Appendix A: Basis and results of the techno-economic analyses

1. Feedstock cost calculation

Table A.1. Material, processes, cost and calculations used to determine an approximate baseline switchgrass cost

Switchgrass Budget		QTY	Unit	Price /Unit	Yr 1 (Establishment)	Yr 2	Yr 3	Yr 4-20	Total	Present value[5]	
SELECT CASH EXPENSES											
Plant Material											
	Seed	8	8 lbsPLS/A	10	80	0	0	0	80	80	
Soil Fertility										0.0	
	Nitrogen[1] (Diammonim phosphate)	40	kg/expected ton per acre	1	40	0	0	0	40	40	
	Coadyuvante[1] (Speed wet maxion)	0	kg/expected ton per acre	1	0	0	0	0	0	0	
	Coadyuvante [1] (Agral 90)	0	kg/expected ton per acre	2	1	3	4	4	81	61	
	Fertilizer application[1] (Urea)	80	per acre	0	0	22	22	22	410	312	
	Soil Testing[3]		per soil test	15	3	1	1	1	22	17	
Weed Control											
	Burn-Down[1](Glyphosate)	4 L	acre	7	7	0	0	0	7	7	
	Atrazine [1]	1,5 L	acre	23	23	0	0	0	23	23	
	Sprayer-3 sprays[2]	2	acre	12	23	0	0	0	23	23	
Establishment & Maintenance											
	Brush Mowing[2]	1	acre	25	25	0	0	0	25	25	
	Moldboard Plow[2]	1	acre	24	24	0	0	0	24	24	
	Disking-2 passes[2]	2	acre	18	35	0	0	0	35	35	
	Soil Finish-2 passes[2]	2	acre	19	38	0	0	0	38	38	
	Drill[2]	1	acre	18	18	2	0	0	21	20	
Harvesting											
	Mowing/conditioning[2]	1	acre	16	0	16	16	16	308	234	
	Baling - lg round[2&4]	6.5	bale	8	0	78	50	50	975	747	
	Grinding [7]	6.5	dry t/acre	2	0	10	10	10	197	150	
Transport	Transportation cost[8]	6.5	dry t/acre	9	0	43	55	55	1,032	783	
TOTAL CASH EXPENSES					316	175	158	158	3,339	2,619	
REVENUES											
Biomass	Mature yield (estimation)	6.5	dry t		0.0	5.0	6.5	6.5	121		
	Revenue Stream			30	0	150	194	194	3,644	2,763	
REV ABOVE EXPENSES					-315.7	-25.0	35.8	35.8	304	144	**NPV**
					EQUAL ANNUAL INCOME (Annualized over 20 years)					**10.6**	
					BREAK EVEN PAYBACK PERIOD[6]				17.7	**11.0 years**	

This budget assumes a mature yield of 16 t/hectare, and an average transportation distance of 50 km, and is only a base to select possible switchgrass costs for the sensitivity analysis.

Assumptions	
Interest Rate (%)	4%
Number of years of growth	20
INPUTS	
Weight of Bale (lbs)	1800

Footnotes:

[1]Based on requirements for uruguayan production, Source. Personal communication Guillermo Siri

[2]Custom Rates from 2014 Penn State Extension

[3]Grid sampling in 5 acre units, every 3 years (applied)

[4]Havested at 15% moisture & the bale weight used was 810 kg/bale.

[5]Shows the discounted value over the production period.

[6]Pay back period is calculated by determing when revenues exceed establishme

[7] Grinding cost based on Sokhansanj 2009

[8] Transportation cost based on "Dirección Nacional de transporte precios de referencia 2015", MTOP 2015

2. Equipment description, scaling factors and scaling variables

The following table shows the characteristics of the equipment purchased, scaling factors and the scaling variable considered. Streams mentioned here can be seen on the simplified flow diagrams at the materials and methods section. Streams considered as scaling variable can be found In Tables A.10 to A.15, and in the diagrams of Appendix B.

Table A.2. Equipment description, scaling factors and scaling variables

EQPT NO	EQUIPMENT TITLE	VENDOR	DESCRIPTION	HP	MATERIAL	$	Quote Year	Scaling Variable	Scaling Val	Units	Scaling Exp	Inst Factor	Location factor
C-101	Transfer Conveyor	Dearborn Midwest	160 MTPH ea., enclosed, 60 in. x 65 ft	20 hp ea.	CS	$5.397.000	2009	Stream 101	94697	kg/hr	0,60	1,7	1.25
C-102	High Angle Transfer Conveyor	Dearborn Midwest	160 MTPH ea., enclosed, 72 in. wide	50 hp ea.	CS	INCLUDED							
C-103	Reversing Load-in Conveyor	Dearborn Midwest	320 MT / hr, enclosed, 84 in. wide	20 hp	CS	INCLUDED							
C-104	Dome Reclaim System	Cambelt	100 MTPH ea.	45 kw ea.	CS	$3.046.000	2009	Stream 101	94697	kg/hr	0,60	1,7	1.25
C-105	Reclaim Conveyor	Dearborn Midwest	100 MTPH ea., enclosed, 48 in. x 125 ft.	10 hp ea.	CS	INCLUDED							
C-106	High Angle Transfer Conveyor	Dearborn Midwest	100 MTPH, enclosed, 72 in. wide	20 hp	CS	INCLUDED							
C-107	Elevated Transfer Conveyor	Dearborn Midwest	100 MTPH, enclosed, 48 in. x 200 ft.	10 hp	CS	INCLUDED							
C-108	Process Feed Conveyor	Dearborn Midwest	70 MTPH ea., enclosed, 42 in. x 25 ft.	5 hp ea.	CS	INCLUDED							
M-101	Truck Scale	St. Louis Scale	10' x 70', 200,000 lb		CONCRETE	$110.000	2009	Stream 101	94697	kg/hr	0,60	1,7	1,25
M-102	Truck Dumper	Jeffrey Rader	70' x 55 ton x 63 degree	2 x 50 hp	CS	$484.000	2009	Stream 101	94697	kg/hr	0,60	1,7	1,25
M-103	Truck Dumper Hopper	Jeffrey Rader	3500 cu.ft. hopper,drag chain conveyor	50 hp ea.	CS	$502.000	2009	Stream 101	94697	kg/hr	0,60	1,7	1,25
M-104	Concrete Feedstock Storage Dome	Domtec	98 ft. dia., 160 ft. high., 4000 MT		CONCRETE	$3.500.000	2009	Stream 101	94697	kg/hr	0,60	1,7	1,25
M-105	Belt Scale	Tecweigh	Scale plus processor		CS	$10.790	2009	Stream 101	94697	kg/hr	0,60	1,7	1,25
M-106	Dust Collection System	Sly	8500 ACFM	25 hp ea.	CS	$279.900	2009	Stream 101	94697	kg/hr	0,60	1,7	1,25
	AREA 200												
A-204	Flash Tank Agitator	UET Mixers	Side-mounted, 3 x 75 hp. (170 kW)	170 kW	316LSS	$90.000	2009	Stream 254b	252891	kg/hr	0,50	1,5	1,25
A-208	Water/solid Hold Tank Agitator	UET Mixers	Side-mounted, 3 x 75 hp. (170 kW)	170 kW	316LSS	$90.000	2009	Stream 217	264116	kg/hr	0,50	1,5	1,25
A-209	Conditioning Tank Agitator	Lotus		10 hp	SS	$21.900	2009	Stream 228	410369	kg/hr	0,50	1,5	1,25
A-210	Conditioning Static Mixer	KOMAX			SS	$5.000	2009	Stream 275	157478	kg/hr	0,50	1,0	1,25
A-224	In line mixer Agitator	Lotus		20 hp	SS	$0	2009	Stream 239	410846	kg/hr	0,50	1,5	1,25
C-201	Transfer Conveyor	Andritz	800 mm x 7600 mm (2'-8" x 25')	40 kW ea.	AL-6XN	INCLUDED							
C-202	Distribution Conveyor	Andritz	800 mm x 7600 mm (2'-8" x 25')	40 kW ea.	AL-6XN	INCLUDED							
C-203	Overfeed Conveyor	Andritz	800 mm x 7600 mm (2'-8" x 25')	40 kW ea.	AL-6XN	INCLUDED							
C-204	Pressurized Heating Screw	Andritz	2500 mm x 9500 mm (8' x 31')	75 kW	Dup. 2205	INCLUDED							
C-205	Pressurized Pre-heater Discharge	Andritz	850 mm x 3500 mm (2'-10" x 12')	40 kW ea.	Dup. 2205	INCLUDED							
C-206	Pressurized Transport - No. 1	Andritz	900 mm x 3500 mm (3' x 12')	20 kW	Incoloy 825-CLAD; CS	INCLUDED							
C-207	Pressurized Transport - No. 2	Andritz	1200 mm x 3500 mm (4' x 12')	40 kW	Incoloy 825-CLAD; CS	INCLUDED							
H-201	Pretreatment Water Heater	Mueller	29.9 MMBtu		304SS	$92.000	2010	Stream QH201	-8	Gcal/hr	0,70	2,2	1,25
H-202	Pretreatment Heater exchanger	Mueller	29.9 MMBtu		304SS	$34.000	2009	Stream QH202	-2	Gcal/hr	0,70	2,2	1,25
H-244	Waste Vapor Condenser	Mueller	Copied H-201		304SS	$34.000	2009	Stream QH244	2	Gcal/hr	0,70	2,2	1,25
M-201	Doffing Roll Storage Bins	Andritz	60 cu. m. (2100 cu.ft.) with conveyors/scrapers	40 kW ea.	304/316SS	INCLUDED							

EQPT NO	EQUIPMENT TITLE	VENDOR	DESCRIPTION	HP	MATERIAL	$	Quote Year	Scaling Variable	Scaling Val	Units	Scaling Exp	Inst Factor	Location factor
M-202	Pin Drum Feeder	Andritz		15 kW ea.	316LSS	INCLUDED							
M-**203**	Plug Screw Feeder	Andritz		1100kW ea.	316LSS	INCLUDED							
M-204	Prehydrolysis / Vertical Preheater	Andritz	16' x 62' - 10 min. residence time	45 kW	Dup. 2205	INCLUDED							
M-205	Pin Drum Feeder	Andritz		15 kW ea.	Incoloy 825-CLAD; CS	INCLUDED							
M-206	Plug Screw Feeder	Andritz		1100 kW ea.	Incoloy 825-CLAD; CS	INCLUDED							
P-201	Sulfuric Acid Pump	Goulds	9 GPM, 245 FT TDH		316SS	$8.000	2009	Stream 710	3720	kg/hr	0,80	2,3	1,25
P-204	Flash Tank Discharge Pump	Viking	900 GPM, 150 FT TDH	75	316SS	$17.408	2010	Stream 223	204390	kg/hr	0,80	2,3	1,25
P-201	Water/Solid Tank Discharge	Viking	900 GPM, 150 FT TDH	75	316SS	$17.408	2010	Stream 217	292407	kg/hr	0,80	2,3	1,25
P-209	Hydrolyzate Pump	Goulds	1771 GPM, 150 FT TDH	100	316SS	$22.500	2009	Stream 228	402194	kg/hr	0,80	2,3	1,25
P-205	Diluted Hydrolyzate Pump	Goulds	1771 GPM, 100 FT TDH	60	316SS	$22.500	2009	Stream 254b	402194	kg/hr	0,80	2,3	1,25
P-213	Water filtrate tank	Viking	900 GPM, 150 FT TDH	75	316SS	$17.408	2010	Stream 254b	292407	kg/hr	0,80	2,3	1,25
C-205	Hydrolysate Washed Solids Belt Conveyor					$80.000	2000	Stream 254b	91633	kg/hr	0,76	1,5	1,25
S-205	Pneumapress filter	Aden 2002				$1.575.000	2000	Stream 254b	50299	kg/hr	0,70	1,1	1,25
T-201	Sulfuric Acid Tank		12,800 gal, 24hr residence time		PLASTIC	$6.210	2010	Stream 710	1981	kg/hr	0,70	3,0	1,25
T-204	Flash Tank		23' x 48' - 110,000 gal.		SS316	$511.000	2009	Stream 223	264116	kg/hr	0,70	2,0	1,25
T-**208**	Water/solid Tank		2.6 atm, 130C operating 30 min. hold = 30,000 gal		SS316	$203.000	2009	Stream 217	264116	kg/hr	0,70	2,0	1,25
T-207	Pretreatment Reactor		Tao 2011			$3.600.000	2009	Stream DRY101	83333	kg/hr	0,60	1,5	1,25
T-**209**	Conditioning Tank	Mueller	118,000 gal, 1hr residence time		SS304	$236.000	2009	Stream 228	410369	kg/hr	0,70	2,0	1,25
T-**205**	Hydrolyzate tank	Mueller	118,000 gal		SS304	$236.000	2009	Stream 220	41037	kg/hr	0,70	2,0	1,25
T-**213**	Filtration tank	Mueller	118,000 gal		SS304	$236.000	2009	Stream s205wash	410369	kg/hr	0,70	2,0	1,25
	AREA 300												
A-**300**	Ethanol Fermentor Agitator	Lotus		30 hp	SS304	$52.500	2009	Number of fermenters	1	ea	1,00	1,5	1,25
A-**301**	Seed Hold Tank Agitator	Lotus		15 hp	SS304	$31.800	2009	Stream 304	40414	kg/hr	0,50	1,5	1,25
A-**304**	4th Seed Vessel Agitator	Lotus		7.5 hp	SS	$26.000	2009		2	ea	0,50	1,5	1,25
A-**305**	5th Seed Vessel Agitator	Lotus		10 hp	SS	$43.000	2009		2	ea	0,50	1,5	1,25
A-**306**	Beer Surge Tank Agitator	Lotus		20 hp	SS304	$68.300	2009	Stream 501	425878	kg/hr	0,50	1,5	1,25
A-**308**	Enzyme-Hydrolysate Mixer	GLV	inline mixer 1673 gpm	100 hp	SS316	$109.000	2009	Stream t310fd	379938	kg/hr	0,50	1,7	1,25
F-**300**	Ethanol Fermentor	Mueller	1500m3 (scaled from humbird at 0.7 factor)		304SS	$441.529	2009	Number of fermenters	1	ea	1,00	1,5	1,25
F-**301**	1st Seed Fermentor	A&B Process	20 gallon skid complete - $37,700 ea		304SS	$75.400	2009	Stream 303	44355	kg/hr	0,70	1,8	1,25
F-**302**	2nd Seed Fermentor	A&B Process	200 gallon skid complete - $58,300 ea		304SS	$116.600	2009	Stream 303	44355	kg/hr	0,70	1,8	1,25
F-**303**	3rd Seed Fermentor	A&B Process	2000 gallon skid complete - $78,800 ea		304SS	$157.600	2009	Stream 303	44355	kg/hr	0,70	1,8	1,25
F-**304**	4th Seed Fermentor	Mueller	20,000 gallon, incl. coil - $176,000 ea		304SS	$352.000	2009	Stream 303	44355	kg/hr	0,70	2,0	1,25
F-**305**	5th Seed Fermentor	Mueller	200,000 gallon, incl. coil - $590,000 ea		304SS	$1.180.000	2009	Stream 303	44355	kg/hr	0,70	2,0	1,25
H-**300**	Fermentation Cooler	Alfa Laval	Plate & frame		304SS	$86.928	2009	Number of fermenters	12	ea	1,00	2,2	1,25
H-**304**	4th Seed Fermentor Coil	Mueller	incl. w/ tank		304SS	INCLUDED							
H-**305**	5th Seed Fermentor Coil	Mueller	incl. w/ tank		304SS	INCLUDED							
H-**310**	Fermentor Batch Cooler	Alfa Laval	Plate & frame		SS304	$23.900	2009	Stream QC310	5	Gcal/hr	0,70	1,8	1,25
P-**300**	Fermentation Recirc/Transfer Pump	Goulds	340 GPM, 150 FT	20	316SS	$47.200	2009	Number of fermenters	12	ea	0,80	2,3	1,25
P-**301**	Seed Hold Transfer Pump	Goulds	190 GPM, 150 FT TDH	10	316SS	$8.200	2009	Stream 304	43149	kg/hr	0,80	2,3	1,25
P-**302**	Seed Transfer Pump	Goulds	190 GPM, 615 FT TDH	40	316SS	$24.300	2009	Stream.304	43149	kg/hr	0,80	2,3	1,25
P-**306**	Beer Transfer Pump	Goulds	2152 GPM, 171 FT TDH	125	316SS	$26.800	2009	Stream 501	488719	kg/hr	0,80	2,3	1,25
P-**310**	Saccharification Transfer Pump	Goulds	352 GPM, 150 FT TDH	20	316SS	$47.200	2009	Stream 306	421776	kg/hr	0,80	2,3	1,25
T-**301**	Seed Hold Tank	Mueller	300,000 gallon		316SS	$439.000	2009	Stream 304	40414	kg/hr	0,70	1,8	1,25
T-**306**	Beer Storage Tank	Mueller	500,000 gallon		316SS	$636.000	2009	Stream 501	425878	kg/hr	0,70	1,8	1,25
T-**310**	Saccharification Tank	Caldwell	250,000 gal each - 19' dia. x 120' tall		304SS	$3.840.000	2009	Stream 306	421776	kg/hr	0,70	2,0	1,25
	AREA 400												

EQPT NO		EQUIPMENT TITLE	VENDOR	DESCRIPTION	HP	MATERIAL	$	Quote Year	Scaling Variable	Scaling Val	Units	Scaling Exp	Inst Factor	Location factor
D-**408**		THF distillation column+reboiler, condenser and reflux pump		D=6,9 m, H=37,3 m 56 trays		CS, SS317	$11.927.000	2009	Stream s205liq	175080	kg/hr	0,60	1,0	1,25
D-**409**		Furufral distillatin column +reboiler, condenser and reflux pump		D=2,3 m, H=25,1 m 36 trays		SS317, SS304, SS316L	$2.993.000	2009	Stream s205liq	175080	kg/hr	0,60	1,0	1,25
D-**410**		Acid distillation column +reboiler, condenser and reflux pump		D=3,1 m, H=49,5 m 76 trays		SS317, SS316L	$3.981.000	2009	Stream s205liq	175080	kg/hr	0,60	1,0	1,25
E-**401**		Hemicellulose evaporator 1st effect		22280 sf each., 135 BTU/hr sf F			$544.595	1996	Stream 221	278645	kg/hr	0,68	2,1	1,25
E-**402**		Hemicellulose evaporator 2nd effect					$435.650	1996	Stream 221	278645	kg/hr	0,68	2,1	1,25
E-**403**		Hemicellulose evaporator 3rd effect					$435.650	1996	Stream.221	278645	kg/hr	0,68	2,1	1,25
H-**406**		Heat exchanger		A=389.4 m2		T150A	$1.083.000	2009	Stream s205liq	175080	kg/hr	0,70	1,0	1,25
H-**407**		Heat exchanger		A=1427,3m2		T150A, SS304(Shell)	$3.398.000	2009	Stream s205liq	175080	kg/hr	0,70	1,0	1,25
P-**401**		Hemicelloulose pump	Viking	900 GPM, 150 FT TDH	75	316SS	$17.408	2010	Stream 221	292407	kg/hr	0,80	2,3	1,25
P-**402**		Concentrated hemicellulose pump	Viking	900 GPM, 150 FT TDH	75	316SS	$17.408	2010	Stream s205liq	292407	kg/hr	0,80	2,3	1,25
P-**403**		Concentrated hemicellulose Pump	Goulds	2 GPM, 100 FT TDH	0,5	CS	$3.000	2009	Stream s205liq	163	kg/hr	0,80	3,1	1,25
R-**404**		Biophasic reactor furfural		D=2m, H=12m		titanium clad	$732.000	2009	Stream 221	175080	kg/hr	0,60	1,0	1,25
T-**401**		Hemicellulose tank	Mueller	118,000 gal		SS304	$236.000	2009	Stream s205liq	410369	kg/hr	0,70	2,0	1,25
T-**402**		Concentradted hemicellulose Tank		12,800 gal		SS304	$102.000	2009	Stream S205liq	1615	kg/hr	0,70	1,8	1,25
T-**405**		Decanter		D=2,5m, H=7,5m		titanium clad	$436.000	2009	Stream s205liq	175080	kg/hr	0,70	1,0	1,25
		AREA 500												
A-	530	Filtrate Tank Agitator	Lotus		7.5 hp	SS	$26.000	2009	Stream 572	337439	kg/hr	0,50	1,5	1,25
C-	501	Lignin Wet Cake Conveyor	KWS/Barnard-Boe	Belt 100 ft. long x 24" wide, enclosed	10	SS304	$70.000	2009	Stream 571	28630	kg/hr	0,80	1,7	1,25
C-	502	Lignin Wet Cake Screw	KWS/Barnard-Boe	Screw conveyor - 25 ft lg x 14" dia	15	SS304	$20.000	2009	Stream 571	28630	kg/hr	0,80	1,7	1,25
D-	501	Beer Column	Megtec	14' dia. x 76' tall, 32 trays, 24" spacing		316SS	$3.407.000	2009	Stream 511	30379	kg/hr	0,60	2,4	1,25
D-	502	Rectification Column	Megtec	Top 13' dia. x 68' h, Bottom 4'6" x 31' h		316SS	INCLUDED							
H-	501	Beer Column Reboiler	Megtec	S & T		316SS;CS	INCLUDED							
H-	502	Rectification Column Reboiler	Megtec	S & T		316SS;CS	INCLUDED							
H-	504	Beer Column Condenser	Megtec	S & T		316SS;CS	INCLUDED							
H-	505	Rectification Column Condenser	GEA Rainey	92.2 MM Btu/hr 3 cells	300 tot	CS	$487.000	2010	Stream QCD502	23	Gcal/hr	0,60	2,8	1,25
H-	512	Beer Column Feed Interchanger	Megtec	Plate & Frame		316SS	INCLUDED							
M-	503	Molecular Sieve Package (9 pieces)	Delta-T			SS	$2.601.000	2009	Stream 515	22687	kg/hr	0,60	1,8	1,25
M-	505	Pressure Filter Pressing Compr	Atlas-Copco	460 SCFM, 300 psig	150 hp		$75.200	2009	Stream sqairi	808	kg/hr	0,60	1,6	1,25
M-	507	Pressure Filter Drying Compr	Atlas-Copco	4000 SCFM, 130 psig (ea)	700 hp ea.		$405.000	2009	Stream 557	12233	kg/hr	0,60	1,6	1,25
P-	501	Beer Column Bottoms Recirc Pump	Megtec	10,000 gpm	200	316SS	INCLUDED							
P-	503	Beer Column Reflux Pump	Megtec	15 gpm	2	316SS	INCLUDED							
P-	504	Rectification Column Btms Pump	Megtec	150 gpm	15	316SS	INCLUDED							
P-	505	Rectification Column Reflux Pump	Megtec	500 gpm	50	316SS	INCLUDED							
P-	506	Beer Column Stillage Pump	Megtec	2000 gpm	75	316SS	INCLUDED							
P-	508	Rectification Column to seed train pump	Warman		100 hp	SS	$17.057	2010	Stream 535	31815	kg/hr	0,80	2,3	1,25
P-	515	Scrubber Bottoms Pump	Goulds	108 GPM, 104 FT TDH		316SS	$6.300	2009	strm.551	24527	kg/hr	0,80	2,3	1,25
P-	530	Filtrate Tank Discharge Pump	Sulzer	590 GPM, 100 FT TDH SIZE 4X3-13		SS	$13.040	2010	Stream 551	31815	kg/hr	0,80	2,3	1,25
P-	531	Feed Pump	Warman	1014 GPM 230 FT TDH SIZE 8X6-15	100 hp	SS	$18.173	2010	Stream 571	31815	kg/hr	0,80	2,3	1,25
P-	532	Manifold Flush Pump	Warman		100 hp	SS	$17.057	2010	Stream 571	31815	kg/hr	0,80	2,3	1,25
P-	533	Cloth Wash Pump	Warman		150 hp	SS	$29.154	2010	Stream 571	31815	kg/hr	0,80	2,3	1,25
P-	581	Filtrate Discharge Pump	Sulzer	590 GPM, 100 FT TDH SIZE 4X3-13	75 hp	SS	$13.040	2010	Stream 571	31815	kg/hr	0,80	2,3	1,25
S-	505	Pressure Filter	Larox	384 sq. m fitration area ea incl packing		SS316	$3.294.700	2010	Stream 571	31815	kg/hr	0,80	1,7	1,25
T-	503	Beer Column Reflux Drum	Megtec	4' dia, 6' high, 50 psig design		316SS	INCLUDED		Stream 571					
T-	505	Rectification Column Reflux Drum	Megtec	4' dia, 6' high, 50 psig design		316SS	INCLUDED							
T-	512	Vent Scrubber	Envitech	Inlet Gas: 9681 acfm, 91°F, 1.97 % Eth.		SS304;PP	$215.000	2009		22608	kg/hr	0,60	2,4	1,25
T-	530	Filtrate Tank		13,750 gal 14' dia x 12' H		SS	$103.000	2010	Stream 523	31815	kg/hr	0,70	2,0	1,25
T-	531	Feed Tank		20,300 gal 14' dia x 18' H		SS	$174.800	2010	Stream 571	31815	kg/hr	0,70	2,0	1,25

