Coupling the benefits of grassland crops and green biorefining to produce protein, products and services for the green transition

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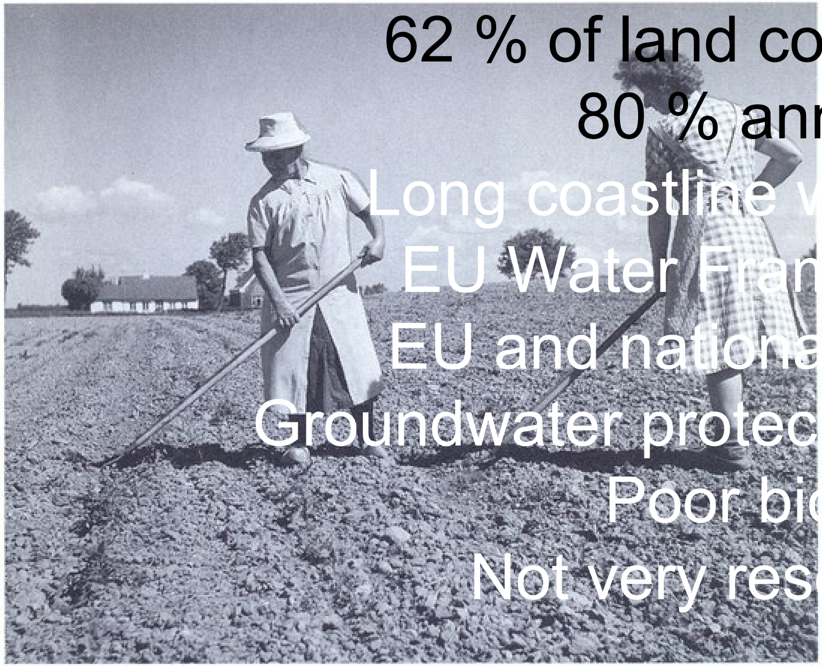
Danish (and European) agriculture has developed a lot
However, is highly contested



62 % of land cover in agriculture
80 % annual crops
Long coastline with shallow fiords
EU Water Framework Directive
EU and national climate policies
Groundwater protection for drinking water
Poor biodiversity
Not very resource efficient

Grasslands provide ecosystem services, which differ between grassland types: permanent undisturbed – improved grasslands

Grasslands are fantastic

but where are their markets?

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Field experiments at Aarhus University since 2012 on the effects of cropping systems on productivity (carbon capture) and environment

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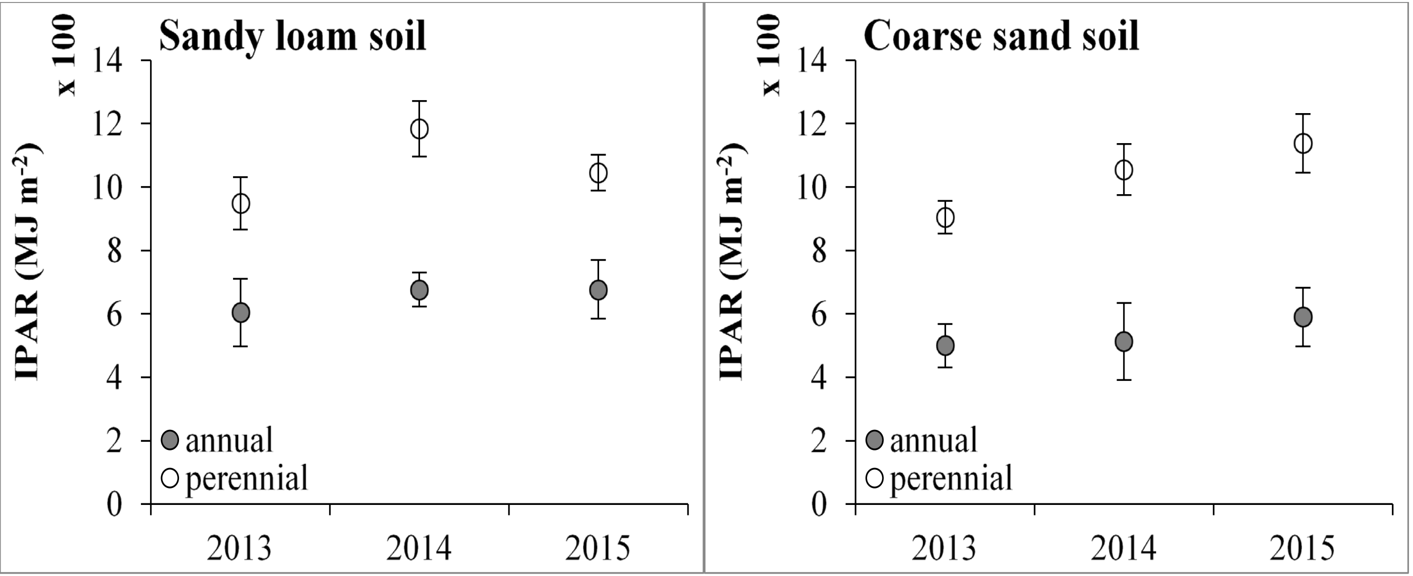
Annual intercepted PAR almost double in grasses compared with annual crops



