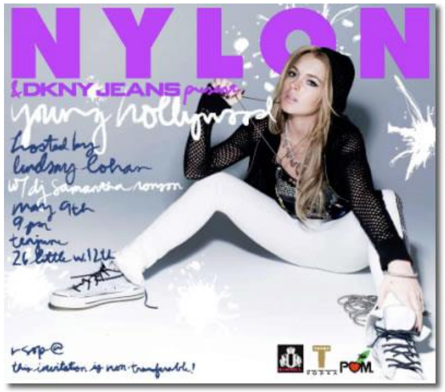
Acrylonitrile



Glutamic acid

N-Methylpyrrolidone

Diaminobutane



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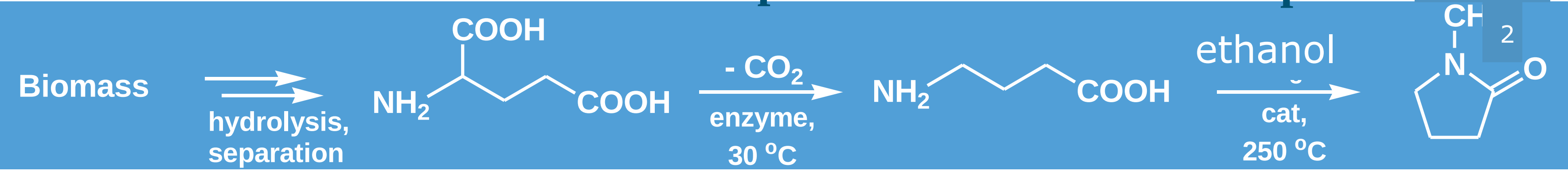
The route to NEP, new vs conventional NMP

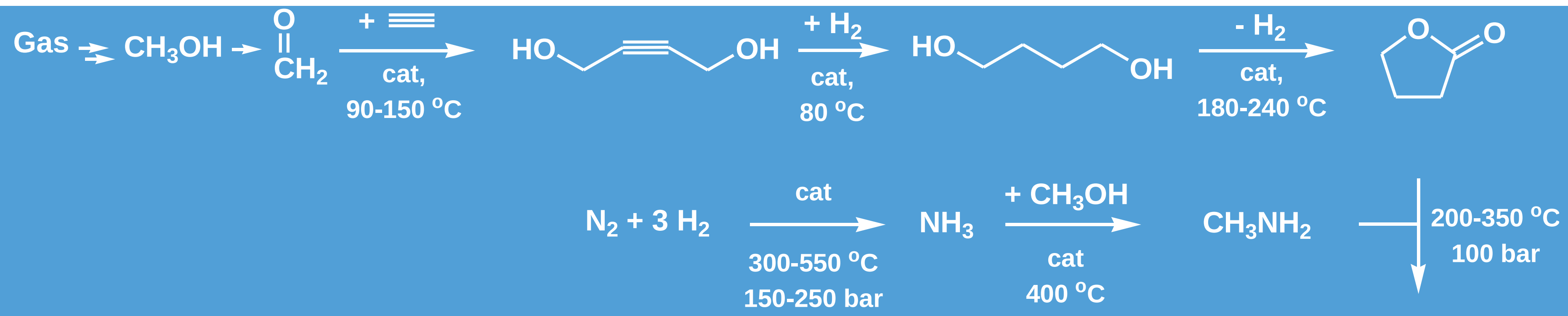
New route

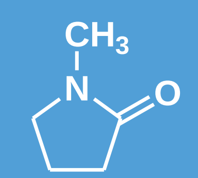
step 1 **step 2**



Glutamic acid *NEP*

Conventional route





Amino acids contain N and O.

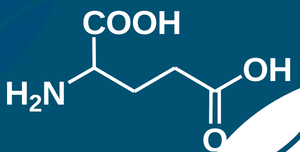
□ Less steps (= factories) & energy for the same product!

Biobased NMP, makes an ethanol plant profitable

500 Million liters bioethanol

(~ 400 kton) =200M€

360 kton DDGS (~130 € / ton) =46M€



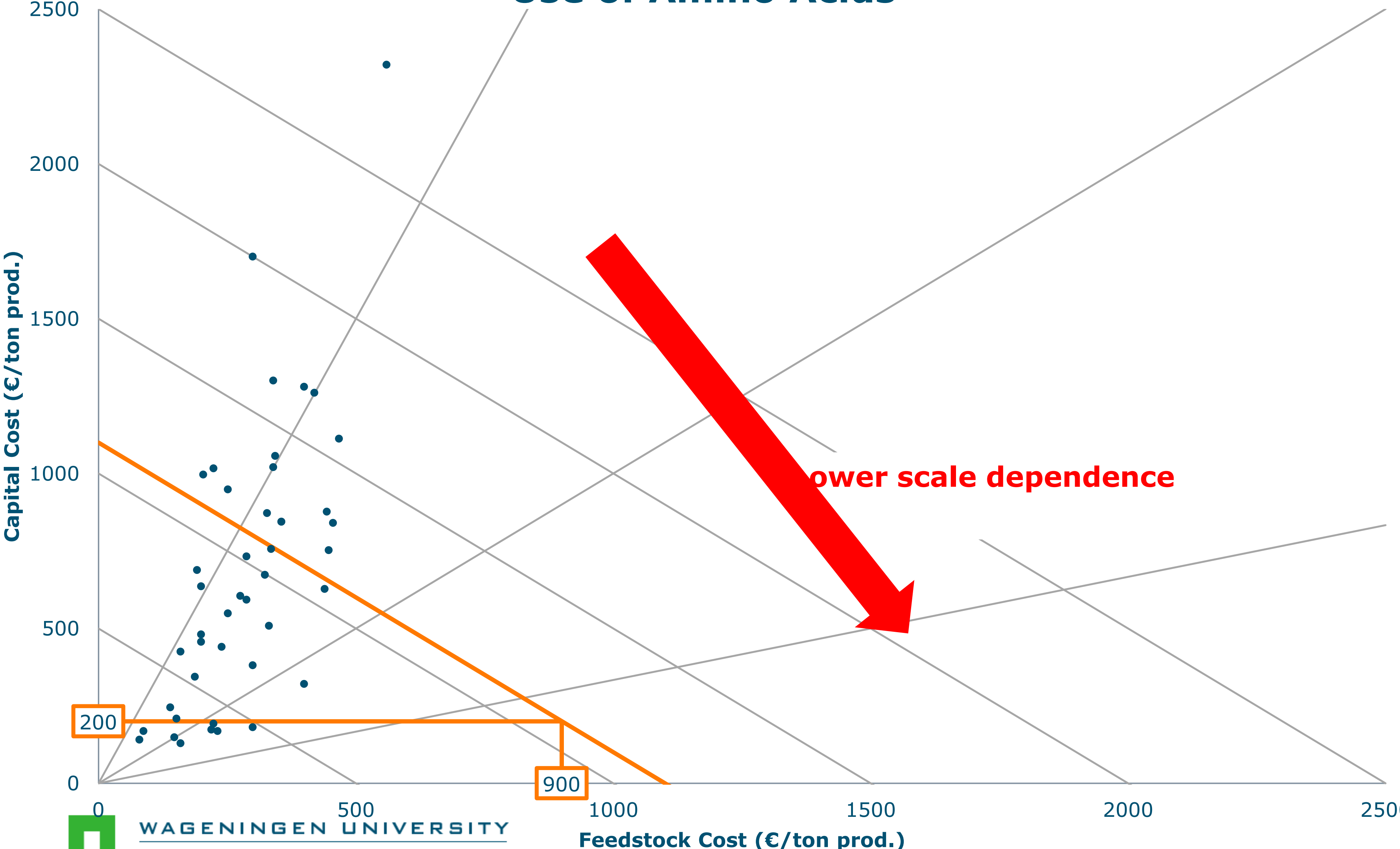
23 kton NMP

(~2500 € / ton)

