Anaerobic Digestion Feedstock Acquisition under Uncertainty and Scheduling Optimisation with Dynamic Demand

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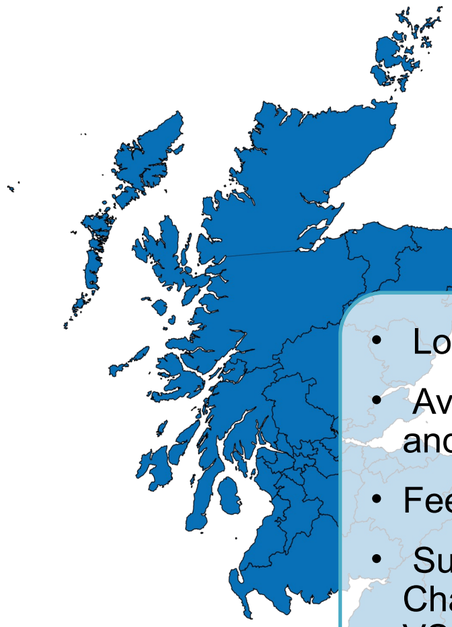
Supergen Bioenergy

Project Overview

- My research is a part of a bigger project (AI4AD) aiming to develop AI tools to enable radical efficiency improvements in AD biogas production.
- Current AD processes lack *flexibility* and *predictability* due to the inherent complexity of the microbial interaction in different operational and feedstock conditions.
- Also, various *availability* and *uncertainty* issues are pertained to feedstocks, gas demand and prices.
- This necessitates more rigorous *scheduling* and utilisation of predictive measures to enhance decision making process.

Phase I: Optimal AD Scheduling



- Location
- Availability periods and seasonality
- Feed weight
- Substrate Characteristics: TS, VS, EBMP, TBMP, k, C/N
- GWP factors
- Digester volume and operational limitations

Feed data

CoD function

- Takes Pair combination of Feeds (A,B), (A,C,D), (B,F),…
- Calculates The optimal fraction (x_A, x_B), leading to maximum BMP of the pair.

Storage

Price prediction

- Takes feed data, storage and price prediction
- Calculates the schedule for storage and supply for the Max. revenue and minimum GWP & feed cost.

Scheduling function

Results

Optimal feeding and gas supply schedule

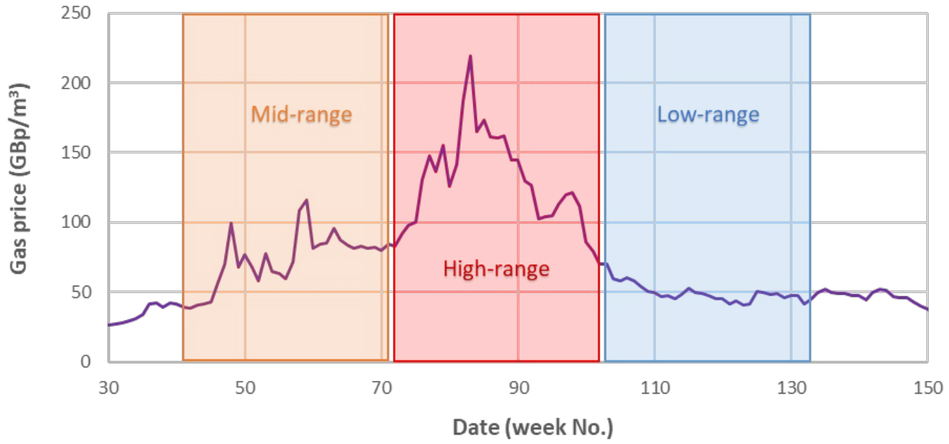
Case Study

- The study covers three different time periods of natural gas price fluctuations: **Low**, **Mid** and **High**-range.
- The weekly price of biogas is determined according to the Office of Gas and Electricity Market, ofgem, from February 2021 to February 2024.
- Feed data are acquired from our project industrial partners, Ixora energy Ltd. and future biogas Ltd.
- The case study includes various scenarios for availability and seasonality of the feeds.
- Study base case:

