TECHNOLOGY AND EQUIPMENT FOR LIGNOCELLULOSIC WASTE CONVERSION TO BIOFUELS AND BIOPRODUCTS WITH HIGH ADDED VALUE

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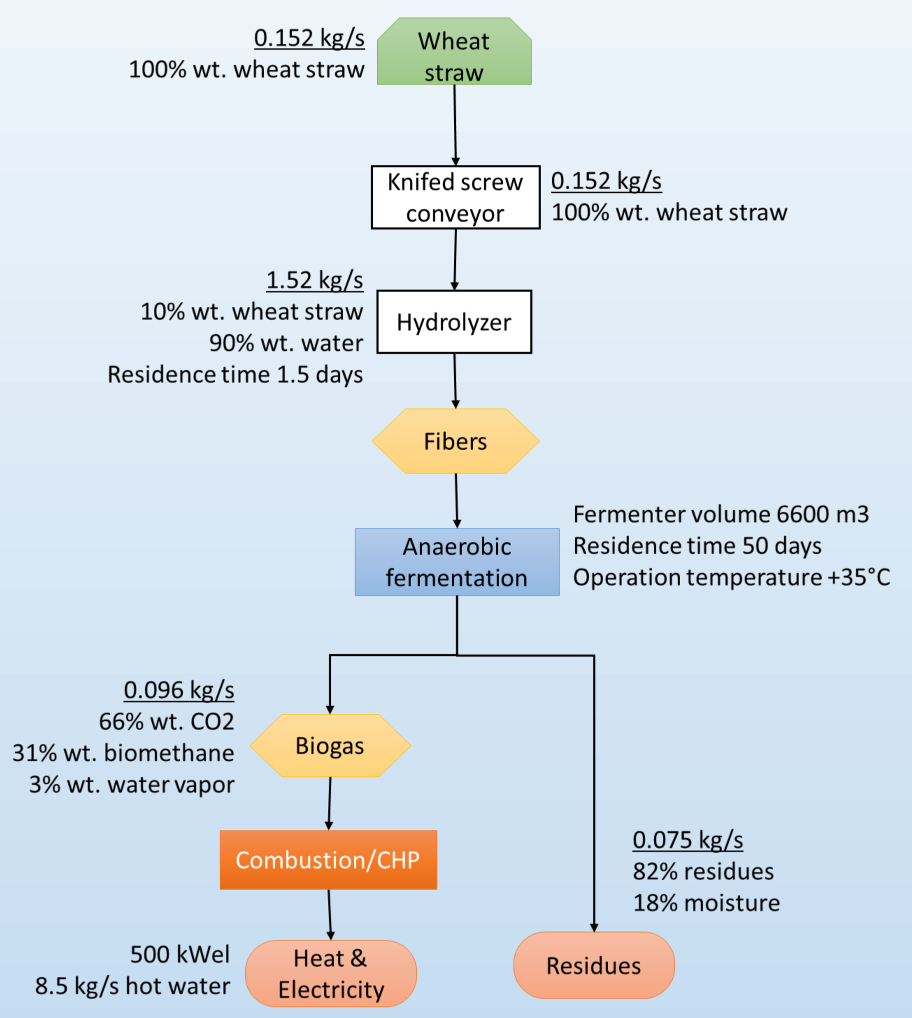
INTRODUCTION

The study examines the feasibility of biogas biorefineries as a sustainable platform for material and energy recycling. The hypothesis tested is the design of biogas plants within the biorefinery concept can be economically attractive without subsidies. The investigation considers various concepts of biogas plants and biorefineries, with differing substrate pretreatment methods and product processing techniques. Parametric models are created for each concept, allowing a comparison of mass and energy balances, technical maturity, and economic feasibility. Analysis shows that all concepts except biogas upgrading are unfeasible with negative payback periods, while biogas upgrading still lacks investment appeal.

