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APPENDICES

Appendix A Components Considered in PRO/II

Table A1 List of components considered in PRO/II simulations, the alias used, and the chemical formula

	Component name	Component alias	Chemical formula
1	Cellulose	CELLULOS	$C_6H_{10}O_5$
2	Hemicellulose	HCELLULO	$C_5H_8O_4$
3	Galactan	GALACTAN	$C_6H_{10}O_5$
4	Mannan	MANNAN	$C_6H_{10}O_5$
5	Arabinan	ARABINAN	$C_5H_8O_4$
6	Lignin	LIGNIN	$C_{7.3}H_{13.9}O_{1.3}$
7	Glucose	C6	$C_6H_{12}O_6$
8	Mannose	C6M	$C_6H_{12}O_6$
9	Galactose	G6G	$C_6H_{12}O_6$
10	Xylose	C5	$C_5H_{10}O_5$
11	Arabinose	C5A	$C_5H_{10}O_5$
12	Cellobiose	C12	$C_{12}H_{22}O_{11}$
13	Ethanol	ETHANOL	C_2H_6O
14	Water	WATER	H_2O
15	Sulfuric Acid	SULFURIC	H_2SO_4
16	Furfural	FURFURAL	$C_5H_4O_2$
17	Ammonia	NH3	NH_3
18	Oxygen	O2	O_2
19	Carbon Dioxide	CO2	CO_2
20	Glycerol	GLYCEROL	$C_3H_8O_3$
21	Succinic Acid	SUCCINIC	$C_4H_6O_4$
22	Lactic Acid	LACTIC	$C_3H_6O_3$
23	Hydroxymethylfurfural	HMF	$C_6H_6O_3$
24	Xylitol	XYLITOL	$C_5H_{12}O_5$
25	Acetic Acid	ACETIC	$C_2H_4O_2$
26	Corn Steep Liquor	CLS	H_2O

Table A1 List of components considered in PRO/II simulations, the alias used, and the chemical formula (continue)

	Component name	Component alias	Chemical formula
27	*Zymomonas Mobilis* (bacteria)	ZM	$CH_{1.8}O_{0.5}N_{0.2}$
28	*Cellulase* (enzyme)	CELLULAC	$CH_{1.57}NOS$
29	Calcium Hydroxide	CAHYDROX	$Ca(OH)_2$
30	Calcium Sulphate (Gypsum)	CASO4	$CaSO_4$
31	Ash	ASH	$C_6H_{10}O_5$
32	Nitrogen	NITROGEN	N_2

Appendix B Chemical Reactions Implemented in PRO/II

Table B1 List of reactions taking place in the pretreatment reactor (Wooley *et al.*, 1999)

	Reaction	Conversion	Modeled
1	$Cellulose_n + nWater \longrightarrow nGlucose$ $C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$	Cellulose	0.134
2	$Cellulose_n + n/2Water \longrightarrow n/2Cellobiose$ $C_6H_{10}O_5 + ½H_2O \longrightarrow ½C_{12}H_{22}O_{11}$	Cellulose	0.007
3	$Hemicellulose_n + nWater \longrightarrow nXylose$ $C_5H_8O_4 + H_2O \longrightarrow C_5H_{10}O_5$	Hemicellulose	0.894
4	$Hemicellulose_n \longrightarrow nFurfural + 2nWater$ $C_5H_8O_4 \longrightarrow C_5H_4O_2 + 2H_2O$	Hemicellulose	0.061
5	$Mannan_n + nWater \longrightarrow nMannose$ $C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$	Mannan	0.750
6	$Mannan_n \longrightarrow nHMF + 2nWater$ $C_6H_{10}O_5 \longrightarrow C_6H_6O_3 + 2H_2O$	Mannan	0.044
7	$Galactan_n + nWater \longrightarrow nGalactose$ $C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$	Galactan	0.750
8	$Galactan_n \longrightarrow nHMF + 2nH_2O$ $C_6H_{10}O_5 \longrightarrow C_6H_6O_3 + 2H_2O$	Galactan	0.044
9	$Arabinan_n + nWater \longrightarrow nArabinose$ $C_5H_8O_4 + H_2O \longrightarrow C_5H_{10}O_5$	Arabinan	0.750
10	$Arabinan_n \longrightarrow Furfural + 2nWater$ $C_5H_8O_4 \longrightarrow C_5H_4O_2 + 2H_2O$	Arabinan	0.061

Table B2 List of reactions taking place in overliming process (Wooley *et al.*, 1999)

	Reaction	Conversion	Modeled
11	$Sulfuric\ Acid + Calcium\ Hydroxide \longrightarrow Gypsum$ $H_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4 \cdot 2H_2O$	Sulfuric Acid	1.000

Table B3 List of reactions taking place in SSCF seed fermentation process (Wooley *et al.*, 1999)

	Reaction	Conversion	Modeled
Saccharification Reaction			
12	$Cellulose_n + nWater \longrightarrow nGlucose$ $C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$	Cellulose	0.250
Fermentation Reaction			
	Reaction	**Conversion**	**Modeled**
13	$Glucose \longrightarrow 2Ethanol + 2Carbon\ Dioxide$ $C_6H_{12}O_6 \longrightarrow 2C_2H_6O + 2CO_2$	Glucose	0.900
14	$Glucose + 1.2Ammonia \longrightarrow 6Z.\ mobilis + 2.4Water + 0.3Oxygen$ $C_6H_{12}O_6 + 1.2NH_3 \longrightarrow 6C_{1.8}H_{0.5}O_{0.2} + 2.4H_2O + 0.3O_2$	Glucose	0.040
15	$Glucose + 2Water \longrightarrow 2Glycerol + Oxygen$ $C_6H_{12}O_6 + 2H_2O \longrightarrow 2C_3H_8O_3 + O_2$	Glucose	0.004
16	$Glucose + 2Carbon\ Dioxide \longrightarrow 2Succinic\ Acid + Oxygen$ $C_6H_{12}O_6 + 2CO_2 \longrightarrow 2C_4H_6O_4 + O_2$	Glucose	0.006
17	$Glucose \longrightarrow 3Acetic\ Acid$ $C_6H_{12}O_6 \longrightarrow 3CH_3COOH$	Glucose	0.015
18	$Glucose \longrightarrow 2Lactic\ Acid$ $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Glucose	0.002
19	$3Xylose \longrightarrow 5Ethanol + 5Carbon\ Dioxide$ $3C_5H_{10}O_5 \longrightarrow 5C_2H_6O + 5CO_2$	Xylose	0.800
20	$Xylose + Ammonia \longrightarrow 5Z.\ mobilis + 2Water + 0.25Oxygen$ $C_5H_{10}O_5 + NH_3 \longrightarrow 5C_{1.8}H_{0.5}O_{0.2} + 2H_2O + 0.25O_2$	Xylose	0.040
21	$3Xylose + 5Water \longrightarrow 5Glycerol + 2.5Oxygen$ $3C_5H_{10}O_5 + 5H_2O \longrightarrow 5C_3H_8O_3 + 2.5O_2$	Xylose	0.003
22	$Xylose + Water \longrightarrow Xylitol + 0.5Oxygen$ $C_5H_{10}O_5 + H_2O \longrightarrow C_5H_{12}O_5 + 0.5O_2$	Xylose	0.046
23	$3Xylose + 5Carbon\ Dioxide \longrightarrow 5Succinic\ Acid + 2.5Oxygen$ $3C_5H_{10}O_5 + 5CO_2 \longrightarrow 5C_4H_6O_4 + 2.5O_2$	Xylose	0.009

Table B3 List of reactions taking place in SSCF seed fermentation process (continue)

	Reaction	Conversion	Modeled
24	2Xylose $\longrightarrow$ 5Acetic Acid $2C_5H_{10}O_5 \longrightarrow 5CH_3COOH$	Xylose	0.014
25	3Xylose $\longrightarrow$ 5Lactic Acid $3C_5H_{10}O_5 \longrightarrow 5CH_3CHOHCOOH$	Xylose	0.002

Table B4 List of reactions taking place in SSCF fermentation process (Wooley *et al.*, 1999)

Saccharification Reaction			
	Reaction	**Conversion**	**Modeled**
26	$Cellulose_n$ + n/2Water $\longrightarrow$ n/2Cellobiose $C_6H_{10}O_5 + ½H_2O \longrightarrow ½C_{12}H_{22}O_{11}$	Cellulose	0.012
27	$Cellulose_n$ + nWater $\longrightarrow$ nGlucose $C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$	Cellulose	0.900
28	$Cellobiose_n$ + nWater $\longrightarrow$ 2nGlucose $C_{12}H_{22}O_{11} + H_2O \longrightarrow 2C_6H_{12}O_6$	Cellobiose	1.000
Fermentation Reaction			
	Reaction	**Conversion**	**Modeled**
29	Glucose $\longrightarrow$ 2Ethanol + 2Carbon Dioxide $C_6H_{12}O_6 \longrightarrow 2C_2H_6O + 2CO_2$	Glucose	0.950
30	Glucose+1.2Ammonia $\longrightarrow$ 6*Z. mobilis*+2.4Water+0.3Oxygen $C_6H_{12}O_6 + 1.2NH_3 \longrightarrow 6C_{1.8}H_{0.5}O_{0.2} + 2.4H_2O + 0.3O_2$	Glucose	0.020
31	Glucose + 2Water $\longrightarrow$ 2Glycerol + Oxygen $C_6H_{12}O_6 + 2H_2O \longrightarrow 2C_3H_8O_3 + O_2$	Glucose	0.004
32	Glucose+2Carbon Dioxide $\longrightarrow$ 2Succinic Acid+Oxygen $C_6H_{12}O_6 + 2CO_2 \longrightarrow 2C_4H_6O_4 + O_2$	Glucose	0.006
33	Glucose $\longrightarrow$ 3Acetic Acid $C_6H_{12}O_6 \longrightarrow 3CH_3COOH$	Glucose	0.015

Table B4 List of reactions taking place in SSCF fermentation process (continue)

	Reaction	Conversion	Modeled
34	Glucose $\longrightarrow$ 2Lactic Acid $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Glucose	0.002
35	3Xylose $\longrightarrow$ 5Ethanol + 5Carbon Dioxide $3C_5H_5O_5 \longrightarrow 5C_2H_6O + 5CO2$	Xylose	0.850
36	Xylose+Ammonia $\longrightarrow$ 5*Z. mobilis*+2Water+0.25Oxygen $C_5H_{10}O_5 + NH_3 \longrightarrow 5C_{1.8}H_{0.5}O_{0.2} + 2H_2O + 0.25O_2$	Xylose	0.019
37	3Xylose + 5Water $\longrightarrow$ 5Glycerol + 2.5Oxygen $3C_5H_{10}O_5 + 5H_2O \longrightarrow 5C_3H_8O_3 + 2.5O_2$	Xylose	0.003
38	Xylose + Water $\longrightarrow$ Xylitol + 0.5Oxygen $C_5H_{10}O_5 + H_2O \longrightarrow C_5H_{12}O_5 + 0.5O_2$	Xylose	0.046
39	3Xylose+5Carbon Dioxide $\longrightarrow$ 5Succinic Acid+2.5Oxygen $3C_5H_{10}O_5 + 5CO_2 \longrightarrow 5C_4H_6O_4 + 2.5O_2$	Xylose	0.009
40	2Xylose $\longrightarrow$ 5Acetic Acid $2C_5H_{10}O_5 \longrightarrow 5CH_3COOH$	Xylose	0.014
41	3Xylose $\longrightarrow$ 5Lactic Acid $3C_5H_{10}O_5 \longrightarrow 5CH_3CHOHCOOH$	Xylose	0.002

Table B5 List of reactions taking place in SSCF contamination loss (Wooley *et al.*, 1999)

	Reaction	Conversion	Modeled
42	Glucose $\longrightarrow$ 2Lactic Acid $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Glucose	1.000
43	3Xylose $\longrightarrow$ 5Lactic Acid $3C_5H_{10}O_5 \longrightarrow 5CH_3CHOHCOOH$	Xylose	1.000
44	3Arabinose $\longrightarrow$ 5Lactic Acid $3C_5H_{10}O_5 \longrightarrow 5CH_3CHOHCOOH$	Arabinose	1.000
45	Galactose $\longrightarrow$ 2Lactic Acid $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Galactose	1.000

Table B5 List of reactions taking place in SSCF contamination loss (continue)

	Reaction	Conversion	Modeled
46	Mannose $\longrightarrow$ 2Lactic Acid $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Mannose	1.000