EQPT NO		EQUIPMENT TITLE	VENDOR	DESCRIPTION	HP	MATERIAL	$	Quote Year	Scaling Variable	Scaling Val	Units	Scaling Exp	Inst Factor	Location factor
T-	532	Recycled Water Tank	Harrington Plastic	4000 gal.		HDPE	$1.520	2010	Stream 571	31815	kg/hr	0,70	3,0	1,25
T-	533	Pressing Air Compressor Receiver		1350 gal., 300 psig design		CS	$8.000	2010	Stream 571	31815	kg/hr	0,70	3,1	1,25
T-	534	Drying Air Compressor Receiver		9,000 gal., 150 psig design		CS	$17.000	2010	Stream 571	31815	kg/hr	0,70	3,1	1,25
		AREA 600												
B-	606	Biogas Blower	ADI	3000 ACFM, 10 PSI	200,0		INCLUDED							
C-	614	Aerobic Sludge Screw				CS	$25.000	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
H-	602	Anaerobic Reactor Feed Cooler	ALFA LAVAL	Wide gap plate & frame 2.5 mgd		SS316; CS	$83.863	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
M-	606	Biogas Emergency Flare	ADI				$32.955	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
M-	630	Polymer Addition System	ADI	11.4 gph neat polymer	10,0		$9.300	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
M-	640	Evaporator System					$3.801.095	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
P-	602	Anaerobic Reactor Feed Pump	ADI	2500 gpm submersible rail mounted	50,0	CS	$231.488	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
P-	606	Anaerobic Reactor Recirc Pump	ADI	400 gpm, 50 ft TDH	7,5		INCLUDED							
P-	607	Waste Anaerobic Sludge Pump	ADI	10 gpm	3,0		$93.300	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
P-	609	Return Activated Sludge Pump	ADI		40,0		$177.300	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
P-	610	Reverse Osmosis Feed Pump	ADI		?		INCLUDED							
P-	611	Centrifuge Feed Pump	ADI		10,0		$61.200	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
P-	612	Centrate Pump	ADI		15,0		$70.800	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
P-	616	Treated Water Pump				CS	INCLUDED							
R-	609	Membrane Bioreactor	ADI	Includes membrane CIP and Scour			$5.248.750	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
S-	610	Reverse Osmosis System	ADI				$2.210.979	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
S-	611	Centrifuge					$6.493.500	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
T-	606	Anaerobic Basin	ADI	31 Million gallonwith cover		CONCRETE	$27.000.000	2010	Stream 601	393100	kg/hr	0,60	1,0	1,25
T-	609	Sludge Holding Tank	ADI				INCLUDED							
		AREA 700												
A-	701	Denaturant In-line Mixer		4 inch		SS304	$3.850	2009	Stream 703	23154	kg/hr	0,50	1,0	1,25
A-	720	CSL Storage Tank Agitator	Lotus		10 hp	SS304	$21.200	2009	Stream 735	1393	kg/hr	0,50	1,5	1,25
A-	760	DAP Make-up Tank Agitator	Lotus		5.5 hp	SS304	$9.800	2009	Stream 755	163	kg/hr	0,50	1,5	1,25
A-	750	Cellulase Hold Tank Agitator	Lotus		10 hp	SS316	$26.900	2009	Stream 322	10930	kg/hr	0,50	1,5	1,25
C-	755	DAP and NaCl Bulk Bag Unloader	Flexicon	Super sack unloader			$30.000	2009	Stream 755	163	kg/hr	0,60	1,7	1,25
P-	701	Ethanol Product Pump	Goulds	150 GPM, 112 FT TDH	5,0	CS	$9.200	2009	Stream 515	22681	kg/hr	0,80	3,1	1,25
P-	704	Firewater Pump	Goulds	2500 GPM, 150 FT TDH	125,0	CS	$15.000	2009	Stream 713	8343	kg/hr	0,80	3,1	1,25
P-	710	Gasoline Pump	Goulds	4 GPM, 60 FT	0,5	CS	$3.000	2009	Stream 701	473	kg/hr	0,80	3,1	1,25
P-	720	CSL Pump	Goulds	8 GPM, 80 FT TDH	0,5	CS	$3.000	2009	Stream 735	1393	kg/hr	0,80	3,1	1,25
P-	740	Furfural product pump	Goulds	150 GPM, 112 FT TDH	5,0	CS	$9.200	2009	Stream 404	22681	kg/hr	0,80	3,1	1,25
P-	741	Formic acid product pump	Goulds	150 GPM, 112 FT TDH	5,0	CS	$9.200	2009	Stream 405	22681	kg/hr	0,80	3,1	1,25
P-	742	acetic acid product pump	Goulds	150 GPM, 112 FT TDH	5,0	CS	$9.200	2009	Stream 406	22681	kg/hr	0,80	3,1	1,25
P-	750	Cellulase Transfer Pump	Goulds	59 gpm, 100 FT, TDH SIZE 2X1-10C	3	316SS	$7.357	2010	Stream 322	13399	kg/hr	0,80	2,3	1,25
P-	751	Cellulase Feed Pump	Viking	Gear Pump	1	316SS	$1.500	2009	Stream 322	18168	kg/hr	0,80	2,3	1,25
P-	760	DAP Pump	Goulds	2 GPM, 100 FT TDH	0,5	CS	$3.000	2009	Stream 755	163	kg/hr	0,80	3,1	1,25
P-	771	Chlorhidric acid Pump	Goulds	2 GPM, 100 FT TDH	0,	CS	$3.000	2009	Stream 402	163	kg/hr	0,80	3,1	1,25
P-	772	THF make-up Pump	Goulds	2 GPM, 100 FT TDH	0,5	CS	$3.000	2009	Stream 403	163	kg/hr	0,80	3,1	1,25
T-	701	Ethanol Product Storage Tank	Mueller	750,000 gal., 7 day storage, Floating roof		A285C	$1.340.000	2009	Stream 515	22681	kg/hr	0,70	1,7	1,25
T-	704	Firewater Storage Tank		600,000 gal - 4 hrs @ 2500 gpm		Glass lined	$803.000	2009	Stream 713	8343	kg/hr	0,70	1,7	1,25
T-	706	Ammonia Storage Tank	Chemithon	28,000 gal		SA- 516-70	$196.000	2010	Stream 717	1171	kg/hr	0,70	2,0	1,25
T-	710	Gasoline Storage Tank		65,000 gal., floating roof		CS	$200.000	2009	Stream 701	473	kg/hr	0,70	1,7	1,25
T-	720	CSL Storage Tank		70,000 gal		Glass lined CS	$70.000	2009	Stream 735	1393	kg/hr	0,70	2,6	1,25
T-	740	Furfural storage tank		70,000 gal		Glass lined CS	$70.000	2009	Stream 404	1393	kg/hr	0,70	2,6	1,25
T-	741	Formic acid storage tank		70,000 gal		Glass lined CS	$70.000	2009	Stream 405	1393	kg/hr	0,70	2,6	1,25
T-	742	Acetic acid storage tank		70,000 gal		Glass lined CS	$70.000	2009	Stream 406	1393	kg/hr	0,70	2,6	1,25
T-	750	Cellulase Hold Tank	Mueller	80,000 gal		304SS	$248.070	2009	Stream 322	10930	kg/hr	0,70	1,8	1,25

EQPT NO		EQUIPMENT TITLE	VENDOR	DESCRIPTION	HP	MATERIAL	$	Quote Year	Scaling Variable	Scaling Val	Units	Scaling Exp	Inst Factor	Location factor
T-	755	DAP Bulk Bag Holder	Flexicon	Super sack holder			INCLUDED							
T-	760	DAP Make-up Tank		12,800 gal		SS304	$102.000	2009	Stream 755	1615	kg/hr	0,70	1,8	1,25
T	770	NaCl Make Up Tank		12,800 gal		SS304	$102.000	2009	Stream 401	1615	kg/hr	0,70	1,8	1,25
T-	771	Chlorhidric acid tank		12,800 gal		SS304	$102.000	2009	Stream 402	1615	kg/hr	0,70	1,8	1,25
T-	772	THF makeup tank		12,800 gal		SS304	$102.000	2009	Stream 403	1615	kg/hr	0,70	1,8	1,25
		AREA 800												
H-	801	Burner Combustion Air Preheater	Babcock & Wilcox				INCLUDED							
H-	811	BFW Preheater	Babcock & Wilcox				INCLUDED							
H-	812	Pretreatment/BFW heat recovery	Mueller	9.4 MM Btu/hr		SS304	$41.000	2009	Stream QH812	-2	Gcal/hr	0,70	2,2	1,25
M-	802	Air Intake Fan	Babcock & Wilcox				INCLUDED							
M-	803	Boiler	Babcock & Wilcox	525,000 lb/hr @ 900 psig	2752 kW	CS	$28.550.000	2010	Stream 812	238686	kg/hr	0,60	1,8	1,25
M-	811	Turbine/Generator	Siemens	23.6 kW, 2 extractions			$9.500.000	2010	Stream wtotal	-42200	kW	0,60	1,8	1,25
M-	820	Hot Process Water Softener System	Proctor Sales				$78.000	2010	Stream 812	235803	kg/hr	0,60	1,8	1,25
M-	830	Amine Addition Pkg.	Proctor Sales				$40.000	2010	Stream 812	235803	kg/hr	0,00	1,8	1,25
M-	832	Ammonia Addition Pkg	Proctor Sales				INCLUDED							
M-	834	Phosphate Addition Pkg.	Proctor Sales				INCLUDED							
P-	804	Condensate Pump	Proctor Sales			SS316	INCLUDED							
P-	811	Turbine Condensate Pump	Proctor Sales			SS304	INCLUDED							
P-	824	Deaerator Feed Pump	Proctor Sales			SS304	INCLUDED							
P-	826	BFW Pump	Proctor Sales			SS316	INCLUDED							
P-	828	Blowdown Pump	Proctor Sales			CS	INCLUDED							
P-	830	Amine Transfer Pump	Proctor Sales			CS	INCLUDED							
T-	804	Condensate Collection Tank	Proctor Sales			A285C	INCLUDED							
T-	824	Condensate Surge Drum	Proctor Sales			SS304	INCLUDED							
T-	826	Deaerator	Proctor Sales	Tray type		CS;SS316	$305.000	2010	Stream 812	235803	kg/hr	0,60	3,0	1,25
T-	828	Blowdown Flash Drum	Proctor Sales			CS	INCLUDED							
T-	830	Amine Drum	Proctor Sales			SS316	INCLUDED							
		AREA 900												
M-	902	Cooling Tower System	Marley SPX	44,200 gpm	750 hp	FIBERGLASS	$1.375.000	2010	Stream 945	10037820	kg/hr	0,60	1,5	1,25
M-	904	Plant Air Compressor	Rogers Machinery	400 SCFM@125 psig	150 hp		$28.000	2010	Stream DRY101	83333	kg/hr	0,60	1,6	1,25
M-	908	Chilled Water Package	Trane	2 x 2350 tons (14.2 MM kcal/hr)	3400 hp		$1.275.750	2010	Stream QCHWOP	14	Gcal/hr	0,60	1,6	1,25
M-	910	CIP System		100,000 GAL		SS04	$421.000	2009	Stream 914	63	kg/hr	0,60	1,8	1,25
P-	902	Cooling Water Pump	Goulds	16,120 GPM, 100 FT TDH 20X20-28	500,0	CS	$283.671	2010	Stream 945	10982556	kg/hr	0,80	3,1	1,25
P-	912	Make-up Water Pump	Goulds	685 GPM, 75 FT TDH SIZE 6X4-13	20,0	CS	$6.864	2010	Stream 904	155564	kg/hr	0,80	3,1	1,25
P-	914	Process Water Circulating Pump	Goulds	2285 GPM, 75 FT TDH SIZE 8X6-13	75,0	CS	$15.292	2010	Stream 905	518924	kg/hr	0,80	3,1	1,25
S-	904	Instrument Air Dryer	Zeks	670 SCFM - CYCLING TYPE		CS	$15.000	2009	Stream DRY101	83333	kg/hr	0,60	1,8	1,25
T-	904	Plant Air Receiver	Rogers Machinery	3800 gal - 72" x 228" vertical		CS	$16.000	2009	Stream DRY101	83333	kg/hr	0,60	3,1	1,25
T-	914	Process Water Tank No. 1		250,000 gal		CS	$250.000	2009	Stream 905	451555	kg/hr	0,70	1,7	1,25

3. Detailed information for fixed and variable operating costs

Variable operating costs:

Table A. 3 Variable operating costs considered for the TEA

Raw Material		Price ($/ t)	Year of price quote	2015 Cost ($ /t)	Cost reference
Raw Materials					
NONE	Feedstock	30	2015	30	For base case, modifying the excel spreadsheet from (Jacobson & Helsel 2014)
A200	Sulfuric Acid, 93%	100	2009	117	(Humbird et al. 2011) Basic Chemical, Omaha via HGI
	Ammonia	500	2009	584	(Humbird et al. 2011) Terra Industries via HGI, anhydrous, delivery to Iowa
A300	Corn Steep Liquor	63	2009	74	(Humbird et al. 2011) Corn Products via HGI
	Diammonium Phosph	1100	2009	1286	(Humbird et al. 2011) Ronas Chemicals via HGI
	Sorbitol	1255	2009	1467	(Humbird et al. 2011) Coast Southwest via HGI
	Enzyme (per t of protein)	4240	2015	4240	Selected for base case
	PEG	1920	2014	1888	https://www.zauba.com/export-PEG+6000/hs-code-2909-hs-code.html
A400	NaCl	39	2007	50	(Xing et al. 2011)
	HCl	240	2007	309	(Xing et al. 2011)
	Makeup THF	3889	2007	5026	(Xing et al. 2011)
A600	Caustic (as pure)	167	2009	195	(Humbird et al. 2011)
A800	Boiler chemicals	3111	1991	6508	(Humbird et al. 2011)
	Wood for boiler	56	2012	56	(Ministerio de Industria Energía y Minería 2012)
A900	Cooling tower chemicals	2222	1999	3900	(Humbird et al. 2011)
	Makeup water	0.73	2015	0.73	https://www.energy.gov/sites/prod/files/2017/10/f38/water_wastewater_escalation_rate_study.pdf
Waste Streams					
A800	Disposal of ash	20.2	1993	41	(Humbird et al. 2011)
By-Products and Credits					
	Furfural	1800,0	2015		(Biddy et al. 2016)
	Acetic acid	850,0	2015		(Biddy et al. 2016)
	Formic acid	650	2014		(Aligoli et al. 2018)
	Purchased Electricity	0,170/kWh	2015		(UTE 2015)
	Grid Electricity	0,092/kWh	2015		(Elender 2012)

Note: Costs for chemicals quoted in the US were multiplied by a factor of 1.1 in the analyses to account for transportation according to: http://worldfreightrates.com/freight

Table A. 4. Fixed operating costs considered for the TEA.

	Number required	Total	2015 Cost/year	Cost reference
Labor & Supervision				
Plant Manager	1	153894	153894	(Uruguay XXI 2015)
Plant Engineer	2	216840	216840	(Uruguay XXI 2015)
Maintenance Supr	1	51103	51103	(Uruguay XXI 2015)
Maintenance Tech	4	107692	107692	(Uruguay XXI 2015)
Lab Manager	1	94159	94159	(Uruguay XXI 2015)
Lab Technician	2	53846	53846	(Uruguay XXI 2015)
Shift Supervisor	3	153309	153309	(Uruguay XXI 2015)
Shift Operators	9	242307	242307	(Uruguay XXI 2015)
Yard Employees	2	53846	53846	(Uruguay XXI 2015)
Clerks & Secretaries	3	80769	80769	(Uruguay XXI 2015)
Total Salaries		1207765	1207765	(Uruguay XXI 2015)
Labor Burden (12,5%)		150970,625	150970,6	(Uruguay XXI 2015)
Other Overhead				
Maintenance	0,03 of ISBL		802006,1	(Uruguay XXI 2015)
Property Insur. & Tax	0,007 of FCI		954056,4	(Uruguay XXI 2015)
ISBL: inside-battery-limits equipment costs for areas 200, 300, 400, and 500				

4. Results of the discounted cash flow rate of return analyses

Table A. 5. Discounted cash flow rate of return analyses for cases 1 to 17.