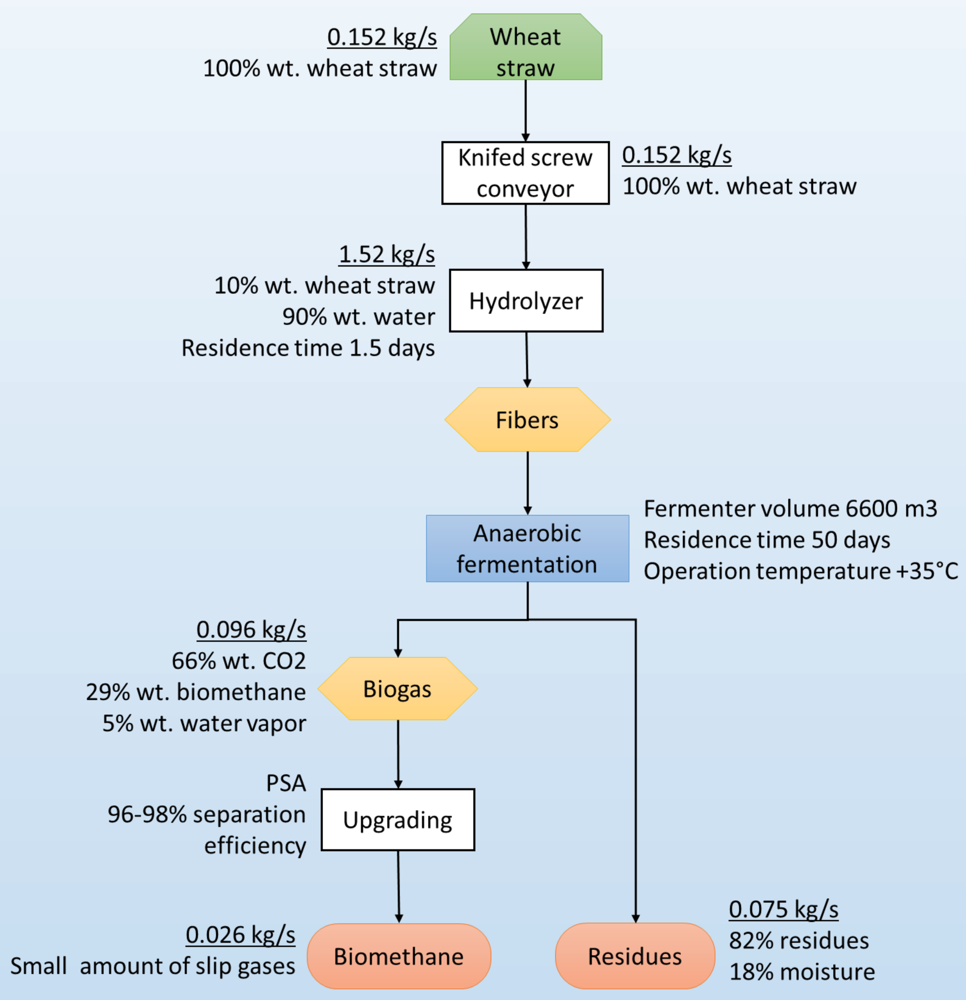
OBJECTIVES

- To create a general parametric model of biogas biorefinery enabling a comparative evaluation of mass and energy balances, technical maturity and design economics, including sensitivity analysis.
- To investigate an innovative technological set treating lignocellulosic biomass in biorefinery concept to reach investment attractiveness without any subsidies.

