Feasibility Assessment of a Bioethanol Plant in the Northern Netherlands

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Abstract: Due to the exhaustion and increased pressure regarding the environmental and political aspects of fossil fuels, the industrial focus has switched towards renewable energy resources. Lignocellulosic biowaste can come from several sources, such as industrial waste, agricultural waste, forestry waste, and bioenergy crops and processed into bioethanol via a biochemical pathway. Although much research has been done on the ethanol production from lignocellulosic biomass, the economic viability of a bioethanol plant in the Northern Netherlands is yet unknown, and therefore, examined. In this thesis, the feasibility study of a bioethanol plant treating sugar beet pulp, cow manure, and grass straw is conducted using the simulation software SuperPro Designer. Results show that it is not economically viable to treat the tested lignocellulosic biomass for the production of bioethanol, since all three original cases result in a negative net present value (NPV). An alternative would be to exclude the pretreatment step from the process. Although this results in a lower production of bioethanol per year, the plant treating sugar beet pulp (SBP) and grass straw (GS) becomes economically viable since the costs have significantly decreased.

Keywords: lignocellulosic biowaste; bioethanol; plant design; saccharification; co-fermentation; viability

1. Introduction

The depletion of fossil fuel sources, the wobbling prices of fuels, and the increased pressure regarding environmental and social aspects have increased the industrial focus towards renewable energy resources such as organic waste [1–9]. Organic residues have been considered an inexpensive, renewable, widely available, and environmentally friendly feedstock for biofuels production [10–14]. Currently, large quantities of biofuels are generated from first-generation resources, such as starch, corn, and sugar [15–19]. Although this is a more efficient way of producing fuel compared to fossil fuel sources, the drawback of using first-generation resources is that these products are part of the food supply. The increased demand for first-generation resources negatively affected the availability of food [20–24]. Additionally, first-generation resources require large amounts of fertile land, and most agricultural land is already occupied. Therefore, a better fitting source for the production of biofuels is organic residues since they have no negative impact on food production or land use, resulting in a more sustainable feedstock utilization for the production of bioethanol [25–28].

Lignocellulose is a natural composition consisting of cellulose, hemicellulose, and lignin. The dry weight mainly consists of cellulose, namely 35–50%, a further 20–35% of hemicellulose, and around 10–25% of lignin [29]. Lignocellulosic waste can come from several sources, namely industrial waste (e.g., recycled newspaper, food industry residues, sawdust), agricultural waste (e.g., bagasse, rice straw, corn stover), forestry waste (e.g., wood chips, grasses, hard and softwood), bioenergy crops (e.g., common reeds, switchgrass), and municipal solid waste [30–32]. The lignocellulosic biomass

can be converted into bioethanol via a biochemical pathway. Biochemical conversion is based on enzymatic hydrolysis of the biomass into sugars. These sugars are fermented, and after distillery of the fermentation liquid, pure ethanol is obtained.

From the early 2000s to 2012, the biofuel consumption in Europe flattened out after increasing steadily. In 2017, 2718 t of oil equivalents (toe) of bioethanol was consumed for transport in Europe, of which 121 toe was consumed by the Netherlands [33]. Although much research has been done on the ethanol production from lignocellulosic biomass [34–44], the economic viability of a bioethanol plant in the Northern Netherlands is yet unknown. Therefore, this research aims to investigate the feasibility of a bioethanol plant treating organic residues (sugar beet pulp and grass straw) in the Northern Netherlands. In this study, the economic analysis is conducted to evaluate the profitability of the plant based on net present value (NPV) and internal rate of return (IRR). This study provides techno-economic information to a broad audience and can also be used as a baseline study for further business investigations.

2. Materials and Methods

2.1. Feedstocks

Sugar beet pulp (SBP) is a byproduct of sugar beet processing and is a type of lignocellulosic biomass which can be used for the production of bioethanol. SBP is the remainder of the cossettes after treatment with warm water to extract the sugar [45]. From one metric ton of sugar beet, 160 kg of sugar, 500 kg wet pulp, and 38 kg of molasses can be obtained [46]. In 2018, the harvest of sugar beets in the Northern Netherlands was 2,108,596 t [47,48], meaning a total of 1,054,298 t SBP was available. SBP mainly consists of polysaccharides, such as cellulose (22–30%), hemicellulose (24–32%), lignin (1–2%), pectin (38–62%), and small amounts of fat, protein, and ash, which leads to a dry matter content of 75–85% [46]. Since the sugar beets are harvested from mid-September until the beginning of December, SBP is not vastly available. To solve this problem, SBP can be bought and stored at −20 °C, so the SBP can be continuously processed throughout the year [46].

Grass straw (GS) is a byproduct of grass seed production and mostly consists of cellulose (40–50%), hemicellulose (25–35%) and lignin (15–25%) [49]. Due to the high content of cellulose and hemicellulose, GS is a promising feedstock for the production of bioethanol. Grass straw is available throughout the whole year if it is not frozen. In 2018, 933,020 hectares were occupied as grassland in the north of the Netherlands [50], which produced 3 metric tons of straw per hectare per year [51]. The composition of the feedstocks used in SuperPro Designer (Intelligen: New Jersey, USA) can be found in Table 1.

Table 1. Composition of the feedstocks.