Table B6 List of reactions taking place in combustion process

	Reaction	Conversion	Modeled
47	$Cellulose_n$ + 6nOxygen $\longrightarrow$ 5nWater + 6nCarbon Dioxide $C_6H_{10}O_5 + 6O_2 \longrightarrow 5H_2O + 6CO_2$	Cellulose	0.800
48	$Hemicellulose_n$+5nOxygen $\longrightarrow$ 4nWater+5nCarbon Dioxide $C_5H_8O_4 + 5O_2 \longrightarrow 4H_2O + 5CO_2$	Hemicellulose	0.800
49	$Mannan_n$ + 6nOxygen $\longrightarrow$ 5nWater + 6nCarbon Dioxide $C_6H_{10}O_5 + 6O_2 \longrightarrow 5H_2O + 6CO_2$	Mannan	0.800
50	$Galactan_n$ + 6nOxygen $\longrightarrow$ 5nWater + 6nCarbon Dioxide $C_6H_{10}O_5 + 6O_2 \longrightarrow 5H_2O + 6CO_2$	Galactan	0.800
51	$Arabinan_n$ +5nOxygen $\longrightarrow$ 4nWater+5nCarbon Dioxide $C_5H_8O_4 + 5O_2 \longrightarrow 4H_2O + 5CO_2$	Arabinan	0.800
52	$Lignin_n$+10.13nOxygen $\longrightarrow$ 6.95nWater+7.30nCarbon Dioxide $C_{73}H_{139}O_{13} + 10.13O_2 \longrightarrow 6.95H_2O + 7.30CO_2$	Lignin	0.800

Appendix C Main Process Condition for Base Case Design

Table C1 Hydrolysis reactor

List	Value
Agent	Dilute sulfuric acid
Acid concentration (w/w)	1 %
Residence time	1 min
Temperature	180 °C
Pressure	10.0 atm
Solids in the reactor (w/w)	47.5 %

Table C2 Blowdown tank

List	Value
Temperature	102 °C
Pressure	1 atm

Table C3 Detoxification

List	Value
Type	Overliming (50 °C)
Alkali	Calcium hydroxide
Residence time	1 hr for overliming and 4 hr for reacidification

Table C4 SSCF seed fermenter

List	Value
Temperature	40 °C
Initial solids level (w/w)	21.0 %
Residence time	24 hr
Enzyme	Cellulase
Biocatalyst	*Zymomonas Mobilis*
Enzyme level (w/w)	2 % of cellulose
Corn steep liquor level (w/w)	0.25 %
Pressure	1 atm

Table C5 SSCF fermenter

List	Value
Temperature	40 °C
Initial solids level (w/w)	21.0 %
Residence time	7 days
Enzyme	Cellulase
Biocatalyst	*Zymomonas Mobilis*
Enzyme level	2 % of cellulose
Inoculum level (w/w)	10 % of hydrolyzate
Corn steep liquor level (w/w)	0.25 %
Pressure	1 atm

Table C6 Beer distillation

List	Value
Pressure	1.77 atm
Stages	32
Feed stage	4
Reflux ratio	3.2

Table C7 Rectification column

List	Value
Pressure	1.77 atm
Stages	60
Feed stage	50
Reflux ratio	3.2

Appendix D Bioethanol Conversion Process Flowsheet and Stream Tables Implemented in PRO/II

D.1 Process Flowsheet

D.1.1 Base Case

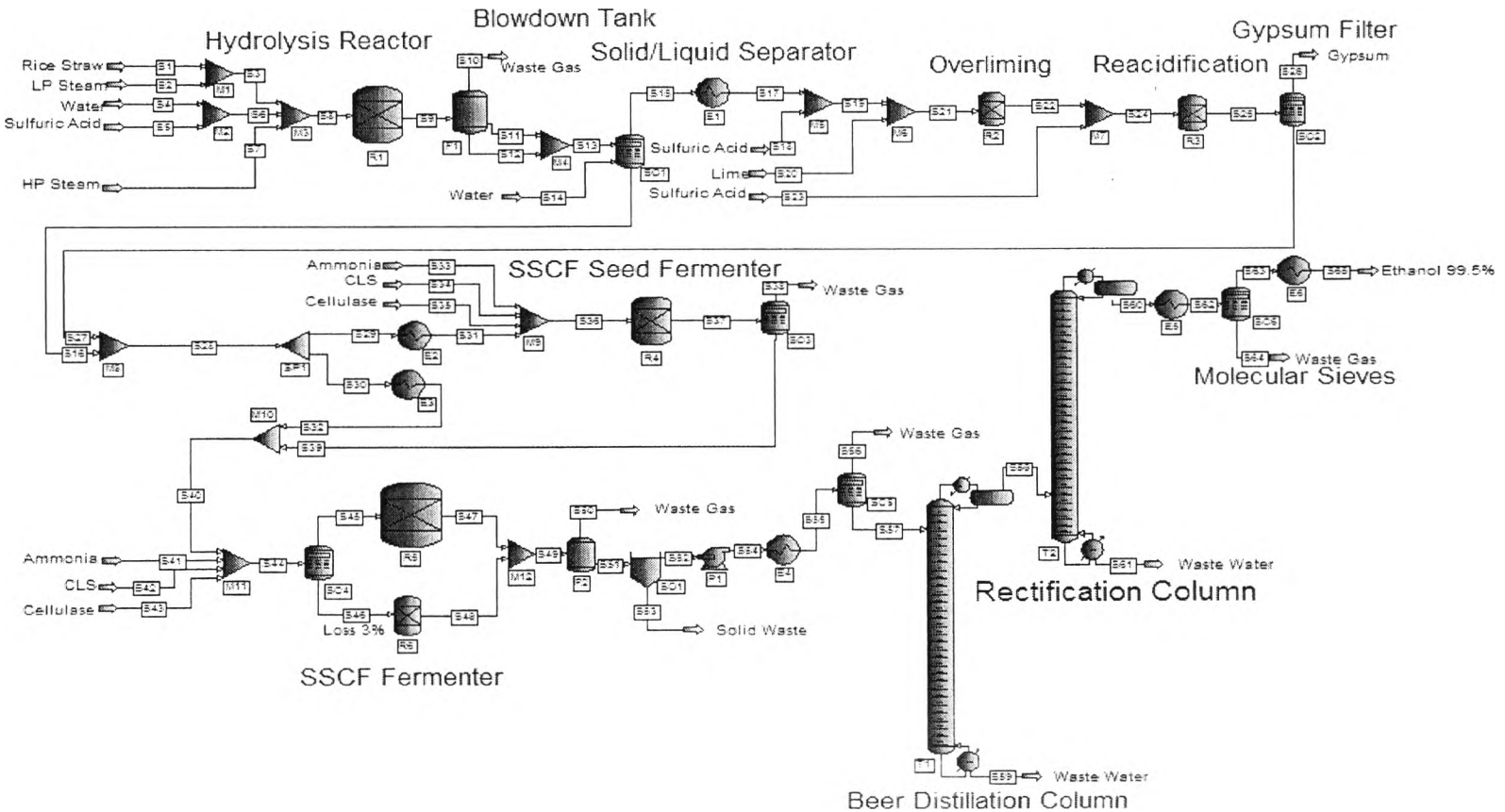

Figure D1 Flowsheet of the bioethanol production process from rice straw for base case design.

D.1.2 Alternative 1: Base Case with Heat Integration

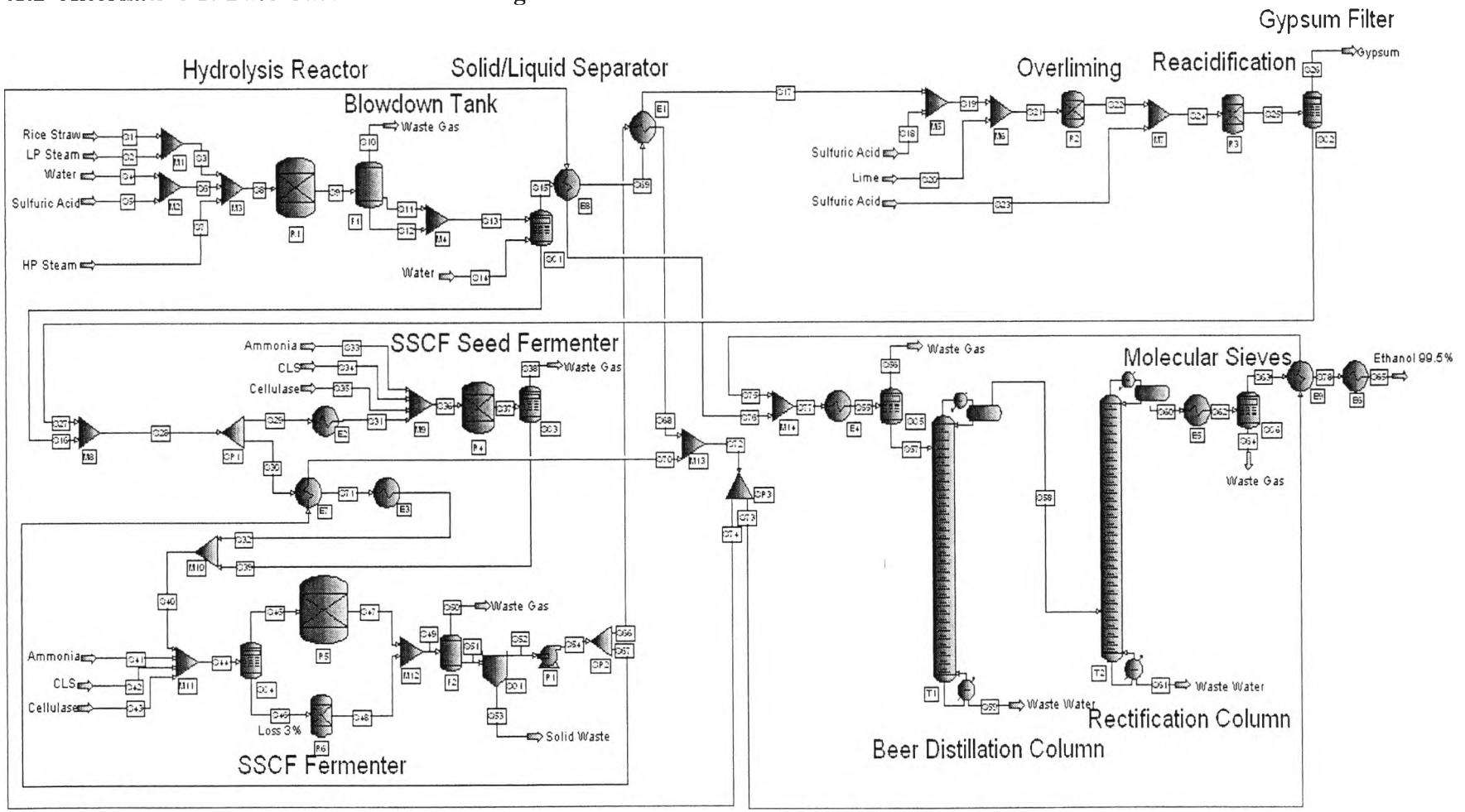

Figure D2 Flowsheet of the bioethanol production process from rice straw for alternative 1 design.

