Feasibility of biogas production from sugar industry wastes

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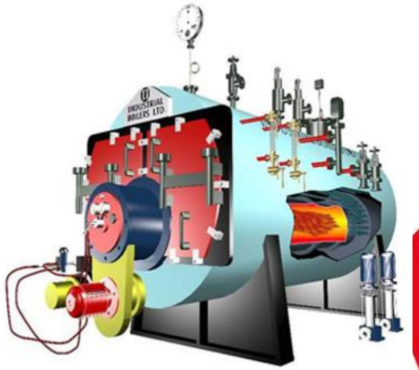

ICON-SMART Conference, Manado, Indonesia 21-22 Sept 2023

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Sugar Industry in Australia

- Sugarcane – the second major agricultural crop grown over 343,039 ha mainly in QLD (95%) and NSW (5%)
- 24 (2019) to 22 Sugar Mills in operation
- 30.09 m t cane (2021)
- 4.12 m t sugar
    - 85% of raw sugar is exported
- $2.5 billion worth & provide 9,800 direct and >23,650 indirect jobs in regional areas.

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Source: Canegrowers, 2022; Australian Sugar Milling Council, 2022

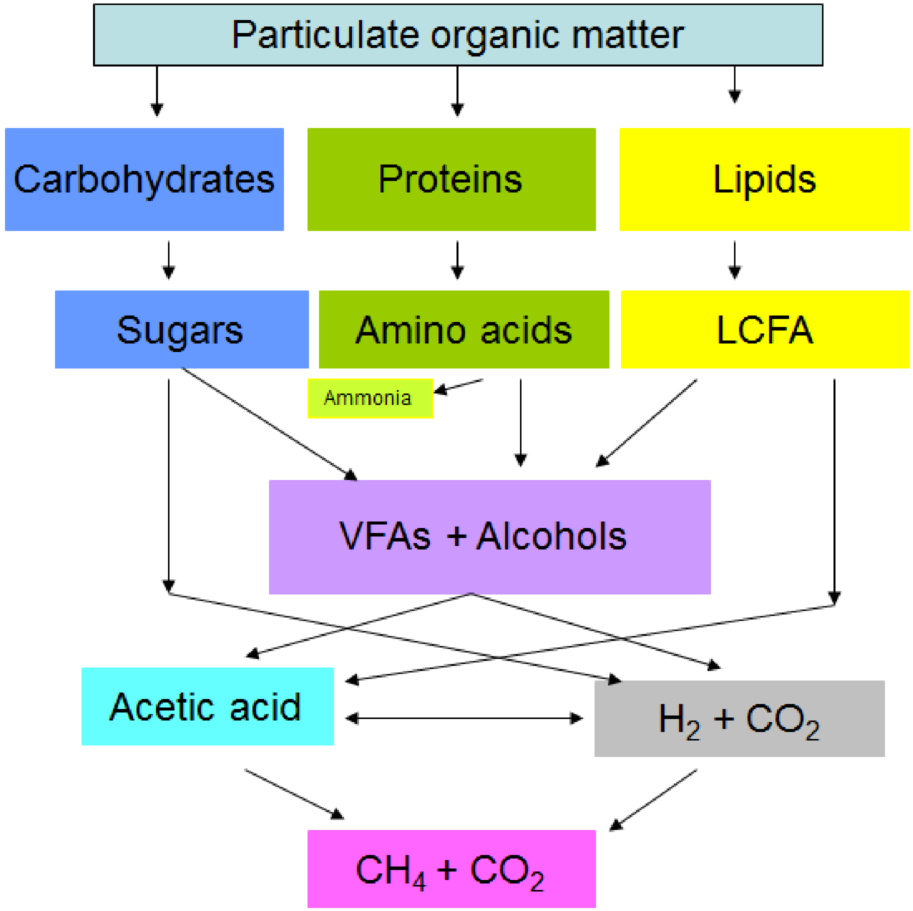
Problem

- Falling cane supply - mill under-utilisation
- High costs of production.
- Weighted average cost of sugar production: A$433/t in 2021
- Five-year average raw sugar price A$436/t
- Only 6 out of 13 mills
- Financial viability of milling operations is compromised
    - Limited value-add revenue diversification
    - No additional revenue flows

Source: Australian Sugar Milling Council, 2022

Anaerobic digestion

- Anaerobic digestion is the breakdown of complex organic matter by simple microorganisms into methane, carbon dioxide and water in the absence of oxygen.
- Biogas is a mixture of CH_4 (50-70%) and CO_2 (30-50%).
- Biogas is an environmental friendly CO_2 -neutral, clean, cheaper and versatile biofuel that can be used for heat, and/or electricity in CHP or upgraded as a transport fuel.



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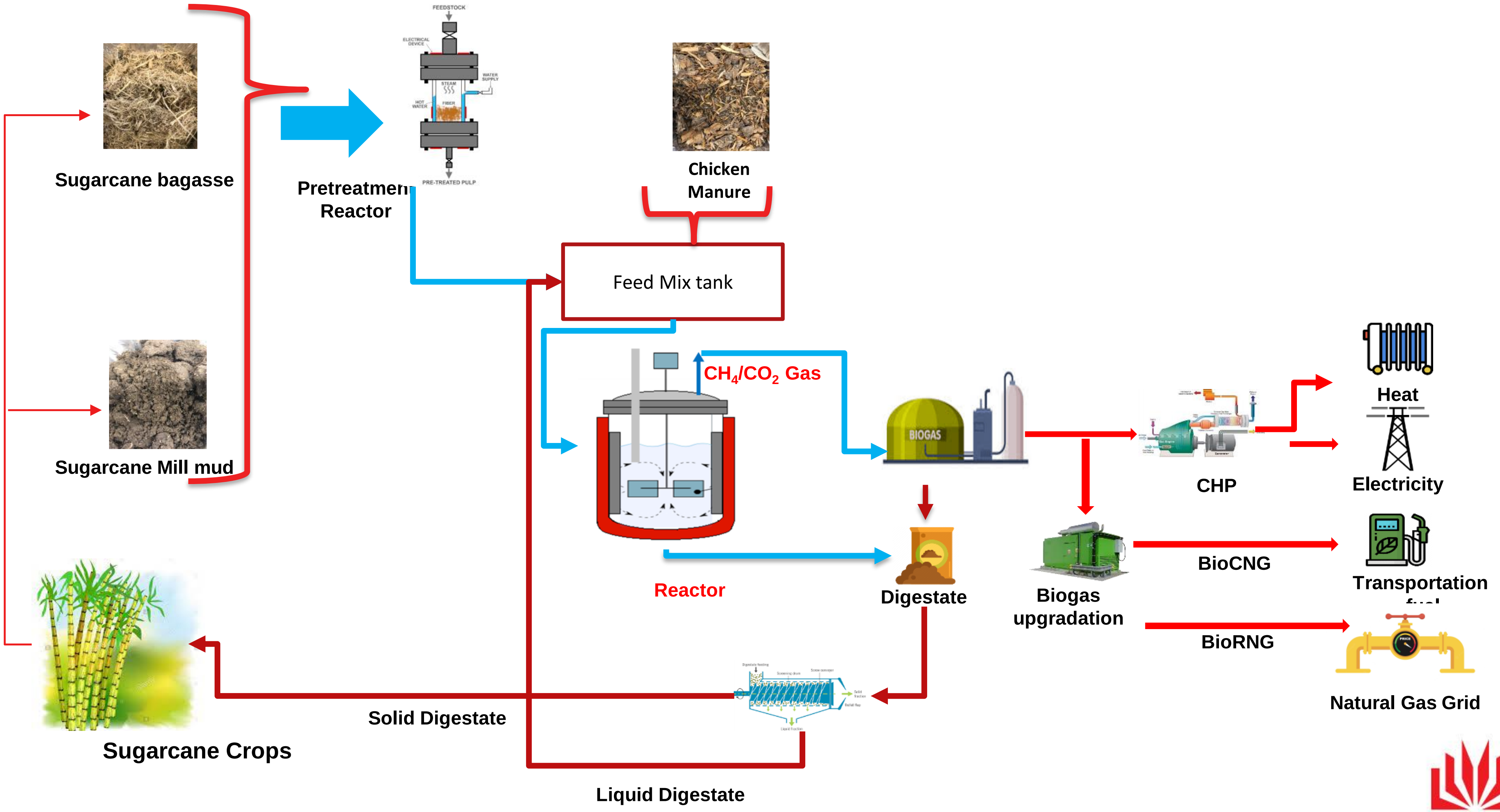
Techno-Economic Assessment of Sugar Industry by-products