=58 M€/y

Low scale dependency when capital costs are relatively low

Use of Amino Acids



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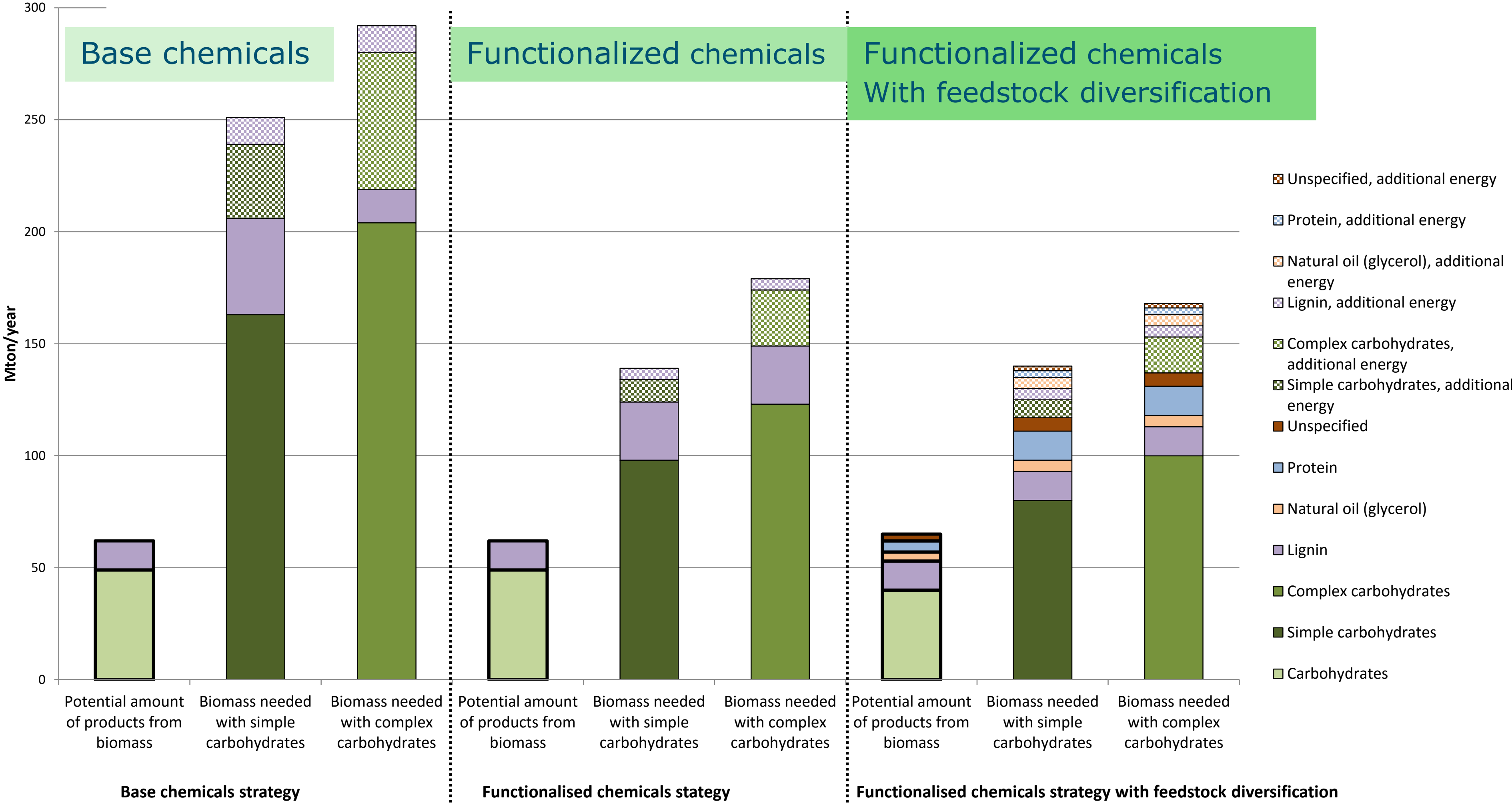
http://www.biobasedeconomy.nl/wp-content/uploads/2011/08/Can-production-of-bulk-chemicals-on-a-small-scale-be-competative-formated-20131126FINAL.pdf

Amount of biomass needed under different strategies for EU chemical industry

Using molecular functionalities will lead to increased efficiency of biomass used



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Bos & Sanders, BioFPR, 2013

Second generation ethanol costs a lot of capital and energy and will not give much value! **False hope?**

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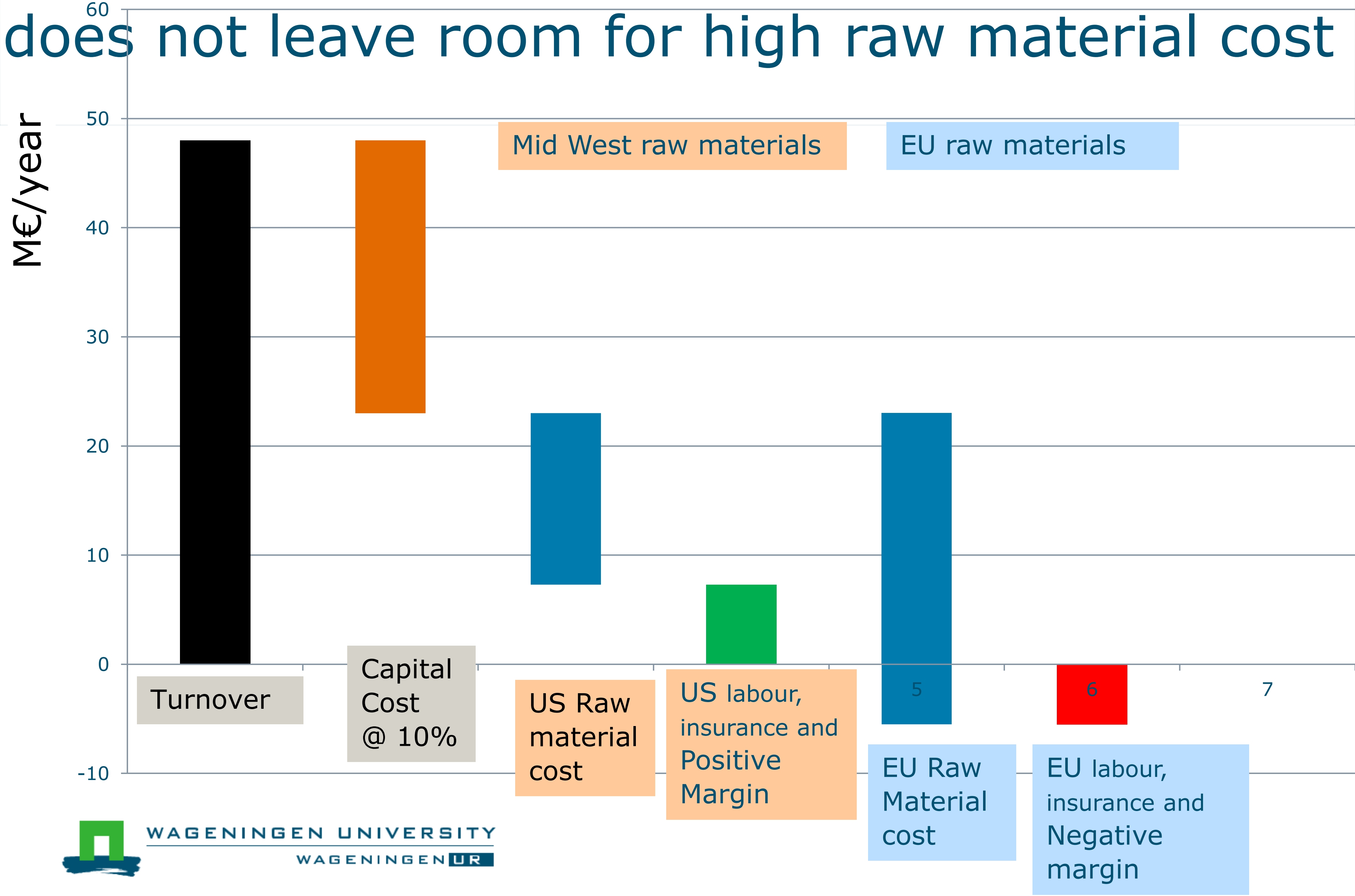
Heat exchange requires high capital cost and does not leave room for high raw material cost