D.1.3 Alternative 2: Wastewater Exchange Heat as Utility

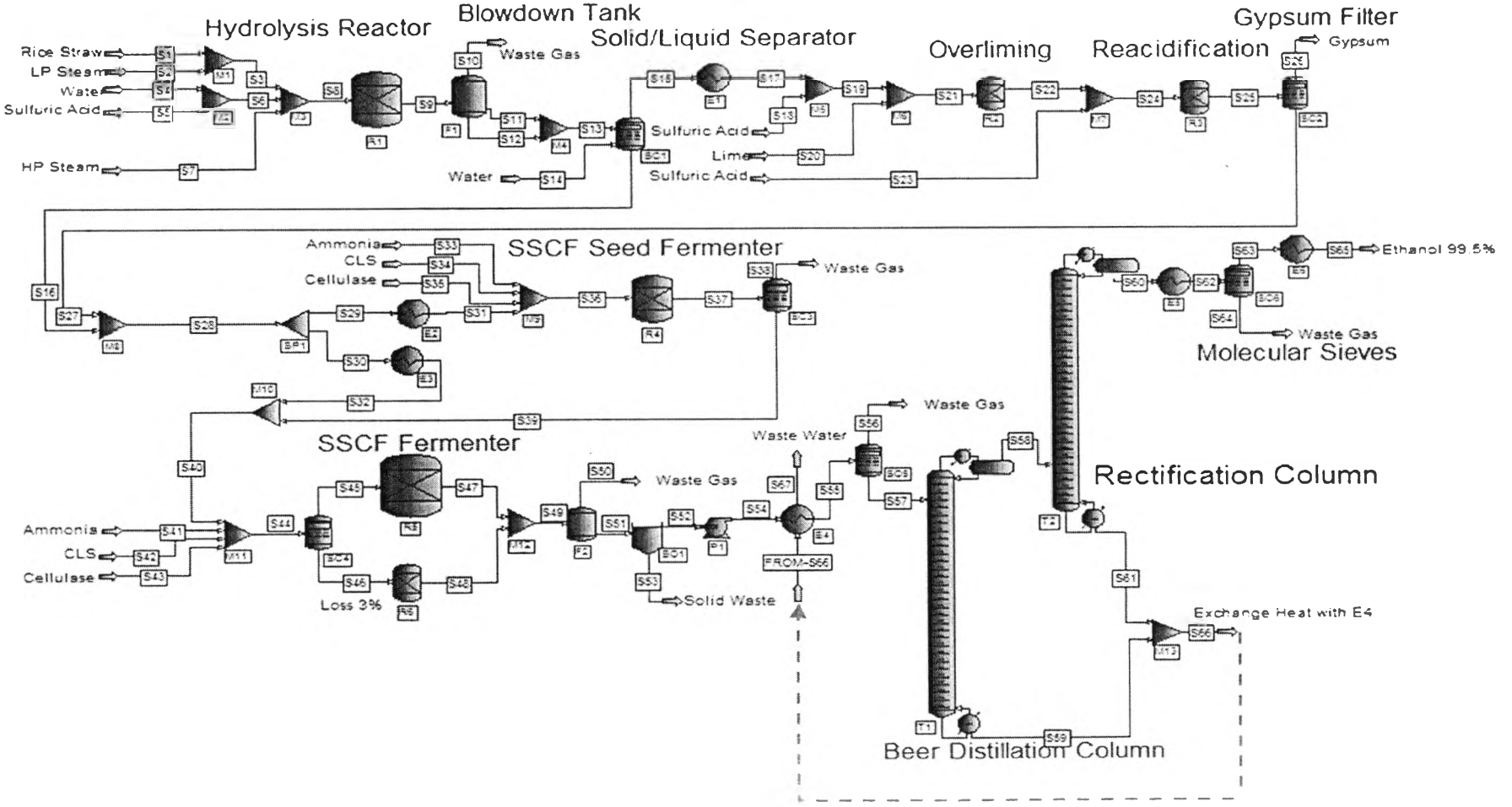

Figure D3 Flowsheet of the bioethanol production process from rice straw for alternative 2 design.

D.1.4 Alternative 3: Wastewater Recover by Double Effect Evaporators

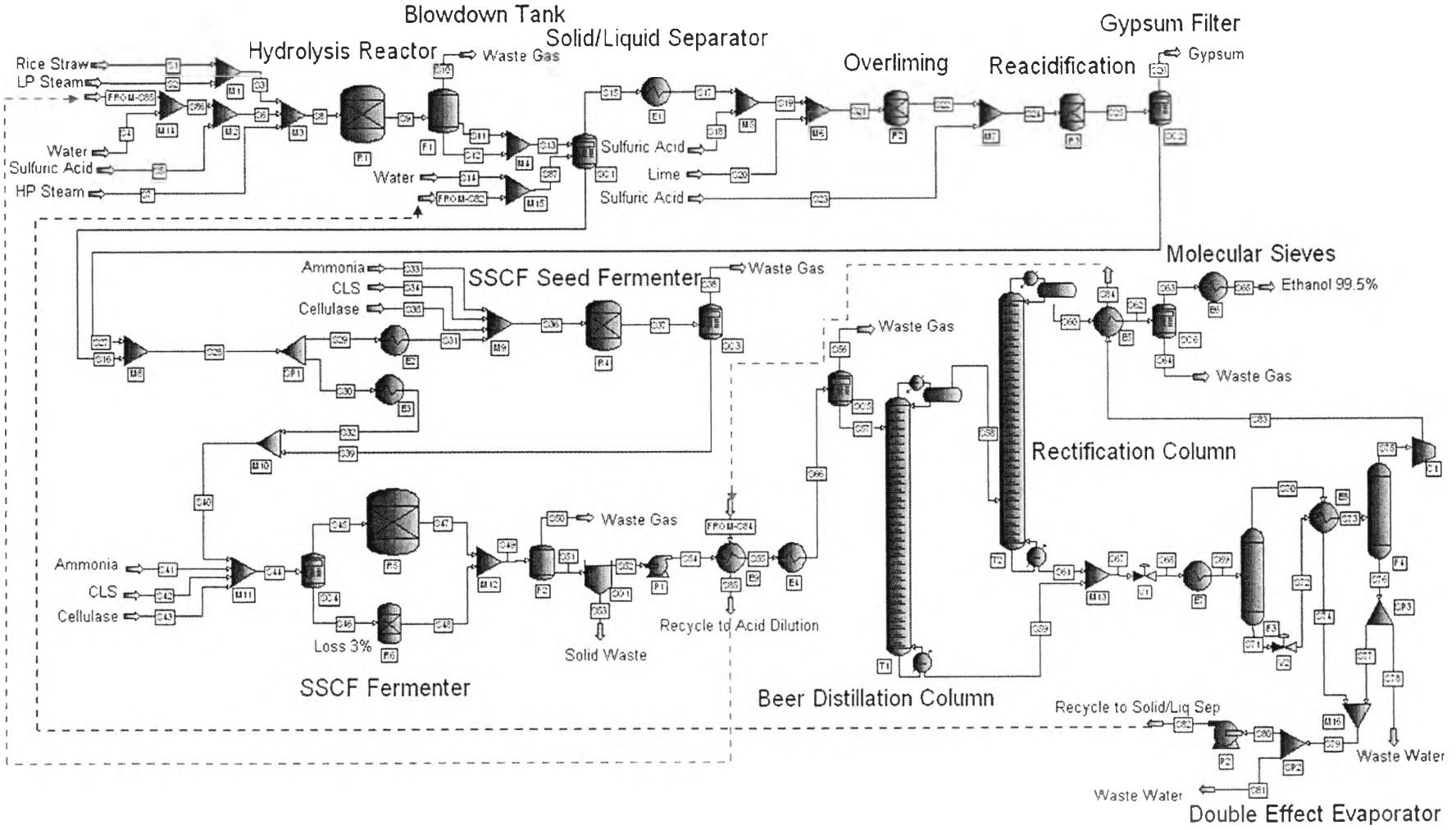

Figure D4 Flowsheet of the bioethanol production process from rice straw for alternative 3 design.

D.1.5 Alternative 4: Wastewater Recover by Membranes

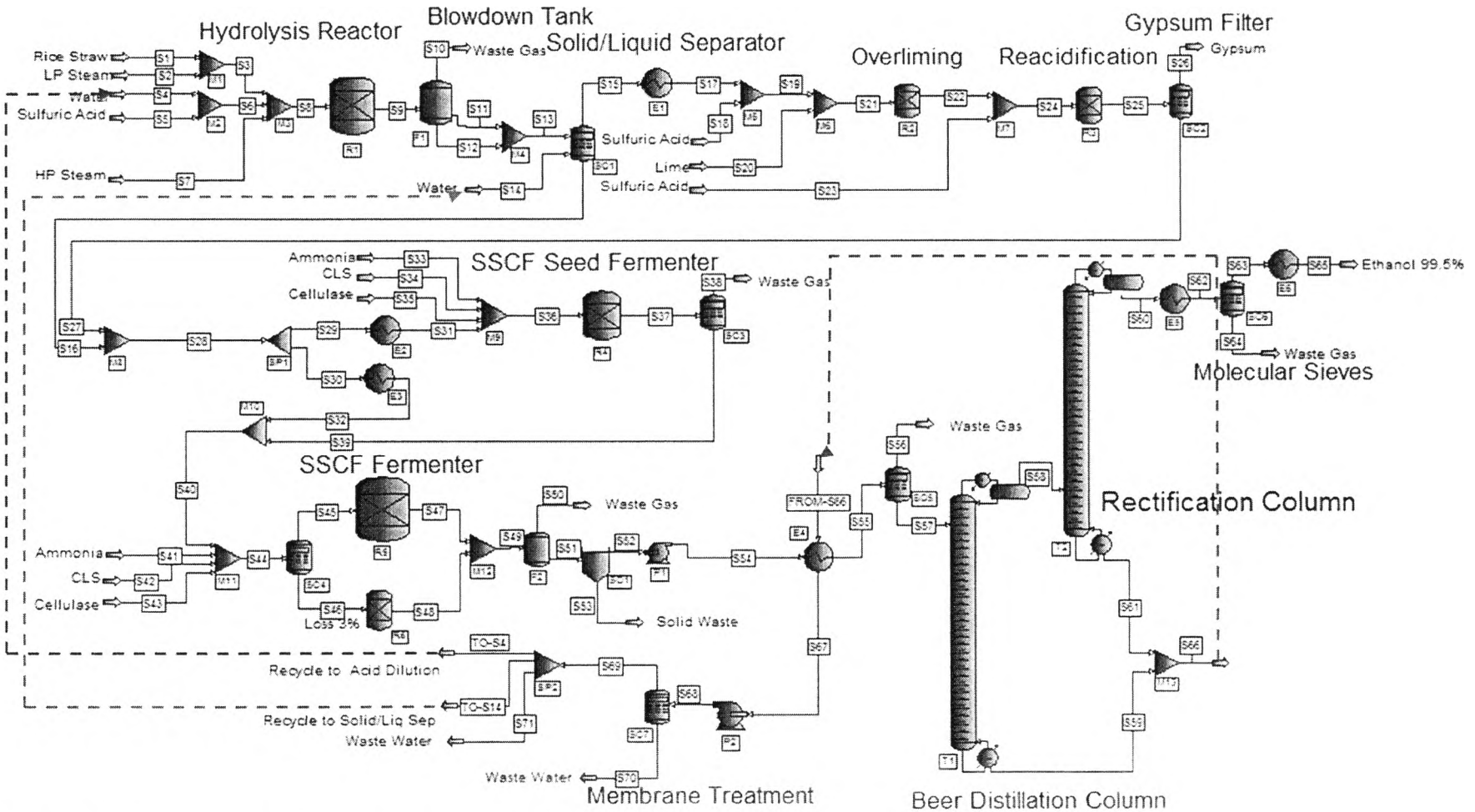

Figure D5 Flowsheet of the bioethanol production process from rice straw for alternative 4 design.