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Methane potential of sugar industry by-products

Feedstock	TS	VS	C	N	C/N	Methane yields	
	% w/w	% w/w	%	%		NL-CH_4/kg-VS_{added}	Nm^3-CH_4/ton-FM
Shredded Cane	30.86	27.23	41.17	0.27	149.73	338.19	91.21
Evaporated sugar syrup	66.35	66.11	34.17	0.20	169.35	446.62	295.26
Sugarcane bagasse	48.86	44.08	42.01	0.27	156.84	282.38	124.49
Sugarcane trash	67.63	63.24	43.83	0.42	103.16	244.56	154.67
Mill Mud	22.66	15.53	35.34	1.55	22.77	365.25	56.71
Molasses							
Rum distillery wastewater							
Chicken Manure	74.30	61.95	42.10	3.67	11.48	271.95	168.48
Cow Manure	11.27	9.20	42.75	2.69	15.92	363.90	33.49

Feasibility study Scenarios

Project parameters	Scenario 1 CHP	Scenario 2 CHP + BioCNG	Scenario 3 CHP + BioRNG
Biogas use	Electricity generation, grid supply CHP	30% electricity generation, 70% biogas upgrading CHP + BioCNG	30% electricity generation, 70% biogas upgrading CHP + BioRNG
Biogas plant outputs	Electricity Digestate	Electricity BioCNG BioCO_2 Digestate	Electricity BioRNG BioCO_2 Digestate
Grid electricity required for biogas plant	No	No	No

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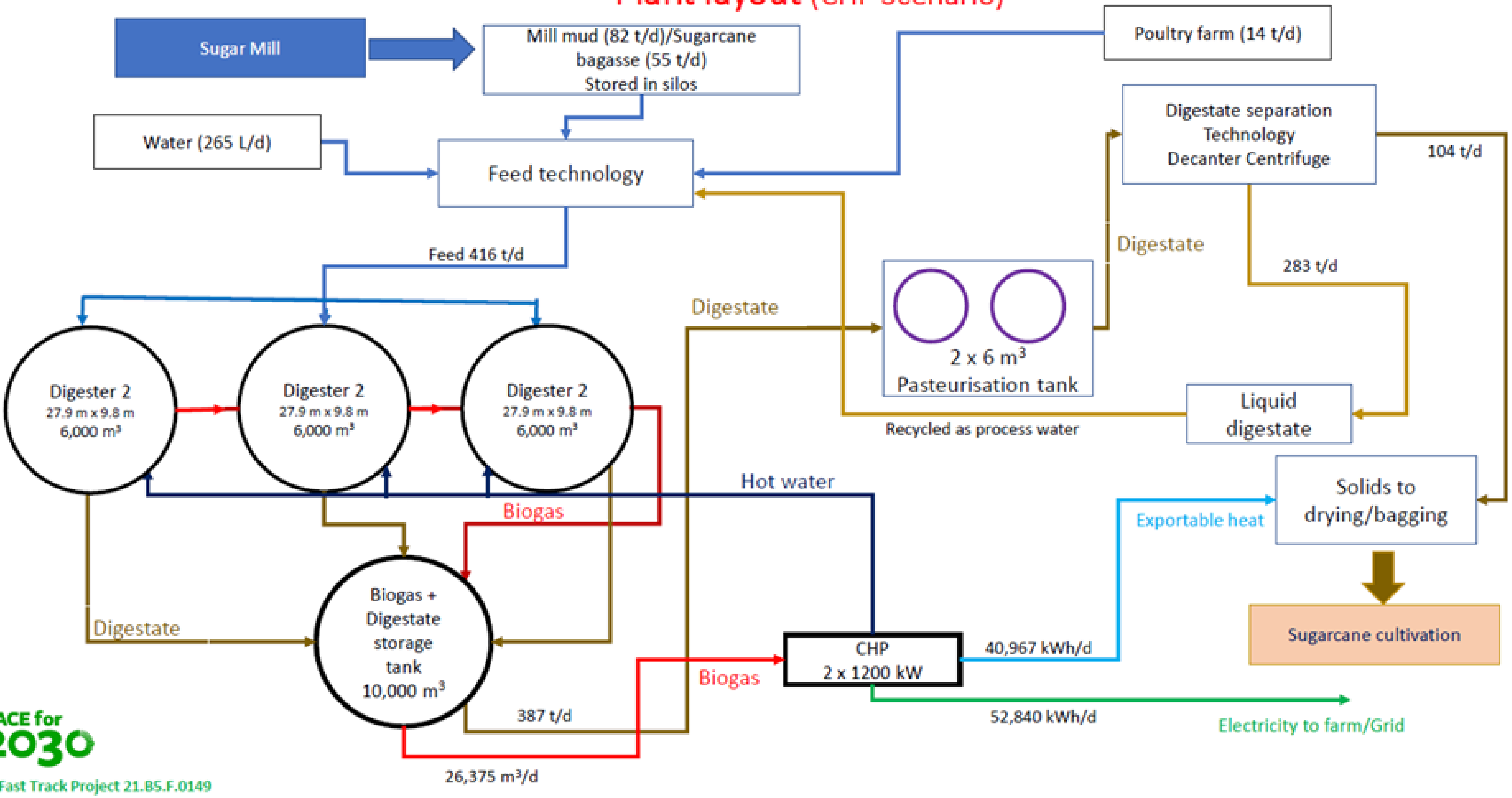
Biogas From Agricultural Waste: A Techno-Economic Evaluation