CASE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Minimum Ethanol Selling Price (MESP)($/L):	0.89	1.08	0.72	1.14	0.85	0.80	0.99	0.79	1.14	0.83	0.86	1.07	1.15	1.02	0.71	0.76	0.80
Contributions ($/L):																	
Feedstock	0.11	0.11	0.11	0.14	0.14	0.09	0.28	0.14	0.14	0.14	0.14	0.18	0.14	0.14	0.14	0.14	0.14
Furfural,acetic and formic acid production	0.00	0.00	0.00	0.00	-0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.12	0.12	0.12	0.09	0.09	0.09
Conversion to ethanol	0.78	3.60	0.61	1.00	0.79	0.62	0.62	0.56	0.91	0.60	0.62	0.77	0.90	0.76	0.48	0.52	0.57
Ethanol production (m3/year at 20ºC)	26729.9	13375.2	53503.3	20231.6	20958.1	20958.1	20958.1	20958.1	20958.1	20979.9	20957.6	16080.3	20958.1	20958.1	20958.1	20958.1	20958.1
Ethanol yield (L/dry ton feedstock)	305.5	305.7	305.7	231.2	0.1	239.5	241.4	239.5	239.5	239.8	239.5	183.8	239.5	239.5	239.5	239.5	239.5
Feedstock cost ($/dry ton)	30	30	30	30	30	20	60	30	30	30	30	30	30	30	30	30	30
Internal Rate of Return (After-Tax)(%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Equity Percent of Total Investment(%)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Capital Costs ($)																	
Feedstock	7500000	4900000	11300000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000
Pretreatment	3400000	2300000	5300000	3400000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000
Saccharification & Fermentation	8600000	4900000	15400000	8600000	6500000	6500000	6500000	6500000	6500000	6500000	6500000	6500000	6500000	6500000	6500000	6500000	6500000
Furfural,acetic and formic acid production	0	0	0	0	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000
Distillation and solids recovery	7900000	5000000	12400000	7100000	7000000	7000000	7000000	7000000	7000000	7000000	7000000	6400000	7000000	7000000	7000000	7000000	7000000
Wastewater treatment	17600000	11800000	26800000	17900000	19800000	19800000	19800000	19800000	19800000	19800000	19800000	20000000	19800000	19800000	19800000	19800000	19800000
Storage	1500000	900000	2400000	1300000	1600000	1600000	1600000	1600000	1600000	1500000	1600000	1400000	1700000	1600000	1500000	1600000	1600000
Boiler/turbogenerator	25900000	17300000	39000000	28600000	23000000	23000000	23000000	23000000	23000000	22900000	23200000	25100000	23000000	23100000	23000000	23000000	23000000
Utilities	2300000	1700000	3200000	2400000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000
Total installed equipment cost	74700000	48800000	115800000	76800000	78400000	78400000	78400000	78400000	78400000	78200000	78600000	79900000	78500000	78500000	78300000	78400000	78400000
Added Direct + Indirect Costs ($)	64300000	41800000	99800000	65300000	68200000	68200000	68200000	68100000	68200000	67900000	68400000	69000000	68200000	68200000	68200000	68100000	68200000
Total Capital Investment (TCI)	131500000	85700000	204300000	134600000	139100000	139100000	139100000	139000000	139100000	138600000	139500000	141400000	139200000	139200000	138900000	139000000	139100000
Manufacturing Costs (cents/L ethanol)																	
Feedstock	10.8	10.8	10.8	14.3	13.8	9.2	27.6	13.8	13.8	13.8	13.8	18.0	13.8	13.8	13.8	13.8	13.8
Raw Materials	18.7	12.2	18.7	24.8	23.2	23.2	23.2	17.3	55.0	22.2	24.2	29.0	23.2	8.2	8.2	13.2	18.1
Co products	-6.0	-5.4	-6.9	-12.6	-41.9	-41.9	-41.9	-41.9	-42.2	-42.0	-42.2	-58.8	-41.9	-41.9	-41.9	-41.9	-42.0
Fixed Costs	10.8	17.6	7.1	14.3	14.4	14.4	14.4	14.4	14.4	14.4	14.4	18.8	14.4	14.4	14.4	14.4	14.4
Capital Depreciation	15.7	20.2	12.1	21.3	21.0	21.0	21.0	21.0	21.0	21.0	21.0	28.0	21.0	21.0	21.0	21.0	21.0
Average Return on Investment	38.7	52.1	29.6	52.4	54.3	54.3	54.3	54.7	51.5	54.1	54.4	71.8	84.9	86.2	55.5	55.1	54.7
Ethanol yields calculated for a theoretical maximum of 469 L/t																	
Ethanol production (m3/yr)	38710	19355	77420	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710
Case ethanol Yield (Actual/Theoretical)(%)	69	69	69	52	54	54	54	54	54	54	54	42	54	54	54	54	54

Table A. 6. Discounted cash flow rate of return analyses for cases 18 to 34.

CASE	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Minimum Ethanol Selling Price (MESP)($/L):	0.89	0.94	0.83	0.83	0.85	0.85	0.86	0.88	0.79	0.90	0.96	1.08	0.85	0.85	0.86	0.88	0.88
Contributions ($/L):																	
Feedstock	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.15	0.16	0.18	0.14	0.14	0.14	0.14	0.14
Furfural,acetic and formic acid production	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.11	0.12	0.09	0.09	0.09	0.09	0.10
Conversion to ethanol	0.66	0.71	0.60	0.60	0.61	0.62	0.63	0.65	0.57	0.65	0.69	0.78	0.61	0.62	0.63	0.65	0.64
Ethanol production (m3/year at 20ºC)	20958.1	20958.1	20958.1	20958.1	20958.1	20958.1	20958.1	20958.1	22733.0	19410.4	18308.5	16101.5	20958.1	20958.1	20958.1	20958.1	20034.5
Ethanol yield (L/dry ton feedstock)	239.5	239.5	239.5	239.5	239.5	239.5	239.5	239.5	259.8	221.8	209.2	184.0	239.5	239.5	239.5	239.5	229.0
Feedstock cost ($/dry ton)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Internal Rate of Return (After-Tax)(%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Equity Percent of Total Investment(%)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Capital Costs ($)																	
Feedstock	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000
Pretreatment	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4500000
Saccharification & Fermentation	6500000	6500000	5500000	5500000	6500000	6500000	7600000	8600000	6500000	6500000	6500000	6500000	6500000	6500000	7600000	8600000	6500000
Furfural,acetic and formic acid production	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000
Distillation and solids recovery	7000000	7000000	7000000	7000000	7000000	7000000	7000000	7000000	7100000	6900000	6900000	6800000	7000000	7000000	7000000	7000000	6900000
Wastewater treatment	19800000	19800000	19800000	19800000	19800000	19800000	19800000	19800000	19800000	19800000	19700000	19800000	19800000	19800000	19800000	19800000	19800000
Storage	1600000	1600000	1600000	1600000	1600000	1600000	1600000	1600000	1700000	1600000	1500000	1400000	1600000	1600000	1600000	1600000	1500000
Boiler/turbogenerator	23000000	23000000	23100000	23100000	23100000	23100000	23100000	23100000	22200000	23800000	24300000	25400000	23100000	23100000	23100000	23100000	23500000
Utilities	2100000	2100000	2000000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2200000	2100000	2100000	2100000	2100000	2100000
Total installed equipment cost	78400000	78400000	77400000	77500000	78500000	78500000	79600000	80600000	77800000	79100000	79400000	80500000	78500000	78500000	79600000	80600000	78700000
Added Direct + Indirect Costs ($)	68200000	68200000	67100000	67000000	68100000	68100000	69100000	70200000	67600000	68600000	68900000	69400000	68100000	68100000	69000000	70100000	68400000
Total Capital Investment (TCI)	139100000	139100000	137000000	137000000	139100000	139100000	141200000	143300000	137900000	1.4E+08	140800000	142400000	139100000	139100000	141100000	143200000	139600000
Manufacturing Costs (cents/L ethanol)																	
Feedstock	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	12.7	14.9	15.8	18.0	13.8	13.8	13.8	13.8	14.4
Raw Materials	28.2	33.2	23.2	23.2	23.2	23.2	23.2	23.2	21.3	25.0	26.5	30.1	23.2	23.2	23.2	23.2	24.2
Co products	-41.9	-41.9	-42.3	-42.2	-42.0	-41.8	-41.7	-41.4	-37.4	-46.9	-50.2	-59.3	-42.0	-41.8	-42.0	-41.5	-44.6
Fixed Costs	14.4	14.4	14.2	14.2	14.4	14.4	14.6	14.8	13.3	15.6	16.5	18.8	14.4	14.4	14.6	14.8	15.1
Capital Depreciation	21.0	21.0	20.5	20.5	21.0	21.0	21.5	21.5	19.4	22.7	24.6	27.9	21.0	21.0	21.5	21.5	22.0
Average Return on Investment	53.8	53.4	53.6	53.6	54.3	54.3	54.9	56.0	49.4	59.2	62.7	72.3	54.3	54.3	54.9	56.0	57.1
Ethanol yields calculated for a theoretical maximum of 469 L/t																	
Ethanol production (m3/yr)	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710
Case ethanol Yield (Actual/Theoretical)(%)	54	54	54	54	54	54	54	54	59	50	47	42	54	54	54	54	52

Table A. 7. Discounted cash flow rate of return analyses for cases 35 to 51.

CASE	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Minimum Ethanol Selling Price (MESP)($/L):	0.92	1.01	1.12	0.81	0.83	0.88	0.91	0.97	1.04	0.87	0.89	0.95	0.98	1.04	0.92	0.94	1.00
Contributions ($/L):																	
Feedstock	0.15	0.17	0.19	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16
Furfural,acetic and formic acid production	0.10	0.11	0.13	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11
Conversion to ethanol	0.67	0.73	0.81	0.58	0.59	0.65	0.68	0.74	0.81	0.62	0.64	0.70	0.73	0.79	0.66	0.67	0.74
Ethanol production (m3/year at 20ºC)	19116.6	17277.2	15432.6	20996.1	20979.4	20930.2	20896.7	20847.7	20773.7	19445.1	19429.7	19386.9	19353.7	19303.2	18339.9	18326.4	18283.9
Ethanol yield (L/dry ton feedstock)	218.5	197.5	176.4	240.0	239.8	781202.5	238.8	238.3	237.4	222.2	222.1	221.6	221.2	220.6	209.6	209.4	209.0
Feedstock cost ($/dry ton)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Internal Rate of Return (After-Tax)(%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Equity Percent of Total Investment(%)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Capital Costs ($)																	
Feedstock	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000
Pretreatment	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4600000	4600000	4500000	4500000	4500000	4500000	4600000	4500000	4500000	4500000
Saccharification & Fermentation	6500000	6500000	6500000	6000000	6200000	7900000	8300000	10000000	11800000	6000000	6200000	7900000	8300000	10000000	6000000	6200000	7900000
Furfural,acetic and formic acid production	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000
Distillation and solids recovery	6800000	6500000	6300000	6900000	6900000	7100000	7100000	7200000	7300000	6800000	6900000	7000000	7000000	7100000	6800000	6800000	6900000
Wastewater treatment	19900000	19900000	20000000	18500000	19100000	20600000	21800000	23300000	25400000	18600000	19100000	20700000	21700000	23300000	18600000	19100000	20600000
Storage	1500000	1500000	1400000	1600000	1600000	1600000	1600000	1600000	1600000	1500000	1500000	1600000	1600000	1600000	1500000	1500000	1500000
Boiler/turbogenerator	23900000	24800000	25500000	23200000	23100000	22900000	22800000	22700000	24300000	23900000	23900000	23800000	23600000	23500000	24500000	24400000	24200000
Utilities	2100000	2100000	2200000	2100000	2100000	2100000	2100000	2000000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000	2100000
Total installed equipment cost	79100000	79700000	80300000	76700000	77400000	80600000	82100000	85300000	91000000	77300000	78100000	81500000	82700000	86100000	77900000	78500000	81600000
Added Direct + Indirect Costs ($)	68600000	69000000	69400000	66800000	67500000	70100000	71400000	73900000	78600000	67400000	67800000	70500000	71800000	74300000	67500000	68200000	70900000
Total Capital Investment (TCI)	140200000	141200000	142200000	136000000	137400000	143200000	146000000	151700000	162100000	137200000	138400000	144500000	147000000	152900000	137900000	139200000	145000000
Manufacturing Costs (cents/L ethanol)																	
Feedstock	15.1	16.8	18.8	13.8	13.8	13.8	13.8	13.9	13.9	14.9	14.9	14.9	15.0	15.0	15.8	15.8	15.8
Raw Materials	25.4	28.1	31.5	22.8	23.0	23.4	23.7	24.2	26.0	24.6	24.8	25.2	25.6	26.1	26.1	26.3	26.8
Co products	-47.4	-54.1	-62.3	-42.9	-42.8	-41.1	-40.3	-39.0	-39.8	-47.6	-47.2	-45.8	-44.8	-43.5	-51.4	-50.9	-49.4
Fixed Costs	15.8	17.5	19.6	14.2	14.3	14.8	15.0	15.4	16.1	15.4	15.5	16.0	16.2	16.7	16.3	16.4	17.0
Capital Depreciation	23.0	26.0	29.2	20.5	21.0	21.5	22.0	23.0	24.6	22.6	22.6	23.7	16.2	25.4	24.0	24.0	25.2
Average Return on Investment	60.2	66.7	75.3	53.0	53.3	56.0	57.1	59.4	63.7	57.4	58.2	60.7	24.3	64.3	61.3	62.2	64.8
Ethanol yields calculated for a theoretical maximum of 469 L/t																	
Ethanol production (m3/yr)	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710
Case ethanol Yield (Actual/Theoretical)(%)	49	45	40	54	54	54	54	54	54	50	50	50	50	50	47	47	47

Table A. 8. Discounted cash flow rate of return analyses for cases 49 to 68.

CASE	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
Minimum Ethanol Selling Price (MESP)($/L):	1.03	1.10	1.04	1.05	1.13	1.17	1.24	0.99	0.76	0.77	0.82	0.85	0.90	0.90	0.80	0.97	0.73
Contributions ($/L):																	
Feedstock	0.16	0.16	0.18	0.18	0.18	0.18	0.18	0.17	0.13	0.13	0.13	0.13	0.13	0.15	0.12	0.14	0.13
Furfural,acetic and formic acid production	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.09	0.09	0.09	0.09	0.09	0.03	0.02	0.02	0.03
Conversion to ethanol	0.77	0.83	0.73	0.75	0.82	0.86	0.94	0.70	0.54	0.56	0.61	0.63	0.69	0.72	0.65	0.81	0.57
Ethanol production (m3/year at 20ºC)	18249.9	18199.2	16136.1	16121.2	16076.0	16040.4	15988.1	16898.9	22771.0	22754.1	22705.3	22668.6	22614.8	18679.1	23247.6	20402.4	21513.8
Ethanol yield (L/dry ton feedstock)	208.6	208.0	184.4	184.2	183.7	183.3	596742.1	193.1	260.2	260.0	259.5	259.1	258.5	215.1	267.7	235.0	247.8
Feedstock cost ($/dry ton)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Internal Rate of Return (After-Tax)(%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Equity Percent of Total Investment(%)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Capital Costs ($)																	
Feedstock	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000
Pretreatment	4500000	4600000	4500000	4500000	4500000	4500000	4600000	4500000	4500000	4500000	4500000	4500000	4600000	4500000	4600000	4500000	4500000
Saccharification & Fermentation	8300000	10000000	6000000	6200000	7900000	8300000	10000000	6000000	6000000	6200000	7900000	8300000	10000000	6400000	6700000	6500000	6600000
Furfural,acetic and formic acid production	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	5300000	7300000
Distillation and solids recovery	7000000	7100000	6700000	6700000	6800000	6900000	7000000	6600000	7000000	7000000	7100000	7200000	7300000	6600000	7300000	6900000	7100000
Wastewater treatment	21700000	23300000	18600000	19100000	20600000	21800000	23300000	18600000	18600000	19100000	20700000	21800000	23300000	19200000	20400000	19600000	20000000
Storage	1500000	1500000	1400000	1400000	1400000	1500000	1500000	1500000	1700000	1700000	1700000	1700000	1700000	1500000	1700000	1500000	1700000
Boiler/turbogenerator	24100000	24000000	25400000	25500000	25200000	25200000	25100000	25000000	22300000	22200000	22100000	22000000	22600000	23100000	23100000	22700000	23300000
Utilities	2100000	2100000	2200000	2200000	2100000	2100000	2100000	2200000	2100000	2100000	2000000	2000000	2000000	2100000	2100000	2000000	2200000
Total installed equipment cost	83100000	86500000	78700000	79500000	82400000	84200000	87500000	78300000	76100000	76700000	79900000	81400000	85400000	77300000	79800000	76500000	80200000
Added Direct + Indirect Costs ($)	72100000	74600000	68000000	68700000	71500000	72600000	75200000	67600000	66100000	67000000	69600000	70800000	73800000	67100000	69100000	66300000	69400000
Total Capital Investment (TCI)	147700000	153600000	139200000	140700000	146400000	149300000	155200000	138400000	134700000	136200000	142000000	144700000	151700000	136900000	141400000	135300000	142100000
Manufacturing Costs (cents/L ethanol)																	
Feedstock	15.9	15.9	17.9	18.0	18.0	18.0	18.1	17.1	12.7	12.7	12.7	12.8	12.8	15.5	12.4	14.2	13.5
Raw Materials	27.1	27.7	29.7	29.9	30.4	30.9	31.5	28.3	21.0	21.2	21.6	21.9	22.7	23.3	23.1	23.8	22.6
Co products	-48.4	-47.1	-60.5	-60.1	-58.3	-57.3	-55.9	-56.8	-38.2	-37.9	-36.7	-35.9	-35.7	-47.8	-37.5	-30.0	-52.7
Fixed Costs	17.2	17.7	18.6	18.7	19.3	19.6	20.2	17.7	13.1	13.1	13.6	13.8	14.2	16.0	13.1	14.5	14.3
Capital Depreciation	25.8	26.9	27.3	27.9	28.6	29.3	30.6	26.0	18.9	18.9	19.8	20.3	21.2	23.0	19.4	21.1	20.9
Average Return on Investment	66.0	68.6	70.6	71.1	74.6	76.2	79.3	66.9	48.3	49.0	51.1	52.0	54.8	60.4	49.4	53.5	54.5
Ethanol yields calculated for a theoretical maximum of 469 L/t																	
Ethanol production (m3/yr)	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	35559	41861	35488	41932
Case ethanol Yield (Actual/Theoretical)(%)	47	47	42	42	42	41	41	44	59	59	59	59	58	53	56	57	51

Table A. 9 Discounted cash flow rate of return analyses for cases 69 to 71 and BB1 to BB15

CASE	69	70	71	BB1	BB2	BB3	BB4	BB5	BB6	BB7	BB8	BB9	BB10	BB11	BB12	BB13	BB14	BB15
Minimum Ethanol Selling Price (MESP)($/L):	0.84	0.85	0.77	0.95	1.04	0.96	0.99	0.88	0.88	0.86	0.86	0.93	0.96	1.00	0.99	0.83	0.82	0.84
Contributions ($/L):																		
Feedstock	0.14	0.14	0.15	0.16	0.12	0.19	0.12	0.12	0.12	0.13	0.13	0.17	0.18	0.12	0.12	0.12	1.24	0.13
Furfural,acetic and formic acid production	0.02	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.12	0.02
Conversion to ethanol	0.67	0.69	0.59	0.77	0.89	0.74	0.85	0.74	0.74	0.71	0.71	0.73	0.75	0.86	0.85	0.68	0.02	0.70
Ethanol production (m3/year at 20ºC)	20968.6	20948.4	19231.3	18250.2	23778.1	15032.7	23880.3	23556.1	23556.1	22549.2	22549.2	16763.8	16322.3	23620.5	23842.3	23398.6	23842.3	22955.0
Ethanol yield (L/dry ton feedstock)	241.5	241.3	221.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Feedstock cost ($/dry ton)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Internal Rate of Return (After-Tax)(%)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Equity Percent of Total Investment(%)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Capital Costs ($)																		
Feedstock	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000	7500000
Pretreatment	4500000	4600000	4500000	4200000	4200000	4500000	4200000	4600000	4600000	4500000	4500000	4500000	4500000	4500000	4500000	4500000	4200000	4500000
Saccharification & Fermentation	6400000	6700000	6400000	2400000	2400000	7000000	2400000	7300000	7300000	7000000	7000000	8600000	8600000	5500000	5500000	5500000	2400000	5500000
Furfural,acetic and formic acid production	6400000	6400000	7300000	11400000	6300000	6400000	7100000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	6400000	5500000	6400000
Distillation and solids recovery	6700000	7200000	6700000	6400000	6400000	6600000	6400000	7200000	7200000	7000000	7000000	6800000	6800000	7100000	7100000	7100000	6400000	7000000
Wastewater treatment	19100000	20400000	19300000	7000000	7200000	18600000	7000000	21800000	21800000	18600000	18600000	19800000	19800000	19800000	19800000	19800000	7100000	19800000
Storage	1600000	1600000	1600000	21800000	21800000	1300000	18600000	1700000	1700000	1600000	1600000	1400000	1400000	1700000	1700000	1700000	19800000	1600000
Boiler/turbogenerator	21000000	25100000	23400000	1500000	1700000	26000000	1700000	21700000	21700000	22400000	22400000	25000000	25300000	21700000	21600000	21700000	1700000	22100000
Utilities	2000000	2200000	2200000	24200000	21400000	2200000	21700000	2000000	2000000	2100000	2100000	2200000	2200000	2000000	2000000	2000000	21600000	2000000
Total installed equipment cost	75200000	81700000	78900000	86400000	78900000	80100000	76600000	80200000	80200000	77100000	77100000	82200000	82500000	76200000	76100000	76200000	76200000	76400000
Added Direct + Indirect Costs ($)	65800000	70300000	68600000	79000000	71300000	69400000	69100000	69500000	69500000	67400000	67400000	71300000	71300000	66500000	66400000	66400000	68600000	66800000
Total Capital Investment (TCI)	133500000	144500000	140000000	154000000	139900000	142000000	136100000	142200000	142200000	137000000	137000000	146000000	146300000	135200000	135000000	135100000	134900000	135700000
Manufacturing Costs (cents/L ethanol)																		
Feedstock	13.8	13.8	15.0	15.9	12.2	19.3	12.1	12.3	12.3	12.8	12.8	17.3	17.7	12.3	12.1	12.4	12.1	12.6
Raw Materials	23.1	23.2	22.6	12.3	48.6	13.9	47.5	29.5	29.5	30.0	30.0	12.8	13.2	48.2	47.8	29.2	28.6	29.7
Co products	-39.5	-44.6	-59.8	-47.7	-34.2	-65.7	-35.3	-34.5	-34.5	-38.4	-38.4	-55.5	-57.5	-35.6	-35.1	-36.0	-35.1	-37.2
Fixed Costs	14.2	14.6	15.8	17.9	12.7	20.2	12.6	13.0	13.0	13.4	13.4	18.6	19.1	12.6	12.4	12.7	12.4	12.9
Capital Depreciation	20.0	22.0	22.9	26.8	18.5	29.9	18.0	19.1	19.1	19.1	19.1	27.4	28.2	18.2	18.0	18.4	18.0	18.7
Average Return on Investment	52.2	56.3	60.4	70.0	45.8	78.7	44.3	48.6	48.6	49.1	49.1	72.7	74.9	44.4	43.8	46.4	45.5	47.6
Ethanol yields calculated for a theoretical maximum of 469 L/t																		
Ethanol production (m3/yr)	38710	38710	38782	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710	38710
Case ethanol Yield (Actual/Theoretical)(%)	54	54	50	47	61	39	62	61	61	58	58	43	42	61	62	60	62	59

5. Material and energy flows

More information on the streams appearing in the tables can be seen in the flow diagrams (Appendix B).