D.1.6 Alternative 5: Lignin Combustion

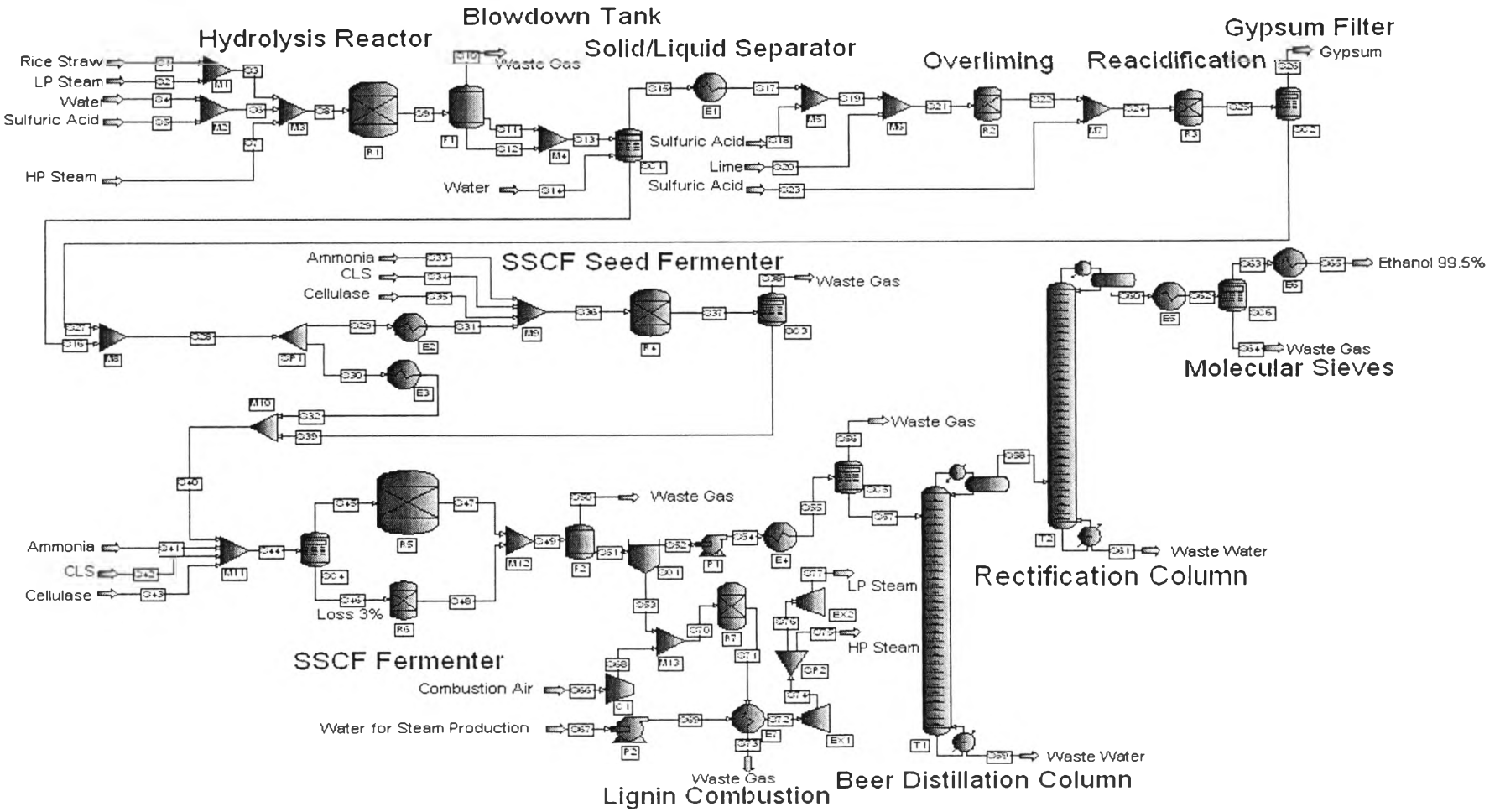

Figure D6 Flowsheet of the bioethanol production process from rice straw for alternative 5 design.

D.1.7 Alternative 6: Wastewater Exchange Heat as Utility and Lignin Combustion

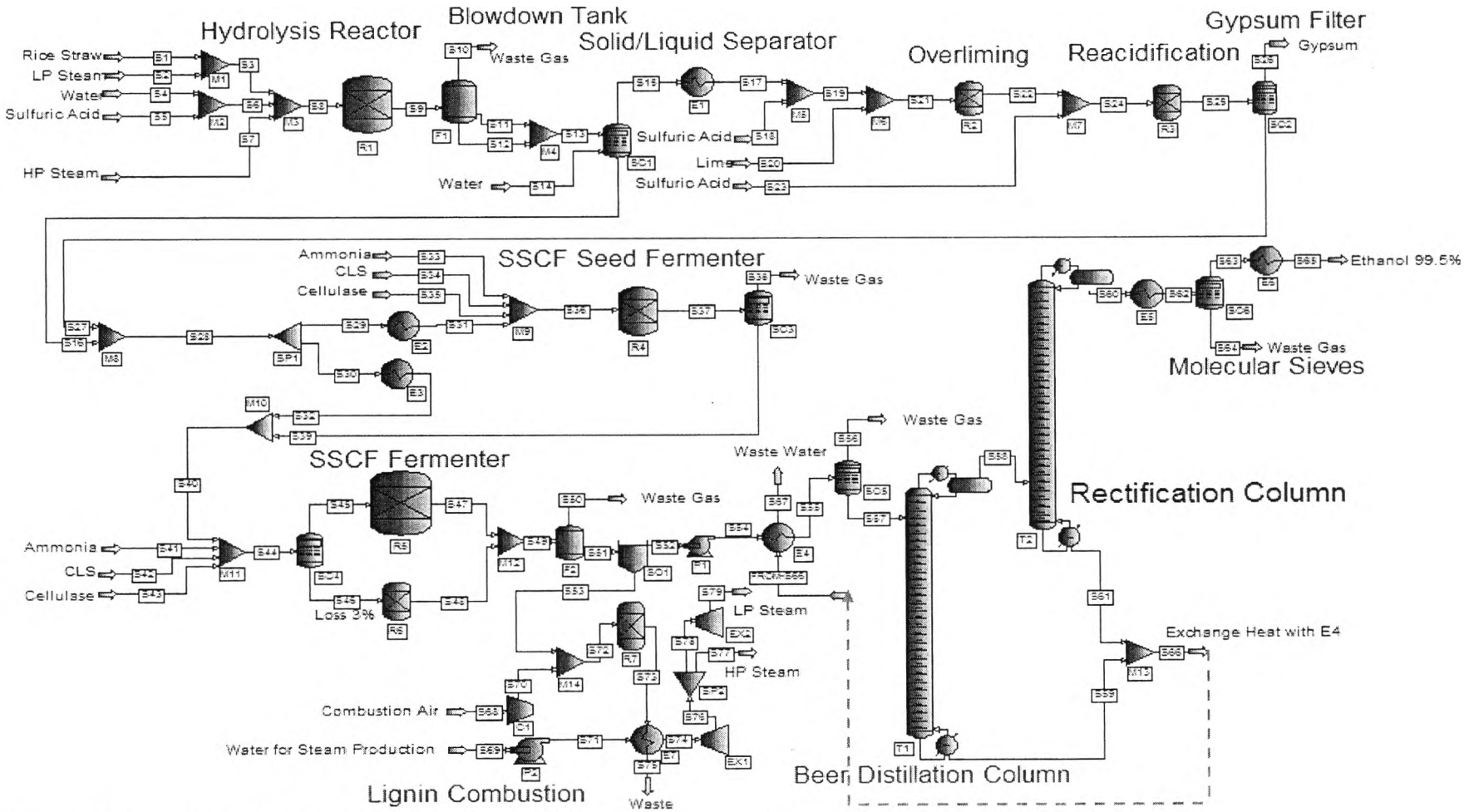

Figure D7 Flowsheet of the bioethanol production process from rice straw for alternative 6 design.

D.1.8 Alternative 7: Wastewater Recover by Double Effect Evaporators and Lignin Combustion

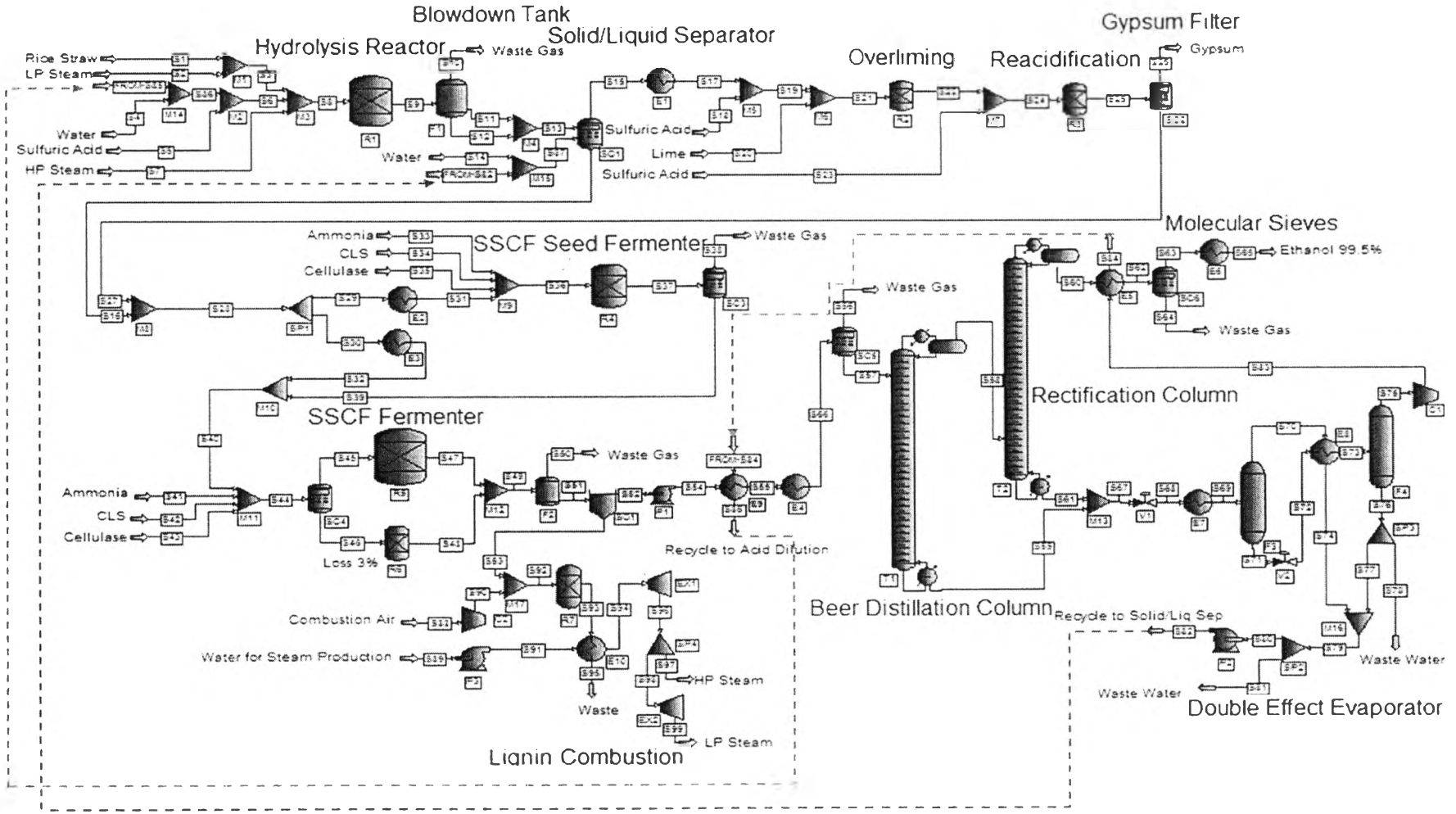

Figure D8 Flowsheet of the bioethanol production process from rice straw for alternative 7 design.

D.1.9 Alternative 8: Wastewater Recover by Membranes and Lignin Combustion

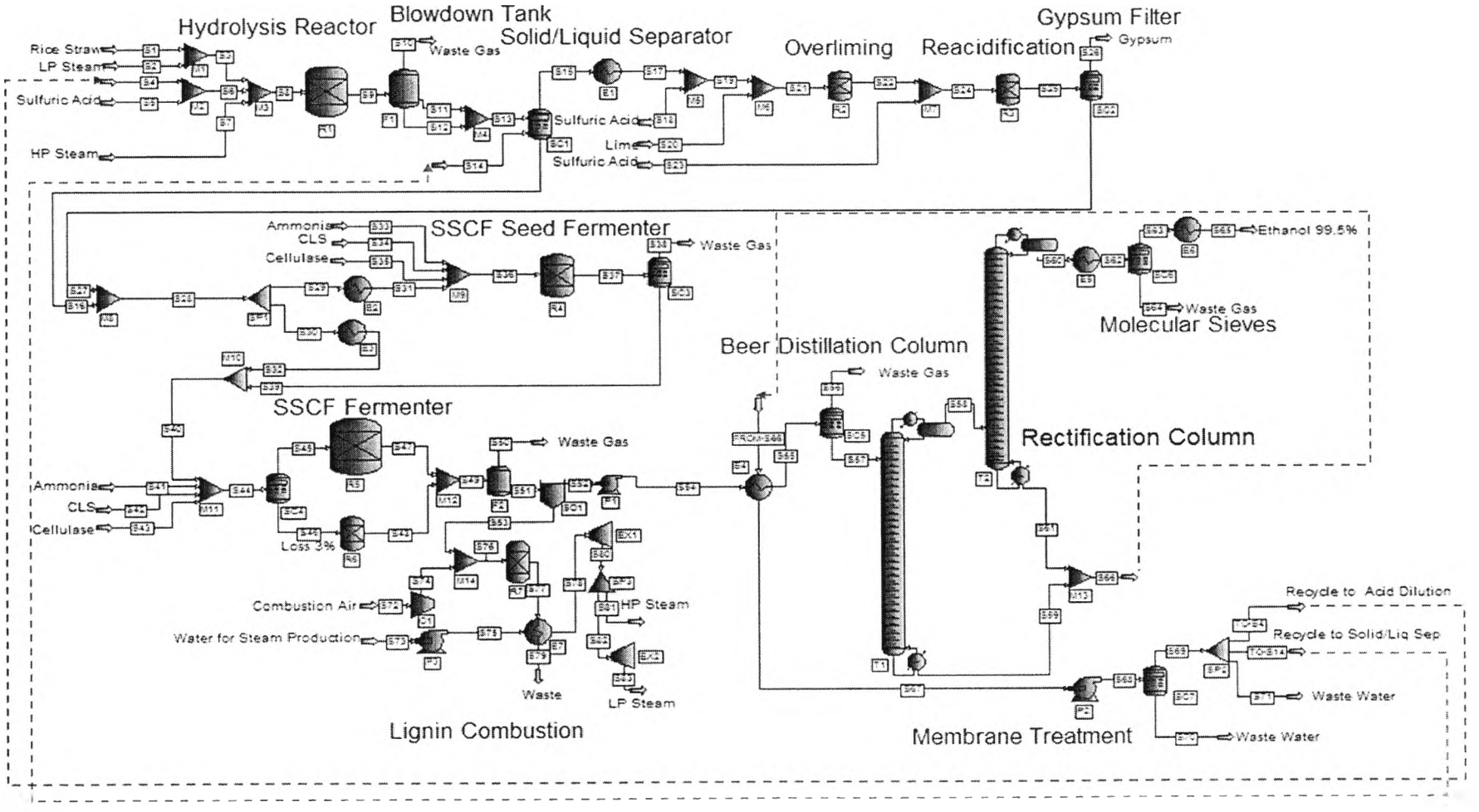

Figure D9 Flowsheet of the bioethanol production process from rice straw for alternative 8 design.