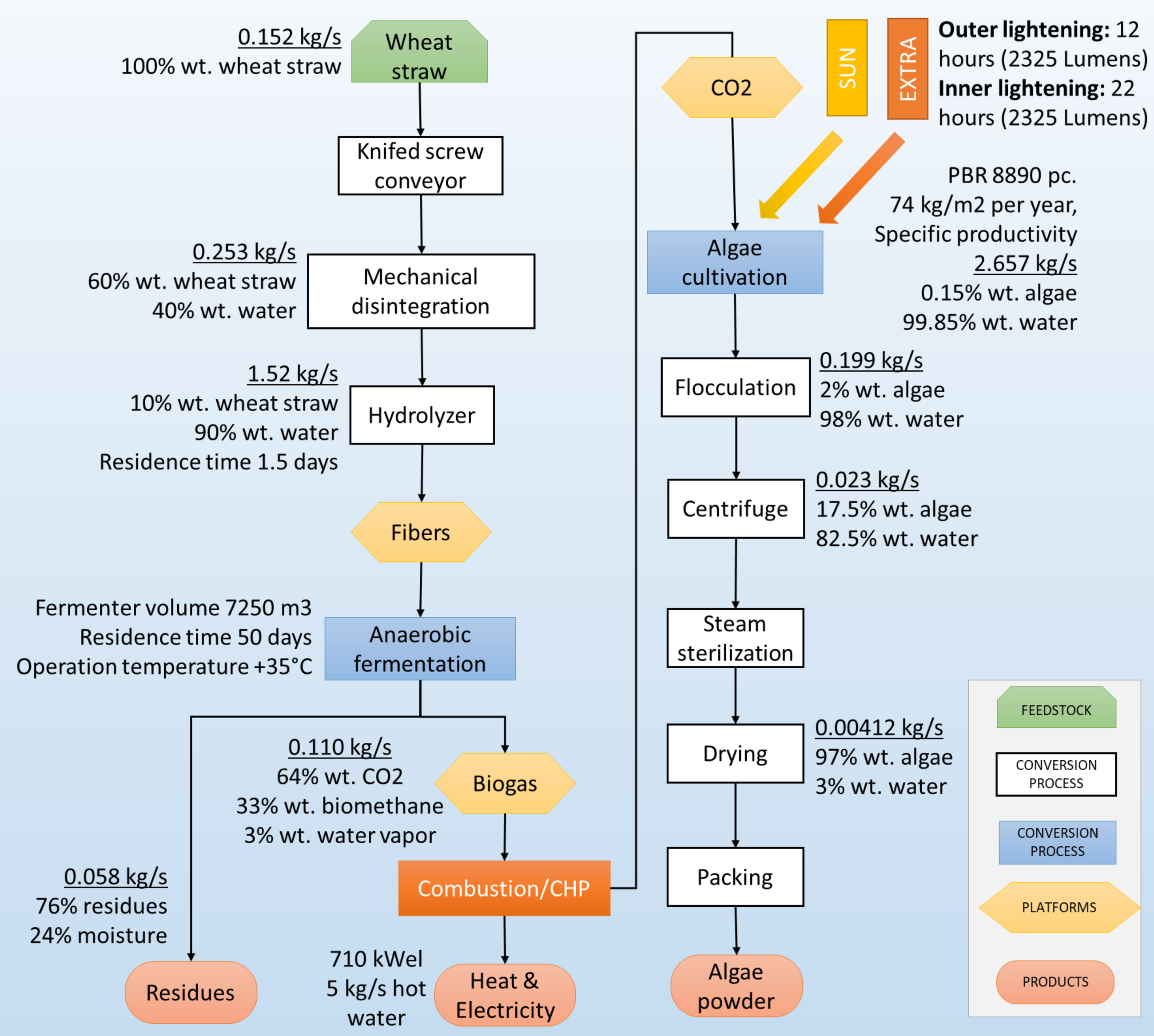
CONVENTIONAL BIOGAS PLANT



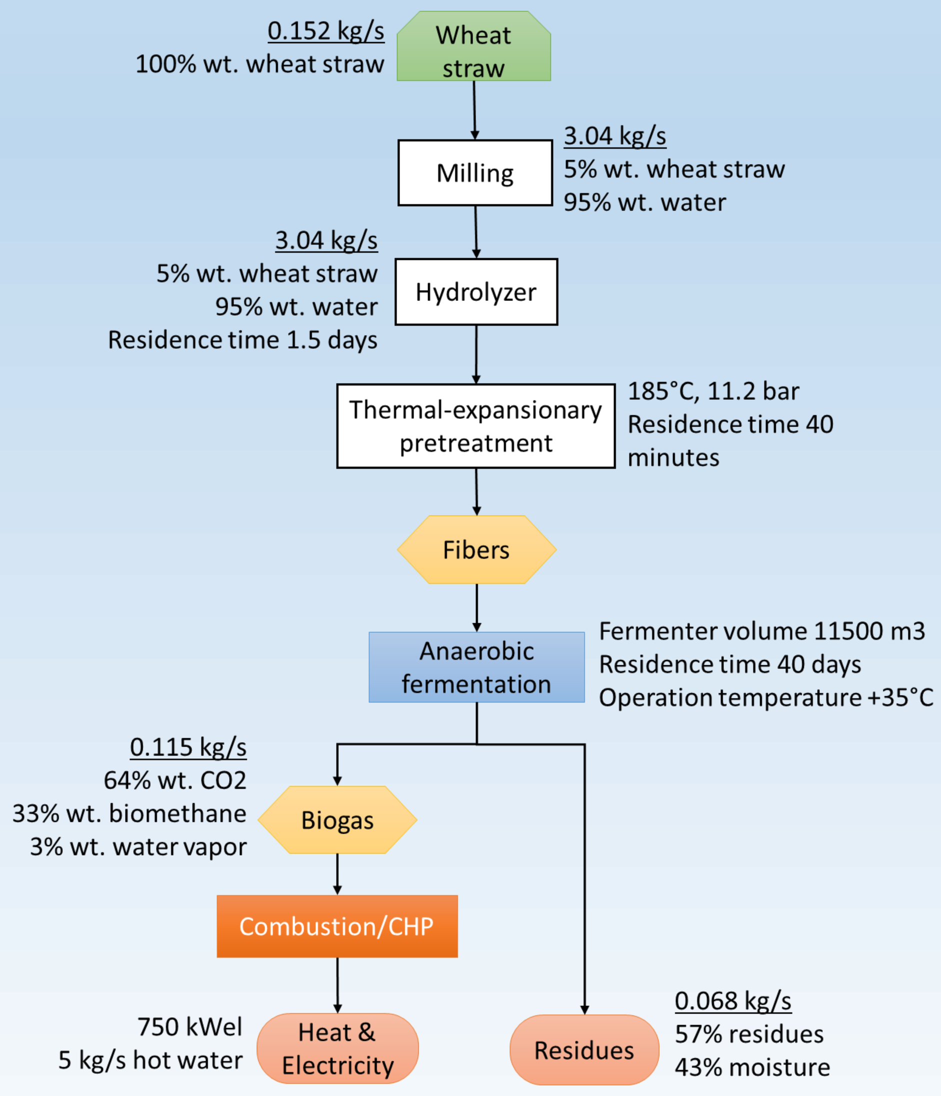
BIOGAS UPGRADE