Table A. 10. Material flows for the main streams for cases 1 to 32.

Stream / Case	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
101 Feedstock	11447	5723	22894	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447
DRY 101 Feedstock (dry base)	10417	5208	20833	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417
217	63096	31577	126570	62910	62968	62968	62968	62968	62968	62962	62976	62835	62968	62968	62968	62968	62968	62968	62968	62968	62968	62968	62968	62968	62968	63022	62928	62905	63007	62968	62968	62968
223	52825	26418	105996	52674	52719	52719	52719	52719	52719	52714	52725	52610	52719	52719	52719	52719	52719	52719	52719	52719	52719	52719	52719	52719	52719	52762	52686	52667	52751	52719	52719	52719
228	52231	26148	104320	52088	36951	36951	36951	36951	36951	36950	36953	36944	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36964	36942	36936	37040	36951	36951	36951
239	52231	26148	104320	52088	36951	36951	36951	36951	36951	36950	36953	36944	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36951	36964	36942	36936	37040	36951	36951	36951
254b	0	0	0	0	50458	50458	50458	50458	50458	50453	50463	50355	50458	50458	50458	50458	50458	50458	50458	50458	50458	50458	50458	50458	50458	50499	50427	50409	50488	50458	50458	50458
273	69	34	138	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	1672	908	2786	1672	16732	16732	16732	16732	16732	16732	16732	16735	16732	16732	16732	16732	16732	16732	16732	16732	16732	16732	16732	16732	16732	16732	16732	16777	16732	16732	16732	16732
303	4326	2207	8697	4409	2877	2877	2877	2877	2877	2873	2886	2953	2877	2877	2877	2877	2877	2877	2877	2877	2877	2877	2877	2877	2877	2904	2856	2839	2842	2877	2877	2877
304	4346	2217	8737	4374	2891	2891	2891	2891	2891	2877	2916	2916	2891	2891	2891	2891	2891	2891	2891	2891	2891	2891	2891	2891	2891	2917	2870	2853	2857	2891	2891	2891
306	52623	26540	104711	52480	37343	37343	37343	37343	37343	37341	37344	37335	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37355	37333	37328	37432	37343	37343	37343
T310FD	52623	26540	104711	52480	37343	37343	37343	37343	37343	37341	37344	37335	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37343	37355	37333	37328	37432	37343	37343	37343
322-Enzyme	678	339	1357	678	675	675	675	675	675	675	675	675	675	169	169	337	506	844	1012	675	675	675	675	675	675	675	675	675	675	675	675	675
322 Enzyme (protein)	109	54	217	109	108	108	108	108	108	108	108	108	108	27	27	54	81	135	162	108	108	108	108	108	108	108	108	108	108	108	108	108
Sorbitol	4	2	9	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
401-NaCl	0	0	0	0	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396
402-HCl	0	0	0	0	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344
403-THF	0	0	0	0	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
404-Furfural	0	0	0	0	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397
405-Acetic acid	0	0	0	0	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219
406-Formic acid	0	0	0	0	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
501	56157	28620	112756	56234	39506	39506	39506	39506	39506	39397	39627	39849	39506	39506	39506	39506	39507	39506	39506	39506	39506	39506	39506	39506	39506	39549	39543	39622	39933	39506	39506	39506
511	3381	1693	6767	2559	2649	2649	2649	2649	2649	2652	2649	2031	2649	2649	2649	2649	2649	2649	2649	2649	2649	2649	2649	2649	2649	2878	2454	2315	2036	2649	2649	2649
515-Dehydrated ethanol to sto	2527	1264	5058	1913	1981	1981	1981	1981	1981	1983	1981	1520	1981	1981	1981	1981	1981	1981	1981	1981	1981	1981	1981	1981	1981	2149	1835	1731	1522	1981	1981	1981
523	2527	1264	5056	1906	1980	1980	1980	1980	1980	1982	1980	1517	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	2148	1833	1728	1519	1980	1980	1980
535-Thin stillage	38934	19860	78271	39677	25896	25896	25896	25896	25896	25855	25972	26579	25896	25896	25896	25896	25896	25896	25896	25896	25896	25896	25896	25896	25896	26135	25706	25550	25576	25896	25896	25896
551	1498	1017	3930	1019	1101	1101	1101	1101	1101	1103	1099	1018	1101	1101	1101	1101	1101	1101	1101	1101	1101	1101	1101	1101	1101	1270	1023	1022	1018	1101	1101	1101
571 Lignin wet cake	5847	2984	11640	5869	5567	5567	5567	5567	5567	5507	5597	5698	5567	5567	5567	5567	5567	5567	5567	5567	5567	5567	5567	5567	5567	5132	5995	6371	6892	5567	5567	5567
572	43260	22066	86968	44086	28774	28774	28774	28774	28774	28728	28858	29533	28774	28774	28774	28774	28774	28774	28774	28774	28774	28774	28774	28774	28774	29038	28562	28389	28418	28774	28774	28774
SQAIRIN	101	52	204	103	71	71	71	71	71	71	71	73	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71	72	73	71	71	71
601 Total flows to wastewater t	54334	27720	108810	55475	65730	65730	65730	65730	65730	65664	65851	66730	65730	65739	65730	65730	65732	65730	65730	65722	65728	65733	65739	65743	65754	65881	65634	65532	65856	65733	65738	65743
701 Gasoline as denaturant	54	27	108	41	42	42	42	42	42	42	42	32	42	42	42	42	42	42	42	42	42	42	42	42	42	46	39	37	32	42	42	42
703-Denaturated ethanol	2581	1291	5166	1954	2023	2023	2023	2023	2023	2025	2023	1553	2023	2023	2023	2023	2023	2023	2023	2023	2023	2023	2023	2023	2023	2195	1874	1768	1555	2023	2023	2023
713-Fire water	929	465	1860	704	729	729	729	729	729	729	729	559	729	729	729	729	729	729	729	729	729	729	729	729	729	790	675	637	560	729	729	729
717-Ammonia	69	34	138	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
735-Purchased CSL	146	75	289	146	101	101	101	101	101	9	200	9	101	101	101	101	101	101	101	101	101	101	101	101	101	102	100	99	99	101	101	101
755-Purchased DAP	18	9	36	18	12	12	12	12	12	1	25	1	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
812	32045	16267	63498	36739	27147	27147	27147	27147	27147	26875	27415	30411	27147	27192	27147	27147	27148	27147	27147	27154	27157	27155	27158	27154	27157	25794	28390	29157	30963	27155	27157	27154
903	20147	10012	39930	23329	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481

Table A. 11. Material flows for the main streams for cases 32 to 64.

Stream / Case	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
101 Feedstock	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447
DRY 101 Feedstock (dry base)	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417
217	62968	62944	62929	62896	62859	62967	62931	63094	63149	62964	63268	63321	62885	62957	63268	62915	63296	62839	63032	63237	62877	63254	62827	62977	63178	63253	63017	63021	62984	63150	63205	62789
223	52719	52699	52687	52660	52630	52718	52688	52821	52866	52715	52963	53007	52651	52709	52963	52675	52987	52613	52771	52938	52644	52952	52603	52726	52890	52951	52759	52762	52731	52867	52912	52572
228	36951	36946	36942	36934	36925	29435	32786	42322	49379	59628	74411	29439	32775	42277	49372	59616	29433	32850	42308	49365	59608	29423	32818	42295	49411	59672	29412	29448	32798	42336	49403	59673
239	36951	36946	36942	36934	36925	29435	32786	42322	49379	59628	74411	29439	32775	42277	49372	59616	29433	32850	42308	49365	59608	29423	32818	42295	49411	59672	29412	29448	32798	42336	49403	59673
254b	50458	50439	50428	50402	50374	50457	50429	50554	50596	50454	50687	50729	50394	50449	50688	50416	50710	50358	50506	50664	50387	50677	50349	50465	50619	50676	50496	50498	50470	50597	50640	50319
273	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	16732	16732	16732	16732	16732	9219	12597	22073	29184	39410	54195	9219	12597	22073	29184	39410	9219	12619	22073	29184	39410	9219	12597	22073	29184	39410	9217	9219	12597	22073	29184	39466
303	2877	2889	2908	2945	2983	2127	2464	3405	4127	5168	6669	2098	2434	3403	4116	5160	2087	2432	3382	4098	5150	2064	2415	3375	4097	5151	2128	2157	2488	3442	4153	5188
304	2891	2895	2906	2928	2951	2136	2475	3422	4149	5197	6707	2107	2445	3421	4138	5189	2096	2444	3400	4120	5179	2074	2427	3393	4120	5180	2117	2165	2499	3459	4175	5217
306	37343	37337	37333	37326	37317	29827	33177	42714	49770	60020	74802	29830	33166	42669	49764	60008	29825	33242	42699	49756	59999	29815	33209	42687	49803	60064	29804	29840	33190	42727	49795	60065
T310FD	37343	37337	37333	37326	37317	29827	33177	42714	49770	60020	74802	29830	33166	42669	49764	60008	29825	33242	42699	49756	59999	29815	33209	42687	49803	60064	29804	29840	33190	42727	49795	60065
322-Enzyme	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
322 Enzyme (protein)	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108
Sorbitol	3	3	3	3	3	2	2	3	4	5	7	2	2	3	4	5	2	2	3	4	5	2	2	3	4	5	2	2	2	3	4	5
401-NaCl	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396
402-HCl	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344
403-THF	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
404-Furfural	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397
405-Acetic acid	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219
406-Formic acid	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
501	39506	39523	39623	39824	40024	31310	34961	45376	53170	64511	80867	31276	34933	45453	53295	64634	31329	35109	45564	53371	64716	31500	35263	45747	53621	64985	31485	31371	35008	45422	53172	64460
511	2649	2533	2417	2184	1951	2656	2655	2646	2642	2636	2623	2462	2459	2450	2446	2441	2322	2317	2311	2306	2297	2043	2040	2032	2027	2017	2137	2884	2878	2870	2866	2859
515-Dehydrated ethanol to sto	1981	1894	1807	1633	1459	1984	1983	1979	1976	1972	1966	1838	1836	1833	1830	1826	1733	1732	1729	1726	1722	1525	1524	1520	1517	1513	1597	2152	2150	2146	2143	2139
523	1980	1892	1805	1630	1456	1988	1984	1976	1972	1968	1964	1840	1837	1830	1826	1823	1735	1731	1725	1722	1719	1524	1522	1517	1514	1512	1597	2158	2153	2144	2139	2134
535-Thin stillage	25896	26000	26168	26507	26848	19146	22180	30642	37139	46513	60023	18884	21907	30631	37040	46441	18779	21889	30437	36879	46348	18576	21733	30375	36875	46359	19154	19410	22392	30976	37379	46695
551	1101	1024	1022	1020	1017	1215	1158	1043	1020	1018	1015	1060	1026	1021	1019	1016	1026	1024	1019	1017	1015	1022	1020	1017	1015	1013	1023	1400	1336	1203	1136	1065
571 Lignin wet cake	5567	5575	5589	5615	5642	5560	5533	5674	5607	5615	5672	6002	5993	5941	6021	6005	6297	6303	6392	6407	6327	6938	6879	6900	6919	6855	6190	5113	5131	5134	5127	5144
572	28774	28889	29076	29452	29831	21274	24644	34047	41266	51681	66692	20982	24341	34035	41156	51601	20865	24321	33819	40976	51497	20641	24147	33750	40972	51510	21282	21567	24880	34418	41532	51883
SQAIRIN	71	71	72	72	73	55	62	82	97	118	149	56	63	83	97	119	56	63	83	98	119	57	64	84	99	121	57	55	62	82	96	118
601 Total flows to wastewater t	65749	65892	66113	66554	66993	58998	62000	70499	77034	86166	99884	59173	61809	70719	76888	86181	59133	61956	70448	76783	86140	59053	61946	70507	77024	86535	59455	59156	62117	70756	77006	86220
701 Gasoline as denaturant	42	40	39	35	31	42	42	42	42	42	42	39	39	39	39	39	37	37	37	37	37	33	32	32	32	32	34	46	46	46	46	46
703-Denaturated ethanol	2023	1934	1846	1668	1490	2027	2025	2021	2018	2014	2008	1877	1876	1872	1869	1865	1770	1769	1766	1763	1758	1558	1556	1553	1550	1545	1631	2198	2196	2192	2189	2184
713-Fire water	729	697	665	601	537	730	729	728	727	725	723	676	675	674	673	672	638	637	636	635	633	561	561	559	558	556	588	791	791	789	788	787
717-Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
735-Purchased CSL	101	101	101	101	101	78	88	117	138	169	213	77	87	116	137	168	77	87	116	137	168	76	86	114	136	167	78	79	89	118	139	170
755-Purchased DAP	12	12	12	12	12	9	11	15	17	22	27	9	11	14	17	21	9	11	14	17	21	9	11	14	17	21	9	9	11	15	17	22
812	27152	27886	28562	29920	31247	27118	27122	27111	27263	27395	30481	28281	28321	28530	28448	28666	29139	29190	29209	29288	29501	30772	30997	30930	31072	31281	30040	25663	25725	25848	25925	27235
903	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481

Table A. 12. Material flows for the main streams for cases 65 to 71 and BB1 to BB15.

Stream / Case	65	66	67	68	69	70	71	BB1	BB2	BB3	BB4	BB5	BB6	BB7	BB8	BB9	BB10	BB11	BB12	BB13	BB14	BB15
101 Feedstock	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447	11447
DRY 101 Feedstock (dry base)	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417	10417
217	62766	63154	62891	63043	62786	63128	62828	63079	63240	63233	63055	63234	63234	63014	63014	63022	63012	63049	63055	63042	63055	63029
223	52513	52911	52657	52778	52549	52871	52562	52809	52941	52935	52790	52936	52936	52756	52756	52762	52755	52784	52790	52779	52790	52768
228	34589	39044	36362	37517	34492	39217	35097	49362	49400	29418	29456	49410	49410	29446	29446	37044	37041	36970	36972	36969	36972	36966
239	34589	39044	36362	37517	34492	39217	35097	49362	49400	29418	29456	49410	49410	29446	29446	37044	37041	36970	36972	36969	36972	36966
254b	50293	50610	50424	50489	50315	50583	50315	50543	50666	50661	50525	50662	50662	50493	50493	50499	50491	50519	50524	50514	50524	50504
273	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	15724	17522	16392	16992	15681	17639	15942	29184	29184	9219	9219	29184	29184	9219	9219	16777	16777	16732	16732	16732	16732	16732
303	2690	3042	2830	2923	2703	3030	2724	4111	4169	2067	2175	4167	4167	2155	2155	2840	2841	2920	2921	2918	2921	2915
304	2703	3057	2843	2937	2715	3045	2737	4134	4191	2077	2184	4189	4189	2164	2164	2855	2856	2933	2935	2932	2935	2929
306	34980	39435	36753	37909	34883	39609	35488	49754	49792	29810	29848	49802	49802	29838	29838	37435	37433	37362	37363	37360	37363	37357
T310FD	34980	39435	36753	37909	34883	39609	35488	49754	49792	29810	29848	49802	49802	29838	29838	37435	37433	37362	37363	37360	37360	37357
322-Enzyme	595	755	675	675	675	675	595	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
322 Enzyme (protein)	95	121	108	108	108	108	95	108	108	108	108	108	108	108	108	108	108	108	108	108	108	108
Sorbitol	3	3	3	3	3	3	3	4	4	2	2	4	4	2	2	3	3	3	3	3	3	3
401-NaCl	396	396	260	500	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396
402-HCl	344	344	229	448	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344	344
403-THF	18	18	15	25	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
404-Furfural	397	397	274	521	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397	397
405-Acetic acid	219	219	156	292	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219	219
406-Formic acid	64	64	42	76	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
501	37083	41757	38873	40115	36886	41915	37575	53382	53180	31600	31413	53189	53189	31365	31365	39874	39913	39576	39581	39571	39581	39563
511	2361	2944	2579	2720	2654	2648	2431	2307	3006	1903	3028	2978	2978	2855	2855	2120	2064	2990	3018	2962	3018	2906
515-Dehydrated ethanol to sto	1766	2197	1929	2034	1982	1980	1818	1726	2248	1421	2257	2227	2227	2131	2131	1585	1543	2233	2253	2212	2253	2170
523	1764	2196	1927	2033	1982	1978	1817	1722	2244	1419	2264	2223	2223	2136	2136	1582	1540	2232	2254	2211	2254	2169
535-Thin stillage	24207	27380	25466	26307	24323	27274	24517	37000	37520	18601	19577	37502	37502	19396	19396	25560	25571	26277	26291	26263	26291	26236
551	1023	1300	1054	1148	1126	1080	1024	1017	1235	1020	1520	1215	1215	1377	1377	1019	1019	1358	1380	1336	1380	1292
571 Lignin wet cake	5455	5748	5521	5611	4873	6284	5504	6282	4843	7132	4836	4898	4898	5150	5150	6776	6853	4893	4856	4931	4856	5006
572	26897	30422	28296	29230	27026	30304	27242	41111	41689	20668	21752	41669	41669	21551	21551	28400	28412	29197	29212	29182	29212	29151
SQAIRIN	67	75	70	72	66	76	68	98	96	57	55	96	96	55	55	73	73	70	70	70	70	71
601 Total flows to wastewater t	62370	69028	64775	66741	62112	69282	63255	77075	77288	59168	59277	77101	77101	59174	59174	65813	65854	65970	65969	65955	65968	65970
701 Gasoline as denaturant	38	47	41	43	42	42	39	37	48	30	48	47	47	45	45	34	33	48	48	47	48	46
703-Denaturated ethanol	1803	2244	1970	2077	2024	2022	1857	1763	2296	1451	2305	2275	2275	2177	2177	1619	1576	2280	2302	2259	2302	2216
713-Fire water	649	808	709	748	729	728	669	635	827	523	830	819	819	784	784	583	568	821	829	813	829	798
717-Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
735-Purchased CSL	94	107	99	102	95	106	96	137	140	75	80	140	140	79	79	99	99	102	102	102	102	102
755-Purchased DAP	12	13	12	13	12	13	12	17	17	9	9	17	17	9	9	12	12	12	12	12	12	12
812	27001	27345	27081	27156	23691	30591	27109	29425	25061	31767	24839	25517	25517	25901	25901	30378	30777	25103	24895	25136	24893	25690
903	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481	58481

Table A. 13. Energy flows for the main streams for cases 1 to 32.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Electric power consumed per area (kW)																																
A100	94	47	189	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
A200	732	445	1304	732	696	696	696	696	696	696	696	696	696	696	696	696	681	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696
A300	359	190	697	341	266	266	266	266	266	264	266	251	266	266	266	266	266	266	266	159	202	244	287	329	414	272	260	257	250	244	287	329
A400	0	0	0	0	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
A500	304	175	566	299	228	228	228	228	228	227	228	226	228	228	228	228	228	228	228	228	228	228	228	228	228	229	227	226	226	228	228	228
A600	414	260	729	411	503	503	503	503	503	502	503	502	503	503	503	503	503	503	503	503	503	503	503	503	503	504	502	501	504	503	503	503
A700	10	9	11	10	27	27	27	27	27	27	28	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
A800	157	105	257	174	140	140	140	140	140	139	141	152	140	140	140	140	140	140	140	140	140	140	140	140	140	135	145	147	153	140	140	140
A900	402	244	718	455	293	293	293	293	293	291	298	328	293	294	293	293	293	293	293	292	293	294	294	295	297	279	308	315	334	294	294	295
Electric power generated and surpluss (kW)																																
Power generated in A800	4538	2315	8869	5827	3312	3312	3312	3312	3312	3260	3413	4219	3312	3335	3312	3312	3325	3312	3312	3331	3332	3331	3332	3331	3331	2948	3665	3875	4343	3331	3332	3331
Surpluss electricity	2065	839	4399	3311	1047	1047	1047	1047	1047	1001	1140	1925	1047	1068	1047	1047	1075	1047	1047	1173	1130	1086	1044	999	913	693	1387	1591	2041	1086	1043	999
Heat streams used in equipment scaling and total heat from boiler (kW).																																
QH201	-2711	-1354	-5442	-2711	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2797	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2807	-2799	-2799	-2799
QH244	4332	2189	8683	4307	4261	4261	4261	4261	4261	4259	4249	4223	4261	4256	4261	4261	4261	4261	4261	4242	4242	4242	4242	4242	4242	4269	4253	4239	4244	4242	4242	4242
QC310	874	441	1738	871	616	616	616	616	616	616	616	616	616	616	616	616	616	616	616	616	616	616	616	616	616	619	613	611	609	616	616	616
QCD502	3478	1772	6990	3307	2463	2463	2463	2463	2463	2459	2467	2359	2463	2463	2463	2463	2463	2463	2463	2463	2463	2463	2463	2463	2463	2513	2426	2402	2362	2463	2463	2463
QBOILER	22894	11633	45373	26291	19467	19467	19467	19467	19467	19244	19666	21762	19467	19467	19467	19467	19467	19467	19467	19467	19467	19467	19467	19467	19467	18457	20319	20880	22167	19467	19467	19467
QH801	1362	692	2706	1568	1151	1151	1151	1151	1151	1140	1163	1303	1151	1151	1151	1151	1151	1151	1151	1151	1151	1151	1151	1151	1151	1089	1208	1251	1328	1151	1151	1151
QCHWOP	714	362	1416	609	547	547	547	547	547	538	546	462	547	547	547	547	547	547	547	455	492	529	565	602	675	580	518	497	457	529	565	602
QH812	-867	-454	-1673	-865	-833	-833	-833	-833	-833	-835	-847	-854	-833	-838	-833	-833	-833	-833	-833	-853	-853	-853	-853	-853	-853	-834	-836	-846	-848	-853	-853	-853

Table A. 14. Energy flows for the main streams for cases 33 to 64.