Plant layout (CHP Scenario)

Singh Farming



RACE for 2030

B5 Fast Track Project 21.B5.F.0149

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Biogas From Agricultural Waste: A Techno-Economic Evaluation

Plant layout (CHP-BioCNG Scenario)

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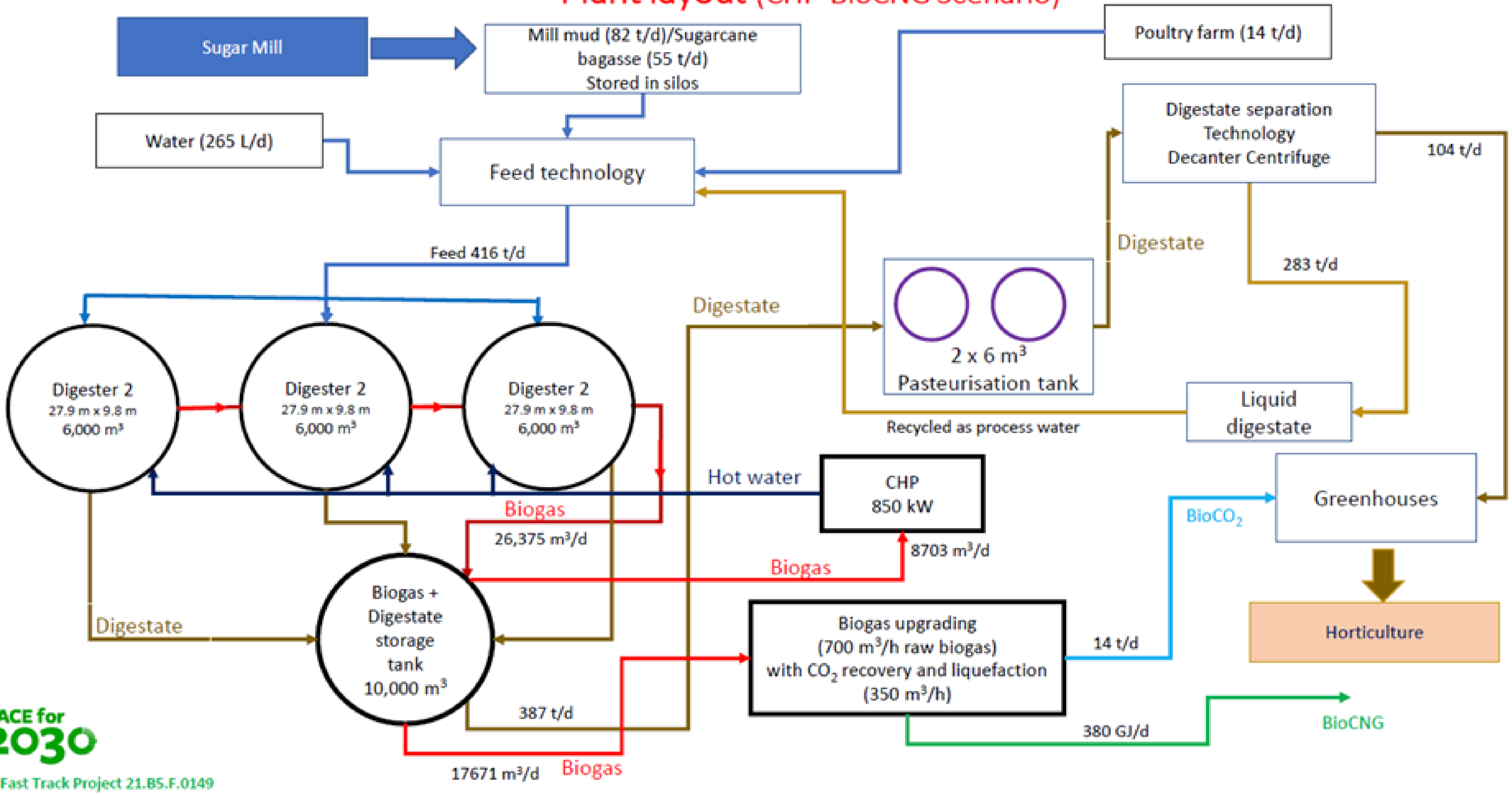

RACE for 2030

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Mass balance

	Units	Scenario 1 CHP	Scenario 2 CHP + BioCNG	Scenario 3 CHP + BioRNG
Total feedstock treated	t/d	151	151	151
Process water/mill wastewater	kL/d	265	265	265
Biogas produced	m^3/d	26,376	26,376	26,376
Electricity generated	kWh/d	61,456	19,797	19,797
	GJ/d	222	71	71
Heat generated	kWh/d	58,304	19,276	19,276
	GJ/d	210	70	70
Biomethane produced	GJ/d	–	380	380
Carbon dioxide produced	t/d	–	14	14
Parasitic demand—electrical	kWh/d	8,615	15,191	14,664
Parasitic demand—heat	kWh/d	17,337	17,337	17,337
Import of electricity	kWh/d	–	–	–
Import of heat (natural gas)	kWh/d	–	–	–
Exportable electricity—grid	kWh/d	52,840	4,605	5,133
Exportable heat	kWh/d	40,967	1,938	1,938
Digestate production	t/d	387	387	387

Assumptions

- EPCM—18% of CapEx
- Contingency—30% of total CapEx.
- O&M costs - 8% of the CapEx
- Feedstock cost of $40/t of chicken manure and $25/t of sugarcane bagasse and $0/t of mill mud.
- Fossil fuel electricity cost at $160/MWh to meet parasitic electrical and heating demand of the biogas plant.
- Biomass ensilation cost of $0.16/kg.
- Biomethane grid connection cost of $0.8/GJ.
- Biogas plant revenue: BioRNG gird injection: $8.5/GJ, BioCNG: $16/GJ and $200/t for uncompressed food-grade BioCO_2.
- Feed-in tariffs of $85/MWh for electricity to grid injection
- Solid digestate at $10/t as soil conditioner.
- Liquid digestate sale is not considered due to low nutrient content.
- Australian Carbon Credit Units (ACCUs) at $30/t CO_2-e
- Green certificates at $3/GJ