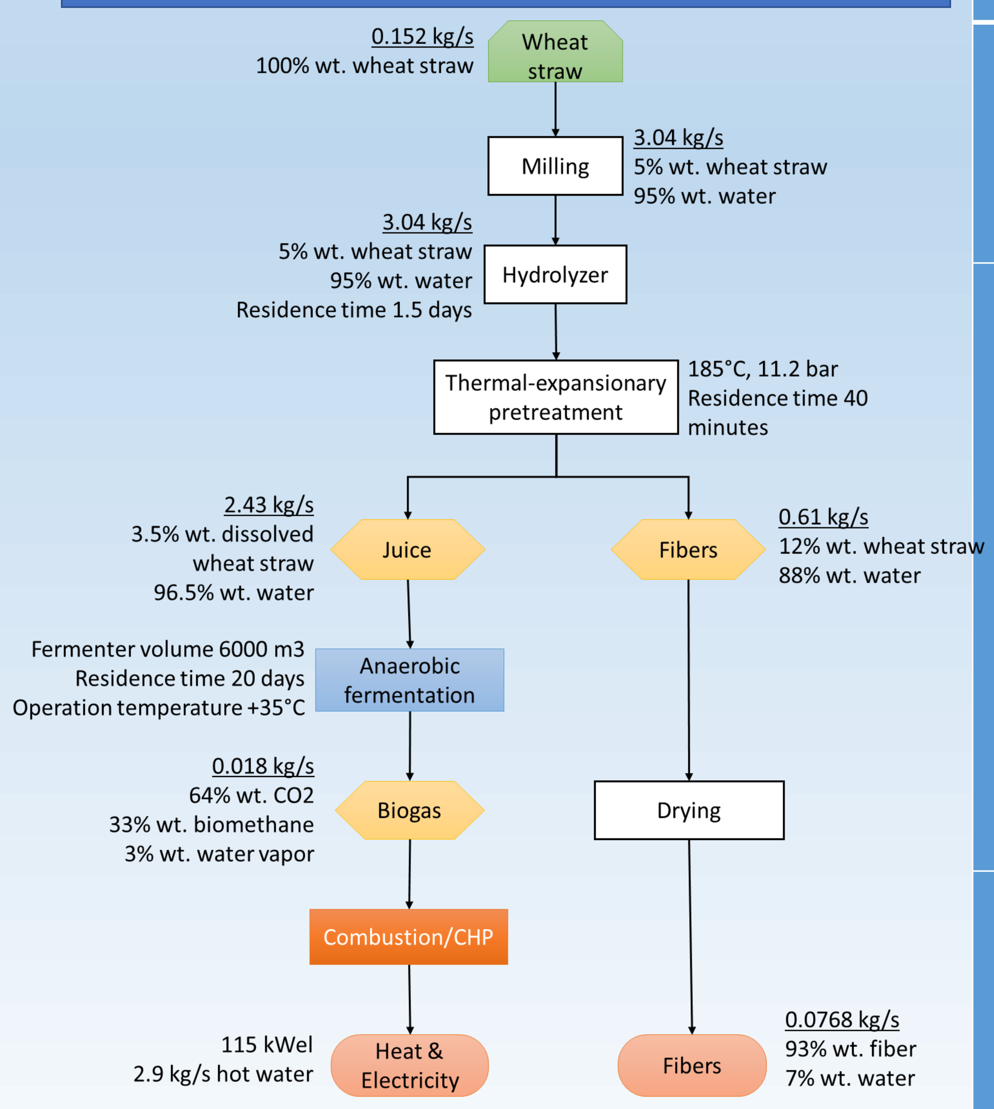
BIOGAS-ALGAE BIOREFINERY

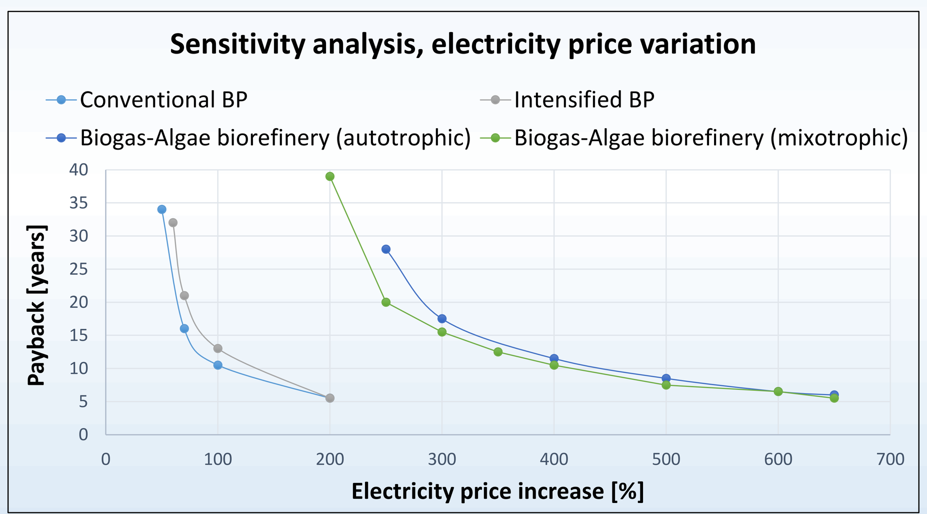


INTENSIFIED BIOGAS PLANT



BIOGAS-FIBER BIOREFINERY