	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
Electric power consumed per area (kW)																																
A100	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
A200	696	696	696	696	696	696	622	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696
A300	372	263	261	257	252	224	243	295	334	390	471	219	237	290	329	385	215	234	286	325	381	208	227	279	318	374	213	230	249	301	340	397
A400	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
A500	228	227	227	226	226	191	208	254	288	338	409	190	206	253	288	337	189	206	253	287	337	189	205	252	287	336	189	193	209	255	290	339
A600	503	502	502	502	502	460	479	533	574	631	718	461	478	534	573	632	461	479	532	572	631	461	479	533	574	634	460	461	480	534	574	632
A700	27	27	27	27	27	27	27	27	28	28	28	27	27	27	28	28	27	27	27	27	28	27	27	27	27	28	27	27	27	28	28	28
A800	140	143	145	150	155	140	140	140	140	139	149	144	144	145	144	144	147	147	147	147	147	153	154	153	153	154	151	135	135	135	135	139
A900	296	302	309	324	338	307	302	284	275	260	273	320	315	299	289	274	329	322	307	298	283	347	342	325	317	303	338	290	286	271	261	258
Electric power generated and surpluss (kW)																																
Power generated in A800	3330	3526	3709	4077	4438	3516	3453	3170	3036	2821	3254	3841	3770	3548	3367	3168	4077	3985	3740	3597	3399	4522	4473	4209	4078	3890	4309	3104	3056	2821	2672	2748
Surpluss electricity	956	1252	1428	1782	2129	1357	1320	829	589	225	396	1670	1553	1191	908	559	1898	1760	1378	1131	783	2329	2231	1831	1593	1252	2123	958	860	488	237	147
Heat streams used in equipment scaling and total heat from boiler (kW).																																
QH201	-2799	-2799	-2799	-2799	-2799	-2848	-2824	-2772	-2729	-2653	-2580	-2872	-2824	-2766	-2739	-2653	-2872	-2822	-2772	-2739	-2653	-2872	-2824	-2772	-2739	-2680	-2857	-2848	-2824	-2772	-2729	-2639
QH244	4242	4255	4251	4242	4231	4211	4214	4291	4341	4394	4519	4218	4217	4289	4354	4397	4221	4199	4291	4348	4390	4217	4211	4275	4338	4402	4195	4221	4238	4314	4365	4390
QC310	616	616	616	616	615	476	539	716	847	1037	1312	474	536	712	844	1034	471	535	711	842	1032	467	530	706	839	1029	473	480	542	719	851	1041
QCD502	2463	2441	2423	2388	2349	2001	2193	2815	3276	3931	4841	1940	2150	2778	3238	3886	1908	2131	2755	3208	3849	1859	2085	2701	3151	3779	1878	2101	2252	2864	3326	3984
QBOILER	19467	19956	20442	21414	22388	19403	19449	19442	19552	19646	21824	20243	20277	20417	20393	20523	20862	20900	20913	20947	21121	22059	22139	22201	22245	22390	21518	18400	18416	18503	18559	19500
QH801	1151	1181	1210	1270	1329	1147	1148	1159	1159	1165	1275	1204	1206	1209	1214	1219	1244	1247	1255	1258	1260	1326	1326	1331	1335	1337	1292	1085	1087	1092	1095	1142
QCHWOP	639	533	520	492	465	512	527	572	605	653	721	483	499	543	576	624	462	478	522	555	603	421	437	481	514	562	445	545	561	605	638	686
QH812	-853	-836	-838	-842	-847	-834	-850	-849	-850	-846	-839	-855	-840	-837	-844	-836	-849	-853	-840	-846	-838	-847	-838	-848	-848	-854	-849	-832	-834	-834	-834	-838

Table A. 15. Energy flows for the main streams for cases 65 to 71 and BB1 to BB15.

	65	66	67	68	69	70	71	BB1	BB2	BB3	BB4	BB5	BB6	BB7	BB8	BB9	BB10	BB11	BB12	BB13	BB14	BB15
Electric power consumed per area (kW)																						
A100	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94	94
A200	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696	696
A300	247	283	261	270	253	277	251	527	198	318	351	256	256	346	346	400	398	211	211	210	211	208
A400	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
A500	216	239	225	231	216	238	218	287	290	188	195	290	290	193	193	226	226	230	230	230	230	229
A600	481	524	497	509	479	526	487	574	575	462	462	574	574	461	461	503	504	504	504	504	504	504
A700	27	28	27	27	27	27	27	27	28	27	27	28	28	27	27	27	27	28	28	28	28	28
A800	140	141	139	141	128	152	141	148	132	156	132	133	133	136	136	151	153	132	132	133	132	135
A900	301	294	262	320	266	328	328	302	253	359	282	255	255	294	294	330	334	270	268	271	268	277
Electric power generated and surpluss (kW)																						
Power generated in A800	3458	3291	2912	3651	2601	4138	3810	3025	2766	4786	3090	2555	2555	3171	3171	4186	4293	2763	2706	2775	2706	2922
Surpluss electricity	1237	975	692	1345	422	1780	1549	371	475	2466	825	211	211	904	904	1739	1842	579	525	592	592	732
Heat streams used in equipment scaling and total boiler heat (kW)																						
QH201	-2799	-2799	-2799	-2799	-2799	-2799	-2799	-2729	-2729	-2872	-2848	-2729	-2729	-2848	-2848	-2807	-2807	-2799	-2799	-2799	-2799	-2799
QH244	4222	4270	4226	4265	4228	4260	4240	4329	4358	4207	4215	4371	4371	4208	4208	4239	4236	4263	4263	4262	4263	4258
QC310	576	651	606	625	576	652	584	842	852	465	482	852	852	479	479	610	609	621	622	621	622	620
QCD502	2286	2632	2416	2508	2336	2578	2324	3210	3357	1837	2172	3352	3352	2087	2087	2376	2367	2538	2545	2532	2545	2520
QBOILER	19311	19523	19389	19556	16965	21895	19403	21053	17948	22742	17772	18158	18158	18538	18538	21756	22030	17966	17828	18103	17828	18379
QH801	1141	1162	1145	1159	1019	1282	1149	1253	852	1361	1046	1068	1068	1091	1091	1307	1321	1058	1051	1064	1051	1078
QCHWOP	495	598	536	558	536	557	506	730	533	499	666	579	579	641	641	596	588	541	545	537	545	529
QH812	-849	-845	-848	-850	-842	-856	-851	-851	-847	-83	-843	-832	-832	-844	-844	-855	-857	-843	-845	-843	-845	-845

Appendix B: Process flow diagrams

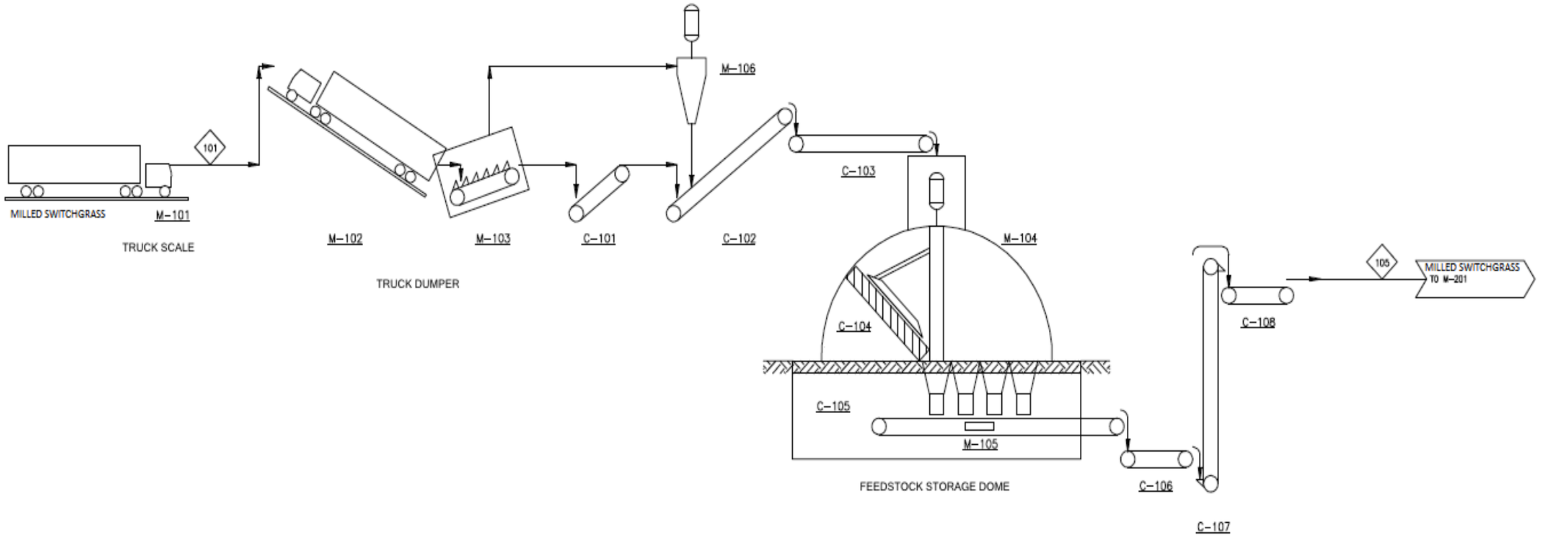

Figure B. 1. Process flow diagram for the feedstock handling area (A100), equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.

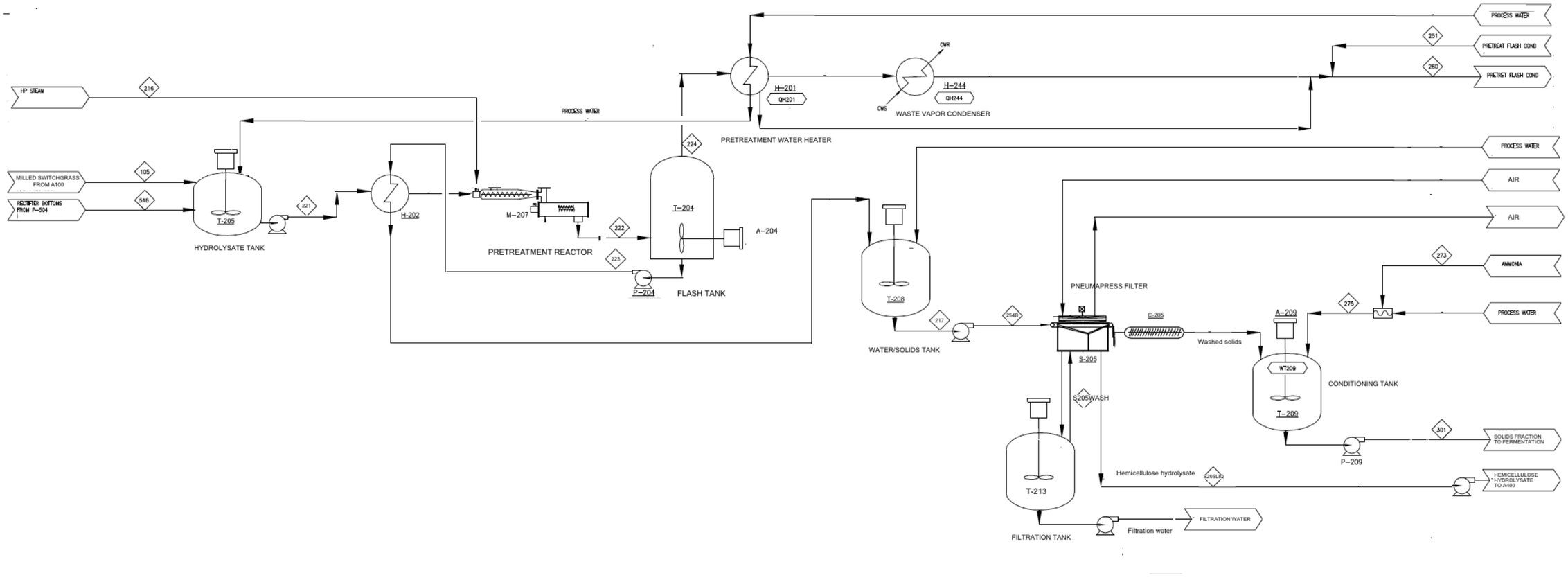

Figure B.2. Process flow diagram for the pretreatment area (A200) for the biorefinery model, equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.

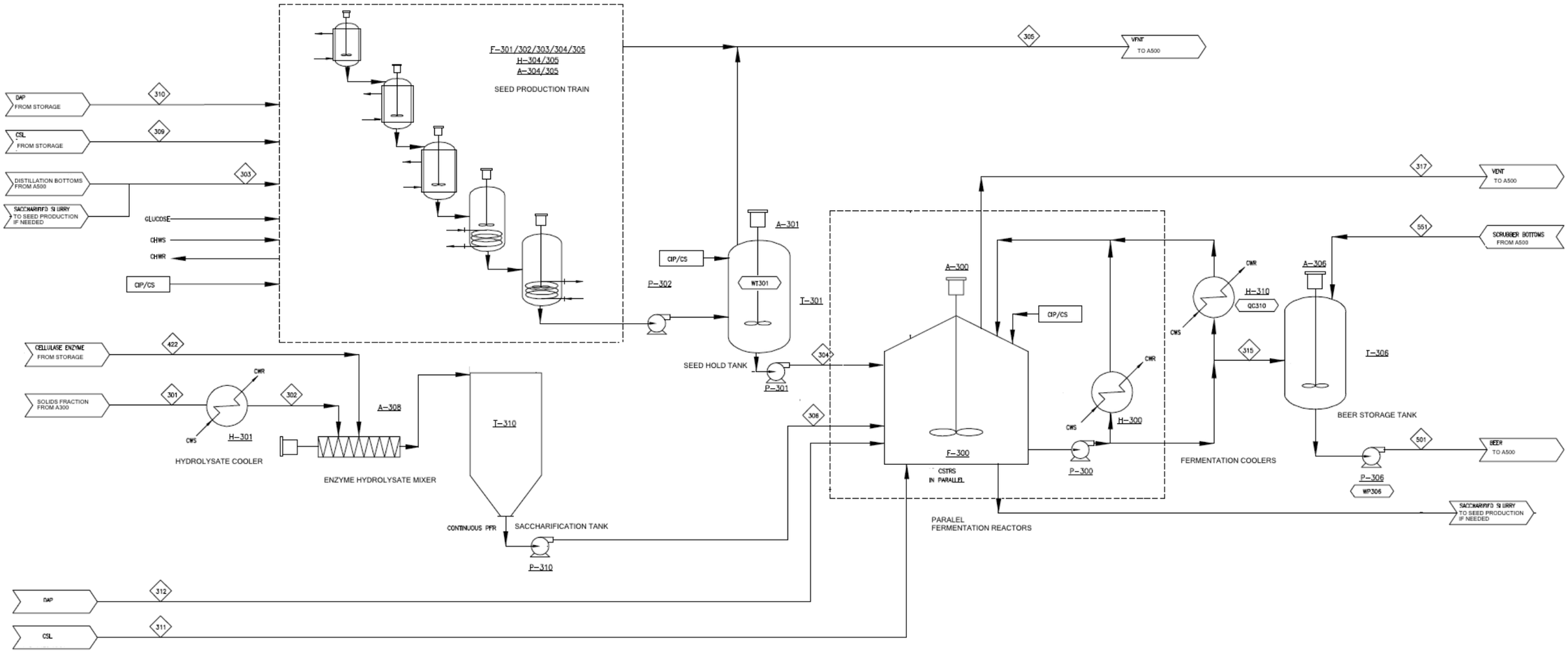

Figure B.3. Process flow diagram for the hydrolysis and fermentation area (A300), equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.

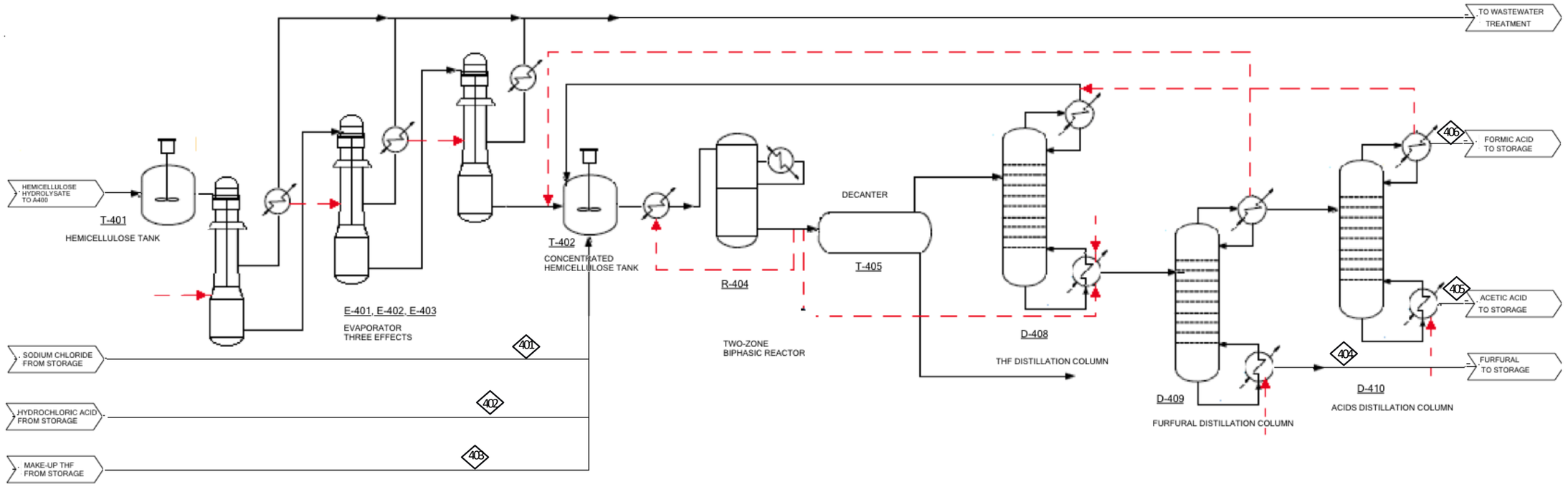

Figure B.4. Process flow diagram for the furfural production area (A400) for the biorefinery model, equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.