Component (Mass %)	SBP	GS
Ash	5.1	8.9
Cellulose	15.1	28.8
Extractives	n.a.	0.5
Fats	n.a.	n.a.
Hemicellulose	18.2	18.8
Lignin	0.9	13.4
Pectin solids	20.8	n.a.
Proteins	10.3	4.7
Trash	n.a.	0.5
Water	29.6	7.0
Dry matter content (%)	70.4	92.5

2.2. Process Design

2.2.1. Front End Operations

To model the process, a quantity of 10,000 metric tons of lignocellulosic biowaste per year was assumed. For the transportation of the biomass to the plant, trucks were used (Figure 1). Since the project focusses on the Northern Netherlands and the plant will be located in the Northern Netherlands, the transportation distance is assumed to be 30 km. It is assumed that the plant will be operating 90% of the time, resulting in an annual operating time of 7884 h, and operating in batch mode. Each batch will be transported with a conveyer belt to the grinder to reduce its size. The grinder performs multiple cycles per batch to decrease the purchase costs of larger scale equipment.
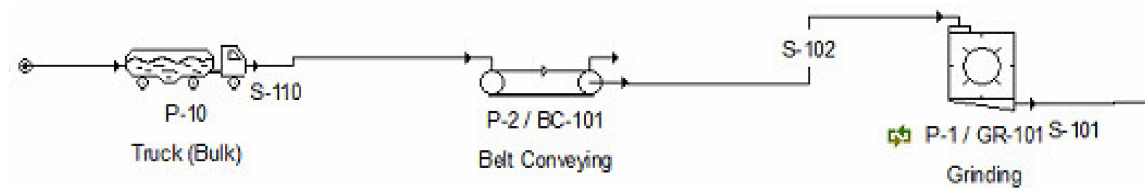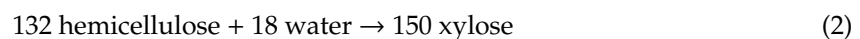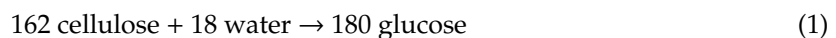

Figure 1. Process flow diagram of front-end operations in SuperPro Designer.

During the scenario analysis, two scenarios were used to see the influence of the change in the process on the economic evaluation. The first scenario included pretreatment, and the second excluded the pretreatment section. The overall batch time of SBP was 72 h which means 109 batches were processed per annum. To reach the yearly supply, the batch size was set to 91,743.12 kg/batch. To make SBP vastly available it can be stored in storage tanks, but this would drastically increase the costs. Therefore, the SBP will be bought from third parties to minimize the costs. SBP will be bought with a purchase price of 14 € per metric ton [52], which results in a raw materials expense of 105,000 €. The overall batch time with GS was 120 h, which means 65 batches per year could be processed. To reach the yearly supply, the batch size was set to 153,846 kg/batch.

2.2.2. Pretreatment

Before the cellulose and hemicellulose can be converted into hexose and pentose sugars, the lignocellulosic biomass must be pretreated to expose the polysaccharide. The biomass was mixed with sulfuric acid in a vessel, where thermal hydrolysis occurred. During thermal hydrolysis, the cellulose is converted to glucose, and the hemicellulose is converted to xylose according to Equations (1) and (2):

$$162 \text{ cellulose} + 18 \text{ water} \rightarrow 180 \text{ glucose} \tag{1}$$

$$132 \text{ hemicellulose} + 18 \text{ water} \rightarrow 150 \text{ xylose} \tag{2}$$

In Figure 2, an equipment overview is given of the pretreatment section. Since SBP has a low lignin and a high pectin content, the substrate only requires a mild pretreatment [46]. Before SBP can be fermented, the cell-wall must be disrupted to expose the polysaccharide. This was done by first milling the SBP to obtain particles from 0.8–1.0 mm [46] for 60 min. After that, the particles were diluted with 2% *w/w* sulfuric acid to obtain a dry matter content of 12% *w/w*. Then, according to [46] thermal pretreatment was performed by heating the solution for 30 min at 121 °C.

Likewise, with SBP, GS was ground for 60 min to reduce its size. After that, dilute acid pretreatment was performed. This was done by treating the GS with a sulfuric acid solution (1% *w/w* of solution) with a solid loading of 20% at 180 °C for 15 min [53]. Several studies investigated the effect of pretreatment on bioethanol production efficiency. However, it is not clear which technique favors maximal glucose and xylose release from the carbohydrate polymers, as well as is cost-efficient, as a financial analysis is required [54–61].
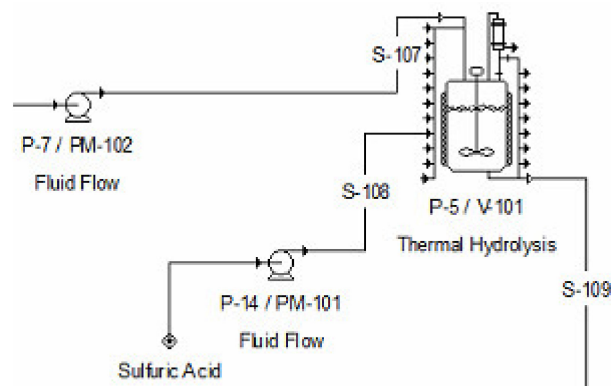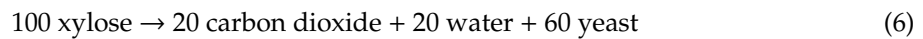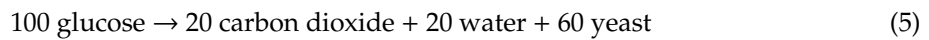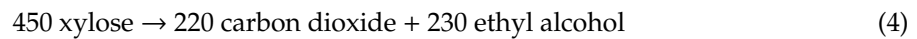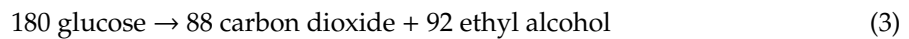
Figure 2. Process flow diagram of pretreatment section in SuperPro Designer.