  Farm-scale AD plant

  10,000 m^3 Digester

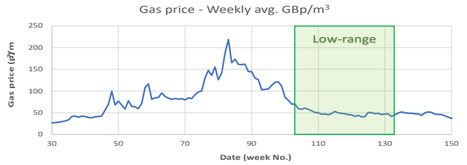
  70 days Retention time



Results

Optimised case without storage

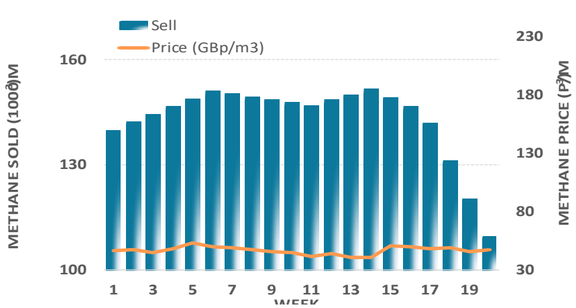
Low frequency gas price variation zone



Feeding Schedule

Feed Name \ Week No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Grass fresh-cut (GFC)																				
Dried maize silage (DMS)																				
Rye silage (RS)																				
Grass silage (GS)																				
Wheat grain (WG)																				
Maize silage (MS)																				
Pig slurry (PS)																				

Bio-methane Supply & Price variation vs. Time



+ GWP Included

Feeding Schedule

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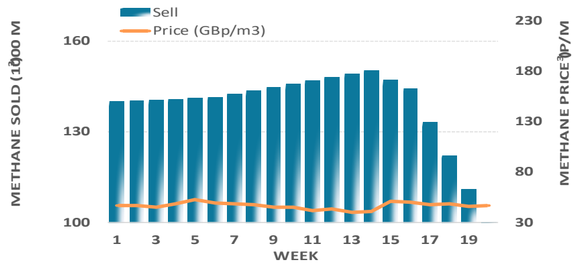