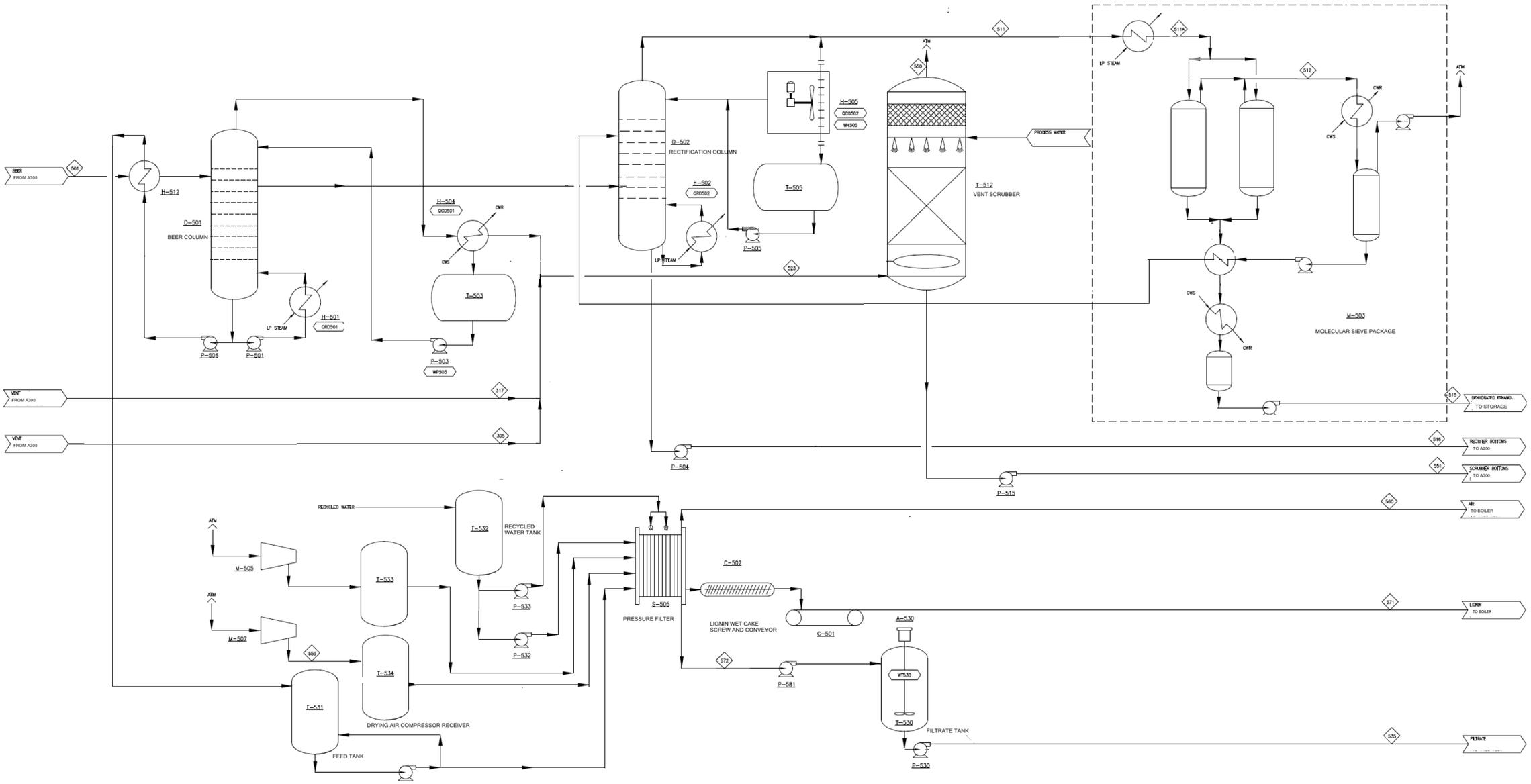

Figure B.5. **Process flow diagram for the ethanol recovery area (A500), equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.**

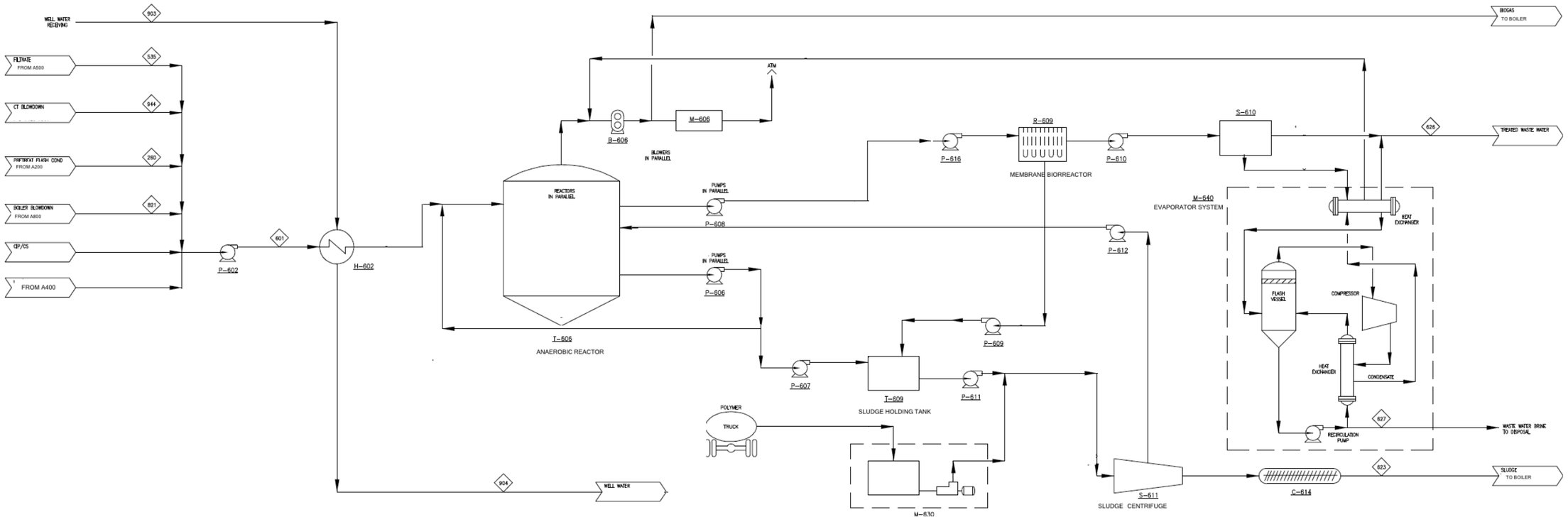

Figure B.6. Process flow diagram for the wastewater treatment (A600), equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.

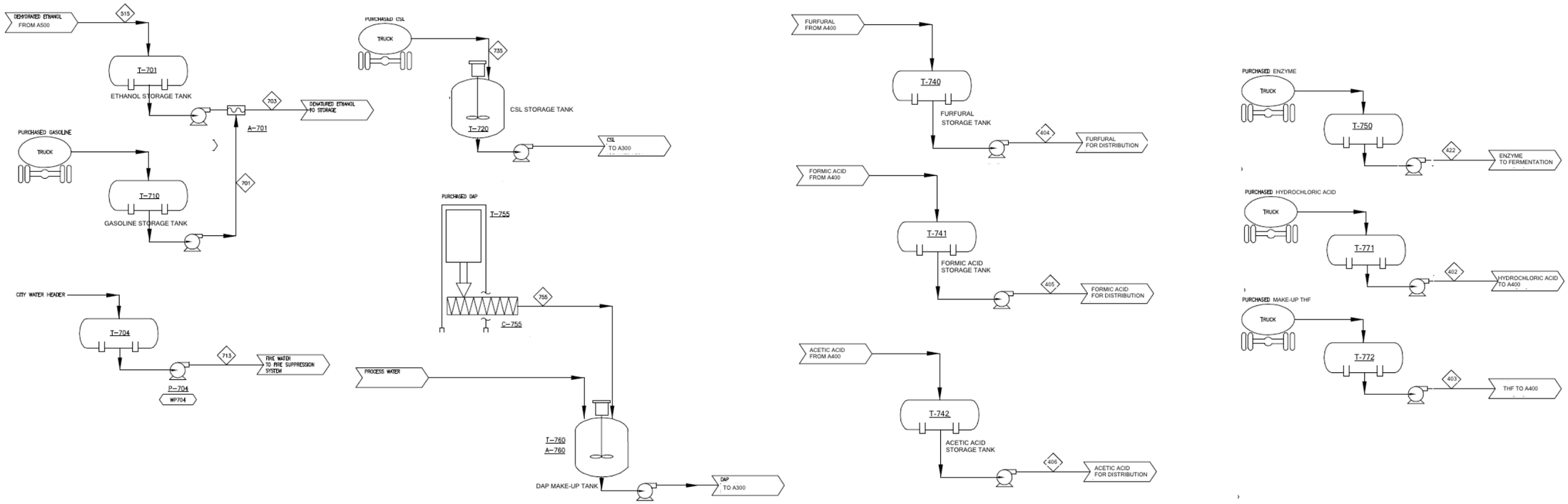

Figure B.7. Process flow diagram for the storage area (A700), for the biorefinery model, equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.

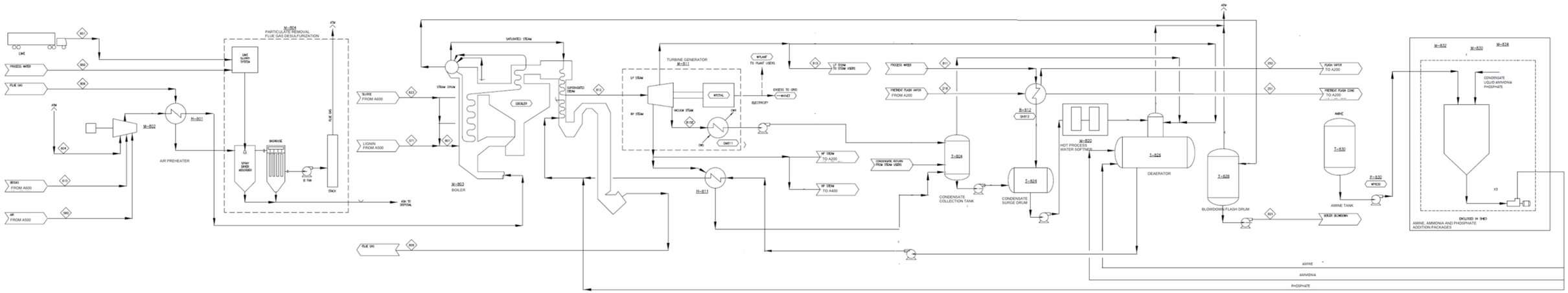

Figure B. 8. Process flow diagram for the boiler area (A800), for the biorefinery model, equipments correspond to those identified in Table A.2, main streams identified inside the diamond shapes.

Appendix C: Supporting information for the environmental assesment

1. Materials and processes defined on SimaPro for this work

Table C. 1. Inventory for "N20 emissions/N fertilizer" corresponding to emissions per kg of fertilizer applied.

Product:				
N2O emissions/N fertilizer 1 kg				
	Database	**Amount**	**Unit**	**Distribution**
Emissions to air	-			
Dinitrogen monoxide	-	0.02	kg	Triangle (0.003-0.08)

Note: 0.02 kg correspond to a 1.3 % emission factor consider the N_2 to N_2O conversion factor of 44/28

Table C. 2. Inventory for Corn Steep Liquor defined based on info from: US Life Cycle Inventory database.

Product:

Corn Steep Liquor 1 kg

Resources	**Database**	**Amount**	**Unit**
Materials/fuels			
Hard coal, from underground and open pit mining, consumption mix, at power plant S	ELCD	0.0003779	kg
Natural gas, at extraction site/US	USLCI	0.00148	m3
Limestone, at mine/US	USLCI	0.0027	kg
Crude oil, production RU, at long distance t.ransport/RER S	Ecoinvent System process	0.000575	kg
Emissions to air			
Carbon dioxide, fossil		6.86E-03	kg
Carbon monoxide, fossil		2.05E-05	kg
Dinitrogen monoxide		6.21E-06	kg
Fluoride		1.12E-07	kg
Formaldehyde		1.73E-09	kg
Hydrocarbons, unspecified		7.64E-06	kg
Hydrogen chloride		1.21E-07	kg
Hydrogen fluoride		1.87E-08	kg
Hydrogen sulfide		3.57E-09	kg
Methane, fossil		1.05E-05	kg
Nitrogen oxides		2.99E-05	kg
Sulfur dioxide		8.22E-03	kg

Defined based on info from: US Life Cycle Inventory database

Table C. 3. Inventory for cellulase enzyme complex defined based on info from: US Life Cycle Inventory database

Product			
Enzyme cellulase Novozymes 1 kg			
Resources	Database	Amount	Unit
Energy, from coal		52.08	MJ
Materials/fuels			
Process water, ion exchange, production mix, at plant, from groundwater RER S	ELCD	0.02085	kg
Emissions to air			
Carbon dioxide		4.089	kg
Ethene		0.0020039	kg
Sulfur dioxide		0.015279	kg

Table C. 4. Inventory for Furfural defined based on info for traditional production from Raman & Gnansounou (2017), case PF-1 R.

Product			
Furfural 1 kg			
Resources	Database	Amount	Unit
Materials/fuels			
Crude oil, production RME, at long distance transport/RER S kg	Ecoinvent System process	0.5	kg
Emissions to air			
Carbon dioxide		0.1	kg

Table C. 5. Electricity grid mix, in percentage per source per year, obtained from http://www.ben.miem.gub.uy/matrices.html

Source	*2017*	*2016*	*2015*	*2014*	*Average*	*Standard deviation*
Thermal, fossil (diesel+fuel oil)	3.67	7.69	15.04	7.46	8.5	4.8
Thermal, fossil (natural gas)	0.6	0.0	0.0	0.0	0.2	0.3
Thermal, biomass	19.7	19.5	18.8	15.7	18.4	1.9
Hydroelectric	51.7	54.1	54.1	67.6	56.9	7.2
Wind	22.7	17.8	11.8	4.4	14.2	7.9
Photovoltaic	1.6	0.9	0.3	0.0	0.7	0.7

Table C. 6. Inventory for the Uruguayan electricity grid mix defined based on Table C. 5.

Products
Electricity grid mix uy 1 kWh

Resources	Database	Amount	Unit	Distribution function
Electricity/heat				
Electricity, hydropower, at run-of-river power plant/RER S	Ecoinvent 3	=1-(W+S+B+NG+O)	kWh	
Electricity, at wind power plant/RER S	Ecoinvent 3	W =0.14	kWh	Normal (2sd=0.158)
Electricity, production mix photovoltaic, at plant/US U	Ecoinvent 3	S=0.007	kWh	Normal (2sd=0.014)
Electricity, biomass, at power plant/US	Ecoinvent 3	B=0.184	kWh	Normal (2sd=0.038)
Electricity, natural gas, at power plant/UCTE S	Ecoinvent 3	NG=0.002	kWh	Normal (2sd=0.004)
Electricity, oil, at power plant/UCTE S	Ecoinvent 3	O=0.085	kWh	Normal (2sd=0.096)

2. Chemical consumption for the cases analyzed

Tables show material consumptions obtained from the material balances performed on Chapter 3. Consumptions are expressed per kg of dry switchgrass processed in the ethanol plant. Doted cells correspond to material consumptions that are the same as those from case 5.

Table C. 7. Material consumptions used for the LCI expressed per kg of dry switchgrass (cases 1, 4, 5, 65, 66, 67, 68, 69 and 70).

Case	1	4	5	65	66	67	68	69	70
Corn Steep Liquor	0.014	0.014	0.0093	0.0090	0.0100	0.0093	0.0097	0.0090	0.0100
Diammonium Phosph	0.0017	0.0017	0.0010	0.0010	0.0014	0.0010	0.0010	0.0010	0.0014
Sorbitol	0.00042	0.00042	0.00028	0.00026	0.00029	0.00027	0.00028	0.00026	0.00029
Cellulase	0.065	0.065	0.065	0.057	0.073	0.065	0.065	0.065	0.065
cooling +boiler chems	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
makeup water	1.93	2.24	5.33	5.33	5.33	5.33	5.33	5.33	5.33
Sodium Chloride	0	0	0.038	0.038	0.038	0.025	0.048	0.038	0.038
HCL	0	0	0.033	0.033	0.033	0.022	0.043	0.033	0.033
THF	0	0	0.0017	0.0017	0.0017	0.0014	0.0024	0.0017	0.0017
Ammonia	0.0066	0.0066	0	0	0	0	0	0	0

Table C. 8. Material consumptions used for the LCI expressed per kg of dry switchgrass (cases 15, 19, 26, 29, 35, 37, 38, 42, BB1, BB2, and BB3).

Case	15	19	26	29	35	37	38	42	BB1	BB2	BB3
Corn Steep Liquor	0.0093	0.0093	0.00968	0.0093	0.0093	0.00968	0.00726	0.0159	0.01313	0.01313	0.00691
Diammonium Phosph	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.00207	0.00173	0.00173	0.0010
Sorbitol	0.00028	0.00028	0.00028	0.00027	0.00028	0.00029	0.00028	0.00028	0.0004	0.0004	0.0002
Cellulase	0.01624	0.09711	0.065	0.065	0.065	0.065	0.065	0.065	0.01071	0.07707	0.01071
cooling +boiler chems	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
makeup wáter	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33
Sodium Chloride	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
HCL	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
THF	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017

Table C. 9. Material consumptions used for the LCI expressed per kg of dry switchgrass (cases BB4, BB5, BB6, BB7, BB8, BB9, BB10, BB11, BB12, BB13, BB14, and BB15).

Case	BB4	BB5	BB6	BB7	BB8	BB9	BB10	BB11	BB12	BB13	BB14	BB15
Corn Steep Liquor	0.00726	0.01313	0.01313	0.00726	0.00726	0.0093	0.0093	0.00968	0.00968	0.00968	0.00968	0.00968
Diammonium Phosph	0.0010	0.00173	0.00173	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010
Sorbitol	0.00021	0.0004	0.0004	0.00021	0.00021	0.00027	0.00027	0.00028	0.00028	0.00028	0.00028	0.00028
Cellulase	0.07672	0.04424	0.04424	0.04424	0.04424	0.01071	0.01071	0.07672	0.07672	0.04424	0.04424	0.04424
cooling +boiler chems	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
makeup water	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33	5.33
Sodium Chloride	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
HCL	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
THF	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	0.0017

3. Results from the life cycle assessment

Table C. 10. GHG emission results (g CO_{2eq}/$Mj_{ethanol}$) divided by material/process for cases 1, 4, 5, 66 , 67, 68, 69, 70, 15, 19, 26, 29, 35, 36, 38, 42)

	Case	1	4	5	65	66	67	68	69	70	15	19	26	29	35	37	38	42
Switchgrass production	Sequestered carbon	-250.77	-331.98	-320.87	-342.16	-304.96	-313.13	-329.50	-296.66	-346.46	-320.87	-320.87	-295.29	-416.88	-351.29	-435.83	-320.24	-322.13
	Glyphosate,Atrazyne, Adjuvant and Diammonium	0.12	0.16	0.15	0.17	0.14	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.20	0.17	0.21	0.15	0.15
	Urea	2.78	3.69	3.56	4.00	3.21	3.66	3.47	3.56	3.56	3.56	3.56	3.28	4.63	3.90	4.84	3.56	3.58
	N2O emissions	2.80	3.71	3.58	4.02	3.23	3.68	3.49	3.58	3.58	3.58	3.58	3.30	4.65	3.92	4.87	3.58	3.60
	Diesel use in farm machinery	0.43	0.57	0.55	0.62	0.49	0.56	0.53	0.55	0.55	0.55	0.55	0.51	0.71	0.60	0.75	0.55	0.55
	Transportation of chemicals	0.56	0.74	0.72	0.81	0.65	0.74	0.70	0.72	0.72	0.72	0.72	0.66	0.93	0.79	0.98	0.72	0.72
	Transportation of switchgrass	1.26	1.67	1.62	1.81	1.46	1.66	1.57	1.61	1.62	1.62	1.62	1.49	2.10	1.77	2.20	1.61	1.62
	Grinding (milling)	1.19	1.58	1.52	1.71	1.37	1.56	1.48	1.52	1.52	1.52	1.52	1.40	1.98	1.67	2.07	1.52	1.53
Ethanol production and distribution	CO2 emissions on the industrial process	190.00	270.00	200.00	220.00	190.00	200.00	200.00	180.00	220.00	200.00	200.00	180.00	280.00	230.00	300.00	200.00	200.00
	Corn Steep liquor	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.01	0.03
	Diammonium phosphate	0.08	0.10	0.06	0.07	0.07	0.06	0.06	0.06	0.08	0.06	0.06	0.05	0.08	0.06	0.08	0.06	0.12
	Sorbitol	0.12	0.16	0.10	0.11	0.10	0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.13	0.11	0.15	0.10	0.11
	Enzyme	40.90	54.10	52.30	51.50	52.90	53.70	50.90	52.20	52.30	13.10	78.20	48.20	68.00	57.30	71.10	52.20	52.50
	Process water	0.86	1.32	6.84	7.69	6.18	7.02	6.67	6.84	6.84	6.84	6.84	6.31	8.89	7.47	9.29	6.84	6.84
	Ammonia	3.08	4.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sodium Chloride	0.00	0.00	1.80	2.02	1.62	1.22	2.21	1.80	1.80	1.80	1.80	1.66	2.34	1.97	2.45	1.80	1.81
	Hydrochloric acid	0.00	0.00	0.52	0.58	0.46	0.35	0.65	0.51	0.52	0.52	0.52	0.47	0.67	0.56	0.70	0.51	0.52
	Tetrahydrofuran	0.00	0.00	1.92	2.15	1.73	1.62	2.64	1.92	1.92	1.92	1.92	1.77	2.50	2.10	2.61	1.92	1.93
	Boiler and chiller chemicals	0.11	0.00	0.11	0.12	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.14	0.12	0.15	0.11	0.11
	Chemicals transportation	1.49	1.98	5.31	5.80	4.94	4.11	6.27	5.29	5.34	4.52	5.84	4.90	6.91	5.83	7.24	5.28	5.66
	Ethanol distribution	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Co-products	Furfural	0.00	0.00	-1.62	-1.82	-1.46	-1.17	-2.05	-1.62	-1.62	-1.62	-1.62	-1.49	-2.10	-1.77	-2.20	-1.62	-1.62
	Acetic Acid	0.00	0.00	-6.49	-7.28	-5.85	-4.63	-8.19	-6.49	-6.49	-6.49	-6.49	-5.97	-8.43	-7.11	-8.82	-6.49	-6.49
	Formic Acid	0.00	0.00	-3.53	-3.96	-3.18	-2.45	-4.29	-3.53	-3.53	-3.53	-3.53	-3.25	-4.59	-3.86	-4.79	-3.53	-3.53
	Electricity	-2.90	-6.07	-1.85	-2.38	-1.32	-1.58	-2.38	-0.79	-3.17	-1.85	-1.85	-0.98	-4.75	-2.90	-5.28	-2.38	-0.53
	Total	-6.58	7.11	-52.39	-53.13	-46.83	-41.35	-64.11	-47.28	-59.24	-92.38	-25.96	-51.34	-50.58	-47.29	-45.95	-52.45	-51.64

Table C. 11. GHG emission results (g CO_{2eq}/$Mj_{ethanol}$) divided by material/process for cases BB1 to BB15)