2.2.3. Saccharification and Fermentation

After pretreatment, the solution went to the saccharification and fermentation section. Since simultaneous saccharification and co-fermentation was used, there was only one vessel required for the hydrolysis and fermentation of the hexose and pentose sugars. Inside the fermenter, reactions such as hydrolysis (Equations (1) and (2)), fermentation (Equations (3) and (4)), and growth of yeast (Equations (5) and (6)) occurred.

$$180 \text{ glucose} \rightarrow 88 \text{ carbon dioxide} + 92 \text{ ethyl alcohol} \tag{3}$$

$$450 \text{ xylose} \rightarrow 220 \text{ carbon dioxide} + 230 \text{ ethyl alcohol} \tag{4}$$

$$100 \text{ glucose} \rightarrow 20 \text{ carbon dioxide} + 20 \text{ water} + 60 \text{ yeast} \tag{5}$$

$$100 \text{ xylose} \rightarrow 20 \text{ carbon dioxide} + 20 \text{ water} + 60 \text{ yeast} \tag{6}$$

The efficiency of Equations (5) and (6) was assumed to be 3%. Furthermore, it was assumed that there were no inhibitors, such as furfurals, formed during the saccharification. In Figure 3, an overview is given of the saccharification and fermentation section.

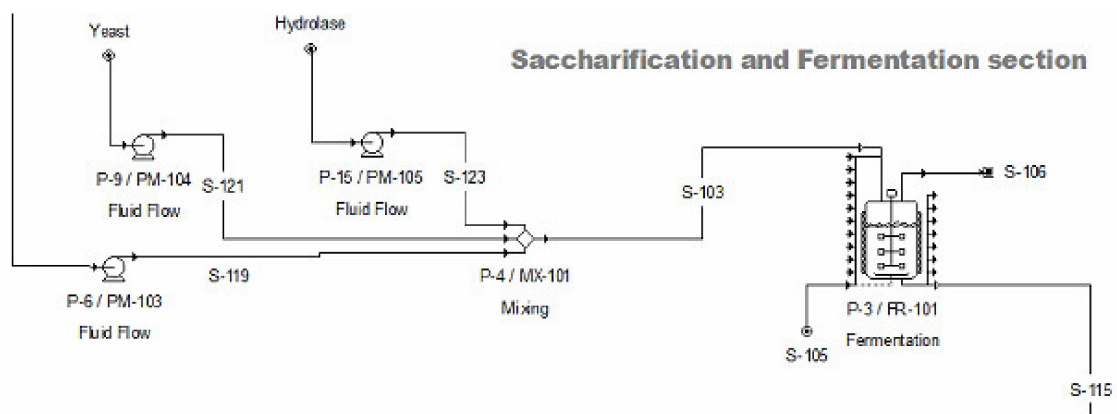**Figure 3.** Process flow diagram of saccharification and fermentation section modelled in SuperPro Designer.

For the hydrolysis, enzymatic hydrolysis is performed by using 0.02 mL/g d.m. of Viscozyme and Ultraflo Max, which was continuously heated and stirred at 40 °C for 6 h. To simulate the enzymes in SuperPro Designer, the component 'Hydrolase' was used. The efficiencies of hydrolysis can be found

in Table 2. For the fermentation, 1 g of Ethanol Red distillery yeast (*S. cerevisiae*) per 1 L of broth is required, which fermented glucose for 24 h at 37 °C. After that, 0.5 g per liter of *Pichia stipites* yeast was added for the fermentation of xylose [46] at the same temperature for 48 h. To simulate the Ethanol Red distillery yeast and *P. stipites* in SuperPro designer, the component 'Yeast' was used. The efficiency of SBP fermentation can be found in Table 2.

Table 2. Efficiencies regarding processing of sugar beet pulp (SBP) during simultaneous saccharification and fermentation.

Process	Efficiency (%)
Cellulose hydrolysis in pretreatment section	10
Hemicellulose hydrolysis in pretreatment section	70
Cellulose hydrolysis in saccharification and fermentation section	72
Hemicellulose hydrolysis in saccharification and fermentation section	72
Fermentation hexose sugars	90
Fermentation pentose sugars	87

During enzymatic hydrolysis, the polysaccharides were converted to simple sugars. A mix of cellulase and hemicellulase was used, with an enzyme loading of 15 FPU/g cellulose [53]. To simulate the enzymes in SuperPro Designer, the component 'Hydrolase' was used. The efficiencies of hydrolysis can be found in Table 3. A genetically modified strain of *Zymomonas mobilis* was used for fermentation in a ratio of 2 mg per 1 g biomass. The process of hydrolysis and fermentation ran for 120 h at 35 °C. To simulate the *S. cerevisiae* LF1 in SuperPro Designer, the component 'Yeast' was used. The efficiency of GS fermentation can be found in Table 3.

Table 3. Efficiencies regarding processing of grass straw (GS) during simultaneous saccharification and fermentation.

