

# Overall system and profitability analyses

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Analyses of the overall system (green biorefineries and supporting agricultural production) to reveal the potential for new investments in green biorefineries and enhance the level of support from the main actors of the supply chain; farmers, biorefinery investors and biorefinery customers (i.e., livestock and energy industry).

Optimization modelling to assess;

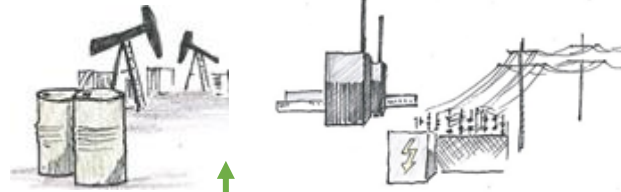
- The feasibility of, and benefits from, new supply chains associated with green biorefineries
- Effects of land use change to integrate grasslands producing biorefinery feedstocks in agricultural landscapes dominated by annual crops, mostly cereals.

The capabilities of the optimization model (for any application scale);

- (1) Configuration and network design of biorefinery supply chain
- (2) Biomass supply and bio-product production planning
- (3) Land use and land use change planning



Renewable energy and fuel production

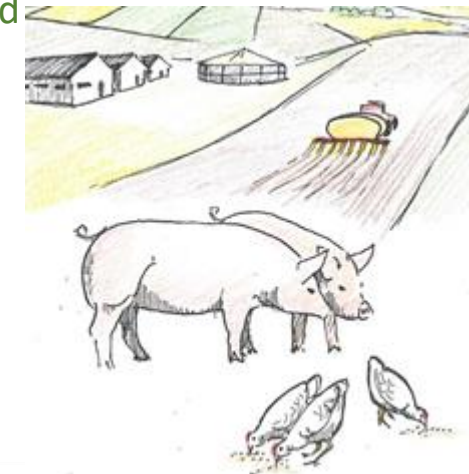


Brown Juice, Press Cake;  
annual production and  
biomethane potential



Feed import

Soybean meal



Feed Protein;  
annual production and  
soymeal substitution  
potential



Configuration and  
network design; how  
many, where and which  
capacity?



Grass; from which farms  
and how much?



Grass production



Size of the area  
changed from  
cropland to produce  
grass for biorefinery  
purposes



Crop production

## Application - southern and central Sweden

Optimization to explore the deployment potential of green biorefineries at scale,  
Benefits from this deployment and commercialization potential