Manevski et al., 2017

EGF 2022
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GRASSLAND AT THE HEART OF CIRCULAR AND SUSTAINABLE FOOD SYSTEMS
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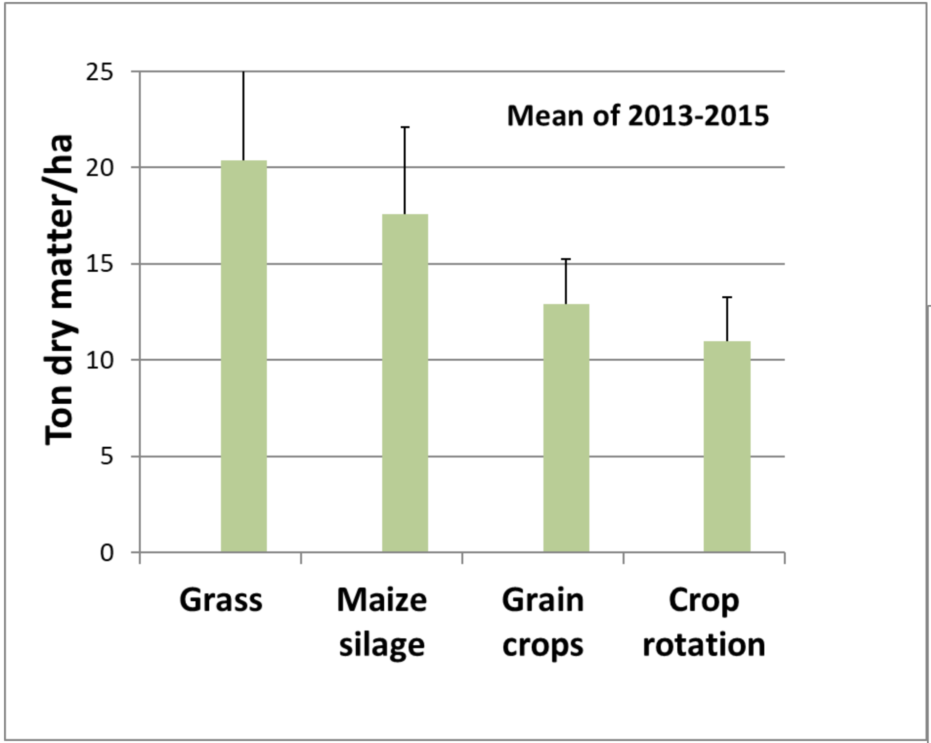
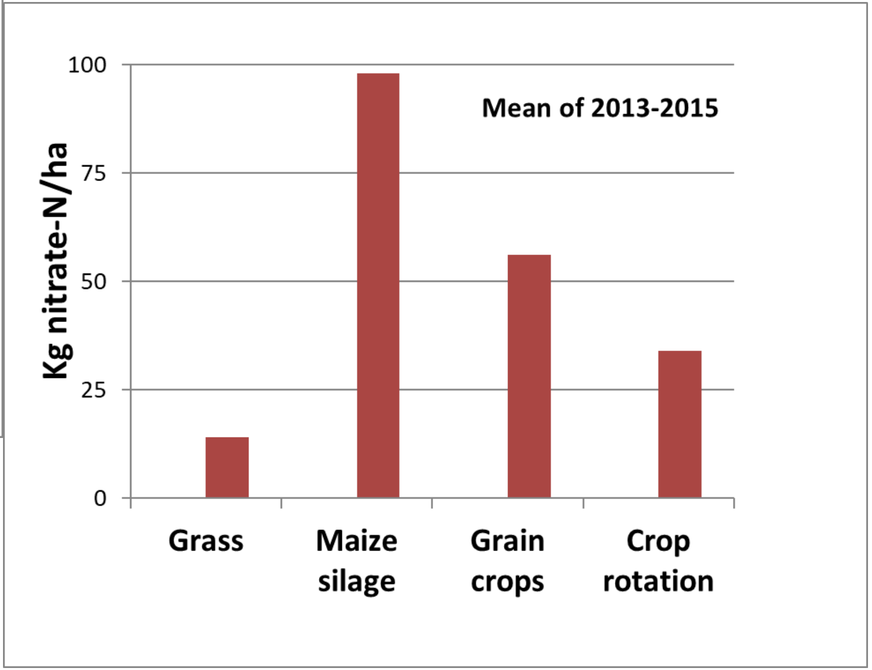
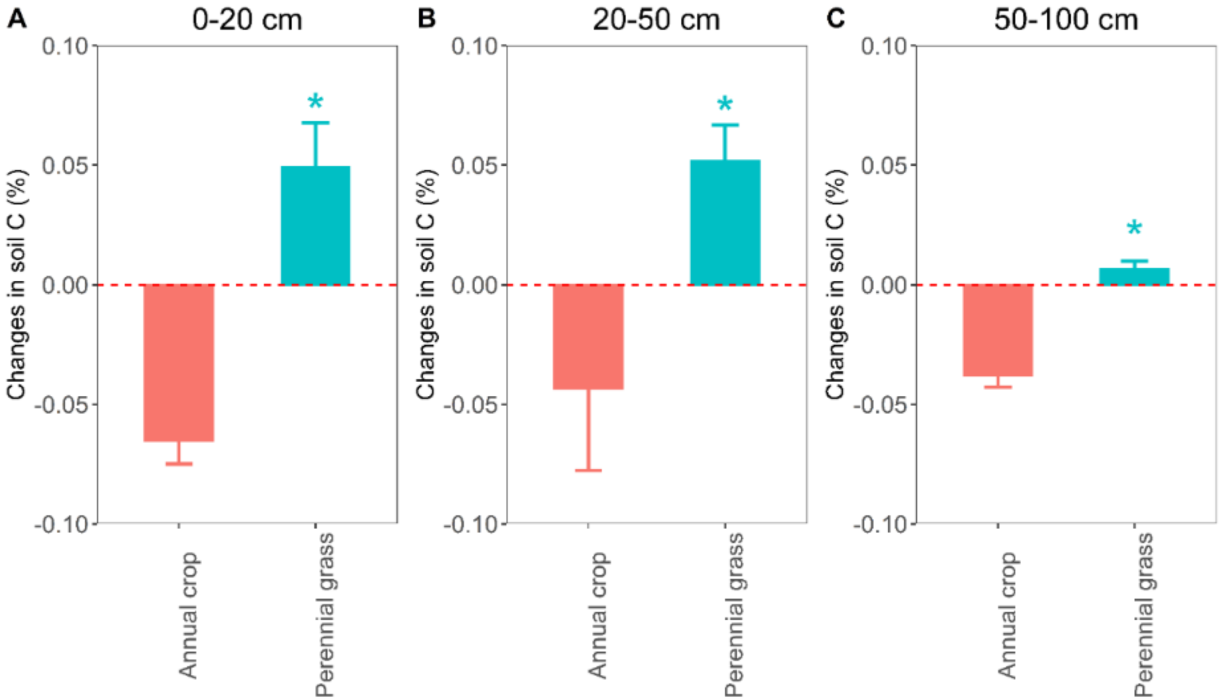
Biomass production (carbon capture) can be doubled and nitrate leaching halved