D.1.10 Alternative 9: Wastewater Exchange Heat as Utility with Heat Integration

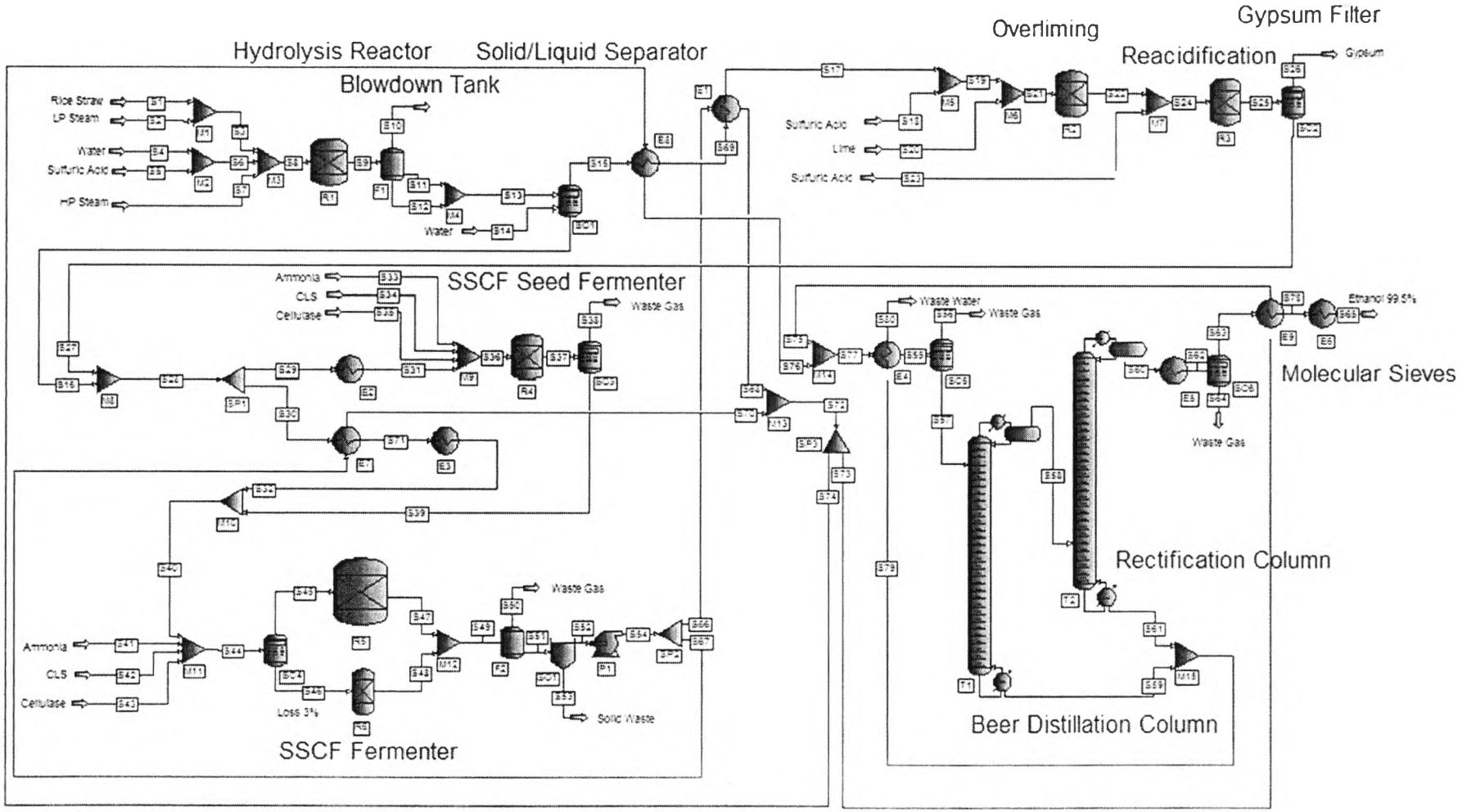

Figure D10 Flowsheet of the bioethanol production process from rice straw for alternative 9 design.

D.1.11 Alternative 10: Wastewater Recover by Double Effect Evaporators with Heat Integration

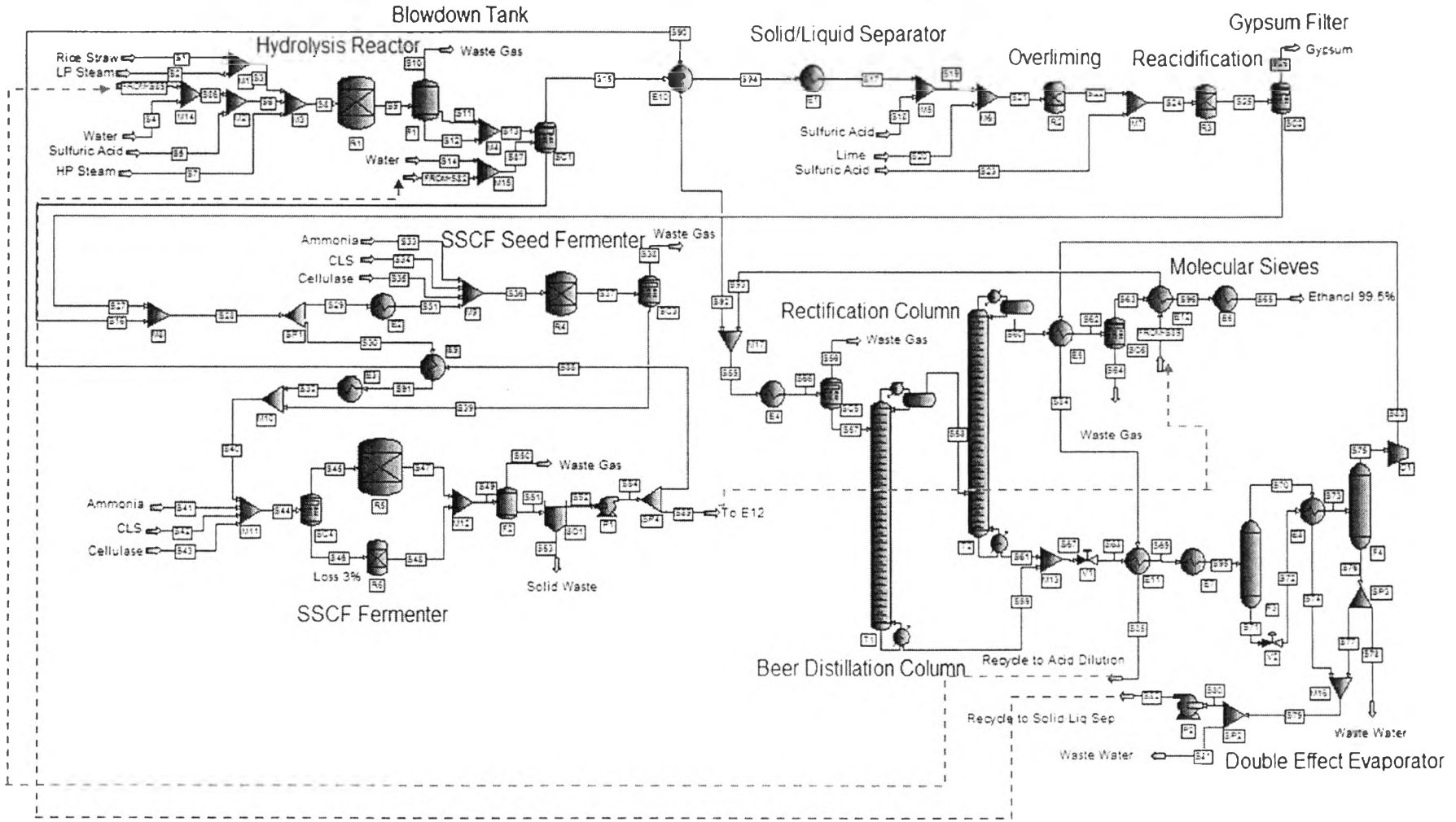

Figure D11 Flowsheet of the bioethanol production process from rice straw for alternative 10 design.

D.1.12 Alternative 11: Wastewater Recover by Membranes with Heat Integration

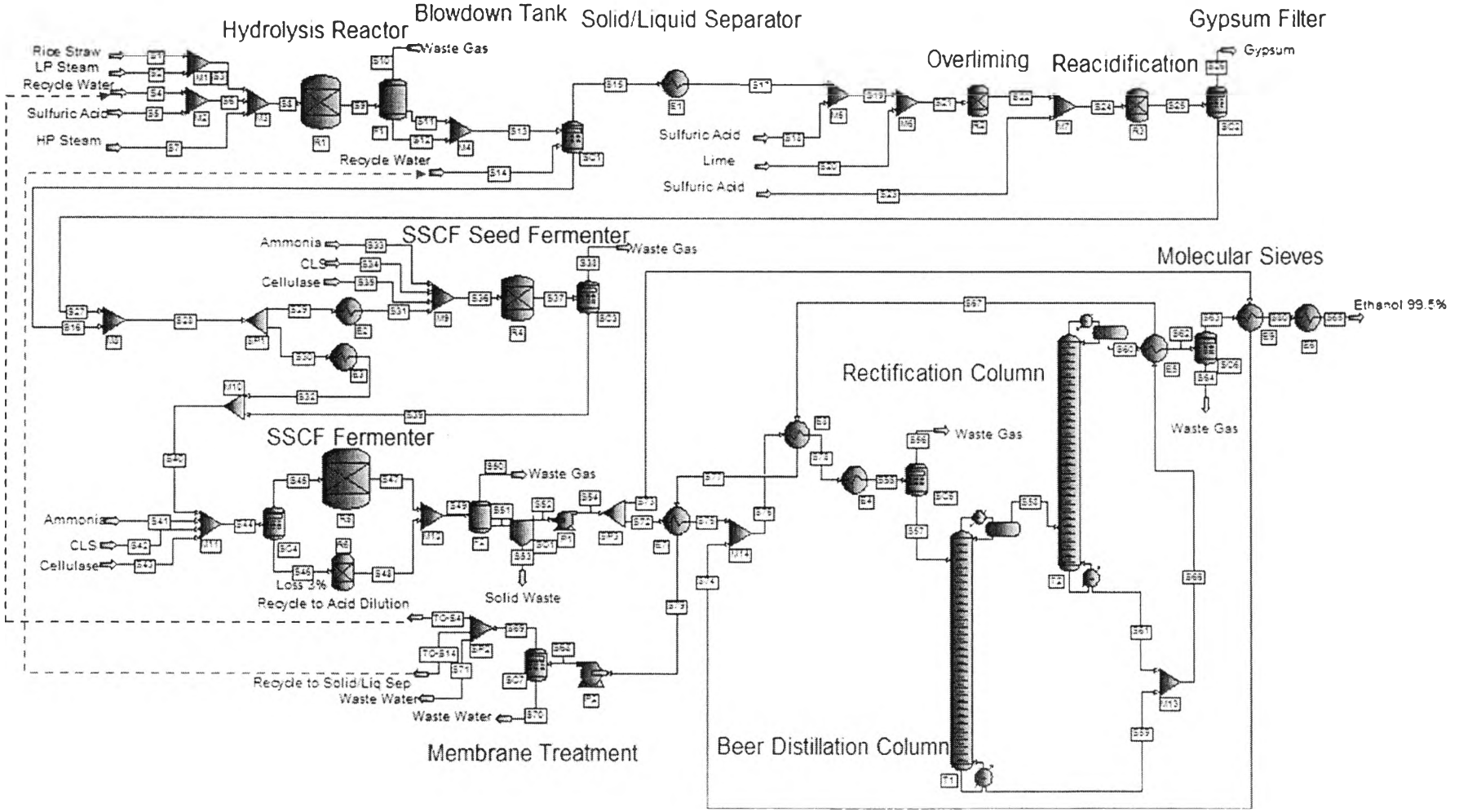

Figure D12 Flowsheet of the bioethanol production process from rice straw for alternative 11 design.