**Optimized configuration of biorefineries and transportation network**

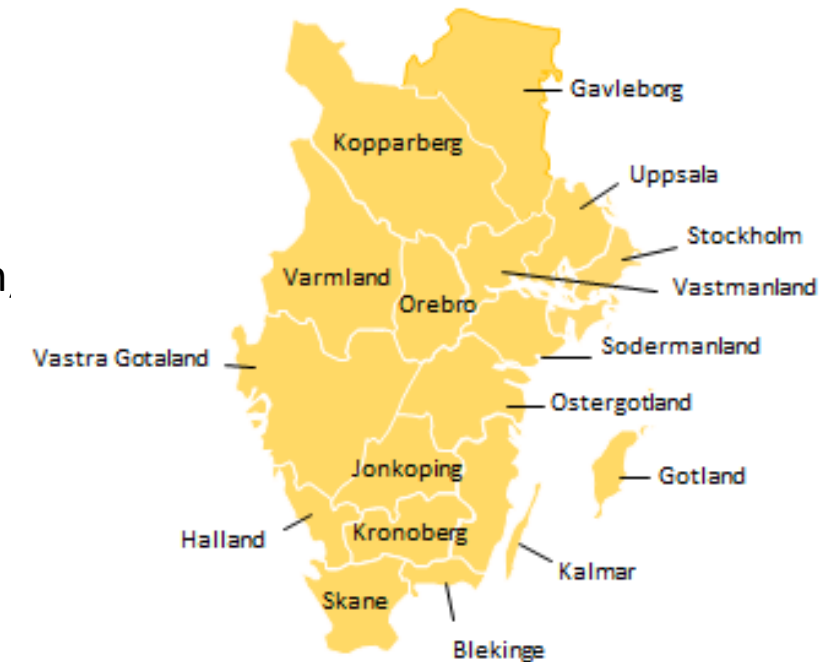
**Protein balance**

**Biorefinery output and substitution potential**

**Business development analyses**

Parameters with significant influence on the deployment and configuration,

1. Market price of grass
2. Upper limit of land use change





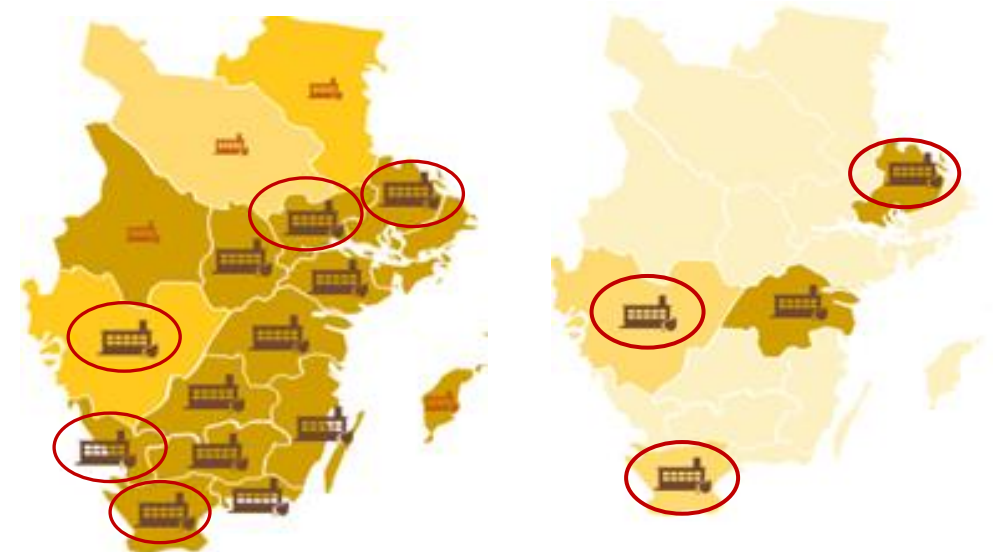
Depending on the configuration and deployment of biorefineries, which is mainly shaped and triggered by the grass price and land use change proportion;

- The total potential for imported soybean meal substitution ranges between 32% and 216%\*.
- Potential to produce biomethane ranges between 410 and 1405 GWh/year.
- Corresponds to 75% to 255% of the biomethane import for transport\*\*
- or to 37% to 127% of biomethane import for substituting natural gas in industry and heating\*\*