Manevski et al., 2017; 2018

Significant difference in soil C change over 5 years between annual and perennial crops – new samples are now taken after 10 years



Chen et al., 2022

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More environmental benefits from conversion of annual crops to grass, clover or alfalfa

- Reduced soil erosion
- Reduced GHG emission (0.5-3.5 ton CO_2-equiv/ha)
- Reduced pesticide use (by factor 40-50)
- Increased biodiversity
- Increased infiltration capacity

Børgesen et al., DCA Report No. 131, 2018

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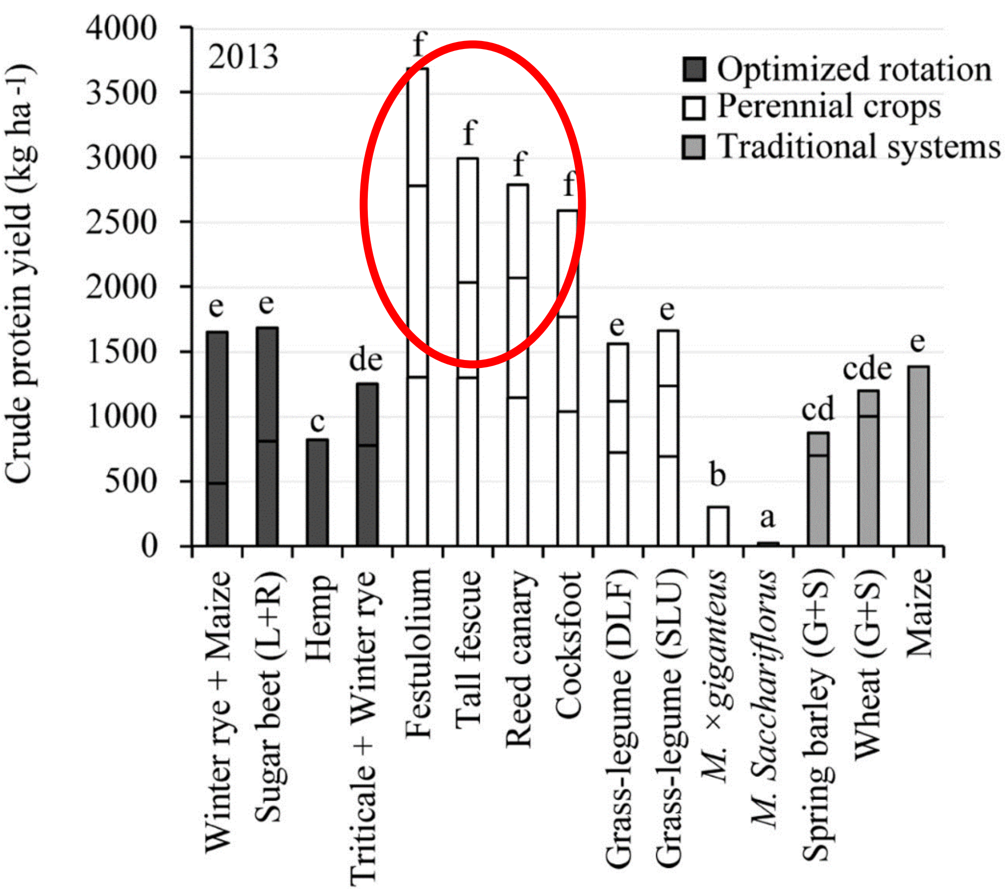
So, what to do with all that grass?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement **N° 862674**