Feed Not Available

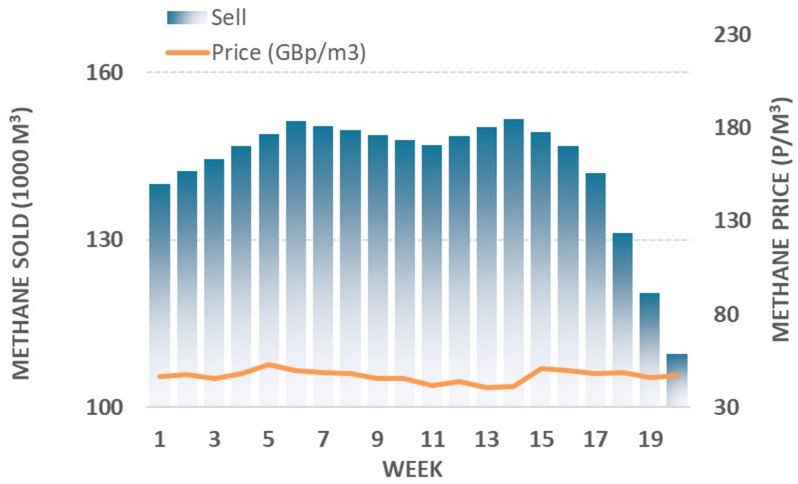
Feed Available

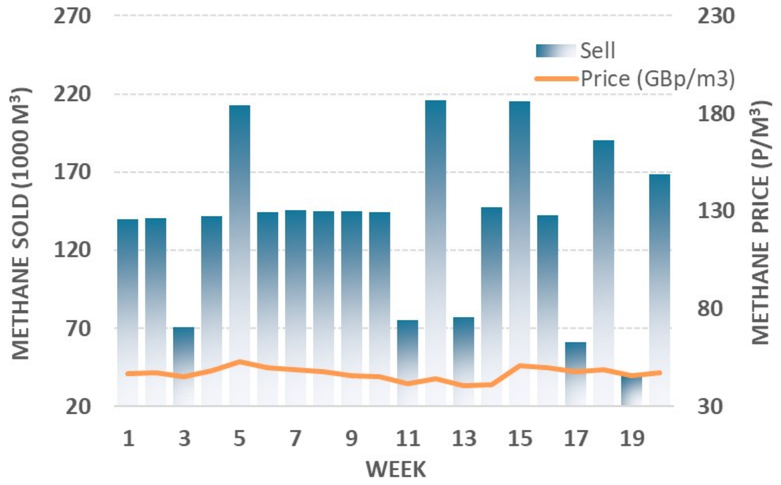
Feed Used

Results

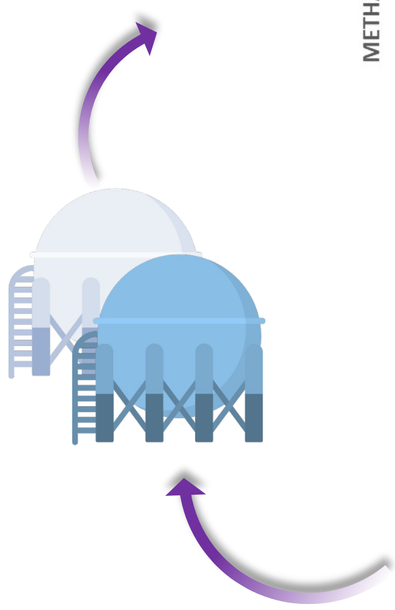
Optimised case with storage

Low frequency gas price variation zone



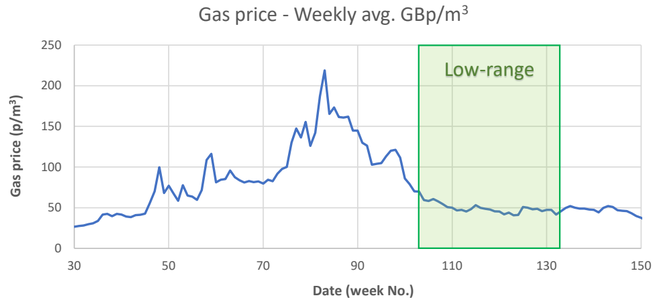


***70 Mm³** / week*



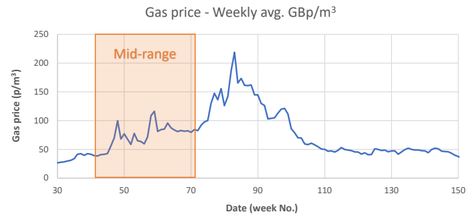
No.	Scenario	Net Revenue (£/yr)	GWP (kg_{CO2e} / yr)	Revenue Increase (%)
S1	Optimised Scheduling	770.1 k	178 k	-
S4	S1 + Min. GWP	755.4 k	19.4 k	-1.9%
S7	S1 + Gas Storage	786 k	178 k	2.0%
S10	S4 + Gas Storage	771 k	19.2 k	2.0%