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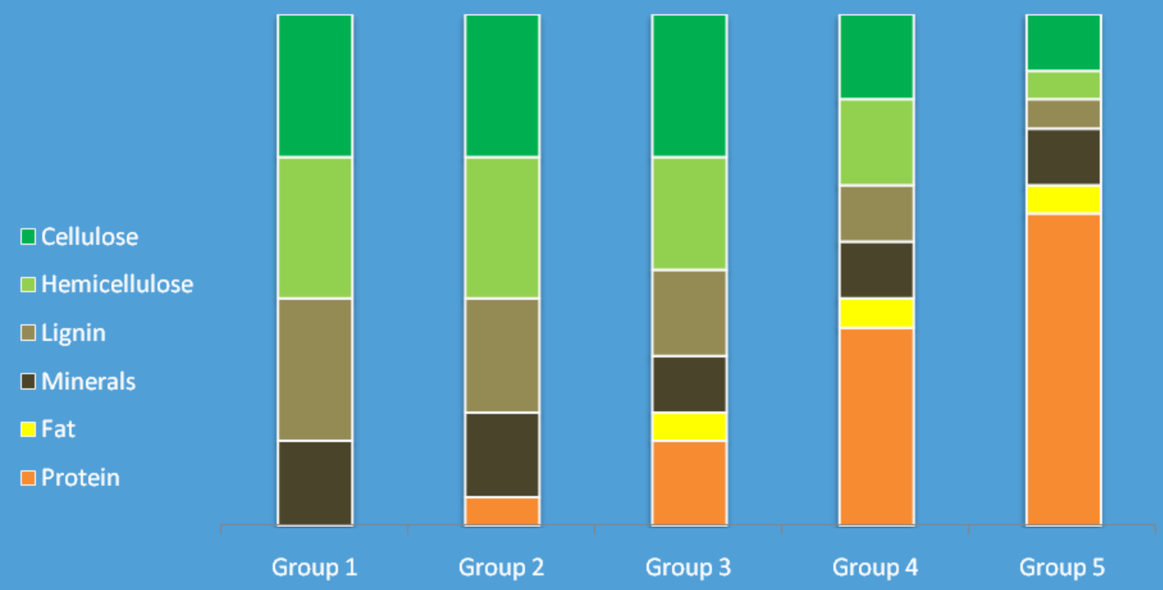
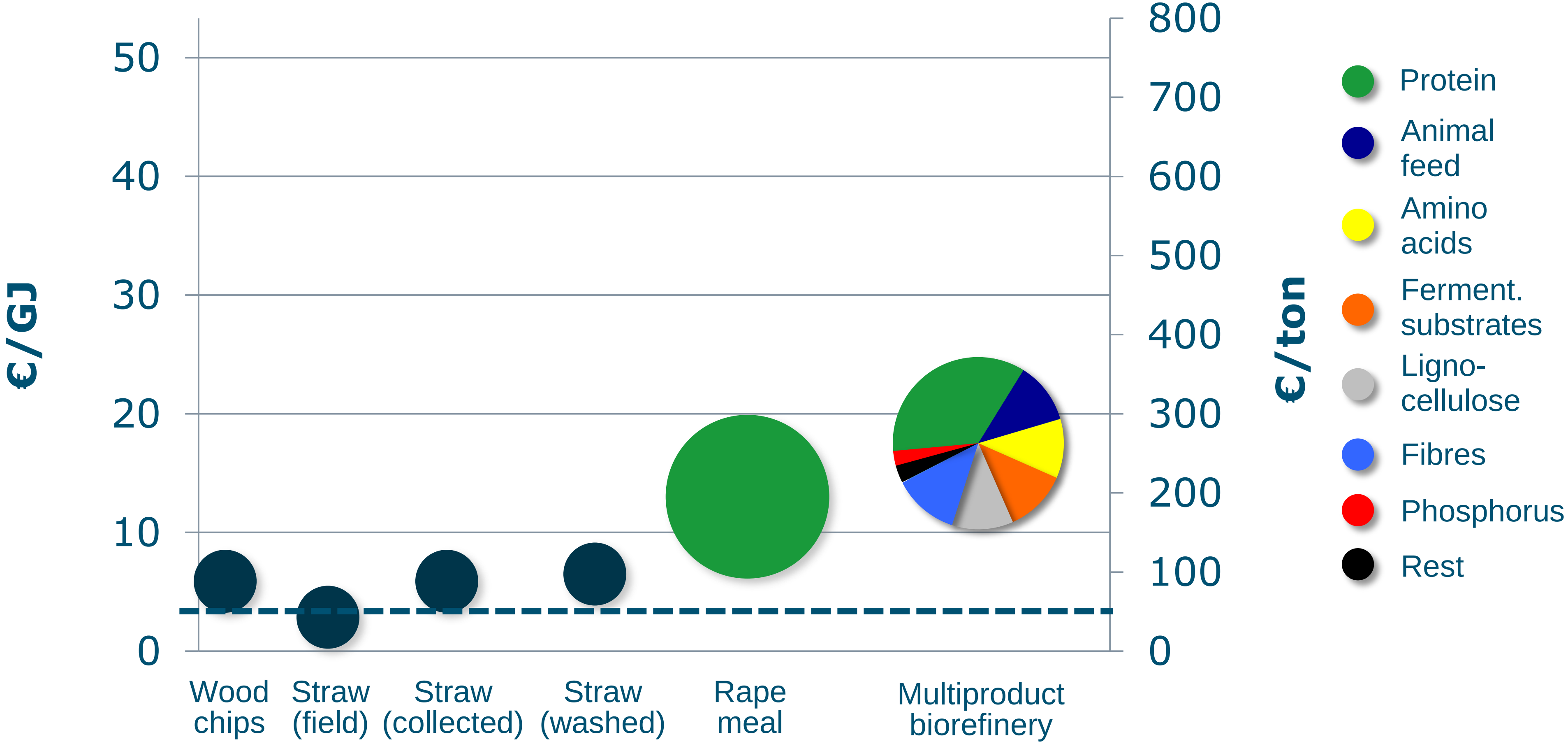
Biorefining of agricultural residues ..