High crude protein content in grasses may be utilised



Solati et al., 2018

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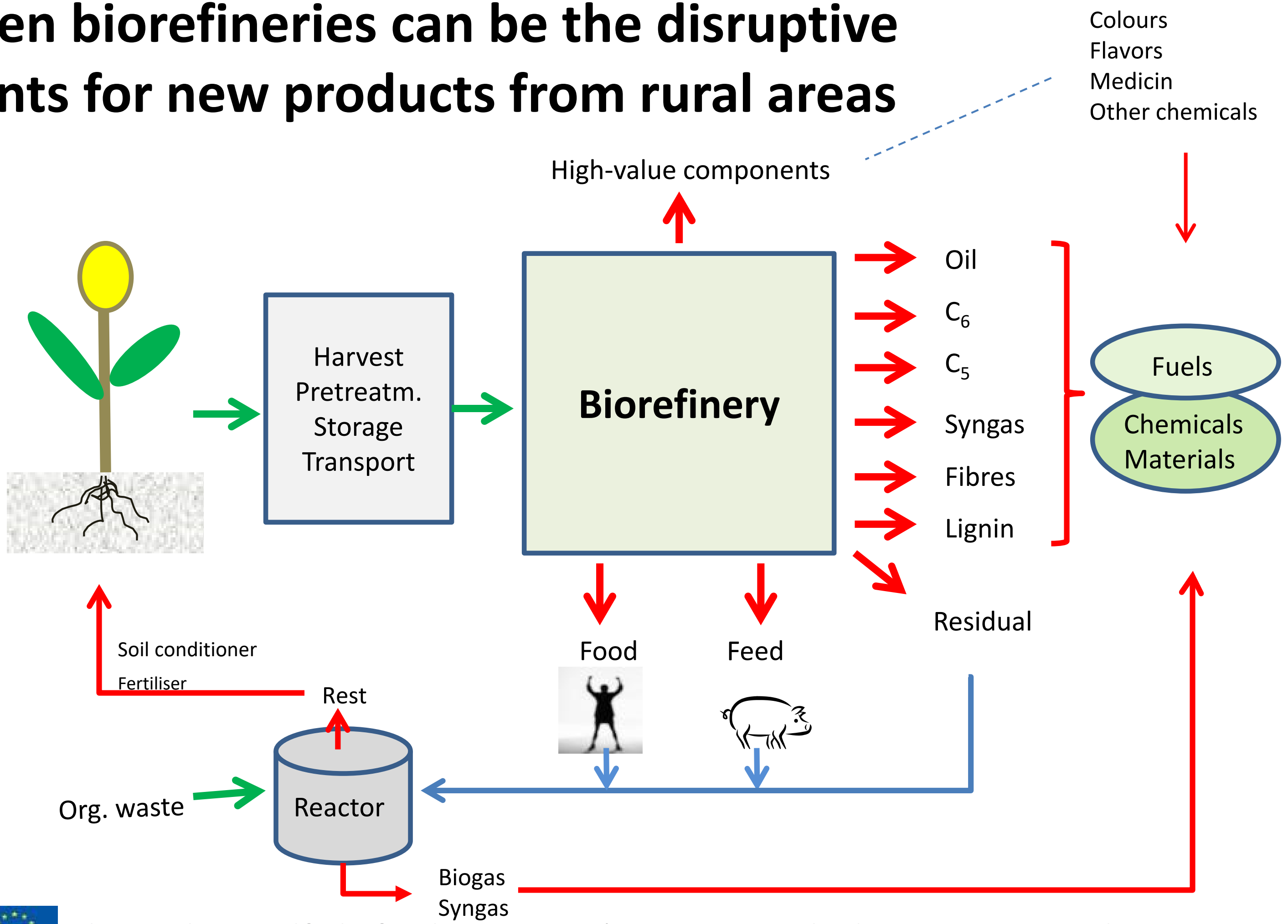
Green biorefineries can be the disruptive agents for new products from rural areas



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The main products from green biorefineries

Pulp (60-70 % of DM; 30-60 % of protein)

- Cattle feed
- Fiber for energy production (Biogas, Biochar, etc)
- Fiber for lignin production
- Fiber for insulation
- Fiber for production of oligosaccharides

Precipitated protein (20-30 % of DM; 40-70 % of protein)

- Protein concentrate as feed for monogastrics
- White protein concentrate for food purposes

Brown juice (10-20 % of DM; 5-10 % of protein, 10-15 % of total N)

- Inorganic salts / fertilizer
- Organic matter for biogas production
- Speciality compounds
  (vitamins, phytoestrogens, saponins etc)

Feeding experiment with green protein to pigs, cows, broilers & egg layers – positive results!