+ 40 k



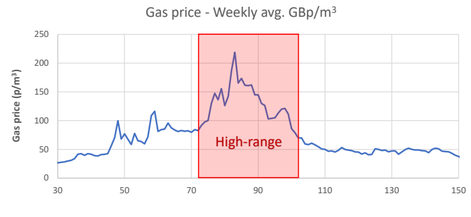
Results

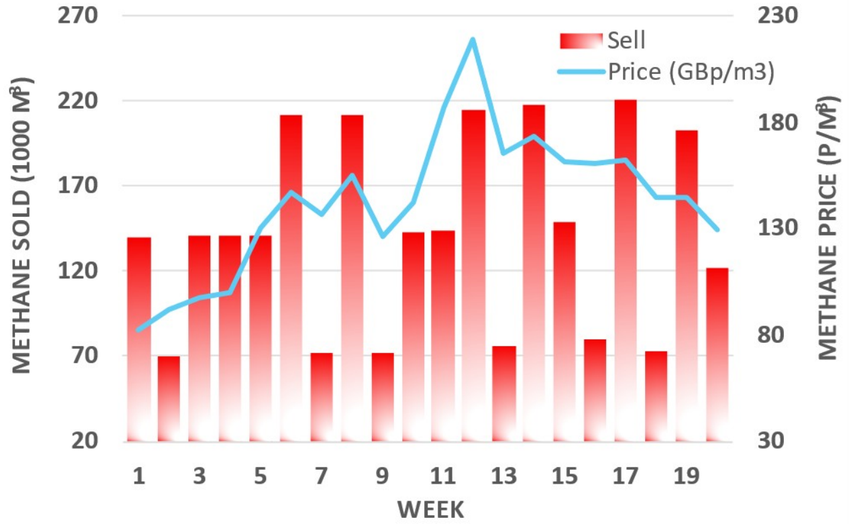
Other Pricing zones (Medium & High frequency) with storage



+ *Storage up to **70 Mm³** / week*

No.	Scenario	Net Revenue (£)	GWP (kg_{CO2e})	Revenue Increase (%)	
S2	Optimised Scheduling	1,425 k	263 k	-	
S5	S2 + Min. GWP	1,384 k	19.2 k	-2.9%	
S8	S2 + Gas Storage	1,527 k	516.5 k	7.1%	
S11	S5 + Gas Storage	1,487 k	19.2 k	7.4%	+ 267 k