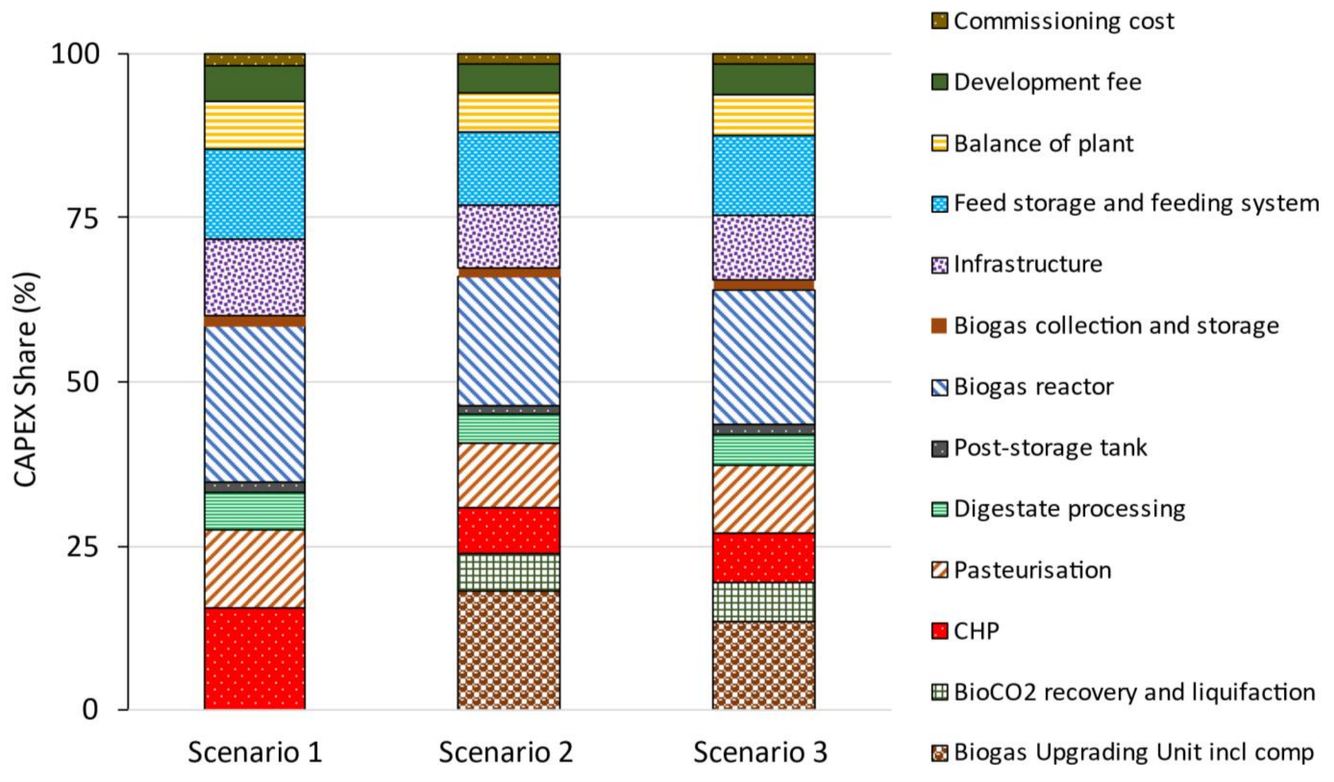
- ACCUs were calculated for the total GHG emissions avoided from use of renewable energy and the associated GHG emissions
- Green certificates were calculated for energy content in the biomethane produced.

Economic composition 2.2 MW biogas plant

Project parameters	Scenario 1 CHP	Scenario 2 CHP + BioCNG	Scenario 3 CHP + BioRNG
	($/year)	($/year)	($/year)
CapEx			
Total CapEx including contingency	17,315,495	21,147,455	20,006,575
Investment required (including EPCM)	20,432,284	24,953,997	23,607,759
Total OpEx	2,405,240	2,711,796	2,731,410
Total revenue	3,384,062	5,357,701	4,339,167
ROI (%)	4.8	10.5	6.7
IRR (%)	1.1	9.2	4.2
Payback period (years)	21	10	15
NPV ($)	–10,579,827	-1,303,418	–8,559,099

CapEx Costs

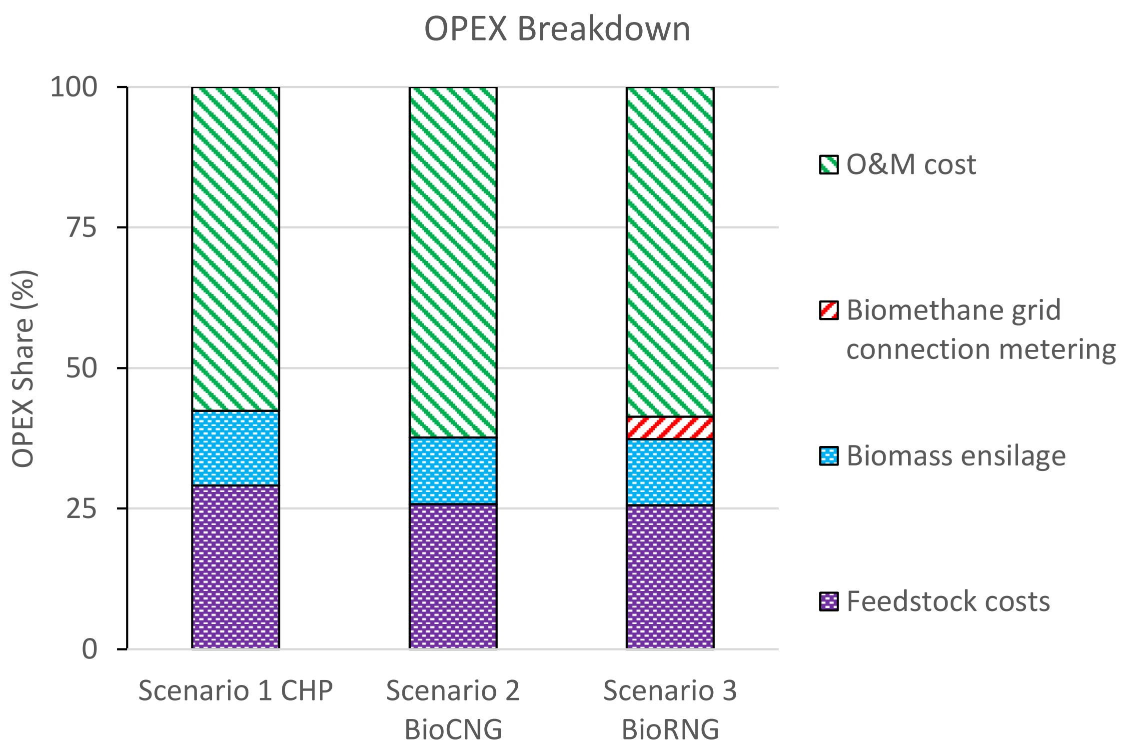
- CapEx varied slightly from Scenario 1 to Scenario 3.