Chemical composition of green protein with 46% and 56% protein respectively and dehulled soybean meal

On DM basis	Protein, 46%	Protein, 56%	Soybean meal
DM, %	97.4	92.32	87.2
Crude protein, %	45.8	56.2	52.4
Lipids, %	10.6	13.8	2.9
Ash, %	12.1	8.30	8.14
Total Dietary fibre, %	29.7	Na[2)]	Na[2)]
Amino acids, g/16 g N			
Lys	5.76	5.75	6.29
Met	2.27	2.03	1.36
Met + Cys	2.73	2.72	2.79
Thr	5.02	4.60	4.06
Trp	2.42	2.21	1.38
EDOMi[1)], %	67.9	72.8	77.8

Feeding experiment with pulp to dairy cattle compared with grass clover

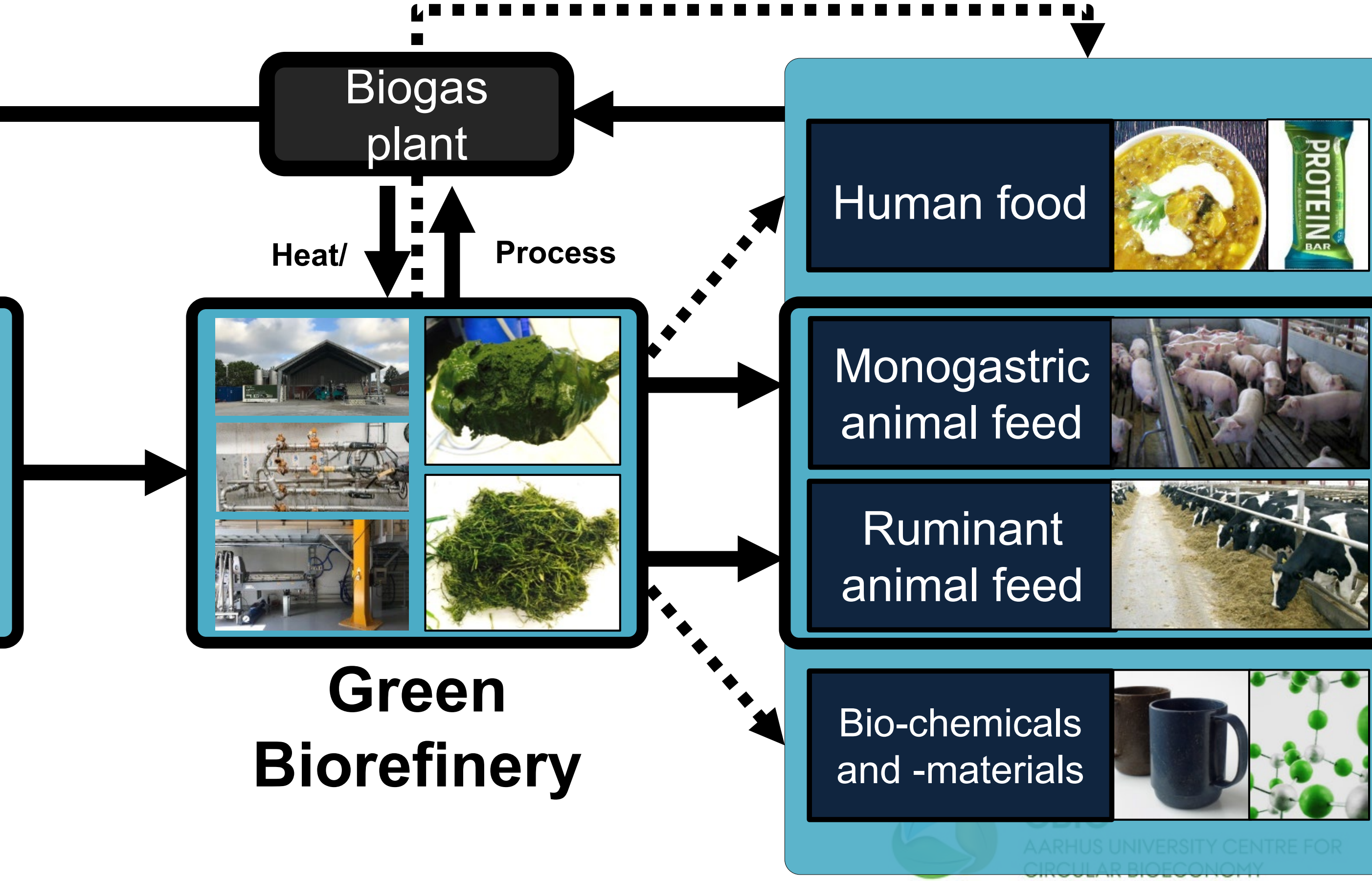
More details on effects of vegetation stage and number of pulpings in upcoming paper