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 ***at small scale***



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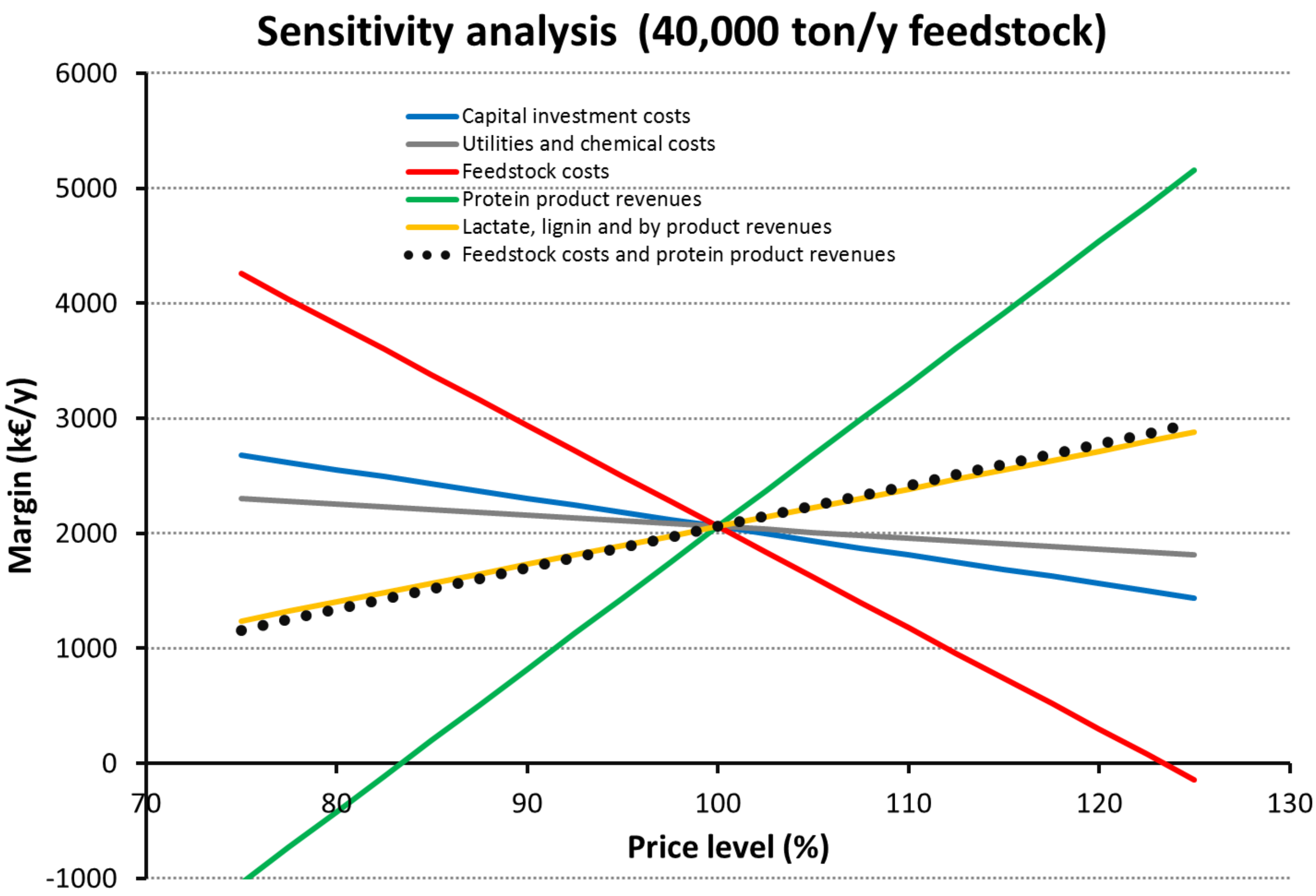
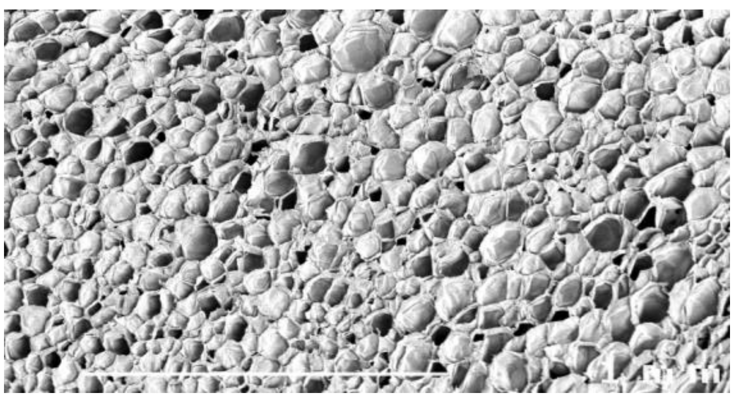
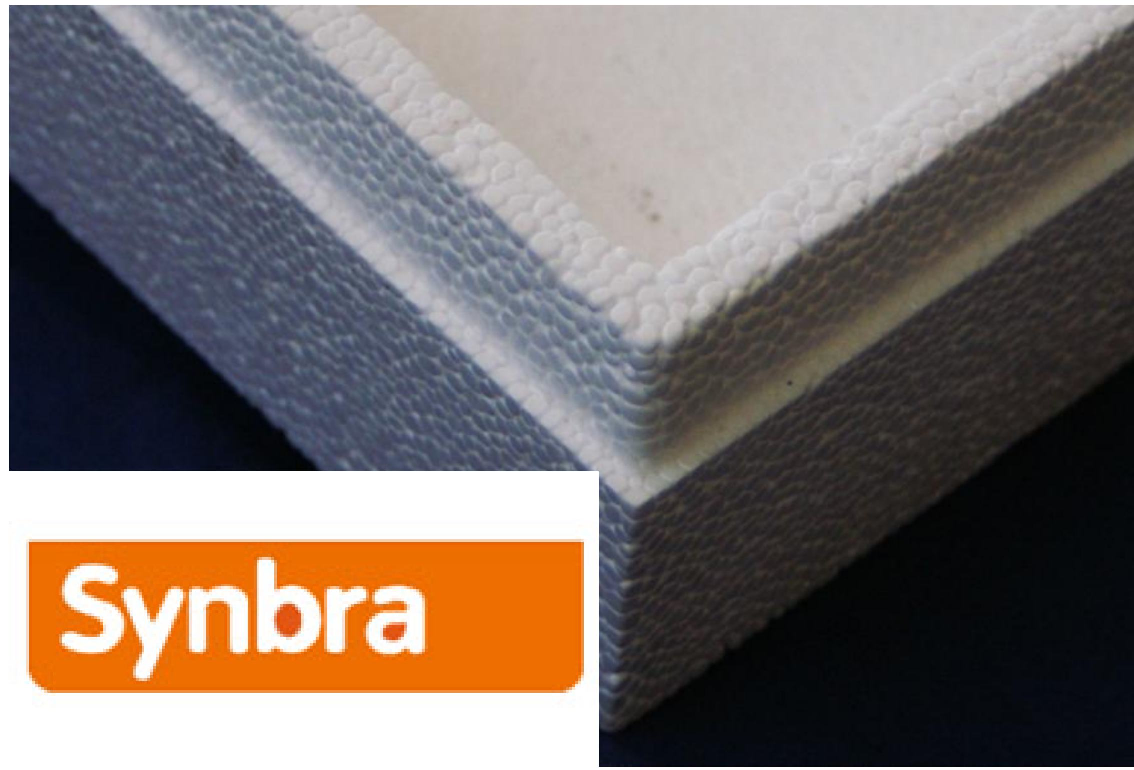
Sensitivity analysis