	Case	BB1	BB2	BB3	BB4	BB5	BB6	BB7	BB8	BB9	BB10	BB11	BB12	BB13	BB14	BB15
Switchgrass production	Sequestered carbon	-367.95	-282.50	-446.58	-281.52	-284.47	-284.47	-297.45	-297.45	-399.51	-410.58	-283.97	-281.03	-286.47	-282.01	-292.115
	Glyphosate,Atrazyne, Adjuvant and Diammonium	0.17	0.13	0.21	0.13	0.13	0.13	0.14	0.14	0.19	0.19	0.13	0.13	0.14	0.13	0.138
	Urea	4.09	3.14	4.96	3.13	3.16	0.00	3.30	3.30	4.44	4.56	3.15	3.12	3.18	3.13	3.244
	N2O emissions	4.11	3.15	4.99	3.14	3.18	3.18	3.32	3.32	4.46	4.58	3.17	3.14	3.20	3.15	3.262
	Diesel use in farm machinery	0.63	0.48	0.76	0.48	0.49	0.49	0.51	0.51	0.68	0.70	0.49	0.48	0.49	0.48	0.500
	Transportation of chemicals	0.83	0.63	1.00	0.63	0.64	0.64	0.67	0.67	0.90	0.92	0.64	0.63	0.64	0.63	0.655
	Transportation of switchgrass	1.85	1.42	2.25	1.42	1.43	1.43	1.50	1.50	2.01	2.07	1.43	1.42	1.44	1.42	1.471
	Grinding (milling)	1.75	1.34	2.12	1.34	1.35	1.35	1.41	1.41	1.90	1.95	1.35	1.33	1.36	1.34	1.387
Ethanol production and distribution	CO2 emissions on the industrial process	240.00	170.00	310.00	170.00	170.00	170.00	180.00	180.00	270.00	280.00	180.00	170.00	170.00	170.00	180.000
	Corn Steep liquor	0.03	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.017
	Diammonium phosphate	0.12	0.09	0.08	0.05	0.09	0.09	0.05	0.05	0.07	0.07	0.05	0.05	0.05	0.05	0.053
	Sorbitol	0.17	0.13	0.10	0.07	0.13	0.13	0.07	0.07	0.13	0.13	0.09	0.09	0.09	0.09	0.095
	Enzyme	9.89	54.60	12.00	54.20	31.60	31.60	33.00	33.00	10.70	11.00	54.70	54.10	31.80	31.30	32.400
	Process water	7.82	6.00	9.51	6.13	6.04	6.04	6.36	6.36	8.53	8.76	6.04	6.00	6.09	6.00	6.222
	Ammonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
	Sodium Chloride	2.07	1.59	2.51	1.58	1.60	1.60	1.67	1.67	2.24	2.30	1.59	1.58	1.61	1.58	1.640
	Hydrochloric acid	0.59	0.45	0.72	0.45	0.46	0.46	0.48	0.48	0.64	0.66	0.46	0.45	0.46	0.45	0.469
	Tetrahydrofuran	2.20	1.69	2.67	1.69	1.70	1.70	1.78	1.78	2.39	2.46	1.70	1.68	1.72	1.69	1.750
	Boiler and chiller chemicals	0.13	0.10	0.15	0.10	0.10	0.10	0.10	0.10	0.14	0.14	0.10	0.10	0.10	0.10	0.100
	Chemicals transportation	5.32	5.05	6.04	4.81	4.53	4.53	4.55	4.55	5.51	5.66	4.89	4.84	4.45	4.43	4.542
	Ethanol distribution	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.280
Co-products	Furfural	-1.86	-1.43	-2.25	-1.42	-1.44	-1.44	-1.50	-1.50	-2.02	-2.07	-1.43	-1.42	-1.45	-1.42	-1.475
	Acetic Acid	-7.44	-5.71	-9.03	-5.69	-5.75	-5.75	-6.02	-6.02	-8.08	-8.30	-5.74	-5.68	-5.79	-5.70	-5.908
	Formic Acid	-4.05	-0.23	-4.91	-3.10	-3.13	-3.13	-3.27	-3.27	-4.40	-4.52	-3.12	-3.09	-3.15	-3.10	-3.214
	Electricity	-1.85	-0.26	-6.07	-1.06	-0.26	-0.26	-1.32	-1.32	-3.96	-4.22	-0.79	-0.79	-1.06	-0.79	-1.320
	Total	-100.10	-38.83	-107.47	-42.15	-67.12	-70.28	-69.35	-69.35	-101.74	-102.24	-33.79	-41.58	-69.80	-65.76	-64.806

Table C. 12. CED fossil energy use (MJ/$Mj_{ethanol}$) divided by material/process for cases 1, 4, 5, 66 , 67, 68, 69, 70, 15, 19, 26, 29, 35, 36, 38, 42)

		1	4	5	65	66	67	68	69	70	15	19	26	29	35	37	38	42
Switchgrass production	Glyphosate,Atrazyne, Adjuvant and Diammonium phospha	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Urea	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.04	0.04
	Diesel use in farm machinery	6.28	8.31	8.03	9.01	7.23	8.24	7.82	8.02	8.03	8.03	8.03	7.39	10.43	8.79	10.91	8.02	8.06
	Transportation of chemicals	8.13	10.76	10.40	11.66	9.37	10.67	10.12	10.38	10.40	10.40	10.40	9.57	13.51	11.39	14.13	10.38	10.44
	Transportation of switchgrass	20.31	26.88	25.98	29.14	23.40	26.67	25.29	25.93	25.98	25.98	25.98	23.91	33.76	28.45	35.29	25.93	26.09
	Grinding (milling)	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01
Ethanol production and distribution	Corn Steep liquor	0.22	0.29	0.19	0.20	0.18	0.19	0.19	0.18	0.20	0.19	0.19	0.18	0.24	0.20	0.26	0.14	0.32
	Diammonium phosphate	1.50	1.99	1.13	1.27	1.42	1.16	1.10	1.13	1.58	1.13	1.13	1.04	1.47	1.24	1.53	1.13	2.35
	Sorbitol	3.90	5.16	3.33	3.46	3.10	3.29	3.24	3.08	3.44	3.33	3.33	3.06	4.17	3.64	4.68	3.32	3.34
	Enzyme	521.00	689.00	666.00	655.00	674.00	684.00	649.00	665.00	666.00	166.00	996.00	613.00	866.00	730.00	905.00	665.00	669.00
	Process water	7.96	12.22	63.11	71.11	56.89	64.89	61.78	63.11	63.11	63.11	63.11	58.22	82.22	69.33	85.78	63.11	63.56
	Ammonia	0.04	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Sodium Chloride	0.00	0.00	0.18	0.21	0.17	0.12	0.23	0.18	0.18	0.18	0.18	0.17	0.24	0.20	0.25	0.18	0.18
	Hydrochloric acid	0.00	0.00	12.80	14.40	11.50	8.77	16.30	12.80	12.80	12.80	12.80	11.80	16.70	14.00	17.40	12.80	12.90
	Tetrahydrofuran	0.00	0.00	0.15	0.17	0.14	0.13	0.21	0.15	0.15	0.15	0.15	0.14	0.20	0.17	0.20	0.15	0.15
	Boiler and chiller chemicals	0.00	0.00	1.24	1.39	1.11	1.27	1.20	1.23	1.24	1.24	1.24	1.14	1.61	1.35	1.68	1.23	1.24
	Chemicals transportation	22.00	29.13	77.35	84.36	71.82	59.97	91.22	77.02	77.80	65.41	85.19	71.28	100.43	84.74	105.32	76.93	82.41
	Ethanol distribution	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70
Co-products	Furfural	0.00	0.00	-183.00	-205.22	-164.83	-132.00	-232.00	-183.00	-183.00	-183.00	-183.00	-168.41	-237.76	-200.35	-248.57	-183.00	-183.00
	Acetic Acid	0.00	0.00	-194.00	-217.55	-174.74	-139.00	-245.00	-194.00	-194.00	-194.00	-194.00	-178.54	-252.05	-212.40	-263.51	-194.00	-194.00
	Formic Acid	0.00	0.00	-72.40	-81.19	-65.21	-50.40	-88.20	-72.40	-72.40	-72.40	-72.40	-66.63	-94.06	-79.27	-98.34	-72.40	-72.40
	Electricity	-34.10	-71.00	-21.70	-27.90	-15.50	-18.60	-27.90	-9.30	-37.20	-21.70	-21.70	-12.40	-55.80	-34.10	-62.00	-27.90	-6.20
	Total	577.98	733.57	419.57	370.29	460.81	550.14	295.35	430.28	405.09	-92.37	757.41	395.69	512.10	448.16	530.81	411.80	445.21

Table C. 13. CED fossil energy use (MJ/$MJ_{ethanol}$) divided by material/process for cases BB1 to BB15)

	BB1	BB2	BB3	BB4	BB5	BB6	BB7	BB8	BB9	BB10	BB11	BB12	BB13	BB14	BB15
Glyphosate,Atrazyne, Adjuvant and Diammonium phospha	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02
Urea	0.05	0.04	0.06	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.03	0.04	0.03	0.04
Diesel use in farm machinery	9.21	7.07	11.18	7.05	7.12	7.12	7.45	7.45	10.00	10.28	7.11	7.03	7.17	7.06	7.31
Transportation of chemicals	11.93	9.16	14.47	9.12	9.22	9.22	9.64	9.64	12.95	13.31	9.20	9.11	9.28	9.14	9.47
Transportation of switchgrass	29.80	22.88	36.16	22.80	23.04	23.04	24.09	24.09	32.35	33.25	23.00	22.76	23.20	22.84	23.66
Grinding (milling)	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01
Corn Steep liquor	0.30	0.23	0.19	0.13	0.23	0.23	0.13	0.13	0.23	0.24	0.17	0.17	0.17	0.17	0.18
Diammonium phosphate	2.24	1.72	1.57	0.99	1.73	1.73	1.05	1.05	1.41	1.44	1.00	0.99	1.01	0.99	1.03
Sorbitol	5.45	4.18	3.31	2.19	4.21	4.21	2.31	2.31	3.99	4.10	2.94	2.91	2.97	2.92	3.03
Enzyme	126.00	696.00	153.00	690.00	402.00	402.00	420.00	420.00	137.00	141.00	696.00	689.00	405.00	399.00	413.00
Process water	72.44	55.56	88.00	55.56	56.00	56.00	58.67	58.67	78.67	80.89	56.00	55.56	56.44	55.56	57.78
Ammonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sodium Chloride	0.21	0.16	0.26	0.16	0.16	0.16	0.17	0.17	0.23	0.24	0.16	0.16	0.16	0.16	0.17
Hydrochloric acid	14.70	11.30	17.80	11.20	11.40	11.40	11.90	11.90	16.00	16.40	11.30	11.20	11.40	11.30	11.70
Tetrahydrofuran	0.17	0.13	0.21	0.13	0.13	0.13	0.14	0.14	0.19	0.19	0.13	0.13	0.13	0.13	0.14
Boiler and chiller chemicals	1.42	1.11	1.72	1.08	1.10	1.10	1.15	1.15	1.54	1.58	1.09	1.08	1.10	1.09	1.13
Chemicals transportation	77.13	73.50	87.60	70.06	65.79	65.79	66.06	66.06	79.78	81.92	71.20	70.46	64.78	64.24	65.97
Ethanol distribution	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70	20.70
Furfural	-209.85	-161.12	-254.70	-160.56	-162.24	-162.24	-169.64	-169.64	-227.85	-234.17	-161.96	-160.28	-163.38	-160.84	-166.60
Acetic Acid	-222.47	-170.80	-270.01	-170.21	-171.99	-171.99	-179.84	-179.84	-241.55	-248.24	-171.69	-169.92	-173.20	-170.51	-176.62
Formic Acid	-83.02	-63.74	-100.76	-63.52	-64.19	-64.19	-67.12	-67.12	-90.15	-92.64	-64.08	-63.41	-64.64	-63.63	-65.91
Electricity	-21.70	-3.10	-71.30	-12.40	-3.10	-3.10	-15.30	-15.50	-46.50	-49.60	-9.30	-9.30	-12.40	-9.30	-15.50
Total	-165.26	505.00	-260.50	484.53	201.38	201.38	191.62	191.42	-210.93	-219.03	493.04	488.41	189.97	191.08	190.69

Table C. 14. Results from Monte Carlo analysis for GHG emissions and fossil energy usage.

		Confidence interval 95%					
Case		Mean	Median	SD	CV	2.50%	97.50%
1	kg CO2/MJ	-0.002	-0.003	0.004	-205.000	-0.008	0.009
	MJ/MJ	0.592	0.592	0.012	2.050	0.568	0.616
4	kg CO2/MJ	0.013	0.012	0.006	48.900	0.005	0.028
	MJ/MJ	0.750	0.750	0.021	2.840	0.708	0.790
5	kg CO2/MJ	-0.050	-0.051	0.005	-10.200	-0.057	-0.036
	MJ/MJ	0.420	0.420	0.012	2.740	0.398	0.443
65	kg CO2/MJ	-0.049	-0.050	0.006	-13.000	-0.058	-0.035
	MJ/MJ	0.371	0.371	0.013	3.590	0.347	0.400
66	kg CO2/MJ	-0.044	-0.045	0.005	-11.400	-0.051	-0.032
	MJ/MJ	0.464	0.464	0.010	2.120	0.445	0.484
67	kg CO2/MJ	-0.038	-0.039	0.005	-14.200	-0.046	-0.025
	MJ/MJ	0.551	0.551	0.011	2.000	0.531	0.575
68	kg CO2/MJ	-0.061	-0.062	0.005	-8.530	-0.068	-0.049
	MJ/MJ	0.296	0.296	0.012	4.070	0.274	0.321
69	kg CO2/MJ	-0.044	-0.045	0.006	-12.700	-0.051	-0.031
	MJ/MJ	0.431	0.431	0.010	2.230	0.412	0.450
70	kg CO2/MJ	-0.056	-0.057	0.006	-11.300	-0.063	-0.038
	MJ/MJ	0.407	0.406	0.014	3.460	0.381	0.435
15	kg CO2/MJ	-0.089	-0.090	0.005	-6.020	-0.097	-0.075
	MJ/MJ	-0.091	-0.092	0.016	-12.700	-0.113	-0.067
19	kg CO2/MJ	-0.023	-0.024	0.006	-26.800	-0.030	0.000
	MJ/MJ	0.759	0.758	0.011	1.450	0.739	0.781
26	kg CO2/MJ	-0.049	-0.050	0.005	-11.200	-0.055	-0.034
	MJ/MJ	0.393	0.392	0.011	2.890	0.375	0.413
29	kg CO2/MJ	-0.036	-0.037	0.008	-21.100	-0.046	-0.019
	MJ/MJ	0.603	0.603	0.019	3.190	0.565	0.640
35	kg CO2/MJ	-0.044	-0.045	0.006	-14.400	-0.052	-0.029
	MJ/MJ	0.446	0.446	0.014	3.110	0.419	0.474
37	kg CO2/MJ	-0.042	-0.043	0.007	-17.900	-0.052	-0.022
	MJ/MJ	0.535	0.534	0.021	3.950	0.494	0.573
38	kg CO2/MJ	-0.049	-0.050	0.005	-10.800	-0.057	-0.036
	MJ/MJ	0.412	0.412	0.013	3.130	0.388	0.439
42	kg CO2/MJ	-0.048	-0.050	0.006	-11.600	-0.056	-0.035
	MJ/MJ	0.445	0.445	0.010	2.230	0.427	0.465
BB1	kg CO2/MJ	-0.097	-0.098	0.006	-6.420	-0.105	-0.082
	MJ/MJ	-0.169	-0.170	0.013	-7.720	-0.193	-0.143
BB2	kg CO2/MJ	-0.040	-0.041	0.005	-12.800	-0.046	-0.028
	MJ/MJ	0.486	0.486	0.008	1.700	0.471	0.504
BB3	kg CO2/MJ	-0.104	-0.105	0.007	-6.980	-0.115	-0.089
	MJ/MJ	-0.295	-0.296	0.024	-8.130	-0.340	-0.247
BB4	kg CO2/MJ	-0.040	-0.040	0.005	-12.000	-0.046	-0.028
	MJ/MJ	0.482	0.482	0.009	1.770	0.465	0.500
BB5	kg CO2/MJ	-0.064	-0.065	0.005	-7.800	-0.071	-0.051
	MJ/MJ	0.200	0.199	0.009	4.400	0.183	0.219
BB6	kg CO2/MJ	-0.064	-0.065	0.005	-7.800	-0.071	-0.051
	MJ/MJ	0.200	0.199	0.009	4.400	0.183	0.219
BB7	kg CO2/MJ	-0.067	-0.068	0.005	-7.940	-0.053	0.000
	MJ/MJ	0.189	0.189	0.011	5.980	0.170	0.209
BB8	kg CO2/MJ	-0.067	-0.068	0.005	-7.940	-0.053	0.000
	MJ/MJ	0.189	0.189	0.011	5.980	0.170	0.209
BB9	kg CO2/MJ	-0.098	-0.099	0.007	-7.510	-0.107	-0.079
	MJ/MJ	-0.213	-0.213	0.018	-8.280	-0.246	-0.177
BB10	kg CO2/MJ	-0.098	-0.099	0.007	-6.850	-0.108	-0.081
	MJ/MJ	-0.221	-0.221	0.018	-7.910	-0.256	-0.187
BB11	kg CO2/MJ	-0.031	-0.032	0.005	-15.100	-0.038	-0.019
	MJ/MJ	0.491	0.490	0.009	1.770	0.474	0.509
BB12	kg CO2/MJ	-0.039	-0.040	0.004	-11.500	-0.045	-0.028
	MJ/MJ	0.481	0.481	0.009	1.830	0.466	0.499
BB13	kg CO2/MJ	-0.067	-0.068	0.005	-7.290	-0.073	-0.054
	MJ/MJ	0.188	0.188	0.009	4.630	0.171	0.207
BB14	kg CO2/MJ	-0.063	-0.064	0.005	-7.300	-0.070	-0.052
	MJ/MJ	0.190	0.190	0.009	4.660	0.173	0.208
BB15	kg CO2/MJ	-0.062	-0.063	0.005	-7.900	-0.069	-0.050
	MJ/MJ	0.189	0.189	0.010	5.150	0.171	0.212

Appendix D: Statistic analyses and optimization, conditions and results.

1. Definition of symbols used in the Appendix.

Symbol	Definition
N	Numer of total cases in the analysis
R^2	Coefficient of determination
R^2_A	Coefficient of determination adjusted for the number of predictos in the model
CV	Coefficient of variation
SS	Sum of squares
MS	Mean squares
DF	Degrees of freedom
F	F statistic value
p-value	p statistic value
T	T statistic value
cpMallows	cpMallows index
Alpha	Significance level
MSD	Minimum significative difference
n	Number of cases in the sample
SD	Standard deviation
LL(95%)	Lower limit
UL(95%)	Upper limit
Est.	Estimate
Coef.	Coefficient

2. Analysis of variance and Fisher comparison for the study of the effect of washing the solids on enzymatic hydrolysis

Analysis of variance

Variable	N	R^2	R^2 A	CV
Hydrolysis efficiency	10	0.97	0.95	3.64

Variance analysis chart (SC type III)

	SS	DF	MS	F	p-value
Model	1381.55	4	345.31	42.07	0.0005
Washes	1381.55	4	345.31	42.07	0.0005
Error	41.05	5	8.21		
Total	1422.60	9			

Test:LSD Fisher Alpha=0.05 MSD=7.36551

Error: 8.2100 FD: 5

Washes	Means	n	SD			
0	56.45	2	2.03	A		
1	77.80	2	2.03		B	
2	85.30	2	2.03			C
3	85.80	2	2.03			C
4	88.75	2	2.03			C

Means with a common letter do not present a significative difference (p > 0.05)

3. Analysis of variance and Fisher comparison for the study of the effect of initial pH effect on enzymatic hydrolysis

For 15% solids content

Analysis of variance

Variable	N	R^2	R^2 A	CV
Hydrolysis efficiency (%)	10	0.98	0.97	3.15

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Model	1156.10	4	289.02	5.40	0.0001
pH	1156.10	4	289.02	75.40	0.0001
Error	19.17	5	3.83		
Total	1175.26	9			

Test:LSD Fisher Alpha=0.05 DMS=5.03270

Error: 3.8330 DF: 5

pH	Mean	n	SD			
7.00	53.00	2	1.38	A		
4.00	54.25	2	1.38	A		
6.00	56.50	2	1.38	A		
5.00	64.60	2	1.38		B	
4.80	82.00	2	1.38			C

Means with a common letter do not present a significative difference(p > 0.05)

For 20% solids content

Analysis of variance

Variable	N	R^2	R^2 A	CV
Hydolysis efficiency (%)	10	0.94	0.89	4.82

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Model	928.18	4	232.04	19.50	0.0030
pH	928.18	4	232.04	19.50	0.0030
Error	59.51	5	11.9		
Total	987.68	9			

Test:LSD Fisher Alfa=0.05 DMS=8.86795

Error: 11.9010 DF: 5

pH	Mean	n	SD			
4.00	55.20	2	2.44	A		
5.00	66.60	2	2.44		B	
5.50	75.95	2	2.44			C
7.00	78.00	2	2.44			C
6.00	82.10	2	2.44			C

Means with a common letter do not present a significative difference(p > 0.05)

For 25% solids content

Analysis of variance

Variable	N	R^2	R^2 A	CV
Hydrolysis efficiency(%)	8	0.96	0.93	2.84

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Model	248.20	3	82.73	33.96	0.0026
pH	248.20	3	82.73	33.96	0.0026
Error	9.75	4	2.44		
Total	257.95	7			

Test:LSD Fisher Alfa=0.05 DMS=4.33361

Error: 2.4363 DF: 4

pH	Mean	n	SD			
4.00	47.20	2	1.10	A		
7.00	54.15	2	1.10		B	
5.00	55.40	2	1.10		B	
6.00	62.90	2	1.10			C

Means with a common letter do not present a significative difference(p > 0.05)

4. Analysis of variance, linear regressions and lack of fit for the study of the effect of solids content, enzyme dosage, and xylanase substitution on enzymatic hydrolysis.

Variables x1, x2 and x3 correspond to coded normalyzed variables for solids content, enzyme dosage and xylanase substitution respectively.