Process	Efficiency (%)
Cellulose hydrolysis in pretreatment section	13
Hemicellulose hydrolysis in pretreatment section	60
Cellulose hydrolysis in saccharification and fermentation section	79
Hemicellulose hydrolysis in saccharification and fermentation section	80
Fermentation hexose sugars	95
Fermentation pentose sugars	70

2.2.4. Ethanol Recovery

After fermentation, the broth was led into the beer column. In the column, the bioethanol was separated from the broth. After the beer column, the ethanol still contained a high amount of water. Therefore, the stream was rectified to reduce the water concentration further. In the absorber, the ethanol concentration is further increased to 99.7%. Thereafter, the ethanol can be sold for 0.78 €/kg. The absorber performs multiple cycles per batch to reduce purchase costs. In Figure 4, an overview is given of the saccharification and fermentation section.
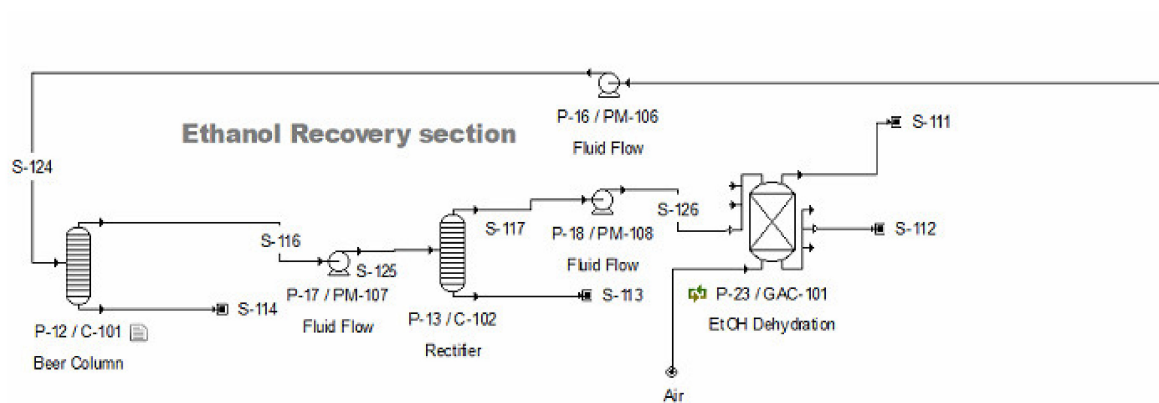
Figure 4. Process flow diagram of ethanol recovery section modelled in SuperPro Designer.

2.3. Economic Assessment

During the economical assessment, the focus was on the net present value (NPV), internal rate of return (IRR), and payback period. Economic viability is obtained when the NPV and IRR are above zero and the payback period is shorter than the operation period of the plant. These values were automatically calculated by SuperPro designer in an executive summary. Besides the NPV, IRR and payback period, SuperPro Designer gave data about the total investment, operating costs, revenue, unit production costs, and gross margin (Table 4). The total capital investment consists of the direct fixed capital, the working capital, and the start-up costs. The operating cost included the expenses of raw materials, labor, facility, laboratory, utilities, and transportation.

Table 4. Executive summary of SBP and GS as feedstock for the production of bioethanol in SuperPro Designer.

Plant Summary	Sugar Beet Pulp (SBP)		Grass Straw (GS)	
	Treated	**Untreated**	**Treated**	**Untreated**
Total Capital Investment (€)	2,584,000	1,931,000	39,450,000	1,993,000
Capital Investment Charged to This Project (€)	2,584,000	1,931,000	39,450,000	1,993,000
Operation Cost (€/year)	1,075,000	456,000	2,202,000	420,000
Revenues (€/year)	1,117,000	964,000	1,593,603	859,000
Batch Size (kg)	13,073	-	30,198	-
Cost Basis Annual Production Rate (kg/year)	1,424,990	1,228,939	1,962,890	1,094,616
Conversion (%)	14.25		19.63	
Unit Production Cost (€/kg)	0.75	0.37	1.12	0.38
Payback Time (years)	-	5.09	-	5.85
IRR (After Taxes) (%)	-	23.05	-	19.30
NPV (at 5% Interest) (€)	−671,000	3,367,000	−10,543,000	2,763,000

Furthermore, any possible subsidies were not included. It was assumed that the capital needed will come from an investor. NPV is the sum of the present values of annual net income earned in the period of project exploitation [62] and is defined as:

$$\text{NPV} = \sum_{k=0}^{N} \frac{c_k}{(1+i)^k} \tag{7}$$

where C_k = net income in the kth year of the period of project exploitation, i = the discount rate, and n = period of the project exploitation.

IRR is the discount rate where the NPV is zero [63] and can be defined as:

$$\text{IRR} = \sum_{k=0}^{N} \frac{c_k}{(1+i)^k} - C_0 = 0 \tag{8}$$

where C_0 = total investment costs.

The payback period is the time required to recover the investment [62,63] and is defined as:

$$\text{Payback period} = \frac{\text{Cost of Investment}}{\text{Annual Cash Inflow}} \tag{9}$$

3. Results and Discussion

Mapping the operating bioethanol plants in the Netherlands, it was found that none of these feedstocks are used for the production of bioethanol; but most of them are focused on corn stover, a feedstock that contains high amounts of cellulose (43.7%) and hemicellulose (23.7%) [64]. The investigation of the viability and sustainability of bioethanol plants is required, to give insights into new pathways for boosting the bioeconomy [65–68]. There will be more fermentable sugars available that result in higher ethanol production, and thus, revenue.

After simulating the processes in SuperPro Designer, the data in Table 4 were acquired. Here it can be seen that ethanol production from GS yields the highest revenues. This can be a result of the significantly higher dry matter content (92.50%) when compared to SBP (70.36%), or the slightly higher efficiencies of carbohydrate polymer conversion in the GS. Therefore, the plant treating GS will obtain the highest revenue. The executive summary for SBP and GS for the production of bioethanol can be found in Table 4.