Scenario 1	Scenario 2	Scenario 3
CHP	CHP + BioCNG	CHP + BioRNG

OpEx Breakdown

- O&M cost – Scenario 2 (62%) than Scenario 1 and 3 (58%)
- Feedstocks cost – Scenario 2 and 3 (26%) than Scenario 1 (29%)
- Biomass pretreatment/storage – 12-13%
- Biomethane grid injection – 4% (Scenario 3)



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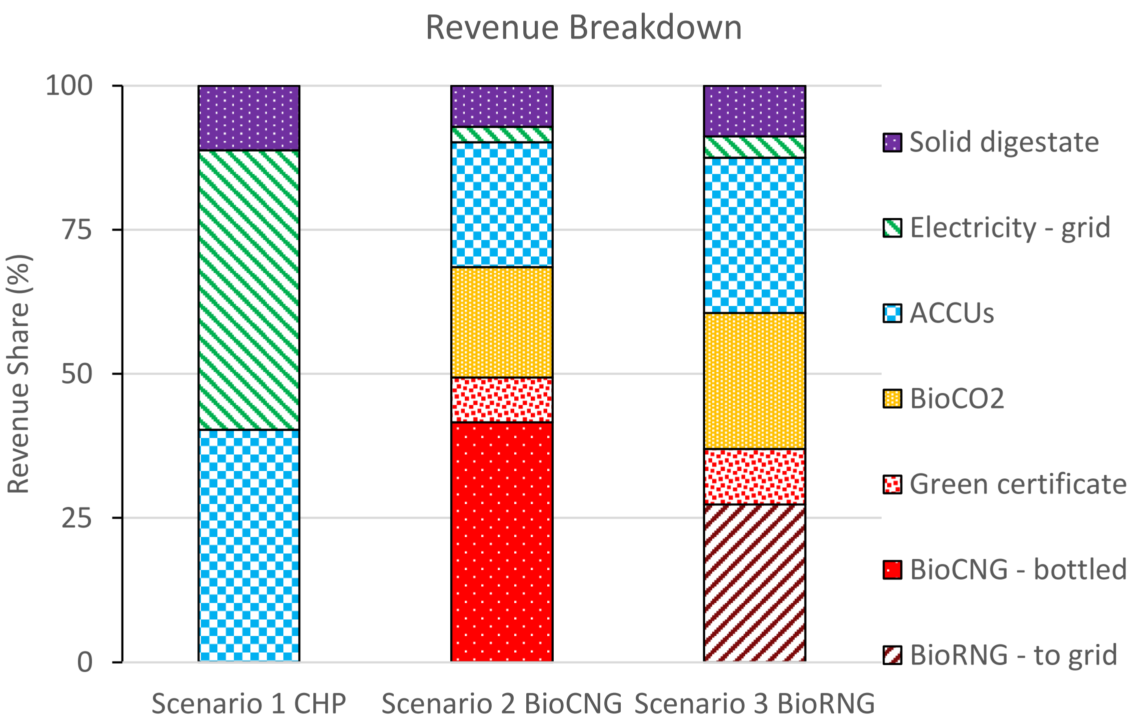
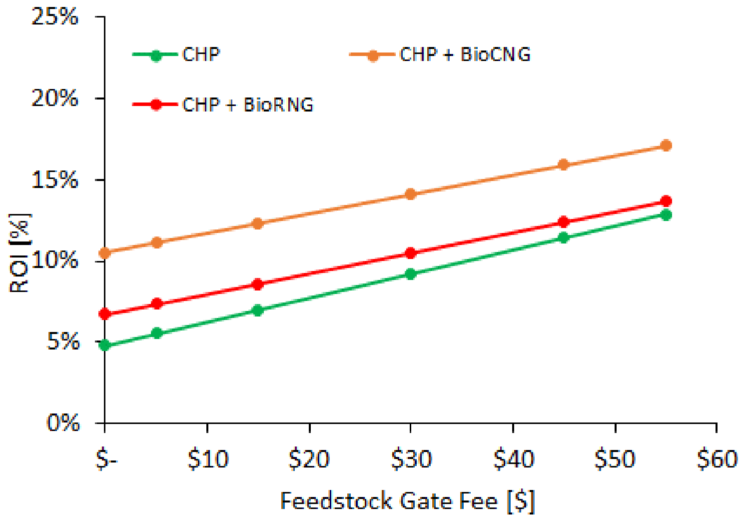
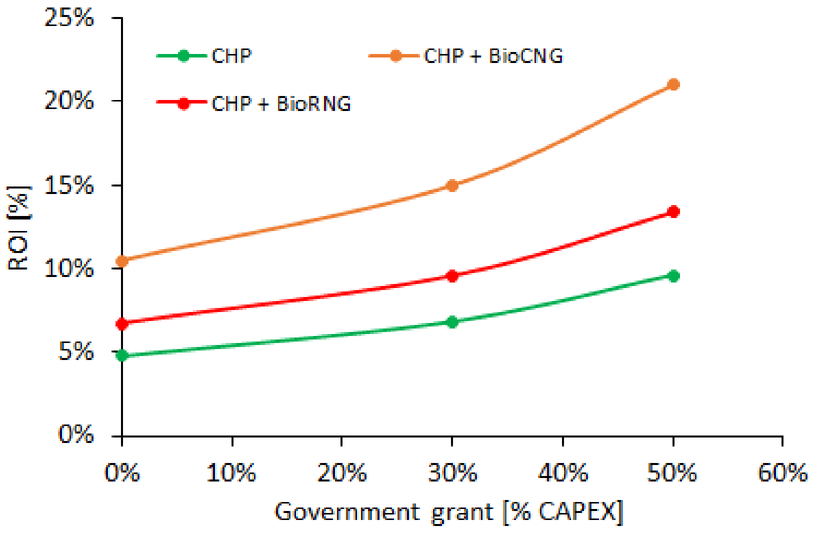
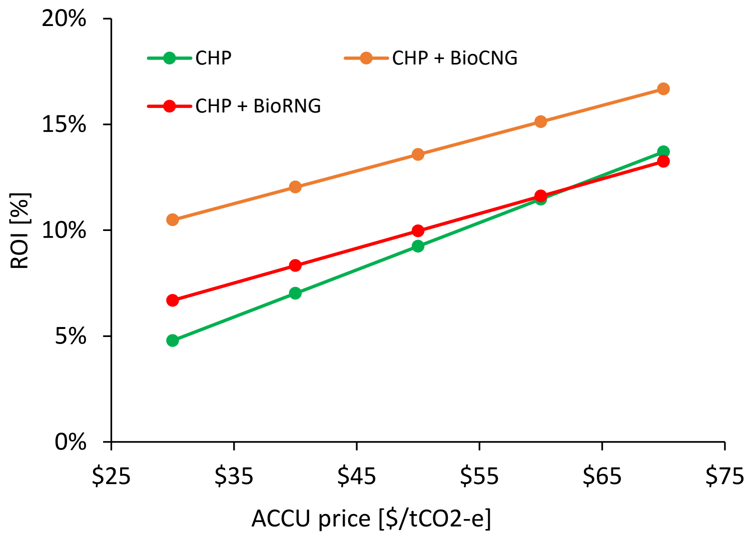
Revenue breakdown