can be fulfilled by the biomethane production from press cake and brown juice

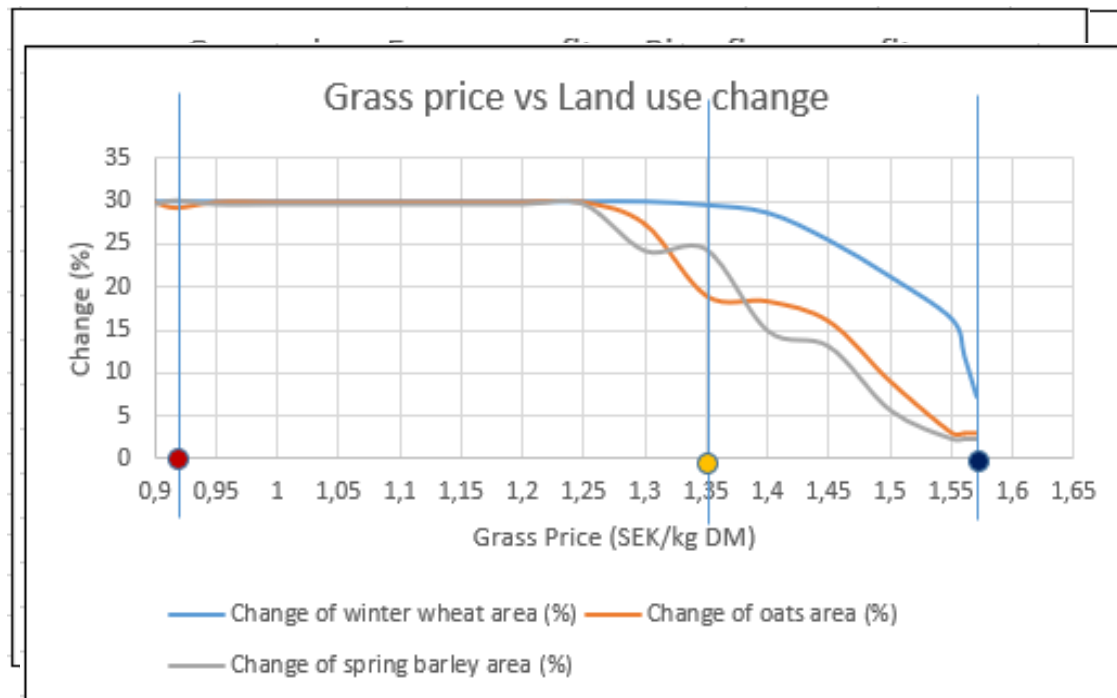
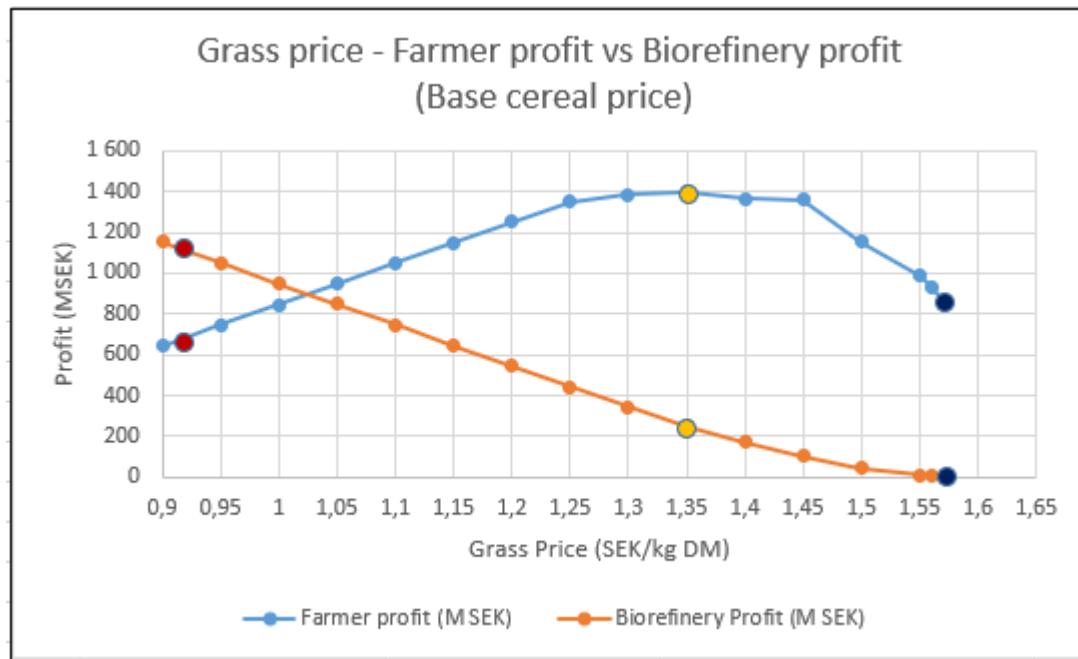
\*Annual soybean meal import as calculated as 167 480 t based on weekly data from European Commission 2021.

\*\*The import of biomethane through the south western gas grid is 1650 GWh, of which 1/3 (550 GWh) is used for transport and 2/3 (1100 GWh) is used for substituting natural gas in industry and heating (Energygas Sverige, 2019).



# Business development based on market price of grass

## Green Valleys



- Break even point for farmer (Profit after LUC > Profit before LUC)
- Maximum profit for farmer
- Break even point for biorefinery (biorefinery investment is not reasonable for the exceeding prices)

## Green Valleys

Then, what happens at farm scale! (Typical rotation change for Vastra Götalands, 1000 ha Cropland)



2622 t DM grass



Year	Crop
1	Spring barley (167 ha)
2	Oats (167 ha)
3	W wheat (167 ha)
4	W Rapeseed (167 ha)
5	W Wheat (167 ha)
6	W Wheat (167 ha)

Year	Crop
1	Spring barley
2	Ley I (grass 1)
3	Ley 2 (grass 2)
4	W Rapeseed
5	W wheat
6	W wheat

Grass from changed oats land (t DM)	1503
Grass from changed winter wheat land (t DM)	1119
<b>Total grass (t DM/year)</b>	<b>2622</b>