D.1.13 Alternative 12: Lignin Combustion with Heat Integration

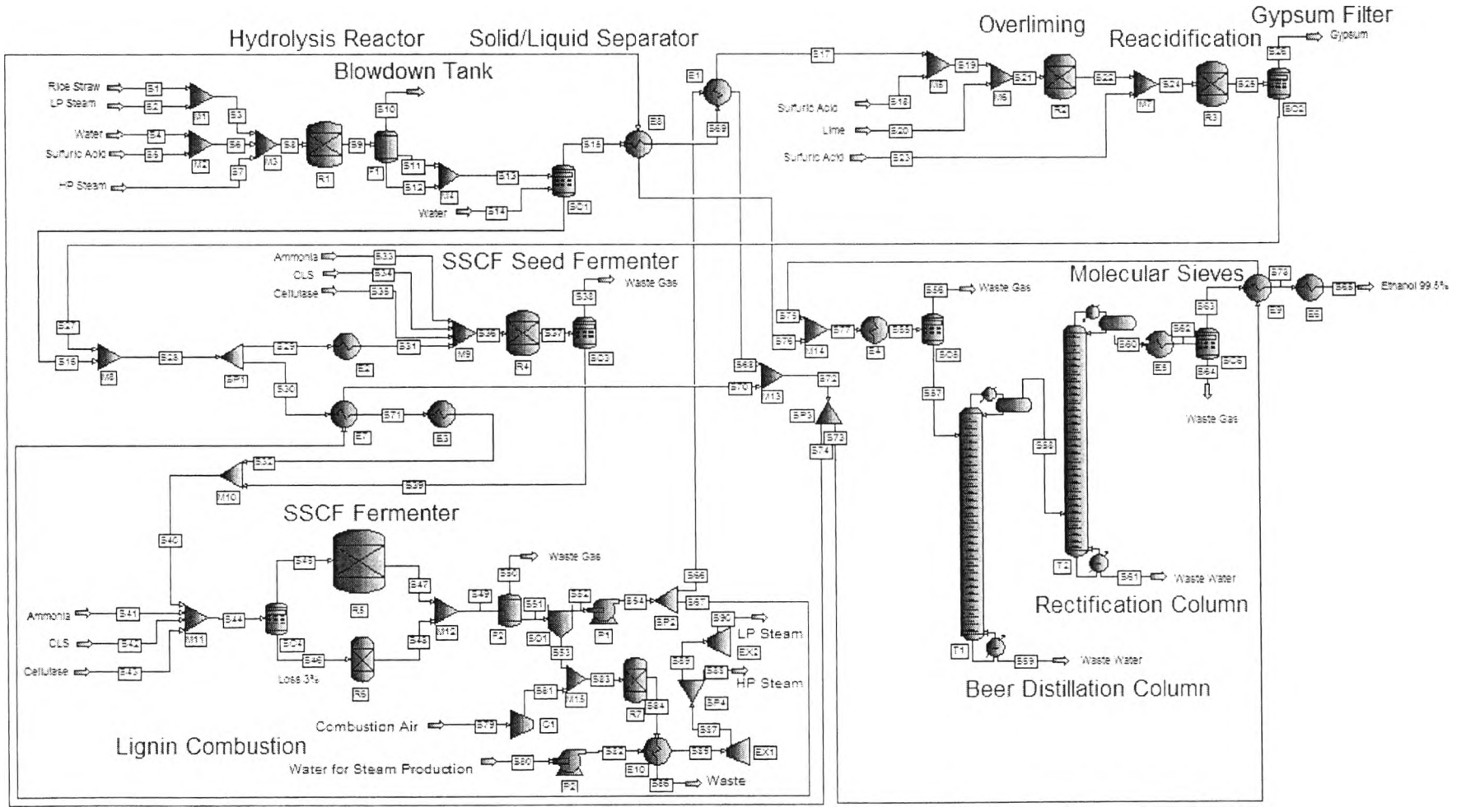

Figure D13 Flowsheet of the bioethanol production process from rice straw for alternative 12 design.

D.1.14 Alternative 13: Wastewater Exchange Heat as Utility and Lignin Combustion with Heat Integration

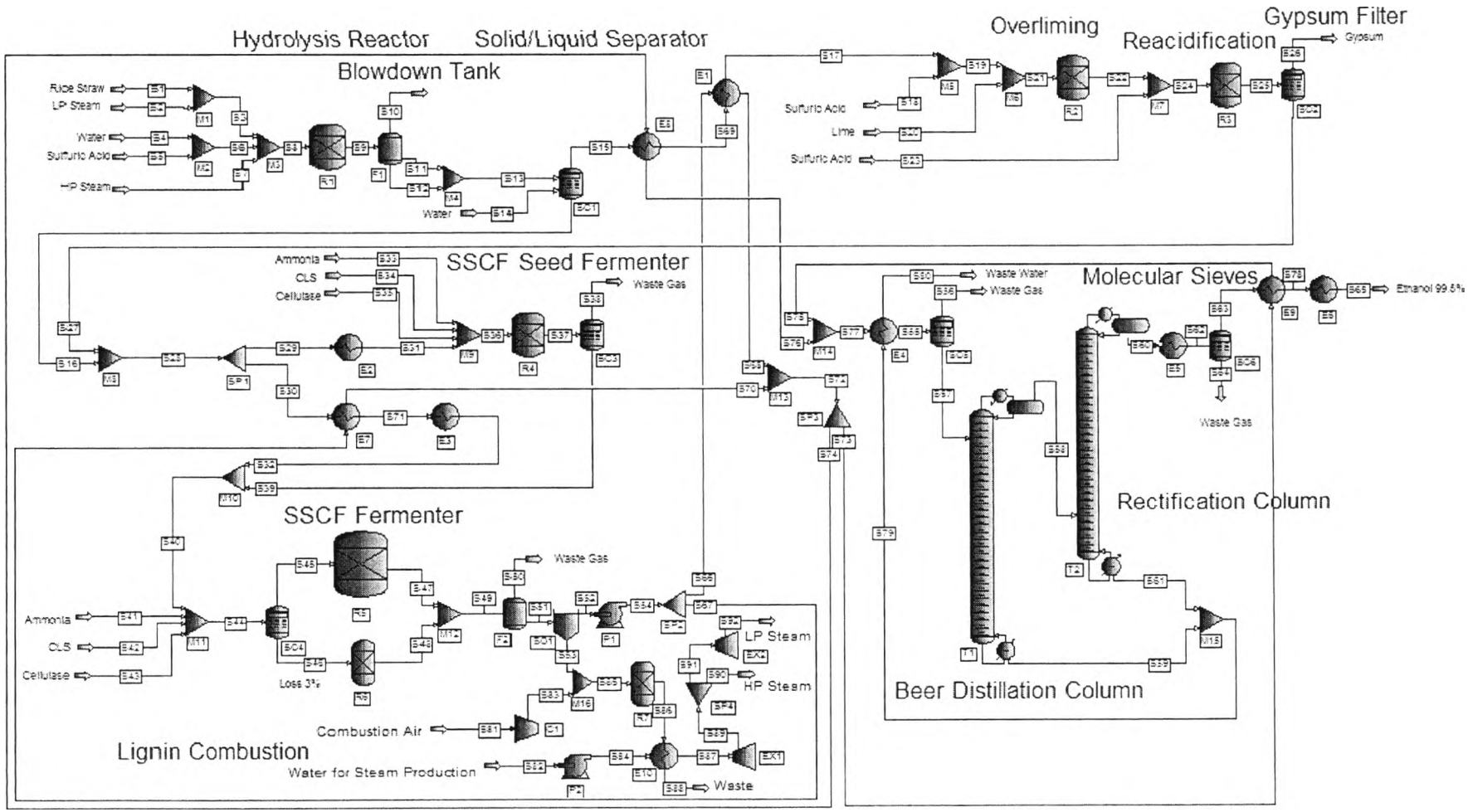

Figure D14 Flowsheet of the bioethanol production process from rice straw for alternative 13 design.

D.1.15 Alternative 14: Wastewater Recover by Double Effect Evaporators and Lignin Combustion with Heat Integration

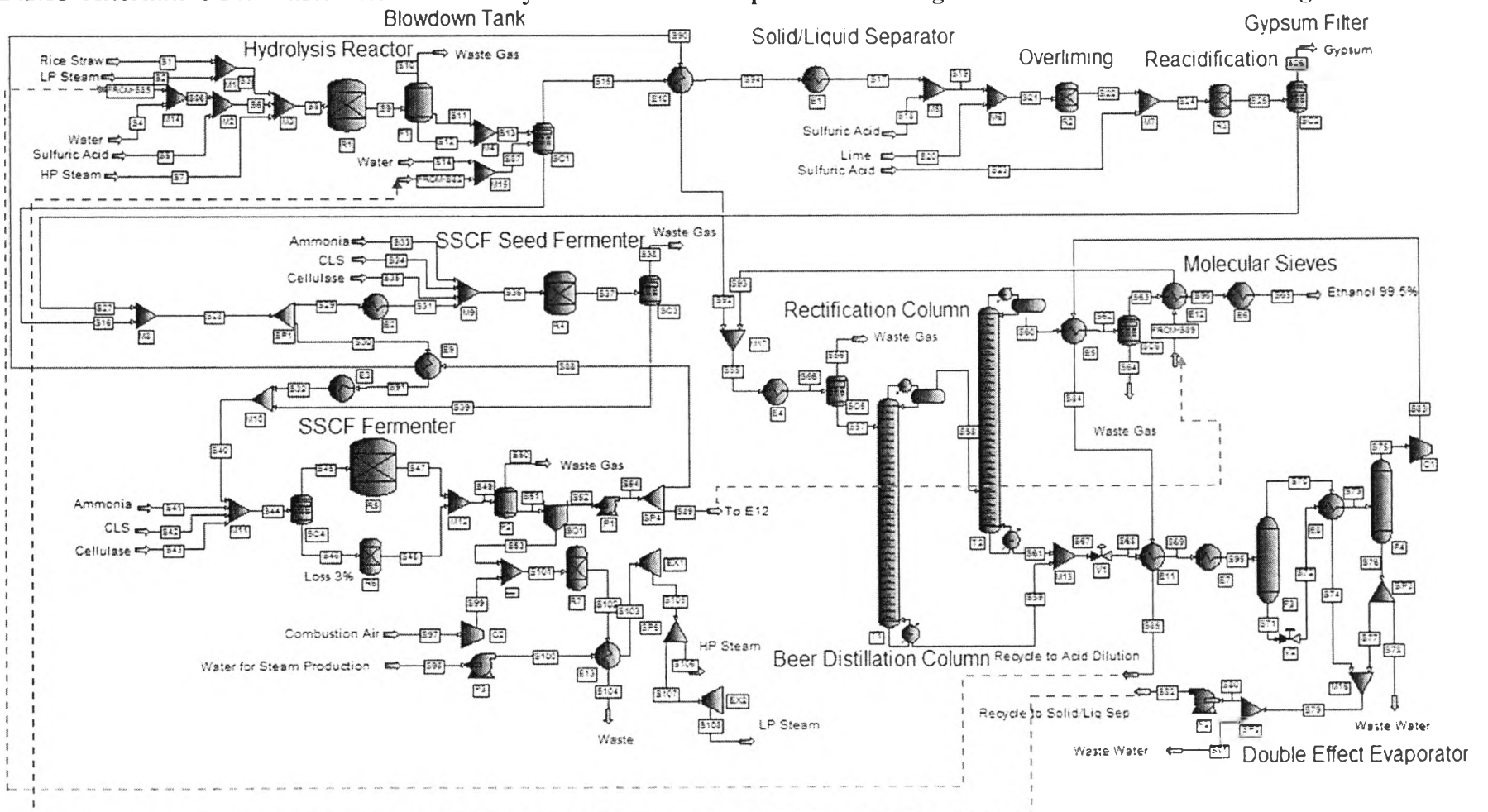

Figure D15 Flowsheet of the bioethanol production process from rice straw for alternative 14 design.