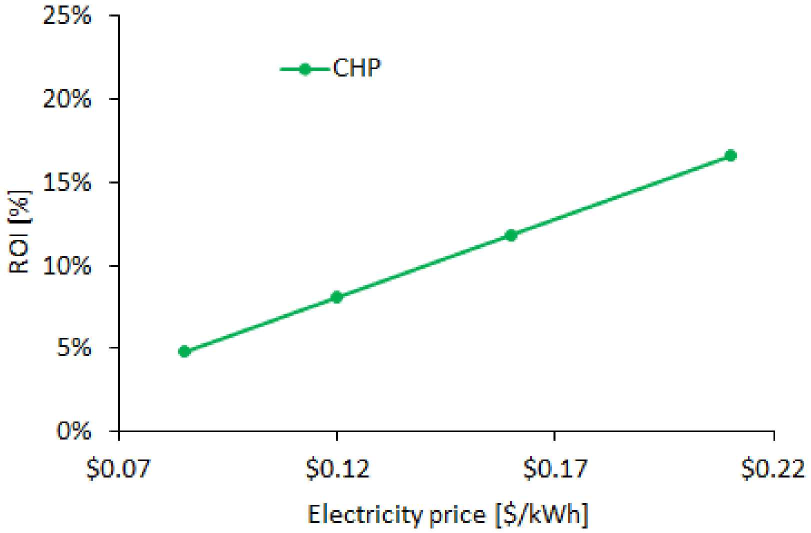


Sensitivity analyses









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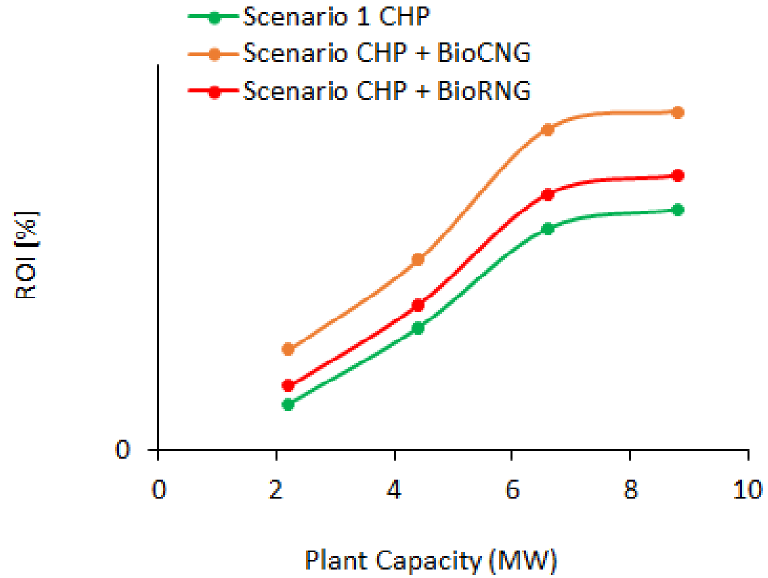
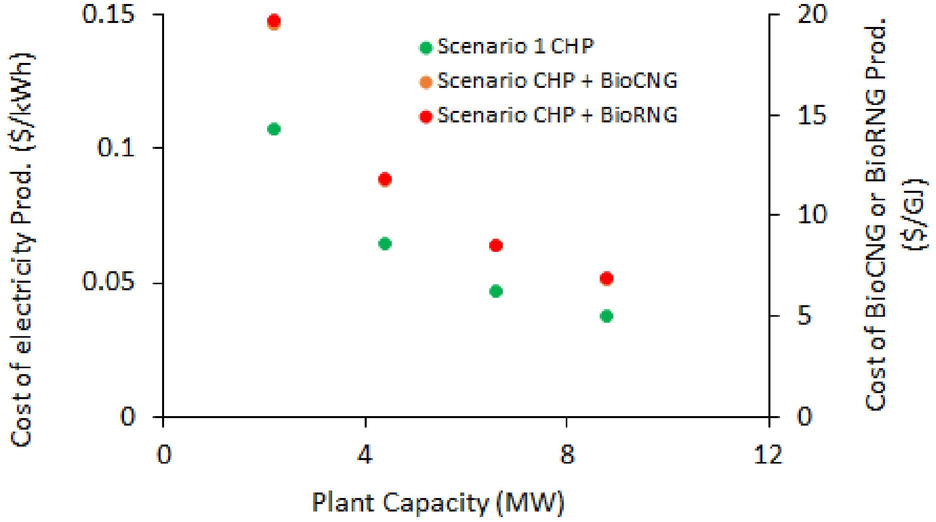
Scale of production

Plant size (MW)	2.2	4.4	6.6	8.8
(GJ/d)	380	759	1,139	1,519
Scenario 1				
ROI (%)	4.8	12.7	22.9	24.9
PBP (year)	21	8	4	4
NPV—25 years, 10% DR ($million)[1]	-10.6	3.8	29.5	45.9
IRR (%)	1.1	11.8	22.8	24.8
Scenario 2				
ROI (%)	10.5	19.8	33.3	35.1
PBP (year)	10	5	3	3
NPV—25 years, 10% DR ($million)[1]	-1.3	26.5	67.8	97.7
IRR (%)	9.2	19.5	33.3	35.1
Scenario 3				
ROI (%)	6.7	15.1	26.5	28.4
PBP (year)	15	7	4	4
NPV—25 years, 10% DR ($million)[1]	- 8.6	11.5	44.4	66.7
IRR (%)	4.2	14.5	26.4	28.4