Feed	Pulp silage	Grass clover silage
DM, %	28	52
Crude Protein, %	18	16
Ash, %	9.3	9.4
NDF, %	45	39
In-vitro dig. OM, %	70	72
DM intake, kg/day	23.0	22.7[2]
ECM[1], kg/day	37.0	33.5[2]
In-vivo digestibility		
OM, %	73	70[2]
NDF, %	63	54[2]
Protein, %	66	60[2]

[1] ECM = Energy Corrected Milk yield; [2] Significant different from pulp silage

(Damborg et al., 2018)

Status of grass biorefining development



Example economics in a production scenario

Capacity assumptions:

- 40 ton fresh biomass/hour
- 21.600 t dry matter/year
- 3000 operational hours/year
- In combination with existing biogas plant

Economic assumptions:

- Biorefinery CAPEX : 3.36 mio EUR
- Depreciation time: 15 year
- 5% Interest rate , 5% Maintenance

- Grass price
- Organic: 0.15 EUR/kg
- Conventional: 0.13 EUR/kg
- Protein price
- Organic: 0.67 EUR/kg
- Conventional: 0.34 EUR/kg
- Fiber pulp price
- Identical to grass price

- Residual juice is not given either any cost or value - It is used for internal energy production at the biogas plant.

Production		
Protein concentrate	3.643*	t DM/yr
Fiber pulp	15.034*	t DM/yr
Rest juice	2.924*	t DM/yr

* Based on assumed production efficiencies

Economy	Scenario	
	Organic	Conventional
	Mio. EUR	Mio. EUR
Income		
Protein concentrate/Fiber	4.70	3.25
Expenses		
Grass	3.33	2.90
Energy and salary	0.19	0.19
Maintenance	0.17	0.17
Depreciation and interest	0.32	0.32
Result	**0.66**	**-0.34**

Green biorefinery demo-plant now paving the way for market introductions – so far two commercial plants

GO-GRASS

Green Valleys
Interreg
Öresund-Kattegat-Skagerrak
European Regional Development Fund
EUROPEAN UNION

gudp

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Increased value from the protein concentrate

Basic scenario: **Feed alternative to soy meal (0.54 EUR/kg)**

Speciality feed

- Extra high protein purity and digestibility – e.g. for fish and young animals
- Optimized amino acid profile (e.g. higher cysteine)
- Utilization of high fat content (primarily α-Linolenic acid)
- Pre- & pro- biotic effects via fermentation of the products

Food protein

- New source of plant based protein for consumption
- New source of functional protein for the food ingredient market

Increased value of the fibre

Basic scenario: **Feed for ruminants or substrate to biomethane (ca 0.13 EUR/kg)**

Thermal conversion, e.g. Pyrolysis

- Supply of internal energy needs for heating and drying
- Biochar production
- Biooilproduction

Further conversion of the fibre fraction.