3D-foamed polylactic structures (Wageningen UR)

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





Synbra

Traditional fermentation engineering challenges

- Maximizing gas transfer
  - Especially with gasses going in and out
  - Oxygen transfer
- Maximizing cooling capacity
- Preventing substrate and product inhibition
  - Fed batch
  - In situ product recovery
- Minimizing costs for product recovery

Anaerobic fermentation of bulkchemicals

Yield: 0.95 g/g or J/J

Productivity: up to 5 times higher →

lower capital requirements

4 projects running

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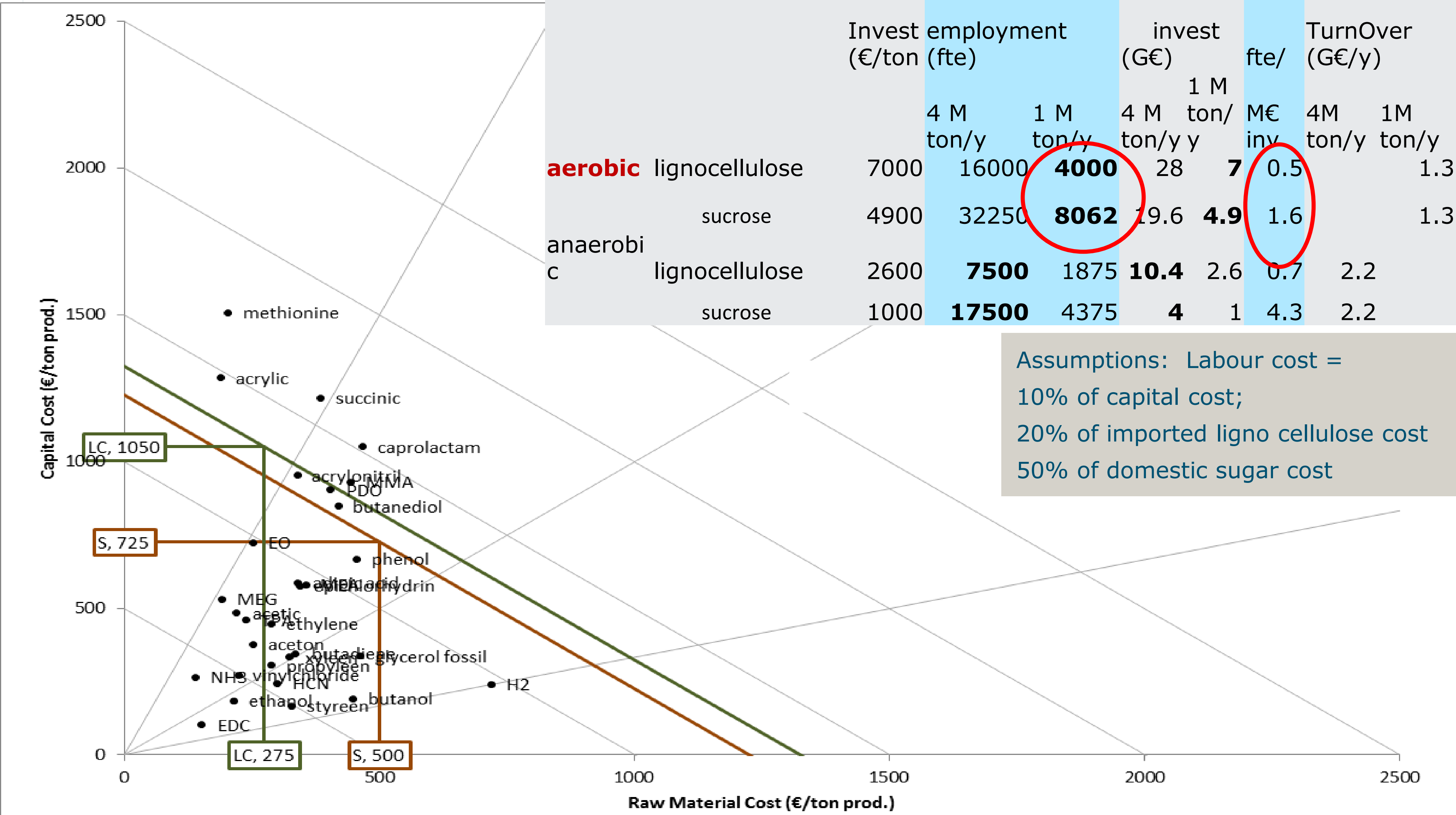
Aerobic Sugar processes → 1250€/ tonne
LC processes→ 1350€/ton



		Invest (€/ton	employment (fte) 4 M ton/y	1 M ton/y	invest (G€) 4 M ton/y	1 M ton/y	fte/ M€ inv	TurnOver (G€/y) 4M ton/y	1M ton/y
aerobic	lignocellulose	7000	16000	**4000**	28	**7**	0.5		1.3
	sucrose	4900	32250	**8062**	19.6	**4.9**	1.6		1.3
anaerobic	lignocellulose	2600	**7500**	1875	**10.4**	2.6	0.7	2.2	
	sucrose	1000	**17500**	4375	**4**	1	4.3	2.2	

Assumptions: Labour cost =
10% of capital cost;
20% of imported ligno cellulose cost
50% of domestic sugar cost