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GHG emissions

Greenhouse gas emissions	Scenario 1 CHP	Scenario 2 CHP + BioCNG	Scenario 3 CHP + BioRNG
	(t/a CO_2-eq)	(t/a CO_2-eq)	(t/a CO_2-eq)
1. Greenhouse gas emissions from fossil fuel use			
a. Transport of chicken manure	–50	–50	–50
2. Emissions from diverting current management practices			
a. Stock piling of mill mud	29,944	29,944	29,944
b. Bagasse as solid fuel in boiler	269	269	269
c. Composting of chicken manure	105	105	105
Subtotal	30,318	30,318	30,318
3. Emissions from replacing fossil fuel electricity or natural gas			
a. Electricity generation	15,429	1,345	1,499
b. Natural gas	–	7,142	7,142
Subtotal	15,429	8,487	8,641
4. Emissions on replacing inorganic fertiliser with digestate			
a. Emissions from equivalent N fertiliser production (urea) and application	287	287	287
b. Emissions from digestate application	–478	–478	–478
Subtotal	–191	–191	–191
Total	45,506	38,564	38,718

Conclusion

- The study shows that a 2.2 MW biogas plant is feasible and can generate approximately 9.35 million Nm^3 of biogas per year through co-digestion of 20,000 tonnes per year of sugarcane bagasse and 30,000 tonnes per year of mill mud with locally available 5,000 tonnes per year of chicken manure.
- Financial analyses showed that total investment required for the biogas plant could vary from $20.43 - $24.95 million and is dependent on the technology and equipment used for biogas use.
- ROI is dependent on the revenues generated especially from variable parameters such as feedstock gate fee, government investment grants and guaranteed feed-in tariffs, ACCUs and green certificates.
- Internalising the environmental benefits of avoided GHG emissions through inclusion of ACCUs and green certificates, ROI for the studied scenarios are 4.8%, 10.6% and 6.7% for Scenario 1, 2 and 3, respectively. Conversely, ROIs without ACCUs and green certificates would be -1.9% to 4.2%.
- Onsite production and/or use of renewable energy will enable the agricultural farmers to achieve sustainable management of these agricultural wastes and achieve decarbonising of agricultural sector.

Thank you

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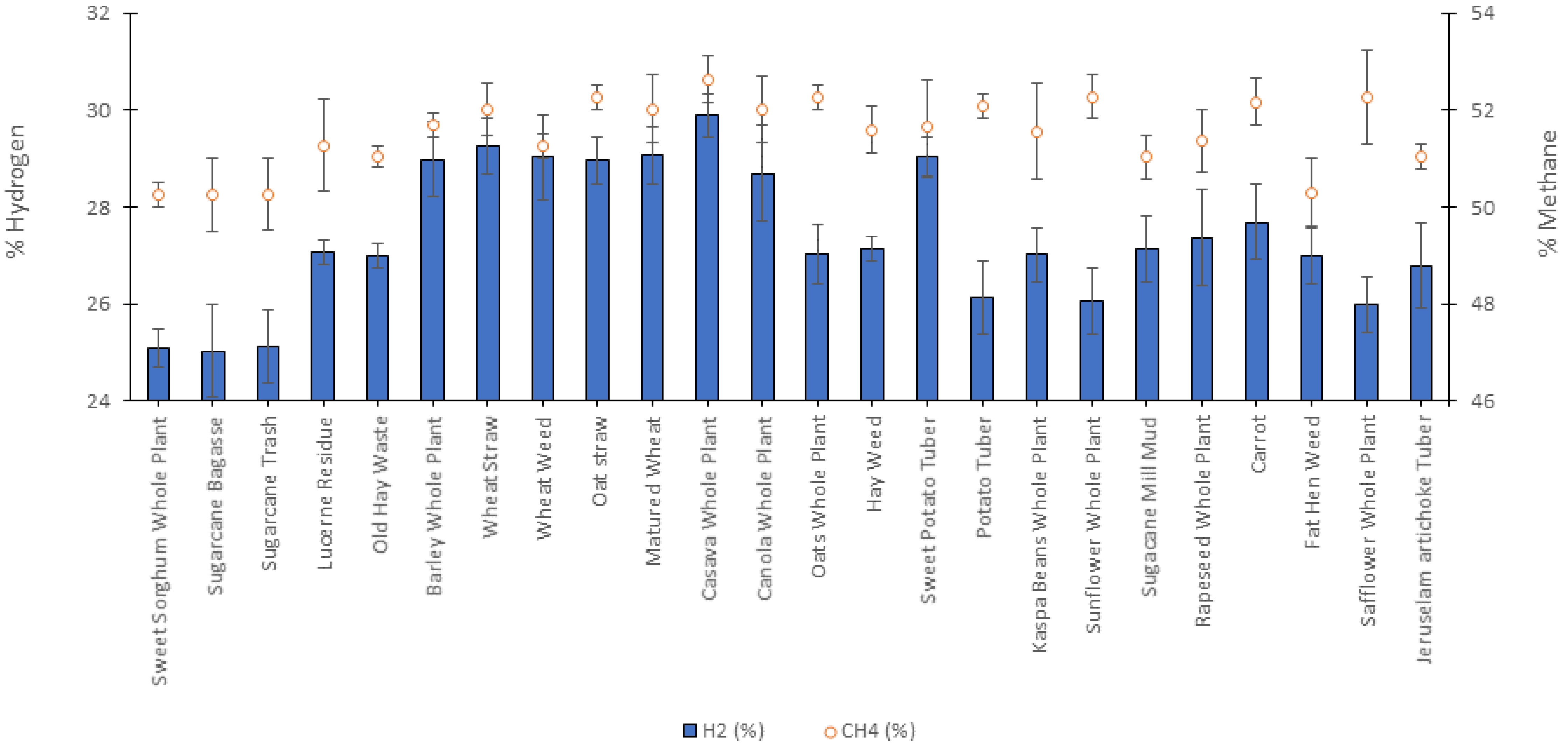
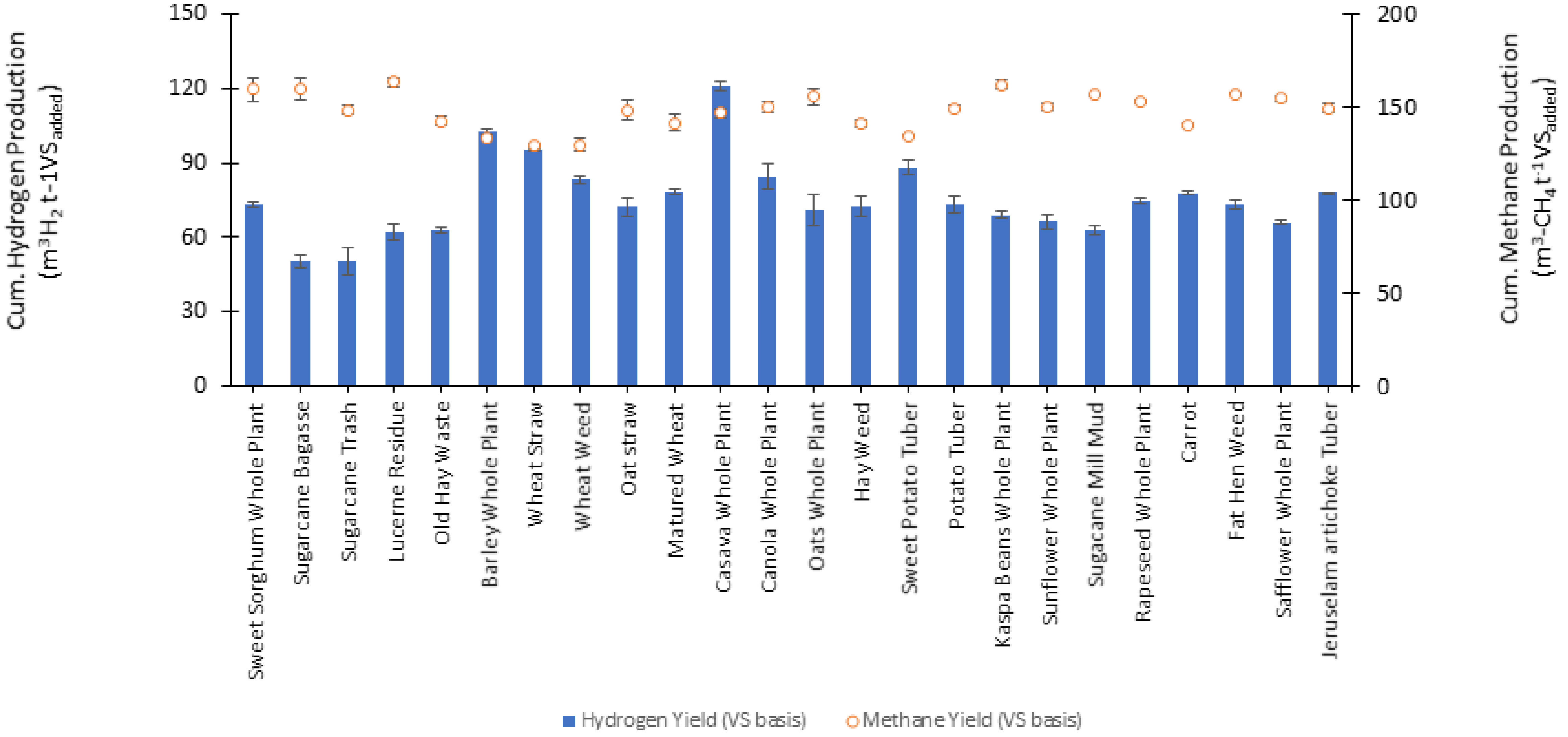
To determine the bioH2 and bioCH4 potential of agricultural crops and residues in batch experiment