- Lignocellulosic biorefinery (LCF-Biorefinery)

www.biowert.com

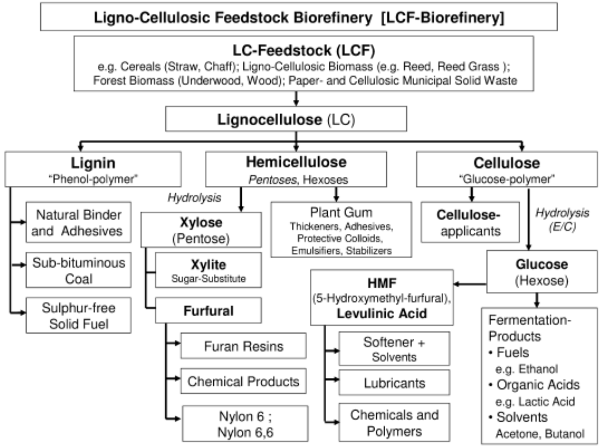

Fig. 1.11 Products of a lignocellulosic feedstock biorefinery (LCF-biorefinery, Phase III) [78, 79, 95].

Applications in Biomaterials

- Insulation materials
- Bio-composites
- Packaging
- Biobased textiles
- Horticulture substrates

Utilization of soluble compounds in the residual juice

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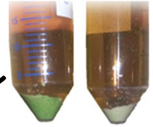
55°C



Green Protein | White Protein

Brown juice

Soluble protein concentrate

Applications in food

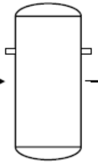
Retentate

Ultrafiltration

Permeate

Retentate

Nanofiltration



Fermentation

Astaxanthin

Single-cell Protein

Permeate

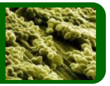
Field

GMO yeast developed and provided by Irina Borodina, DTU BioSustain

Fermentation of BJ to astaxanthin

Screening of yeasts and further studies with *C. utilis*

Fermentation of BJ to single cell protein



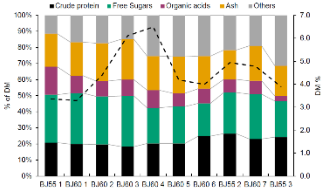
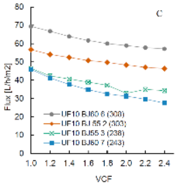


Figure 1 – Variation in composition of brown juice in dry matter produced under different conditions. Dry matter content is on the right (y) axis and refers to the dotted line. Concentration in % of DM of each component is on the left (y)-axis.



Ultrafiltration of brown juice (60°C) – 10kDa UF membrane

VCF	Brix% R	DM% R	**CP% R**	Flux (l/m²/h)	Brix% P	DM%P	**CP% P**
1.0	5.5	4.5	**19.9**	83.0	3.6	2.8	**17.2**
2.0	6.6	5.6	**21.4**	55.0	4.2	3.3	**17.2**
5.0	11.3	10.0	**27.0**	44.0	5.4	4.2	**17.8**
7.4	13.6	11.7	**28.6**	35.0	4.7	3.8	**17.4**

Nanofiltration	Total Sugars g/l
Feed	11.05
Permeate	0.11
Concentrate	49.71

Nutrient	Feed (mg/l)	Concentrate (mg/l)	Permeate (mg/l)
Potassium	3870	9100	2400
Ammonium	1,8	49	10,8
Phosphorous	297,2	1152	26,3

Coupling the benefits of grasslands and green biorefining can deliver raw material for new biobased, local products AND ecosystem services

- Better solar radiation capture
- Soil carbon storage
- Less nutrient losses
- Less pesticide use
- Increased biodiversity
- Farmers licence to produce
- Water Framework Directive
- EU Protein Strategy
- Green Deal

THANK YOU FOR LISTENING

Questions are most welcome!

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RESEARCH AND DEVELOPMENT IN GREEN BIOREFINING

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Green Valleys

Alfa Max Bioraf

MultiPlant
flerårige højværdiafgrøder i økologisk planteproduktion

SuperGrassPork
Økologisk svineproduktion baseret på græs-protein

Miljø- og Fødevareministeriet gudp

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