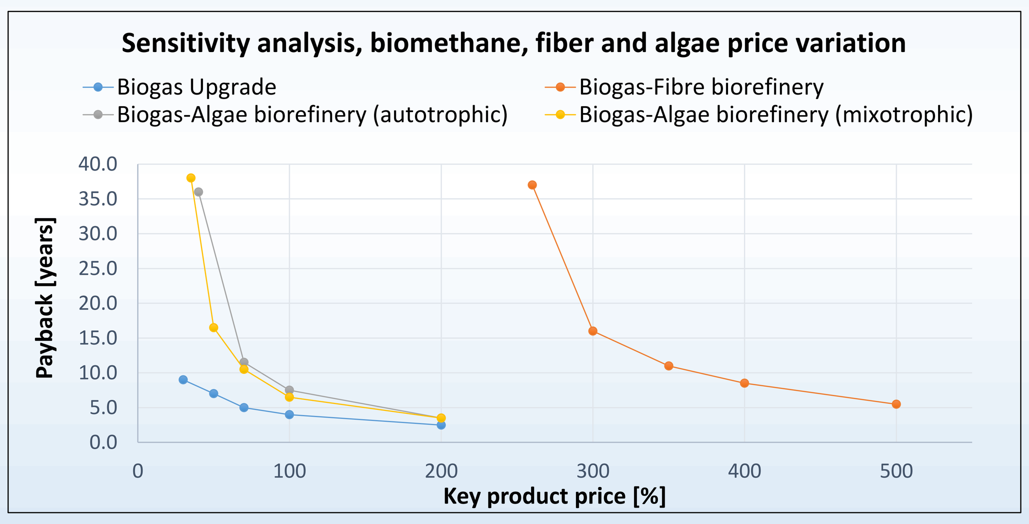


Table of RESULTS comprising of process, cost of production and economic analysis evaluations