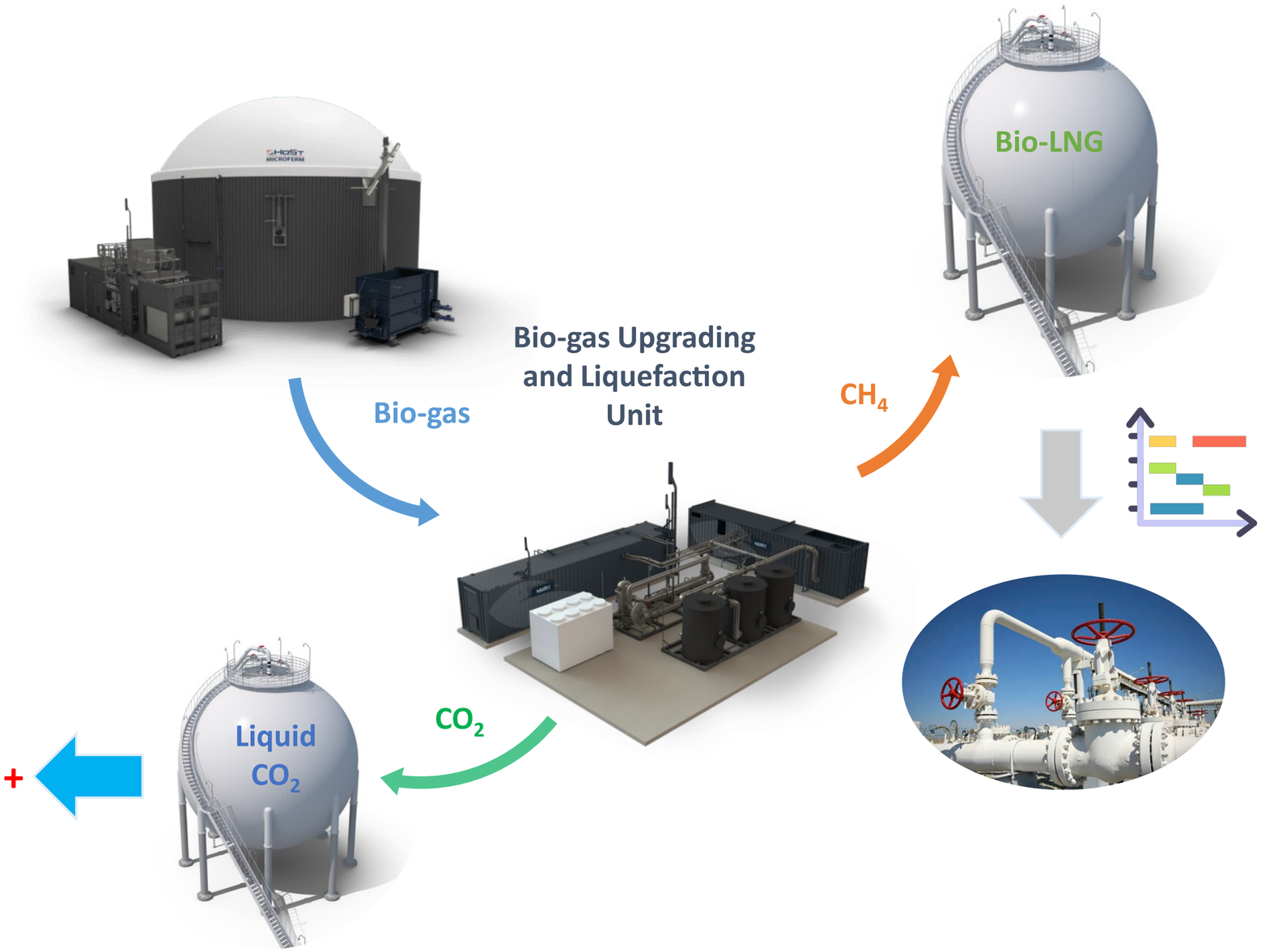


No.	Scenario	Net Revenue (£)	GWP (kg_{CO2e})	Revenue Increase (%)	
S1	Optimised Scheduling	3,660 k	686 k	-	
S4	S1 + Min. GWP	3,488 k	19.2 k	-4.7%	
S7	S1 + Gas Storage	3,783 k	686 k	3.4%	
S10	S4 + Gas Storage	3,612 k	19.3 k	3.6%	+ 322 k

Results

Bio-LNG and Carbon Storage Possibilities

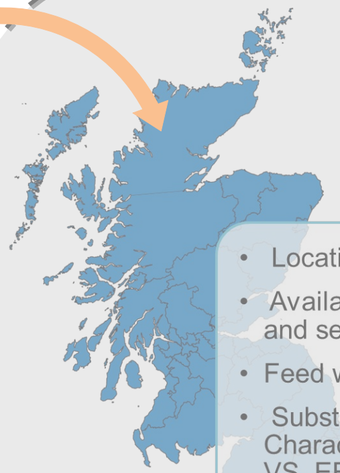
- Large storage of methane for price matching and grid supply optimisation is achievable through **liquefying** processes.
- Current biogas upgrading processes using membrane filtrations does not provide CO_2 storage possibility.
- Liquefaction cycles can facilitate the separation and storage of CO_2 in the form of liquid.
- Extra revenue is conceivable through storage and shipment of CO_2 depending on the ***carbon pricing*** scheme.



Phase II:
Optimisation Under Uncertainty

Feed Acquisition Model

- Takes Weather, Soil Condition in different scenarios
- Decides Land allocation
- Decides crop purchase/sell acc. to each crop yield scenario



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Results

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Phase II:
Results – Platform Interface

futurebiogas

OPTIMAL CROPS SUPPLY UNDER UNCERTAINTY

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Input Data:

Crop	Yield (Base)	Sell Price (Base)	Buy Price (Base)	Planting Cost (Base)	Yield (Best)	Yield (Good)	Yield (Average)	Yield (Bad)	Yield (Worst)
	t/ha	£/t	£/t	£/ha	t/ha	t/ha	t/ha	t/ha	t/ha
Maize	35	55	83	1925	44	38	35	31	26
Rye	35	52	78	1820	42	39	35	30	23
Grain Maize	35	140	210	4900	44	38	35	31	26
Sugar Beet	0	0	45	0	0	0	0	0	0
Grass	0	0	40	0	0	0	0	0	0

Scenario	Probability	Sell Adjustment	Buy Adjustment	Planting Adjustment	Sugar Beet Adjustment	Grass Adjustment
	%	%	%	%	%	%
Best	30%	20%	30%	10%	25%	24%
Good	40%	10%	20%	5%	12%	11%
Average	20%	0%	0%	0%	0%	0%
Bad	9%	-5%	-20%	-10%	-15%	-16%
Worst	1%	-20%	-30%	-20%	-25%	-26%

Constraint	Value	Unit
Total Area	1,500	ha
Maize Minimum Feed Demand	39,460	t/yr
Rye Minimum Feed Demand	5,000	t/yr
Sugar Beet Minimum Feed Demand	2,000	t/yr
Grass Minimum Feed Demand	-	t/yr
Total Minimum Feed Demand	47,350	t/yr

Run Python

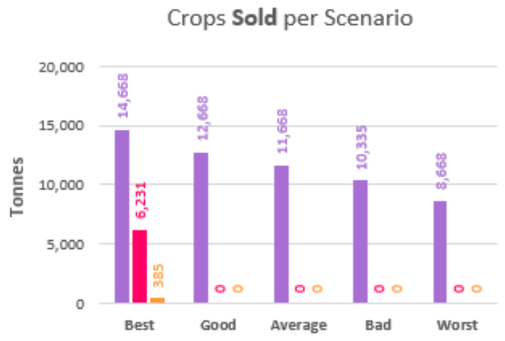
PYOMO

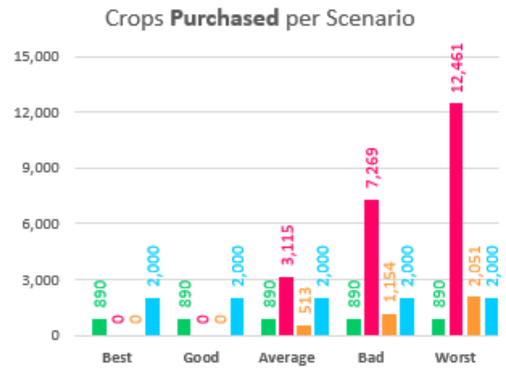
futurebiogas

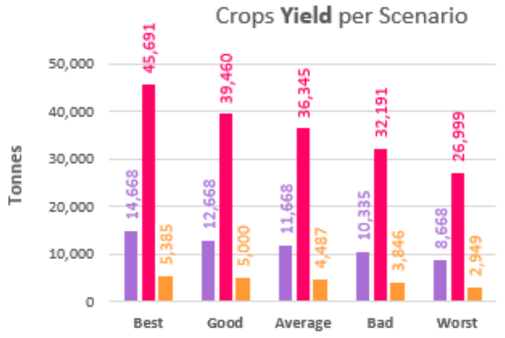
OPTIMAL CROPS SUPPLY UNDER UNCERTAINTY

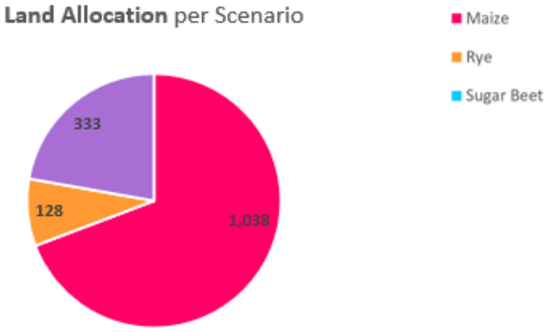
UNIVERSITY OF SURREY

Results:









Acknowledgements

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