From Table 4, it can be concluded that a bioethanol plant that treats SBP is not economically viable since the NPV is negative. The revenue per year is not large enough to cover the total capital investment and the operating costs per year, which results in an NPV of −671,000 €. The high capital costs are due to the building and constructing costs (22.91%) and equipment purchase costs (18.15%), which total of €1,061,000 €. The operation costs mainly consist of utilities (57.78%) which are 621,000 €. The high utility costs mainly result from the high amount of steam required to heat the vessel for 30 min at 121 °C in the pretreatment step. The costs are 328,134 € per year for only V-101, which accounts for 71.62% of the total amount of steam used. Besides, since SBP is not vastly available, 105,000 € per year must be paid to store the SBP to have a constant supply. If it was vastly available, the operating costs would decrease to 970,000 € resulting in a unit production cost of 0.68 €/kg ethanol. In this situation, the IRR is 5.86%, the NPV 207,000 € and the payback time 13.8 years, meaning that it would be economically viable.

As can be seen in Table 4, a bioethanol plant treating GS is not economically viable. Due to the long cycle time, the batches are larger resulting in a larger fermentation vessel. To process the volume, 3 fermenters are needed, which results in high equipment purchase costs and high direct fixed capital costs. Thus, it is a high capital investment because most of the investments consist of the equipment costs. The equipment purchase costs are 18.45% of the total capital investment. Together, with the engineering and construction costs, which are 22.71% of the total capital investment, they are the largest expenses. Besides high equipment costs, more energy is needed since the equipment used is larger. Furthermore, the utility costs and thus operating costs are higher, since the pretreatment requires heating at 180 °C, and this needs to be done with high-pressure steam instead of regular steam. High-pressure steam costs 18.80 €/MT and normal steam 11.28 €/MT, whereby the costs increase to 434,483 €. Besides the use of high-pressure steam, 4,734,017 metric tons of cooling water are needed to cool the pretreated GS in the fermentation vessel since that process must be executed at 37 °C, which further contributes to the high utility costs (70.71% of the total operating costs). Since the costs are too high compared to the revenue, it is not possible to calculate the IRR nor the payback time.

When comparing the different feedstocks used, it can be concluded that SBP is the most viable. Although the numbers are not positive now, better technology/procedures for storing the SBP could provide a way out. For SBP, this could be a solution; but for GS, the gap is too large. Furthermore, in both cases, the equipment purchase costs, building and construction costs, and utility costs are the highest expenses within the total capital investment. By removing the pretreatment section (units V-101, PM-101, PM-102, and the sulfuric acid (Figure 2)) from the pretreatment pathway several

aspects change. The efficiency of the enzymatic hydrolysis of non-pretreated GS will be lower. In the fermentation, less ethanol will be produced and therefore the revenue becomes smaller. Furthermore, the total capital investment decreases since the equipment purchase costs are lower, which also lowers the direct and indirect plant costs. In addition, since the sulfuric acid is no longer used, the volume of the process decreases; and therefore, the equipment costs and the utility costs decrease. Additionally, the raw material costs and waste handling cost decreases since sulfuric acid is no longer needed or disposed of. Compared with corn stover, SBP and GS contain a lower amount of cellulose and hemicellulose, and therefore the revenue from the ethanol production is not high enough to cover the total capital investment and operating costs which leads to a non-economical viable plant.

Since V-101 required heating to 121/180 °C, a large amount of steam was needed to obtain these temperatures. After that, a large amount of cooling water was required to obtain the right temperature for fermentation. Since this is no longer part of the process, the operation costs are significantly lower. In Table 4, it can be found that the production of bioethanol from SBP and GS without pretreatment is viable. SBP gives a payback time of 5.09 years, an IRR of 23.05%, and an NPV of 3,367,000 €. GS provides a payback time of 5.85 years, an IRR of 19.30 and an NPV of 2,763,000 €. Comparing SBP with GS, investing in SBP would be advised since the NPV and IRR are higher. The costs that are saved on the equipment and utilities do not weigh up against the loss in revenue. To break even, the selling price of the ethanol for SBP and GS must be 0.68 €/kg and 0.96 €/kg, respectively, which are too high because the ethanol still must be purified.

4. Conclusions

Analyzing all results, it is found that a plant treating GS produces the highest amount of bioethanol. Although this results in the highest revenue, plants processing GS are not most favorable. Due to the large volumes required, the direct plant costs, indirect plant costs, and operating costs are larger, which results in higher unit production costs. Furthermore, it is found that an ethanol production plant using pretreated SBP or pretreated GS is not viable, since these result in a negative NPV. The content of cellulose and hemicellulose in the biomass is too low, which results in revenue which cannot cover the total capital investment and the operating costs. If the right procedure for storing SBP was available, the plant treating SBP would be viable since the NPV becomes −671,000 €. Furthermore, excluding the pretreatment improved the financial outcome of the cases: the NPV became smaller. Altogether, it is possible to have a viable production process for SBP or GS when the pretreatment section is excluded, or if a suitable storage procedure of SBP is included.

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References

1. Oliveira, A.; Navia, R. Zero waste bio-refineries: The example of Brazilian pulp and paper sector. *Waste Manag. Res.* **2017**, *35*, 1193–1194. [CrossRef] [PubMed]
2. Achinas, S.; Achinas, V.; Euverink, G.J.W. A technological overview of biogas production from biowaste. *Engineering* **2017**, *3*, 299–307. [CrossRef]
3. Chen, J.F. Green chemical engineering for a better life. *Engineering* **2017**, *3*, 279. [CrossRef]
4. Sahajwalla, V. Green processes: Transforming waste into valuable resources. *Engineering* **2018**, *4*, 309–310. [CrossRef]
5. Anjum, M.; Khalid, A.; Qadeer, S.; Miandad, R. Synergistic effect of co-digestion to enhance anaerobic degradation of catering waste and orange peel for biogas production. *Waste Manag. Res.* **2017**, *35*, 967–977. [CrossRef] [PubMed]