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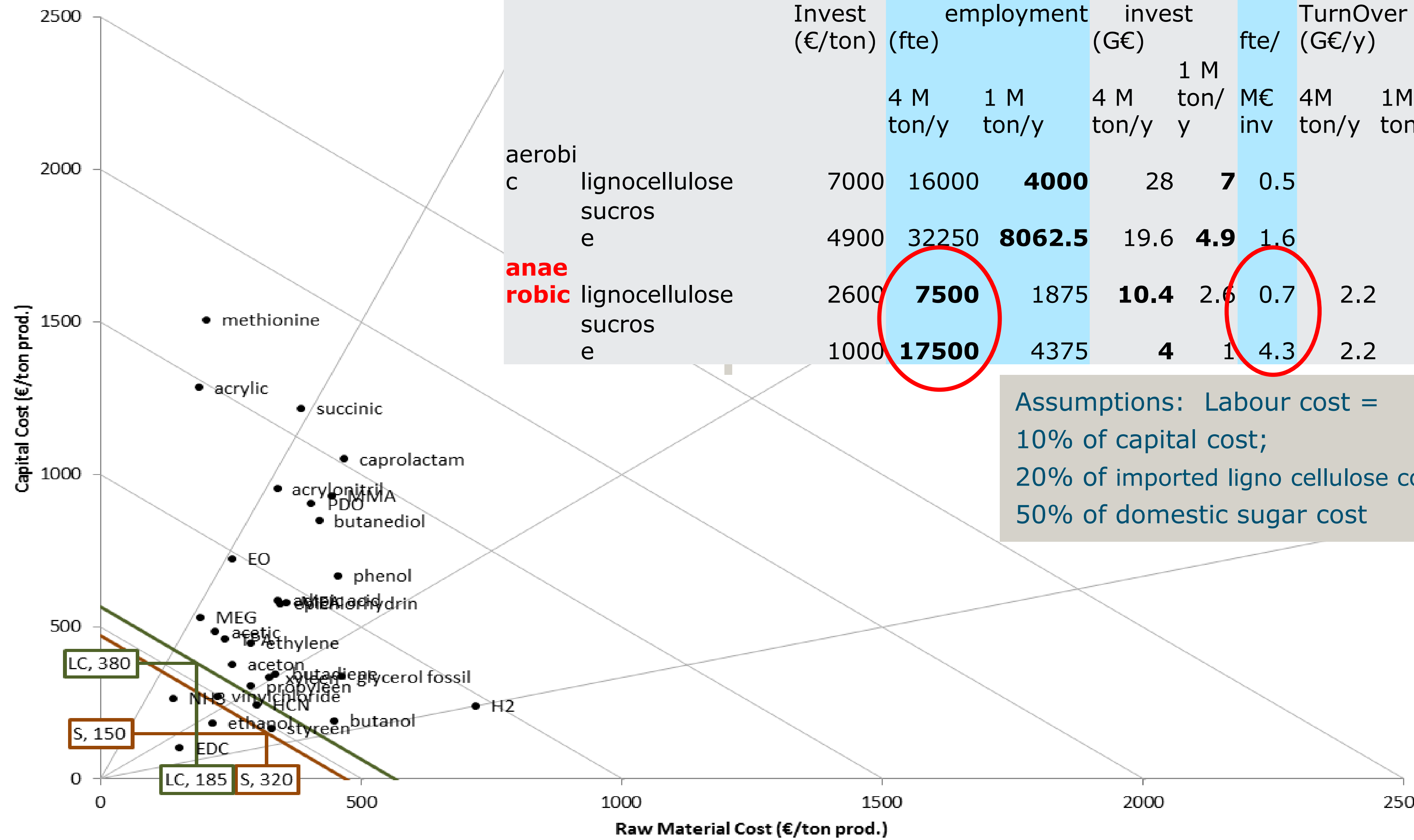
http://www.biobasedeconomy.nl/wp-content/uploads/2011/08/Can-production-of-bulk-chemicals-on-a-small-scale-be-competative-formated-20131126FINAL.pdf

Anaerobic sugar processes →500€/ tonne

LC based processes → 550€/ tonne



		Invest (€/ton)	employment (fte)		invest (G€)		fte/	TurnOver (G€/y)	
			4 M ton/y	1 M ton/y	4 M ton/y	1 M ton/ y	M€ inv	4M ton/y	1M ton/y
aerobic	lignocellulose	7000	16000	**4000**	28	**7**	0.5		1.3
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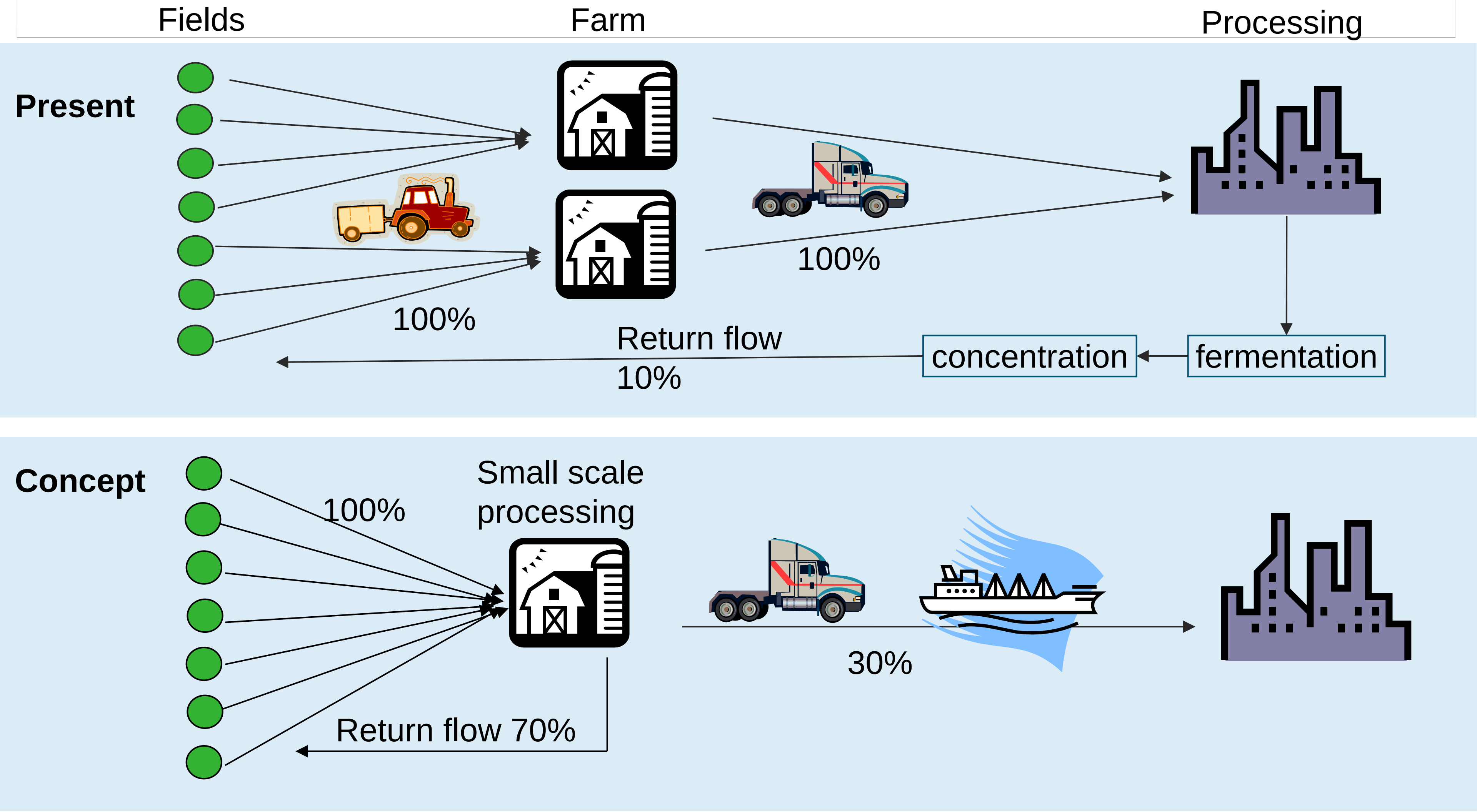
Small scale biorefinery reduces transport cost and seasonality