	Name	Conventional Biogas Plant	Biogas upgrade	Intensified Biogas Plant	Biogas-fiber Biorefinery	Biogas-Algae Biorefinery (auto. growth)	Biogas-Algae Biorefinery (mixo. growth)
PROCESS (Biogas, fiber plant)	Substrate mass flow [$kg_{TS}\ s^{-1}$]	0.152					
	OLR value [$kg_{vs}\ m^{-3}\ d^{-1}$]	2.00	2.00	1.25	2.50	2.00	
	Residence time [days]	50	50	40	20	50	
	Fermenter volume [m^3]	6 600	6 600	11 500	6 000	7 223	
	Biogas yield [$Nm^3\ t^{-1}_{TS}$]	509±58	509±58	633±52	100	605±17	
	Methane yield [$Nm^3\ t^{-1}_{TS}$]	243±49	243±49	362±43	55	343±11	
	Annual residuals production [ton]	1 750	1 750	1 150	-	1 200	
	Annual CO_2 release [ton]	5 300	1 850	5 450	1 250	7 100	
	CHP electric power [kW_{el}]	500	-	750	110	709	709
	Products, and by-products	Heat & electricity, residue	Biomethane, residue	Heat & electricity, residue	Fiber, heat & electricity	Heat & electricity, algae, residue	
PROCESS (Algae plant)	Algae specie [-]	N/A				Chlorella vulgaris	
	PBR type [-]					Co-annular	
	PBR working volume [L]					258	
	PBR area occupation [m^2]					14000	
	Light:Dark ratio [-]					22:2 (internal), 15:7 (external)	12:12 (internal and external)
	Consumable					BBM + sulfuric acid, every 3 days	BBM + sulfuric acid, every 2 days
	Productivity [$g\ L^{-1}\ d^{-1}$]					0.15	
	Resident time [day]					10	
	Annual algae productivity [ton]					107.451	
ECONOMIC ANALYSIS	TFCC [$ mil.]	3.136	3.248	4.973	3.923	16.671	
	Fermenter percentage of ISBL	48%	47%	53%	40%	10%	
	Purchased Capital Cost, algae plant:biogas plant [%]	N/A				77%	
	Variable Operation Cost [$ mil. y^{-1}]	0.09	0.20	0.32	0.55	4.7	4.51
	Fixed Operation Cost [$ mil. y^{-1}]	056	0.60	0.67	0.58	1.681	
	Specific Investment[$(TFCC) kW^{-1}_{el}]	6 300	NA.	6 630	35 660	23 500	
	Gross Profit [$ mil. y^{-1}]	-0.07	0.33	-0.15	-0.72	-0.75	-0.52
	Discounted payback period [year]	negative	17	negative	negative	negative	negative
	NPV at the end of plant lifetime [mil. $]	-3.3	-0.2	-5.6	-9.3	-21.4	-19.5

DISCUSSION

This study analyzes the estimation of different biogas plant realizations without subsidies. It found that biogas plants with thermal-expansionary pre-treatment had the highest biogas and methane yields and the CHP unit in intensified biogas plants had the highest installed electric power. Biogas plants in biorefinery concepts had other key-products, such as fiber and high-value algae. However, the results showed that all concepts, except for biogas upgrade, had negative payback periods, meaning a negative profit. Although biogas upgrade had a positive payback period of 17 years, it was still not economically feasible. Despite these limitations, biogas plants can provide a reliable platform for electricity shortages and can be combined with other technologies to produce different key-products. Designing economically feasible renewable energy projects requires consideration of capital cost, production costs, and revenues from key products. The study shows the potential for biogas to be a reliable and versatile renewable energy source.

CONCLUSION

- Original parametric models were created for individual model technological configurations of the biogas biorefinery, which enabled a comparative evaluation of mass and energy balances, technical maturity, and design economics.
- The dissertation refutes the hypothesis that the design of BP in the biorefinery concept can achieve economic attractiveness without the implementation of subsidized product selling prices.
- Conventional BP showed that it could not be sustainable without subsidies. The electricity price is too low for economic feasibility. However, the production is well known, making the process more reliable and predominantly selectable.
- Biogas upgrade with current assumptions, free raw material mainly, showed the best sustainability, compared to the other concepts. The process is well known. However, the critical factor here is the price of biomethane.
- Intensified BP cannot be sustainable even having free raw material. Subsidies here play a crucial part. Also, the new pre-treatment method process cannot be completely reliable now.
- Biogas-fiber biorefinery showed the worst sustainability. In addition, the value of dry fiber is low, which means selling price growth cannot be foreseen.
- Both biogas-algae biorefineries showed their unsustainability. A critical factor is the selling price of algae. The demand for biogas and algae should go up in the future, making this concept quite promising.

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