6. Chen, P.; Anderson, E.; Addy, M.; Zhang, R.; Cheng, Y.; Peng, P.; Ma, Y.; Fan, L.; Zhang, Y.; Lu, Q.; et al. Breakthrough technologies for the biorefining of organic solid and liquid wastes. *Engineering* **2018**, *4*, 574–580. [CrossRef]

7. Hildebrandt, J.; Bezama, A. Cross-fertilisation of ideas for a more sustainable fertiliser market: The need to incubate business concepts for harnessing organic residues and fertilisers on biotechnological conversion platforms in a circular bioeconomy. *Waste Manag. Res.* **2018**, *36*, 1125–1126. [CrossRef]

8. Marzo, C.; Díaz, A.B.; Caro, I.; Blandino, A. Valorization of agro-industrial wastes to produce hydrolytic enzymes by fungal solid-state fermentation. *Waste Manag. Res.* **2019**, *37*, 149–156. [CrossRef]

9. Zhou, Z.; Tang, Y.; Chi, Y.; Ni, M.; Buekens, A. Waste-to-energy: A review of life cycle assessment and its extension methods. *Waste Manag. Res.* **2018**, *36*, 3–16. [CrossRef]

10. Philippidis, G.; Bartelings, H.; Helming, J.; M'barek, R.; Smeets, E.; Van Meijl, H. The good, the bad and the uncertain: Bioenergy use in the European Union. *Energies* **2018**, *11*, 2703. [CrossRef]

11. Aragie, E.; Balié, J.; MoralesOpazo, C. Does reducing food losses and wastes in sub-Saharan Africa make economic sense? *Waste Manag. Res.* **2018**, *36*, 483–494. [CrossRef] [PubMed]

12. Park, J.H.; Jin, M.H.; Lee, Y.J.; Song, G.S.; Choi, J.W.; Lee, D.W.; Kim, J.G. Two-in-one fuel synthetic bioethanol-lignin from lignocellulose with sewage sludge and its air pollutants reduction effects. *Energies* **2019**, *12*, 3072. [CrossRef]

13. Chang, C.-L.; Li, Y.; McAleer, M. Volatility spillovers between energy and agricultural markets: A critical appraisal of theory and practice. *Energies* **2018**, *11*, 1595. [CrossRef]

14. Bilandžija, N.; Krička, T.; Matin, A.; Leto, J.; Grubor, M. Effect of harvest season on the fuel properties of *Sida hermaphrodita* (L.) Rusby biomass as solid biofuel. *Energies* **2018**, *11*, 3398. [CrossRef]

15. Uçar, S.; Karagöz, S. Co-processing of olive bagasse with crude rapeseed oil via pyrolysis. *Waste Manag. Res.* **2017**, *35*, 480–490. [CrossRef] [PubMed]

16. Solarte-Toro, J.C.; Chacón-Pérez, Y.; Cardona-Alzate, C.A. Evaluation of biogas and syngas as energy vectors for heat and power generation using lignocellulosic biomass as raw material. *Electron. J. Biotechnol.* **2018**, *33*, 52–62. [CrossRef]

17. Ahorsu, R.; Medina, F.; Constantí, M. Significance and challenges of biomass as a suitable feedstock for bioenergy and biochemical production: A review. *Energies* **2018**, *11*, 3366. [CrossRef]

18. Park, J.H.; Jin, M.H.; Lee, Y.J.; Song, G.S.; Choi, J.W.; Lee, D.W.; Choi, Y.C.; Park, S.J.; Song, K.H.; Kim, J.G.; et al. A Solid-state fermentation and composting as alternatives to treat hair waste: A life-cycle assessment comparative approach. *Waste Manag. Res.* **2017**, *35*, 786–790.

19. Smuga-Kogut, M.; Piskier, T.; Walendzik, B.; Szymanowska-Powałowska, D. Assessment of wasteland derived biomass for bioethanol production. *Electron. J. Biotechnol.* **2019**, *41*, 1–8. [CrossRef]

20. Sharifyazd, S.; Karimi, K. Effects of fermentation conditions on valuable products of ethanolic fungus Mucor indicus. *Electron. J. Biotechnol.* **2017**, *30*, 77–82. [CrossRef]

21. Tremouli, A.; Papadopoulou, K.; Kanellos, G.; Lampropoulos, I.; Lyberatos, G. Bioelectricity production from fermentable household waste in a dual-chamber microbial fuel cell. *Waste Manag. Res.* **2018**, *36*, 1037–1042.

22. RedCorn, R.; Fatemi, S.; Engelberth, A.S. Comparing end-use potential for industrial food-waste sources. *Engineering* **2018**, *4*, 371–380. [CrossRef]

23. Wang, J.; Wang, H.; Fan, Y. Techno-economic challenges of fuel cell commercialization. *Engineering* **2018**, *4*, 352–360. [CrossRef]

24. Longjan, G.G.; Dehouche, Z. Nutrient characterisation and bioenergy potential of common Nigerian food wastes. *Waste Manag. Res.* **2018**, *36*, 426–435. [CrossRef]

25. Reißmann, D.; Thrän, D.; Bezama, A. How to identify suitable ways for the hydrothermal treatment of wet bio-waste? A critical review and methods proposal. *Waste Manag. Res.* **2018**, *36*, 912–923. [CrossRef]

26. Sepúlveda-Cervantes, C.V.; Soto-Regalado, E.; Rivas-García, P.; Loredo-Cancino, M.; Cerino-Córdova, F.dJ.; García Reyes, R.B. Technical-environmental optimisation of the activated carbon production of an agroindustrial waste by means response surface and life cycle assessment. *Waste Manag. Res.* **2018**, *36*, 121–130. [CrossRef]