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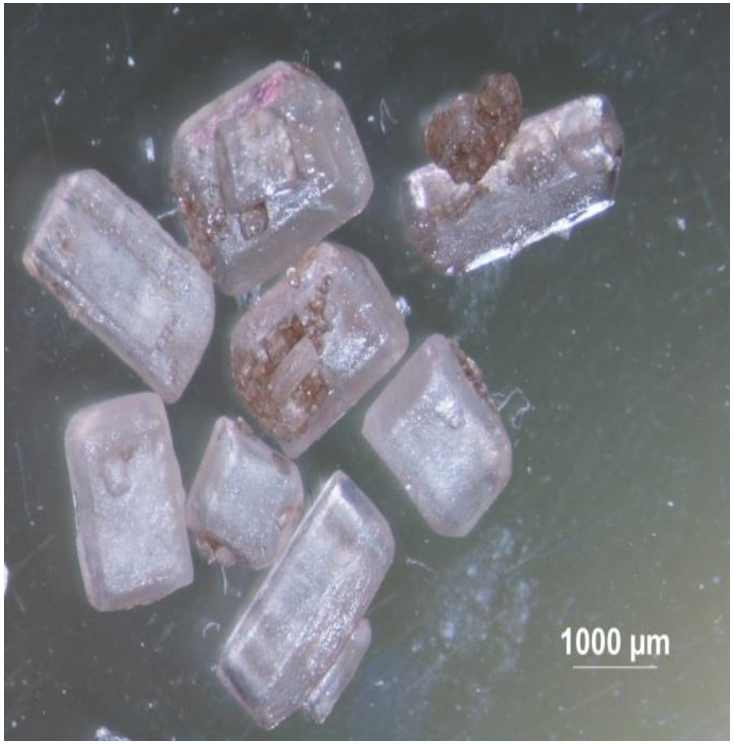
small scale beet sugar production(2-500ha) can beet large scale factories !

Less energy
Less transport
Minerals recycled to field



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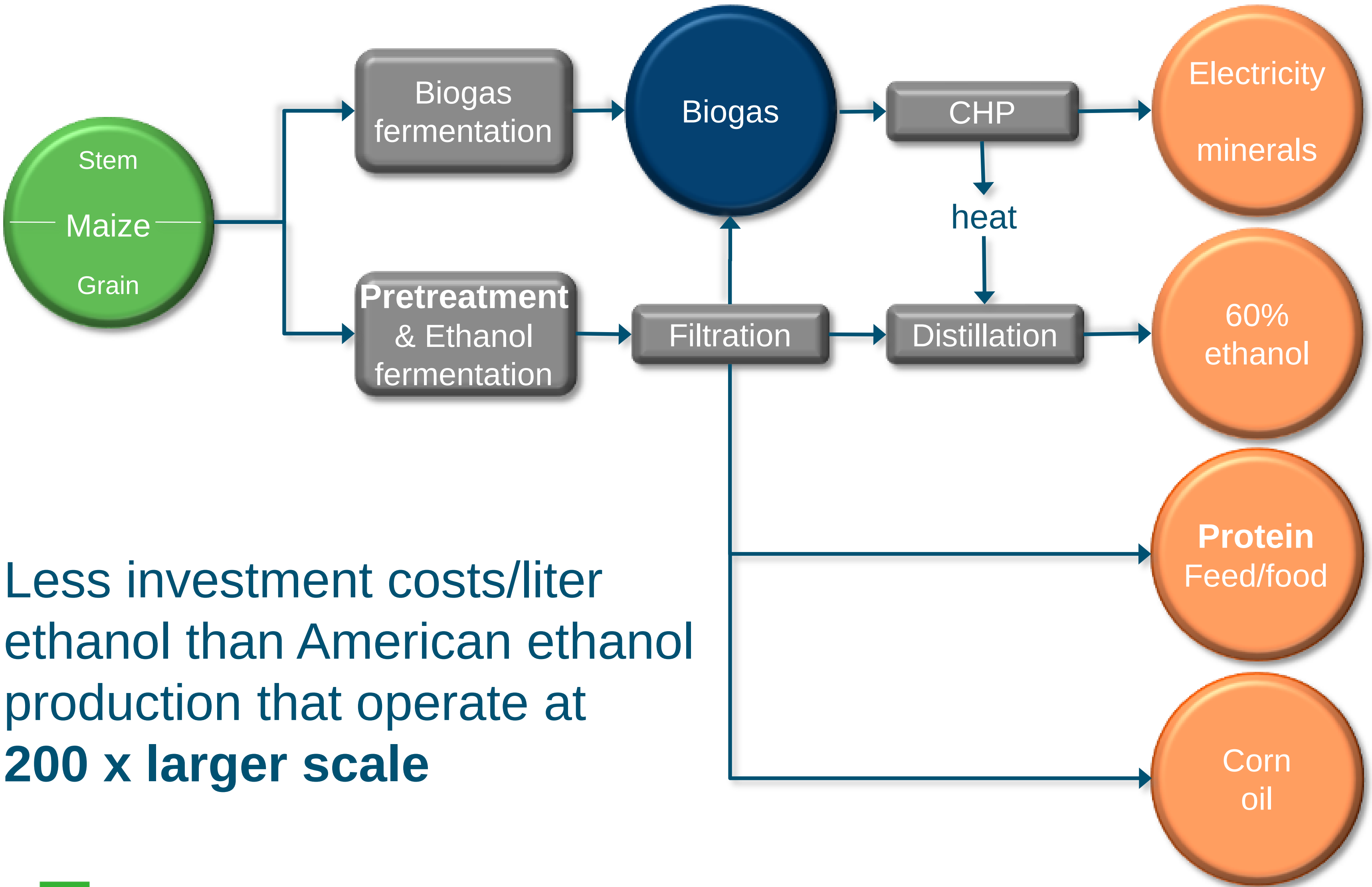
Kolfschoten et al

Small scale biorefinery

- Advantages
  - Lower costs for transportation towards factory and back!
  - Increased storage times of intermediate products; Year around for the precious unit operations
  - Water and minerals stay on site
  - Less waste treatment in central factory
  - More income to farmers
  - Gradual development of market as well as sourcing raw materials

- Disadvantage
  - Economy of scale of required unit operations

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**

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Byosis/Zeafuels (Lelystad, Netherlands)