Total protein loss due to LUC (t/year)	275
<b>Total harvested protein from changed crop area (t/year)</b>	<b>566</b>

Biorefinery product	Annual amount (t/year)	Protein content (t/year)
Protein Concentrate (t/year)	488	229
Press Cake (t/year)	1751	311
Brown Juice (t/year)	383	25
<b>Total protein from biorefinery (t/year)</b>		<b>566</b>

## Effects of yield increase, fertilizer use decrease, SOC increase

Västra Götaland annual crops		Västra Götaland with 2 yr grass/clover	
Crop	Yield, t/ha	Crop	Yield, t/ha
Spring barley	5	Spring barley	5
Oats	5	Ley I (grass 1)	9
W wheat	6,2	Ley 2 (grass 2)	6,7
Winter Rapeseed	3,2	W Rapeseed	3,4
W Wheat	6,7	W wheat	7
W Wheat	5,5	W wheat	5,8

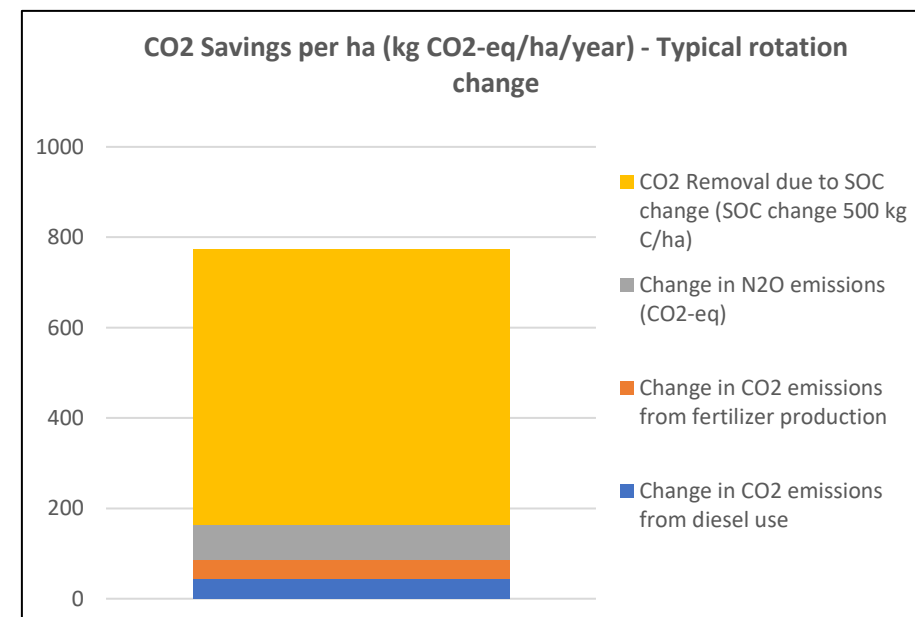
### Protein harvest from current cereal based rotation

	Annual Protein (t/year)
Winter Wheat	399
Oats	142
Spring Barley	100
Winter Rapessed	187
Total	828

### Protein harvest from changed rotation

	Annual Protein (t/year)
Winter Wheat	277
Spring Barley	100
Winter Rapessed	199
Ley	566
Total	1142

Net protein gain after land use change – 314 t/year



## Discussions and future research

- Intensification of grass production – potential effects on the overall system
- Integrated biogas plant or transport of press cake and brown juice (or combination)
- Different pathways for press cake and brown juice utilization
- Overall GHG and energy balance of the system

# Protein balance

Land use change upper bound; 30%	Base grass price	20% higher grass price
Total Protein Loss due to LUC (ton)	179 641	57 810
Total Harvested Protein from Changed Crop Area (ton)	406 080	129 600
Net protein harvest due to LUC (ton)	226 439	71 790
Total Harvested Protein from Grass per ha of Changed Area (ton/ha)	1,73	1,69
Protein Output from Biorefinery per ha of Grassland (ton/ha)	1,73	1,69



# Protein concentrate production and soybean meal substitution potential

Land use change upper bound; 30%	Base grass price	20% higher grass price
Total protein concentrate output (ton/year)	349 680	111 600
Soybean meal substitution potential (ton/year)	335 693	107 136
Imported soybean meal substitution potential (%)	200,4	64
Total press cake output (ton/year)	1 255 840	400 800
Total brown juice output (ton/year)	274 480	87 600