Analyses for glucose concentration, G(g/L)

Analysis of variance

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-valor
Model	16714.48	9	1857.16	103.27	<0.0001
x1*x2	506.25	1	506.25	28.15	0.0032
x1*x3	0.25	1	0.25	0.01	0.9107
x2*x3	4.00	1	4.00	0.22	0.6571
x1	9660.50	1	9660.50	537.19	<0.0001
x1^2	0.69	1	0.69	0.04	0.8529
x2	5460.13	1	5460.13	303.62	<0.0001
x2^2	1078.29	1	1078.29	59.96	0.0006
x3	3.13	1	3.13	0.17	0.6941
x3^2	1.26	1	1.26	0.07	0.8021
Error	89.92	5	17.98		
Total	16804.40	14			

Lineal regression analysis:

Variable	N	R^2	R^2 A
G(g/L)	15	0.99	0.99

Regression coeficients and associated statistic parameters

Coef.	Est.	SD	LL(95%)	UL(95%)	T	p-value	cpMallows
const	133.86	1.20	131.18	136.53	111.52	<0.0001	
x1	34.75	1.12	32.25	37.25	30.95	<0.0001	960.84
x1*x2	11.25	1.59	7.71	14.79	7.08	<0.0001	53.19
x2	26.13	1.12	23.62	28.63	23.27	<0.0001	544.37
x2^2	-16.98	1.64	-20.64	-13.32	-10.33	<0.0001	109.75

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-value
Modelo.	16703.54	4	4175.89	414.04	<0.0001
x1	9660.50	1	9660.50	957.84	<0.0001
x1*x2	506.25	1	506.25	50.19	<0.0001
x2	5460.13	1	5460.13	541.37	<0.0001
x2^2	1076.67	1	1076.67	106.75	<0.0001
Error	100.86	10	10.09		
Total	16804.40	14			

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Model	16703.54	4	4175.89	414.04	<0.0001
x1	9660.50	1	9660.50	957.84	<0.0001
x1*x2	506.25	1	506.25	50.19	<0.0001
x2	6536.79	2	3268.40	324.06	<0.0001
Error	100.86	10	10.09		
Lack of Fit	75.69	4	18.92	4.51	0.0505
Pure Error	25.17	6	4.19		

Analyses for hydrolysis efficiency, H(%)

Analysis of variance

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-value
Modelo.	2986.75	9	331.86	147.49	<0.0001
x1*x2	56.25	1	56.25	25.00	0.0041
x1*x3	0.25	1	0.25	0.11	0.7524
x2*x3	1.00	1	1.00	0.44	0.5345
x1	84.50	1	84.50	37.56	0.0017
x1^2	1.07	1	1.07	0.48	0.5209
x2	2145.13	1	2145.13	953.39	<0.0001
x2^2	696.35	1	696.35	309.49	<0.0001
x3	0.13	1	0.13	0.06	0.8230
x3^2	2.08	1	2.08	0.92	0.3808
Error	11.25	5	2.25		
Total	2998.00	14			

Lineal regression analysis:

Variable	N	R^2	R^2 A
H (%)	15	0.99	0.99

Regression coeficients and associated statistic parameters

Coef	Est.	SD	LL(95%)	UL(95%)	T	p-value	cpMallows
const	97.29	0.47	96.24	98.33	207.22	<0.0001	
x1	-3.25	0.44	-4.23	-2.27	-7.40	<0.0001	57.77
x1*x2	3.75	0.62	2.37	5.13	6.04	0.0001	39.46
x2	16.38	0.44	15.40	17.35	37.29	<0.0001	1393.36
x2^2	-13.66	0.64	-15.09	-12.23	-21.25	<0.0001	454.56

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-value
Model	2982.57	4	745.64	483.29	<0.0001
x1	84.50	1	84.50	54.77	<0.0001
x1*x2	56.25	1	56.25	36.46	0.0001
x2	2145.13	1	2145.13	1390.36	<0.0001
x2^2	696.70	1	696.70	451.56	<0.0001
Error	15.43	10	1.54		
Total	2998.00	14			

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Model	2982.57	4	745.64	483.29	<0.0001
x1	84.50	1	84.50	54.77	<0.0001
x1*x2	56.25	1	56.25	36.46	0.0001
x2	2841.82	2	1420.91	920.96	<0.0001
Error	15.43	10	1.54		
Lack of Fit	4.93	4	1.23	0.70	0.6173
Pure Error	10.50	6	1.75		
Total	2998.00	14			

Analyses for minimum ethanol selling price (enzyme cost: 4.24 $/kg$_{protein}$), MESP[1]($/L)

Lineal regression analysis:

Assays 1 and 2 were identified as outliers by residual analysis.

Variable	N	R^2	R^2 A
M1 ($/L)	15	0.98	0.97

Regression coeficients and associated statistic parameters

Coef	Est.	SD	LL(95%)	UL (95%)		p-value	cpMallows
const	0.84	0.01	0.82	0.85	143.61	<0.0001	
x1*x2	-0.02	0.01	-0.03	-1.3E-03	-2.47	0.0355	10.10
x1	-0.01	4.3E-03	-0.02	-2.9E-04	-2.33	0.0448	9.43
x1^2	0.03	0.01	0.01	0.04	4.21	0.0023	21.74
x2	0.03	4.3E-03	0.02	0.04	6.41	0.0001	45.03
x2^2	0.13	0.01	0.11	0.14	20.08	<0.0001	407.38

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-value
Model	0.07	5	0.01	92.74	<0.0001
x1*x2	9.0E-04	1	9.0E-04	6.10	0.0355
x1	8.0E-04	1	8.0E-04	5.43	0.0448
x1^2	1.1E-03	1	1.1E-03	7.75	0.0212
x2	0.01	1	0.01	41.03	0.0001
x2^2	0.06	1	0.06	403.38	<0.0001
Error	1.3E-03	9	1.5E-04		
Total	0.07	14			

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Model	0.07	5	0.01	92.74	<0.0001
x1*x2	9.0E-04	1	9.0E-04	6.10	0.0355
x1	3.4E-03	2	1.7E-03	11.58	0.0032
x2	0.07	2	0.03	222.21	<0.0001
Error	1.3E-03	9	1.5E-04		
Lack of Fit	6.3E-04	3	2.1E-04	1.79	0.2488
Pure Error	7.0E-04	6	1.2E-04		
Total	0.07	14			

Analyses for minimum ethanol selling price (enzyme cost: 3$/kg$_{protein}$), MESP^2($/L)

Lineal regression analysis:

Variable	N	R^2	R^2 A
M2 ($/L)	15	0.98	0.97

Regression coeficients and associated statistic parameters

Coef	Est.	SD	LL(95%)	UL(95%)	T	p-value	cpMallows
const	0.77	0.01	0.76	0.78	148.70	<0.0001	
x1*x2	-0.01	0.01	-0.02	-3.4E-04	-2.33	0.0450	9.41
x1	-0.01	3.8E-03	-0.02	-1.5E-04	-2.30	0.0468	9.30
x1^2	0.03	0.01	0.01	0.04	4.76	0.0010	26.65
x2	-0.02	3.8E-03	-0.03	-0.01	-5.92	0.0002	39.07
x2^2	0.12	0.01	0.11	0.14	22.24	<0.0001	498.81

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-value
Model	0.06	5	0.01	110.14	<0.0001
x1*x2	6.3E-04	1	6.3E-04	5.41	0.0450
x1	6.1E-04	1	6.1E-04	5.30	0.0468
x1^2	1.2E-03	1	1.2E-03	10.10	0.0112
x2	4.1E-03	1	4.1E-03	35.07	0.0002
x2^2	0.06	1	0.06	494.81	<0.0001
Error	1.0E-03	9	1.2E-04		
Total	0.06	14			

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Modelo.	0.06	5	0.01	110.14	<0.0001
x1*x2	6.2E-04	1	6.2E-04	5.41	0.0450
x1	3.2E-03	2	1.6E-03	13.98	0.0017
x2	0.06	2	0.03	264.94	<0.0001
Error	1.0E-03	9	1.2E-04		
Lack of Fit	5.9E-04	3	2.0E-04	2.62	0.1456
Puro Error	4.5E-04	6	7.5E-05		
Total	0.06	14			

5. Analysis of variance and linear regressions for greenhouse gas emissions and fossil energy use

Variables x1, x2 and x3 correspond to dimensionless normalyzed variables for solids content, enzyme dosage and xylanase substitution respectively.

Analyses for greenhouse gases emissions GHG ($gCO_2/MJ_{ethanol}$)

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-value
Modelo.	7717.88	5	1543.58	274.55	<0.0001
x1*x2	14.06	1	14.06	2.50	0.1482
x1	17.70	1	17.70	3.15	0.1097
x1^2	17.46	1	17.46	3.11	0.1119
x2	7619.95	1	7619.95	1355.35	<0.0001
x2^2	48.70	1	48.70	8.66	0.0164
Error	50.60	9	5.62		
Total	7768.48	14			.

Lineal regression analysis

Non significant terms maintained to avoid lack of fit**.**

Variable	N	R^2	R^2 A
GHG(gco2/MJ)	15	0.99	0.99

Regression coeficients and associated statistic parameters

Coef	Est.	SD	LL(95%)	UL(95%)	T	p-value	cpMallows
const	-64.81	0.96	-66.94	-62.69	-67.26	<0.0001	
x1*x2	1.88	1.27	-0.93	4.68	1.47	0.1693	4.16
x2	30.65	0.90	28.67	32.63	34.00	<0.0001	1158.19
x2^2	-3.66	1.32	-6.56	-0.76	-2.77	0.0181	9.70

Variance analysis chart (SS type I)

SS		DF	MS	F	p-value
Modelo.	7579.47	3	2526.49	388.69	<0.0001
x1*x2	14.06	1	14.06	2.16	0.1693
x2	7515.38	1	7515.38	1156.19	<0.0001
x2^2	50.03	1	50.03	7.70	0.0181
Error	71.50	11	6.50		
Total	7650.97	14			

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Modelo.	7579.47	3	2526.49	388.69	<0.0001
x1*x2	14.06	1	14.06	2.16	0.1693
x2	7565.41	2	3782.70	581.95	<0.0001
Error	71.50	11	6.50		
Lack of Fit	31.73	3	10.58	2.13	0.1750
Error Puro	39.77	8	4.97		
Total	7650.97	14			.

Analyses for fossil energy usage CED ($MJ_{fossil}/MJ_{ethanol}$)

Non-significant lack of fit was not achieved for this model.

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Variance analysis chart (SS type I)

	SS	DF	MS	F	p-valor
Modelo.	912214.91	5	182442.98	1634.32	<0.0001
x1*x2	1722.25	1	1722.25	15.43	0.0035
x1	528.13	1	528.13	4.73	0.0576
x1^2	4.72	1	4.72	0.04	0.8416
x2	902496.13	1	902496.13	8084.53	<0.0001
x2^2	7463.68	1	7463.68	66.86	<0.0001
Error	1004.69	9	111.63		
Total	913219.60	14			.

Lineal regression analysis:

Variable	N	R^2	R^2 A	
CED MJ/MJ	15	1.00	1.00	

Regression coeficients and associated statistic parameters

Coef	Est.	SD	LL(95%)	UL(95)	T	p-value	cpMallows
const	203.14	3.92	194.41	211.87	51.86	<0.0001	
x1	-8.13	3.66	-16.29	0.04	-2.22	0.0509	7.92
x1*x2	20.75	5.18	9.20	32.30	4.00	0.0025	19.03
x2	335.88	3.66	327.71	344.04	91.66	<0.0001	8404.31
x2^2	-44.52	5.36	-56.47	-32.57	-8.30	<0.0001	71.88

Variance analysis chart (SS type I)

	SS	DF	MS	F	p-value
Modelo.	912145.37	4	228036.34	2122.78	<0.0001
x1	528.13	1	528.13	4.92	0.0509
x1*x2	1722.25	1	1722.25	16.03	0.0025
x2	902496.13	1	902496.13	8401.31	<0.0001
x2^2	7398.87	1	7398.87	68.88	<0.0001
Error	1074.23	10	107.42		
Total	913219.60	14			.

Variance analysis chart (SS type III)

	SS	DF	MS	F	p-value
Modelo.	912145.37	4	228036.34	2122.78	<0.0001
x1	528.13	1	528.13	4.92	0.0509
x1*x2	1722.25	1	1722.25	16.03	0.0025
x2	909894.99	2	454947.50	4235.09	<0.0001
Error	1074.23	10	107.42		
Lack of Fit	983.23	4	245.81	16.21	0.0023
Error Puro	91.00	6	15.17		
Total	913219.60	14			

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6. Analysis of variance and Tukey (HSD) results for the Monte Carlo analysis results

Analysis of variance and Tukey HSD results for use of hemicellulose- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	2067316	2	1033658	37951	<0.0001
Whithin groups	81626	2997	27		
Total	2148942	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	15.5200	14.9729to 16.0671	<0.0001
Group 1 vs group 3	-46.2800	-46.8271to -45.7329	<0.0001
Group 2 vs group 3	-61.8000	-62.3471to -61.2529	<0.0001

Analysis of variance and Tukey HSD results for use of hemicellulose- CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	72.2667	2	36.1333	417319	<0.0001
Whithin groups	0.2595	2997	0.0001		
Total	72.5262	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	0.2000	0.1990 to 0.2010	<0.0001
Group 1 vs group 3	-0.1800	-0.1810 to -0.1790	<0.0001
Group 2 vs group 3	-0.3800	--0.3810to -0.3790	<0.0001

Analysis of variance and Tukey HSD results for glucan content- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	19846	2	9923	326	<0.0001
Whithin groups	91218	2997	30		
Total	111064	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	-0.3000	-0.8783 to 0.2783	0.4438
Group 1 vs group 3	5.3000	4.7217 to 5.8783	<0.0001
Group 2 vs group 3	5.6000	5.0217 to 6.1783	<0.0001

Analysis of variance and Tukey HSD results for glucan content- CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	3.2107	2	1.6053	16788	<0.0001
Whithin groups	0.2866	2997	0.0001		
Total	3.4972	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	0.0440	0.0430 to 0.0450	<0.0001
Group 1 vs group 3	0.0800	0.0790 to 0.0810	<0.0001
Group 2 vs group 3	0.0360	0.0350 to 0.0370	<0.0001

Analysis of variance and Tukey HSD results for xylan content- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	262206	2	131103	4814	<0.0001
Whithin groups	81607	2997	27		
Total	343814	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	-11.5000	-12.0470 to -10.9530	<0.0001
Group 1 vs group 3	-22.9000	-23.4470 to -22.3530	<0.0001
Group 2 vs group 3	-11.4000	-11.9470 to -10.8530	<0.0001

Analysis of variance and Tukey HSD results for xylan content- CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	30.2687	2	15.1343	160811	<0.0001
Whithin groups	0.2821	2997	0.0001		
Total	30.5507	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	-0.1270	-0.1280 to -0.1260	<0.0001
Group 1 vs group 3	-0.2460	-0.2470 to -0.2450	<0.0001
Group 2 vs group 3	-0.1190	-0.1200 to -0.1180	<0.0001

Analysis of variance and Tukey HSD results for lignin content- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	68486	2	34243	1073	<0.0001
Whithin groups	95585	2997	32		
Total	164071	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	-5.6000	-6.1920 to -5.0080	<0.0001
Group 1 vs group 3	-11.7000	-12.2920 to -11.1080	<0.0001
Group 2 vs group 3	-6.1000	-6.6920 to -5.5080	<0.0001

Analysis of variance and Tukey HSD results for lignin content- CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	0.0047	2	0.0023	23.3146	<0.0001
Whithin groups	0.2999	2997	0.0001		
Total	0.3046	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	0.0020	0.0010 to 0.0030	<0.0001
Group 1 vs group 3	0.0030	0.0020 to 0.0040	<0.0001
Group 2 vs group 3	0.0010	0.0000 to 0.0020	0.0655

Analysis of variance and Tukey HSD results for enzyme dosage- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	2230940	2	1115470	36807	<0.0001
Whithin groups	90825	2997	30		
Total	2321765	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	39.5000	38.9229 to 40.0771	<0.0001
Group 1 vs group 3	66.4000	65.8229 to 66.9771	<0.0001
Group 2 vs group 3	26.9000	26.3229 to 27.4771	<0.0001

Analysis of variance and Tukey HSD results for enzyme dosage CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	367.0887	2	183.5443	2287186	<0.0001
Whithin groups	0.2405	2997	0.0001		
Total	367.3292	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	0.5120	0.5111 to 0.5129	<0.0001
Group 1 vs group 3	0.8510	0.8501 to 0.8519	<0.0001
Group 2 vs group 3	0.3390	0.3381 to 0.3399	<0.0001

Analysis of variance and Tukey HSD results for hydrolysis efficiency- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	115686	2	57843	1541	<0.0001
Whithin groups	112490	2997	37.		
Total	228177	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	-0.9000	-1.5422 to -0.2578	0. 0029
Group 1 vs group 3	12.7000	12.0578 to 13.3422	<0.0001
Group 2 vs group 3	13.6000	12.9578 to 14.2422	<0.0001

Analysis of variance and Tukey HSD results for hydrolysis efficiency CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	37.5387	2	18.7693	125015.4304	<0.0001
Whithin groups	0.4500	2997	0.0002		
Total	37.9886	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	0.0380	0.0367 to 0.0393	<0.0001
Group 1 vs group 3	0.2540	0.2527 to 0.2553	<0.0001
Group 2 vs group 3	0.2160	0.2147 to 0.2173	<0.0001

Analysis of variance and Tukey HSD results for fermentation efficiency- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	32826	2	16413	406	<0.0001
Whithin groups	120972	2997	40		
Total	153799	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	-5.8000	-6.4660 to -5.1340	<0.0001
Group 1 vs group 3	2.0000	1.3340 to 2.6660	<0.0001
Group 2 vs group 3	7.8000	7.1340 to 8.4660	<0.0001

Analysis of variance and Tukey HSD results for fermentation efficiency CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	13.3307	2	6.6653	52158	<0.0001
Whithin groups	0.3830	2997	0.0001		
Total	13.7137	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	-0.1240	-0.1252 to -0.1228	<0.0001
Group 1 vs group 3	0.0300	0.0288 to 0.0312	<0.0001
Group 2 vs group 3	0.1540	0.1528 to 0.1552	<0.0001

Analysis of variance and Tukey HSD results for solids content- GHG ($gCO_2/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	620.0000	2	310	10.8	<0.0001
Whithin groups	85399.9146	2997	29		
Total	86019.9146	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	0.7000	0.1404 to 1.2596	0.0094
Group 1 vs group 3	-0.4000	-0.9596 to 0.1596	0.2147
Group 2 vs group 3	-1.1000	-1.6596 to -0.5404	<0.0001

Analysis of variance and Tukey HSD results for solids content CED($MJ_{fossil}/MJ_{ethanol}$)

Source of variation	SS	DF	Variance	F	p-value
Between groups	0.0687	2	0.0343	329	<0.0001
Whithin groups	0.3120	2997	0.0001		
Total	0.3806	2999			

	Difference	Confidence Interval 95%	p-value
Group 1 vs group 2	0.0110	0.0099 to 0.0121	<0.0001
Group 1 vs group 3	0.0020	0.0009 to 0.0031	<0.0001
Group 2 vs group 3	-0.0090	-0.0101 to -0.0079	<0.0001

7. Functions, constraints, and results, for optimization analyses.

Optimization of minimum ethanol selling price (enzyme cost: 4.24 $/kg$_{protein}$), MESP[1]($/L)

Function:

function M1 = f(x)

```
M1 = 0.84-0.01.*x(1)+0.03.*x(2)+0.03.*x(1).*x(1)+0.13.*x(2).*x(2)-0.02.*x(1).*x(2);
```

end

Start Point: [0,0]

Bounds:

Lower bound: [-1,-1], upper bound: [1,1]

Optimization of minimum ethanol selling price (enzyme cost: 3 $/kg$_{protein}$), MESP[2]($/L)

Function:

function M2 = f(x)

```
M2 = 0.77-0.01.*x(1)-0.02.*x(2)+0.03.*x(1).*x(1)+0.12.*x(2).*x(2)-0.01.*x(2).*x(1);
```

end

Start Point: [0,0]

Bounds:

Lower bound: [-1,-1], upper bound: [1,1]

Multiple objective optimization for greenhouse gases emissions (gCO_2/MJ$_{ethanol}$) and minimium ethanol selling price ($/L)

Function:

function MESPGHG = f(x)

```
MESPGHG = [0.84-0.01.*x(1)+0.03.*x(2)+0.03.*x(1).*x(1)+0.13.*x(2).*x(2)-0.02.*x(1).*x(2);
-64.81+30.65.*x(2)-3.66.*x(2).*x(2)+1.81.*x(1).*x(2);];
end
```

End

Iterations: 303

Results:

Ranking	MESP	GHG	x1	x2	S (%)	E (mg $_{protein}$/g$_{glucan}$)
1	0,979	-101	0,985	-0,999	24,9	10,0
2	0,838	-68	0,131	-0,105	20,6	36,8
3	0,929	-94	0,760	-0,838	23,8	14,8
4	0,940	-98	0,325	-0,973	21,6	10,8
5	0,871	-83	0,471	-0,561	22,3	23,1
6	0,910	-93	0,290	-0,835	21,4	14,9
7	0,903	-91	0,387	-0,782	21,9	16,5
8	0,860	-81	0,189	-0,516	20,9	24,5
9	0,887	-88	0,205	-0,714	21,0	18,6
10	0,852	-78	0,253	-0,427	21,3	27,2