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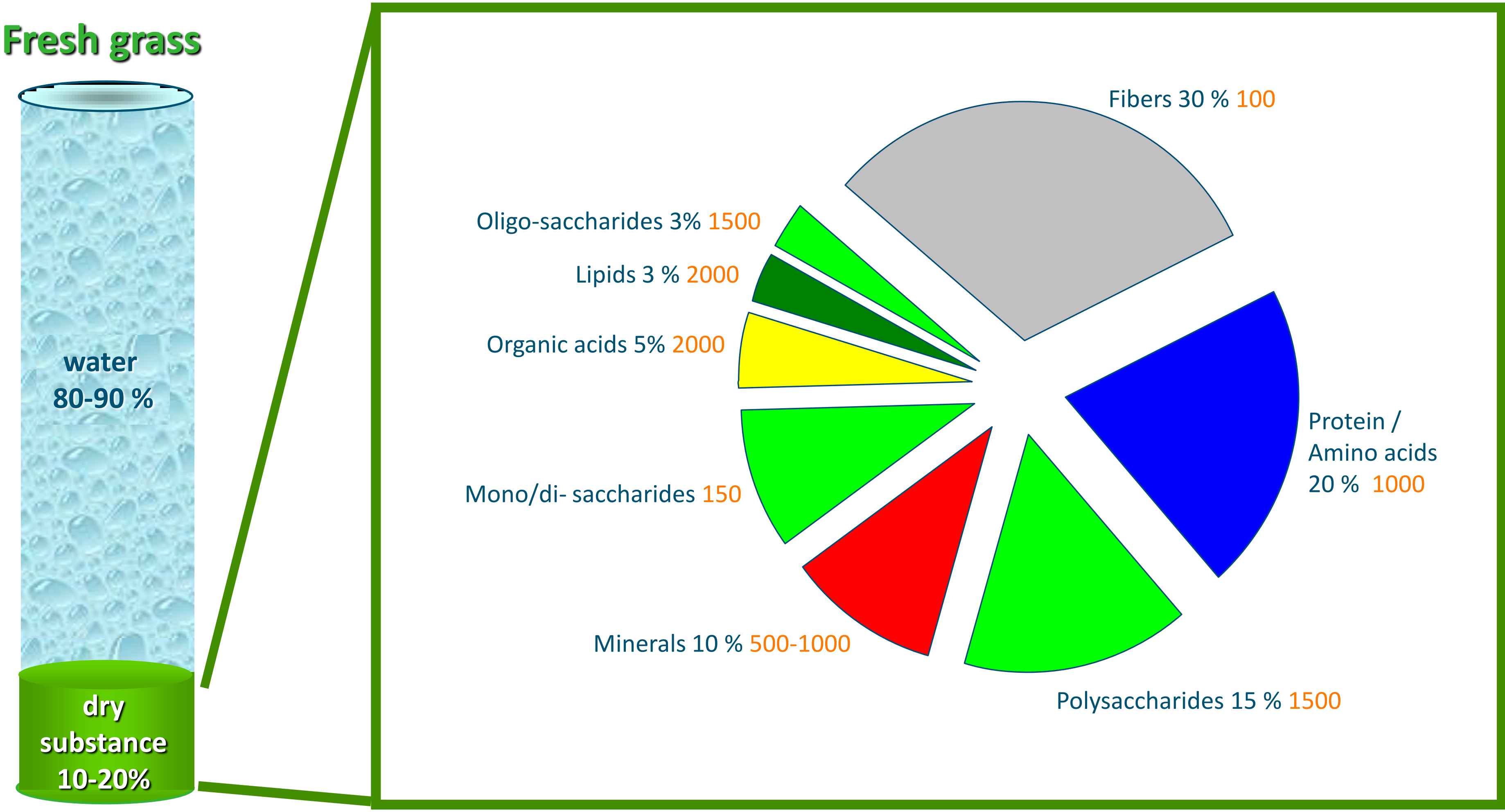
The separated components of grass value 700 – 800 €/ton as compared to 60€/ton raw materials



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3 generations Grassa!refining

1st Generation (2011)
(Friesland)

2nd Generation (2015)
(Uganda)

3rd Generation (2016)
(Netherlands)

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www.grassa.nl

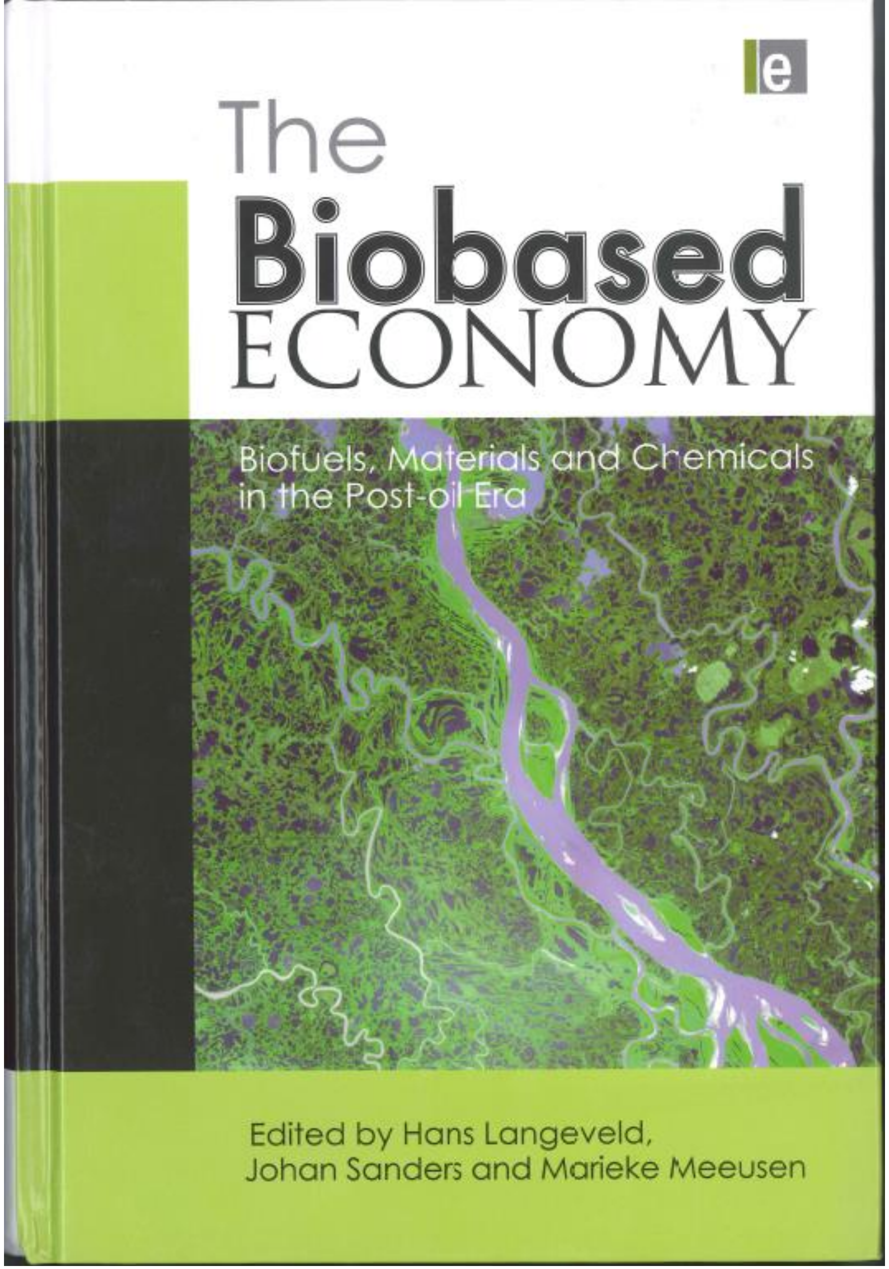
Mobile Grassa Refiner third generation

Just protein is not sufficient to cover the costs

bioraffinery	3 products		8 products	
	income	costs	income	costs
Grass costs		60		60
Process costs		120		440
protein	120		120	
fibers	30		30	
Juice components	55			
minerals			75	
Organ. acids			60	
Amino acids			75	
sugars			12	
FOS			225	
Vitamines A, E			50	
Unsat fatty acids			60	
totaal	**205**	**180**	**707**	**500**

Conclusions

- Biorefinery for feed, materials and chemicals will create good income for agriculture and enables even to compete with coal, natural gas and Brazilian biomass!
- Avoiding heat exchange and small scale processing reduces capital as well as costs for energy and transportation and
- will lead to higher employment



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