D.1.16 Alternative 15: Wastewater Recover by Membranes and Lignin Combustion with Heat Integration

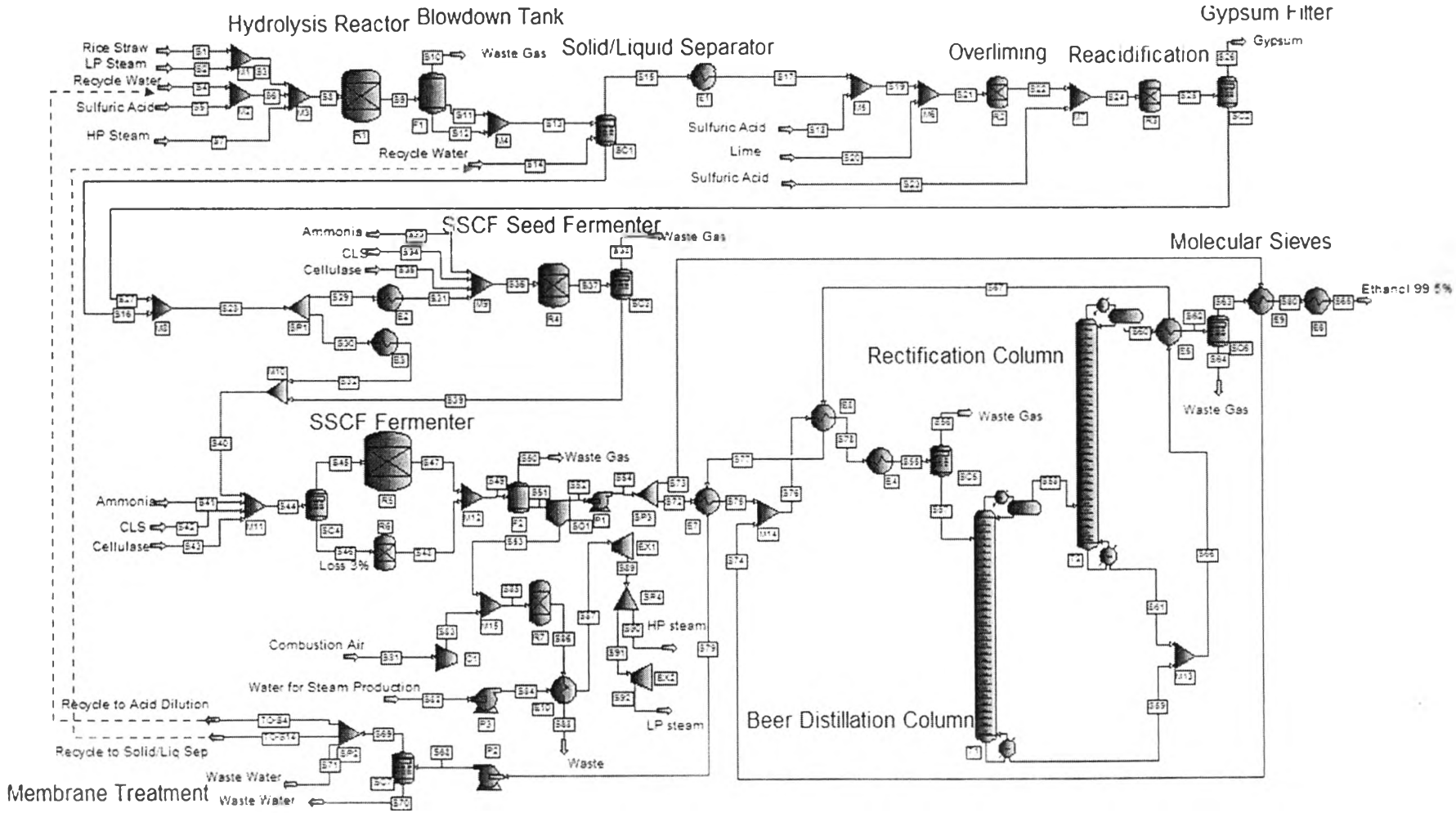

Figure D16 Flowsheet of the bioethanol production process from rice straw for alternative15 design.

D.2 Stream Table of Five Main Ideas

D.2.1 Base Case Design

Table D1 Stream table of the bioethanol process from rice straw for base case design

Stream Name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Stream Phase	Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid	Mixed
Temperature (°C)	30	160	100	30	30	30	268	180	180	101	101	101	101	30	70
Pressure (atm)	1.00	6.00	1.00	1.00	1.00	1.00	13.00	10.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std Liq Rate (L/day)	n/a	114,448	n/a	683,287	7,430	690,717	398,307	n/a	n/a	313,603	1,292,508	n/a	n/a	1,344,441	n/a
Total Mass Rate (kg/day)	1,420,258	114,336	1,534,593	682,613	13,653	696,266	397,914	2,628,774	2,628,774	313,453	1,448,863	866,458	2,315,321	1,343,116	1,966,694
Total Molar Rate (kmol/day)	30,676	6,347	37,023	37,891	139	38,030	22,088	97,140	94,429	17,349	58,641	18,439	77,080	74,554	93,697
Total Solid Mass Rate (kg/day)	1,249,800	n/a	1,249,800	n/a	n/a	n/a	n/a	1,249,800	866,458	n/a	n/a	866,458	866,458	n/a	3,105
Total Enthalpy (GJ/day)	-68.77	13.16	-55.61	3.58	0.02	3.61	46.14	-5.86	27.60	34.99	25.60	-32.99	-7.39	7.05	25.08
Component	Mass Flow (kg/day)														
Cellulose	493,671	0	493,671	0	0	0	0	493,671	424,526	0	0	424,526	424,526	0	2,123
Hemicellulose	287,454	0	287,454	0	0	0	0	287,454	28,611	0	0	28,611	28,611	0	143
Galactan	4,999	0	4,999	0	0	0	0	4,999	1,195	0	0	1,195	1,195	0	6
Mannan	22,496	0	22,496	0	0	0	0	22,496	5,377	0	0	5,377	5,377	0	27
Arabinan	44,993	0	44,993	0	0	0	0	44,993	10,562	0	0	10,562	10,562	0	0
Lignin	161,224	0	161,224	0	0	0	0	161,224	161,224	0	0	161,224	161,224	0	806
Glucose	0	0	0	0	0	0	0	0	73,502	0	73,502	0	73,502	0	51,694
Mannose	0	0	0	0	0	0	0	0	18,747	0	18,747	0	18,747	0	13,183
Galactose	0	0	0	0	0	0	0	0	4,166	0	4,166	0	4,166	0	2,930
Xylose	0	0	0	0	0	0	0	0	292,025	0	292,025	0	292,025	0	205,381
Arabinose	0	0	0	0	0	0	0	0	38,346	0	38,346	0	38,346	0	26,965
Cellobiose	0	0	0	0	0	0	0	0	3,159	0	3,159	0	3,159	0	2,224
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	170,458	114,336	284,794	682,613	0	682,613	397,914	1,365,321	1,316,631	312,335	1,004,296	0	1,004,296	1,343,116	1,650,935
Sulfuric Acid	0	0	0	0	13,653	13,653	0	13,653	13,653	0	13,653	0	13,653	0	9,597
Furfural	0	0	0	0	0	0	0	0	1,851	1,108	743	0	743	0	522
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	0	0	0	0	0	0	0	0	235	10	225	0	225	0	159
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	234,962	0	234,962	0	0	0	0	234,962	234,962	0	0	234,962	234,962	0	0

Table D1 Stream table of the bioethanol process from rice straw for base case design (continue)

Stream Name	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
Stream Phase	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature (°C)	70	50	30	50	30	50	50	30	50	50	50	50	59	59	59
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq Rate (L/day)	n/a	n/a	3,736	n/a	n/a	n/a	n/a	3,839	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Mass Rate (kg/day)	1,691,743	1,966,694	6,864	1,973,558	17,765	1,991,323	1,991,323	7,055	1,998,378	1,998,378	35,542	1,962,836	3,654,578	365,458	3,289,120
Total Molar Rate (kmol/day)	57,937	93,697	70	93,767	240	94,007	94,174	72	94,246	94,318	258	94,060	151,997	15,200	136,798
Total Solid Mass Rate (kg/day)	863,353	3,105	n/a	3,105	17,765	20,869	31,283	n/a	31,283	35,746	34,940	806	864,159	86,416	777,743
Total Enthalpy (GJ/day)	-25.43	18.92	0.01	18.93	-1.98	16.96	18.31	0.01	18.32	18.90	-0.20	19.10	-6.33	-0.63	-5.70
Component	**Mass Flow (kg/day)**														
Cellulose	422,404	2,123	0	2,123	0	2,123	2,123	0	2,123	2,123	2,123	0	422,404	42,240	380,163
Hemicellulose	28,468	143	0	143	0	143	143	0	143	143	143	0	28,468	2,847	25,622
Galactan	1,189	6	0	6	0	6	6	0	6	6	6	0	1,189	119	1,070
Mannan	5,350	27	0	27	0	27	27	0	27	27	27	0	5,350	535	4,815
Arabinan	10,562	0	0	0	0	0	0	0	0	0	0	0	10,562	1,056	9,506
Lignin	160,418	806	0	806	0	806	806	0	806	806	0	806	161,224	16,122	145,102
Glucose	21,808	51,694	0	51,694	0	51,694	51,694	0	51,694	51,694	103	51,591	73,399	7,340	66,059
Mannose	5,564	13,183	0	13,183	0	13,183	13,183	0	13,183	13,183	26	13,157	18,721	1,872	16,849
Galactose	1,236	2,930	0	2,930	0	2,930	2,930	0	2,930	2,930	6	2,924	4,160	416	3,744
Xylose	86,644	205,381	0	205,381	0	205,381	205,381	0	205,381	205,381	411	204,971	291,614	29,161	262,453
Arabinose	11,381	26,965	0	26,965	0	26,965	26,965	0	26,965	26,965	54	26,911	38,292	3,829	34,463
Cellobiose	935	2,224	0	2,224	0	2,224	2,224	0	2,224	2,224	0	2,224	3,159	316	2,843
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	696,477	1,650,935	0	1,650,935	0	1,650,935	1,656,982	0	1,656,982	1,659,574	0	1,659,574	2,356,051	235,605	2,120,446
Sulfuric Acid	4,056	9,597	6,864	16,461	0	16,461	0	7,055	7,055	0	0	0	4,056	406	3,651
Furfural	221	522	0	522	0	522	522	0	522	522	1	521	742	74	668
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	67	159	0	159	0	159	159	0	159	159	0	158	225	23	203
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	17,765	17,765	5,329	0	5,329	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	22,849	0	22,849	32,642	32,642	0	0	0	0
Ash	234,962	0	0	0	0	0	0	0	0	0	0	0	234,962	23,496	211,466

Table D1 Stream table of the bioethanol process from rice straw for base case design (continue)