27. Chen, J.F. Green chemical engineering. *Engineering* **2017**, *3*, 283–284. [CrossRef]

28. Nelson, M.J.; Nakhla, G.; Zhu, J. Fluidized-bed bioreactor applications for biological wastewater treatment: A review of research and developments. *Engineering* **2017**, *3*, 330–342. [CrossRef]

29.	Kupczyk, A.; Mączyńska, J.; Redlarski, G.; Tucki, K.; Bączyk, A.; Rutkowski, D. Selected aspects of biofuels market and the electromobility development in Poland: Current trends and forecasting changes. *Appl. Sci.* **2019**, *9*, 254. [CrossRef]

30.	Demirbas, A. Bioethanol from cellulosic materials: A renewable motor fuel from biomass. *Energy Sources* **2005**, *27*, 327–337. [CrossRef]

31.	Matsakas, L.; Gao, Q.; Jansson, S.; Rova, U.; Christakopoulos, P. Green conversion of municipal solid wastes into fuels and chemicals. *Electron. J. Biotechnol.* **2017**, *26*, 69–83. [CrossRef]

32.	Koçer, A.T.; Özçimen, D. Investigation of the biogas production potential from algal wastes. *Waste Manag. Res.* **2018**, *36*, 1100–1105. [CrossRef] [PubMed]

33.	Sotelo-Navarro, P.; Poggi-Varaldo, H.; Turpin-Marion, S.; Vázquez-Morillas, A.; Beltrán-Villavicencio, M.; Espinosa-Valdemar, R. Biohydrogen production from used diapers: Evaluation of effect of temperature and substrate conditioning. *Waste Manag. Res.* **2017**, *35*, 267–275. [CrossRef] [PubMed]

34.	EurObserv'er. *The State of Renewable Energies in Europe*, 17th ed.; Observ'ER: Pairs, France, 2017.

35.	Phukoetphim, N.; Salakkam, A.; Laopaiboon, P.; Laopaiboon, L. Improvement of ethanol production from sweet sorghum juice under batch and fed-batch fermentations: Effect of sugar levels, nitrogen supplementation, and feeding regimes. *Electron. J. Biotechnol.* **2017**, *26*, 84–92. [CrossRef]

36.	Pradyawong, S.; Juneja, A.; Sadiq, M.B.; Noomhorm, A.; Singh, V. Comparison of cassava starch with corn as a feedstock for bioethanol production. *Energies* **2018**, *11*, 3476. [CrossRef]

37.	Taški-Ajduković, K.; Nagl, N.; Ćurčić, Z.; Zorić, M. Estimation of genetic diversity and relationship in sugar beet pollinators based on SSR markers. *Electron. J. Biotechnol.* **2017**, *27*, 1–7. [CrossRef]

38.	Taiwo, A.E.; Madzimbamuto, T.N.; Ojumu, T.V. Optimization of corn steep liquor dosage and other fermentation parameters for ethanol production by Saccharomyces cerevisiae Type 1 and Anchor Instant Yeast. *Energies* **2018**, *11*, 1740. [CrossRef]

39.	Gronchi, N.; Favaro, L.; Cagnin, L.; Brojanigo, S.; Pizzocchero, V.; Basaglia, M.; Casella, S. Novel yeast strains for the efficient saccharification and fermentation of starchy by-products to bioethanol. *Energies* **2019**, *12*, 714. [CrossRef]

40.	Domínguez, J.; Gómez-Brandón, M.; Martínez-Cordeiro, H.; Lores, M. Bioconversion of Scotch broom into a high-quality organic fertiliser: Vermicomposting as a sustainable option. *Waste Manag. Res.* **2018**, *36*, 1092–1099. [CrossRef]

41.	Sanchez, N.; Ruiz, R.Y.; Infante, N.; Cobo, M. Bioethanol production from *Cachaza* as hydrogen feedstock: Effect of ammonium sulfate during fermentation. *Energies* **2017**, *10*, 2112. [CrossRef]

42.	Franchi, O.; Rosenkranz, F.; Chamy, R. Key microbial populations involved in anaerobic degradation of phenol and p-cresol using different inocula. *Electron. J. Biotechnol.* **2018**, *35*, 33–38. [CrossRef]

43.	Chen, K.H.; Chao, Y.C. Characterization of performance of short stroke engines with valve timing for blended bioethanol internal combustion. *Energies* **2019**, *12*, 759. [CrossRef]

44.	Rujnić-Sokele, M.; Pilipović, A. Challenges and opportunities of biodegradable plastics: A mini review. *Waste Manag. Res.* **2017**, *35*, 132–140. [CrossRef] [PubMed]

45.	Gao, L.; Guo, Q.; Lin, H.; Pan, D.; Huang, X.; Lin, J.; Lin, J. Modeling of lactose enzymatic hydrolysis using Monte Carlo method. *Electron. J. Biotechnol.* **2019**, *40*, 78–83. [CrossRef]

46.	Berlowska, J.; Pielech-Przybylska, K.; Balcerek, M.; Cieciura, W.; Borowski, S.; Kregiel, D. Integrated bioethanol fermentation/anaerobic digestion for valorization of sugar beet pulp. *Energies* **2017**, *10*, 1255. [CrossRef]

47.	Berlowska, J.; Pielech-Przybylska, K.; Balcerek, M.; Dziekońska-Kubczak, U.; Patelski, P.; Dziugan, P.; Kręgiel, D. Simultaneous saccharification and fermentation of sugar beet pulp for efficient bioethanol production. *BioMed. Res. Int.* **2016**, *9*, 1–10.

48.	Centraal Bureau voor de Statistiek. Available online: https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=7100oogs&D1=1-3&D2=25&D3=1&D4=6,22-24&HDR=G2,G3,T&STB=G1&VW=T (accessed on 28 May 2019).