- **Batch experiments**
- 24 agril. Crops/residues
- Inoculum to substrate ratio of 2
- Incubation: 37 °C
- Duration: 30 days
- Measurements: Biogas composition (H_2/CO_2 or CH_4/CO_2)

Hydrogen and methane content in the biogases



Biochemical biohydrogen and methane potentials (based on organic matter)



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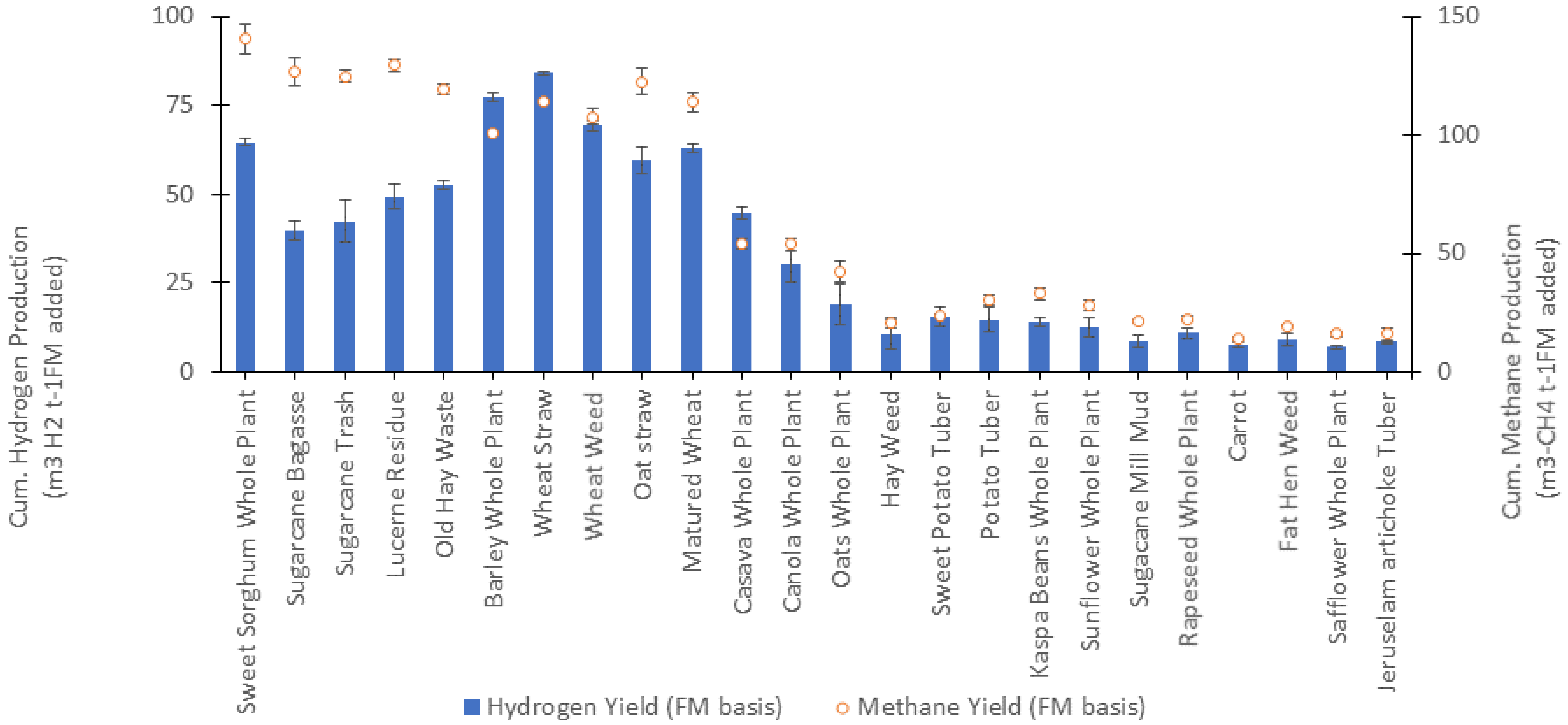
Biochemical biohydrogen and methane potentials (based on fresh matter)



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