49.	Centraal Bureau voor de Statistiek. Available online: https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=80780ned&D1=459-481&D2=1&D3=l&HDR=G1,G2&STB=T&VW=C (accessed on 1 June 2019).

50.	Liu, Y.K.; Chen, W.C.; Huang, Y.C.; Chang, Y.K.; Chu, I.M.; Tsai, S.L.; Wei, Y.H. Production of bioethanol from Napier grass via simultaneous saccharification and co-fermentation in a modified bioreactor. *J. Biosci. Bioeng.* **2017**, *124*, 184–188. [CrossRef]

51. Centraal Bureau in de Statistiek. Available online: https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=81302ned&D1=440-443&D2=l&HDR=G1&STB=T&VW=T (accessed on 2 June 2019).

52. Centraal Bureau in de Statistiek. Available online: https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=7140GRAS&D1=a&D2=1&D3=l&HDR=G2,G1&STB=T&VW=T (accessed on 2 June 2019).

53. IRS. Sugar Beet Growing in the Netherlands; Institute of Sugar Beet Research: 2005. Available online: http://applicaties.irs.nl/ccmsupload/ccmsalg/sugar%20beet%20growing%20in%20the%20netherlands%20.pdf (accessed on 19 Sugust 2019).

54. Kumar, D.; Murthy, G.S. Impact of pretreatment and downstream processing technologies on economics and energy in cellulosic ethanol production. *Biotechnol. Biofuels* **2011**, *4*, 1–19. [CrossRef]

55. Smuga-Kogut, M.; Walendzik, B.; Szymanowska-Powalowska, D.; Kobus-Cisowska, J.; Wojdalski, J.; Wieczorek, M.; Cielecka-Piontek, J. Comparison of bioethanol preparation from triticale straw using the ionic liquid and sulfate methods. *Energies* **2019**, *12*, 1155. [CrossRef]

56. Lemões, J.S.; Lemons e Silva, C.F.; Farias Avila, S.P.; Scherrer Montero, C.R.; dos Anjos e Silva, S.D.; Samios, D.; do Carmo Ruaro Peralba, M. Chemical pretreatment of Arundo donax L. for second-generation ethanol production. *Electron. J. Biotechnol.* **2018**, *31*, 67–74. [CrossRef]

57. Raud, M.; Rooni, V.; Kikas, T. The efficiency of nitrogen and flue gas as operating gases in explosive decompression pretreatment. *Energies* **2018**, *11*, 2074. [CrossRef]

58. Portero-Barahona, P.; Carvajal-Barriga, E.J.; Martín-Gil, J.; Martín-Ramos, P. Sugarcane bagasse hydrolysis enhancement by microwave-assisted sulfolane pretreatment. *Energies* **2019**, *12*, 1703. [CrossRef]

59. Duque, A.; Manzanares, P.; González, A.; Ballesteros, M. Study of the application of alkaline extrusion to the pretreatment of Eucalyptus biomass as first step in a bioethanol production process. *Energies* **2018**, *11*, 2961. [CrossRef]

60. Dziekońska-Kubczak, U.; Berłowska, J.; Dziugan, P.; Patelski, P.; Pielech-Przybylska, K.; Balcerek, M. Nitric acid pretreatment of Jerusalem artichoke stalks for enzymatic saccharification and bioethanol production. *Energies* **2018**, *11*, 2153. [CrossRef]

61. Łukajtis, R.; Kucharska, K.; Hołowacz, I.; Rybarczyk, P.; Wychodnik, K.; Słupek, E.; Nowak, P.; Kamiński, M. Comparison and optimization of Saccharification conditions of alkaline pre-treated triticale straw for acid and enzymatic hydrolysis followed by ethanol fermentation. *Energies* **2018**, *11*, 639. [CrossRef]

62. Dziekońska-Kubczak, U.; Berłowska, J.; Dziugan, P.; Patelski, P.; Balcerek, M.; Pielech-Przybylska, K.; Robak, K. Two-stage pretreatment to improve saccharification of oat straw and Jerusalem artichoke biomass. *Energies* **2019**, *12*, 1715. [CrossRef]

63. Trakulvichean, S.; Chaiprasert, P.; Otmakhova, J.; Songkasiri, W. Comparison of fermented animal feed and mushroom growth media as two value-added options for waste Cassava pulp management. *Waste Manag. Res.* **2017**, *35*, 1210–1219. [CrossRef]

64. Farris, P.W.; Bendle, N.T.; Pfeifer, P.E.; Reibstein, D.J. Marketing and Finance, 1st ed.Pearson Education: Cranbury, NJ, USA, 2010; pp. 337–355.

65. Sun, Y.; Zhang, J.P.; Yang, G.; Yao, M.S. Clean production of corn Stover pulp using KOH+NH 4OH solution and its kinetics during Delignification. *Chem. Ind. Chem. Eng. Q.* **2012**, *18*, 137–145. [CrossRef]

66. Safarian, S.; Unnthorsson, R. An assessment of the sustainability of lignocellulosic bioethanol production from wastes in Iceland. *Energies* **2018**, *11*, 1493. [CrossRef]

67. Gabriel Rullo, P.; Costa-Castelló, R.; Roda, V.; Feroldi, D. Energy management strategy for a bioethanol isolated hybrid system: Simulations and experiments. *Energies* **2018**, *11*, 1362. [CrossRef]

68. Cantero, C.A.T.; Lopez, G.L.; Alvarado, V.M.; Jimenez, R.F.E.; Morales, J.Y.R.; Coronado, E.M.S. Control structures evaluation for a salt extractive distillation pilot plant: Application to bio-ethanol dehydration. *Energies* **2017**, *10*, 1276. [CrossRef]