Stream Name	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45
Stream Phase	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed
Temperature (°C)	41	42	30	30	30	40	40	40	40	41	30	30	30	40	40
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	269	6,219	42,751	n/a	n/a	18,687	n/a	n/a	1,178	9,146	417,432	n/a	n/a
Total Mass Rate (kg/day)	365,458	3,289,120	166	6,213	42,991	414,828	414,827	15,334	399,493	3,688,613	726	9,137	419,771	4,118,247	4,106,122
Total Molar Rate (kmol/day)	15,200	136,798	10	345	2,376	17,931	18,390	354	18,036	154,834	43	507	23,204	178,588	178,510
Total Solid Mass Rate (kg/day)	86,416	777,743	n/a	n/a	845	87,261	77,898	n/a	77,898	855,641	n/a	n/a	8,237	863,878	863,878
Total Enthalpy (GJ/day)	-1.56	-13.99	0.01	0.03	0.18	-1.33	-0.76	0.13	-0.89	-14.88	0.04	0.05	1.79	-13.01	-13.19
Component	**Mass Flow (kg/day)**														
Cellulose	42,240	380,163	0	0	0	42,240	31,680	0	31,680	411,844	0	0	0	411,844	411,844
Hemicellulose	2,847	25,622	0	0	0	2,847	2,847	0	2,847	28,468	0	0	0	28,468	28,468
Galactan	119	1,070	0	0	0	119	119	0	119	1,189	0	0	0	1,189	1,189
Mannan	535	4,815	0	0	0	535	535	0	535	5,350	0	0	0	5,350	5,350
Arabinan	1,056	9,506	0	0	0	1,056	1,056	0	1,056	10,562	0	0	0	10,562	10,562
Lignin	16,122	145,102	0	0	0	16,122	16,122	0	16,122	161,224	0	0	0	161,224	161,224
Glucose	7,340	66,059	0	0	0	7,340	11,976	0	11,976	78,035	0	0	0	78,035	75,694
Mannose	1,872	16,849	0	0	0	1,872	1,872	0	1,872	18,721	0	0	0	18,721	18,159
Galactose	416	3,744	0	0	0	416	416	0	416	4,160	0	0	0	4,160	4,035
Xylose	29,161	262,453	0	0	0	29,161	2,508	0	2,508	264,961	0	0	0	264,961	257,012
Arabinose	3,829	34,463	0	0	0	3,829	3,829	0	3,829	38,292	0	0	0	38,292	37,143
Cellobiose	316	2,843	0	0	0	316	316	0	316	3,159	0	0	0	3,159	3,159
Ethanol	0	0	0	0	0	0	15,310	1,148	14,161	14,161	0	0	0	14,161	14,161
Water	235,605	2,120,446	0	0	42,146	277,751	276,744	138	276,606	2,397,051	0	0	411,534	2,808,586	2,808,586
Sulfuric Acid	406	3,651	0	0	0	406	406	0	406	4,056	0	0	0	4,056	4,056
Furfural	74	668	0	0	0	74	74	0	74	742	0	0	0	742	742
Ammonia	0	0	166	0	0	166	0	0	0	0	726	0	0	726	726
Oxygen	0	0	0	0	0	0	296	296	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	14,476	13,752	724	724	0	0	0	724	724
Glycerol	0	0	0	0	0	0	119	0	119	119	0	0	0	119	119
Succinic Acid	0	0	0	0	0	0	402	0	402	402	0	0	0	402	402
Lactic Acid	0	0	0	0	0	0	73	0	73	73	0	0	0	73	73
HMF	23	203	0	0	0	23	23	0	23	225	0	0	0	225	225
Xylitol	0	0	0	0	0	0	1,359	0	1,359	1,359	0	0	0	1,359	1,359
Acetic Acid	0	0	0	0	0	0	518	0	518	518	0	0	0	518	518
Corn Steep Liquor	0	0	0	6,213	0	6,213	6,213	0	6,213	6,213	0	9,137	0	15,350	15,350
ZM	0	0	0	0	0	0	1,197	0	1,197	1,197	0	0	0	1,197	1,197
Cellulase	0	0	0	0	845	845	845	0	845	845	0	0	8,237	9,082	9,082
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	23,496	211,466	0	0	0	23,496	23,496	0	23,496	234,962	0	0	0	234,962	234,962

Table D1 Stream table of the bioethanol process from rice straw for base case design (continue)

Stream Name	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55
Stream Phase	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid	Solid	Liquid	Liquid
Temperature (°C)	40	40	40	40	40	40	40	40	40	100
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4.76	4.76
Total Std. Liq. Rate (L/day)	7,865	n/a	9,861	n/a	87,564	n/a	3,425,489	n/a	3,425,489	3,425,489
Total Mass Rate (kg/day)	12,125	4,106,123	12,125	4,118,248	72,439	4,045,809	3,552,285	493,524	3,552,285	3,552,285
Total Molar Rate (kmol/day)	77	181,021	135	181,155	1,733	179,422	162,720	16,702	162,720	162,720
Total Solid Mass Rate (kg/day)	n/a	493,524	n/a	493,524	n/a	493,524	n/a	493,524	n/a	n/a
Total Enthalpy (GJ/day)	0.18	17.85	0.05	17.89	0.63	17.27	27.95	-10.68	28.05	60.55
Component	Mass Flow (kg/day)									
Cellulose	0	36,242	0	36,242	0	36,242	0	36,242	0	0
Hemicellulose	0	28,468	0	28,468	0	28,468	0	28,468	0	0
Galactan	0	1,189	0	1,189	0	1,189	0	1,189	0	0
Mannan	0	5,350	0	5,350	0	5,350	0	5,350	0	0
Arabinan	0	10,562	0	10,562	0	10,562	0	10,562	0	0
Lignin	0	161,224	0	161,224	0	161,224	0	161,224	0	0
Glucose	2,341	415,397	0	415,397	0	415,397	415,397	0	415,397	415,397
Mannose	562	18,159	0	18,159	0	18,159	18,159	0	18,159	18,159
Galactose	125	4,035	0	4,035	0	4,035	4,035	0	4,035	4,035
Xylose	7,949	14,650	0	14,650	0	14,650	14,650	0	14,650	14,650
Arabinose	1,149	37,143	0	37,143	0	37,143	37,143	0	37,143	37,143
Cellobiose	0	5,217	0	5,217	0	5,217	5,217	0	5,217	5,217
Ethanol	0	162,664	0	162,664	1,226	161,438	161,438	0	161,438	161,438
Water	0	2,766,864	0	2,766,864	2,152	2,764,711	2,764,711	0	2,764,711	2,764,711
Sulfuric Acid	0	4,056	0	4,056	0	4,056	4,056	0	4,056	4,056
Furfural	0	742	0	742	2	740	740	0	740	740
Ammonia	0	0	0	0	0	0	0	0	0	0
Oxygen	0	2,283	0	2,283	2,058	225	225	0	225	225
Carbon Dioxide	0	141,237	0	141,237	66,986	74,251	74,251	0	74,251	74,251
Glycerol	0	1,217	0	1,217	0	1,217	1,217	0	1,217	1,217
Succinic Acid	0	4,030	0	4,030	0	4,030	4,030	0	4,030	4,030
Lactic Acid	0	738	12,125	12,863	0	12,863	12,863	0	12,863	12,863
HMF	0	225	0	225	0	225	225	0	225	225
Xylitol	0	13,341	0	13,341	0	13,341	13,341	0	13,341	13,341
Acetic Acid	0	5,252	0	5,252	7	5,245	5,245	0	5,245	5,245
Corn Steep Liquor	0	15,350	0	15,350	8	15,342	15,342	0	15,342	15,342
ZM	0	6,444	0	6,444	0	6,444	0	6,444	0	0
Cellulase	0	9,082	0	9,082	0	9,082	0	9,082	0	0
Lime	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0
Ash	0	234,962	0	234,962	0	234,962	0	234,962	0	0

Table D1 Stream table of the bioethanol process from rice straw for base case design (continue)

Stream Name	S56	S57	S58	S59	S60	S61	S62	S63	S64	S65
Stream Phase	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Vapor	Vapor	Vapor	Liquid
Temperature (°C)	100	100	94	117	93	112	100	100	100	40
Pressure (atm)	4.76	4.76	1.77	1.77	1.77	1.77	1.77	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	94,264	3,331,225	228,420	3,102,804	209,398	19,023	209,398	200,000	9,398	200,000
Total Mass Rate (kg/day)	77,469	3,474,816	187,208	3,287,608	168,405	18,803	168,405	159,016	9,389	159,016
Total Molar Rate (kmol/day)	1,844	160,876	5,015	155,861	4,000	1,015	4,000	3,479	521	3,479
Total Solid Mass Rate (kg/day)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	1.01	59.54	10.18	66.23	1.81	0.36	8.19	7.14	1.05	0.64
Component	**Mass Flow (kg/day)**									
Cellulose	0	0	0	0	0	0	0	0	0	0
Hemicellulose	0	0	0	0	0	0	0	0	0	0
Galactan	0	0	0	0	0	0	0	0	0	0
Mannan	0	0	0	0	0	0	0	0	0	0
Arabinan	0	0	0	0	0	0	0	0	0	0
Lignin	0	0	0	0	0	0	0	0	0	0
Glucose	0	415,397	0	415,397	0	0	0	0	0	0
Mannose	0	18,159	0	18,159	0	0	0	0	0	0
Galactose	0	4,035	0	4,035	0	0	0	0	0	0
Xylose	0	14,650	0	14,650	0	0	0	0	0	0
Arabinose	0	37,143	0	37,143	0	0	0	0	0	0
Cellobiose	0	5,217	0	5,217	0	0	0	0	0	0
Ethanol	484	160,954	159,017	1,937	158,222	795	158,222	158,222	0	158,222
Water	2,488	2,762,223	28,153	2,734,070	10,183	17,970	10,183	794	9,389	794
Sulfuric Acid	0	4,056	0	4,056	0	0	0	0	0	0
Furfural	4	735	27	708	0	27	0	0	0	0
Ammonia	0	0	0	0	0	0	0	0	0	0
Oxygen	225	0	0	0	0	0	0	0	0	0
Carbon Dioxide	74,251	0	0	0	0	0	0	0	0	0
Glycerol	0	1,217	0	1,217	0	0	0	0	0	0
Succinic Acid	0	4,030	0	4,030	0	0	0	0	0	0
Lactic Acid	0	12,863	0	12,863	0	0	0	0	0	0
HMF	1	224	0	224	0	0	0	0	0	0
Xylitol	0	13,341	0	13,341	0	0	0	0	0	0
Acetic Acid	2	5,243	8	5,235	0	8	0	0	0	0
Corn Steep Liquor	13	15,329	3	15,326	0	3	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0

D.2.2 Alternative 1 Design

Table D2 Stream table of the bioethanol process from rice straw for alternative 1 design

Stream Name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Stream Phase	Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid	Mixed
Temperature (°C)	30	160	100	30	30	30	268	180	180	101	101	101	101	30	70
Pressure (atm)	1.00	6.00	1.00	1.00	1.00	1.00	13.00	10.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	114,448	n/a	683,289	7,430	690,719	398,307	n/a	n/a	313,602	1,292,512	n/a	n/a	1,344,441	n/a
Total Mass Rate (kg/day)	1,420,262	114,336	1,534,598	682,615	13,653	696,269	397,914	2,628,780	2,628,780	313,453	1,448,867	866,460	2,315,328	1,343,116	1,966,697
Total Molar Rate (kmol/day)	30,676	6,347	37,023	37,891	139	38,030	22,088	97,141	94,429	17,349	58,641	18,439	77,080	74,554	93,697
Total Solid Mass Rate (kg/day)	1,249,803	n/a	1,249,803	n/a	n/a	n/a	n/a	1,249,803	866,460	n/a	n/a	866,460	866,460	n/a	3,105
Total Enthalpy (GJ/day)	-68.77	13.16	-55.61	3.58	0.02	3.61	46.14	-5.86	27.60	34.99	25.60	-32.99	-7.39	7.05	25.08
Component	**Mass Flow (kg/day)**														
Cellulose	493,672	0	493,672	0	0	0	0	493,672	424,528	0	0	424,528	424,528	0	2,123
Hemicellulose	287,455	0	287,455	0	0	0	0	287,455	28,612	0	0	28,612	28,612	0	143
Galactan	4,999	0	4,999	0	0	0	0	4,999	1,195	0	0	1,195	1,195	0	6
Mannan	22,496	0	22,496	0	0	0	0	22,496	5,377	0	0	5,377	5,377	0	27
Arabinan	44,993	0	44,993	0	0	0	0	44,993	10,562	0	0	10,562	10,562	0	0
Lignin	161,225	0	161,225	0	0	0	0	161,225	161,225	0	0	161,225	161,225	0	806
Glucose	0	0	0	0	0	0	0	0	73,503	0	73,503	0	73,503	0	51,694
Mannose	0	0	0	0	0	0	0	0	18,747	0	18,747	0	18,747	0	13,183
Galactose	0	0	0	0	0	0	0	0	4,166	0	4,166	0	4,166	0	2,930
Xylose	0	0	0	0	0	0	0	0	292,026	0	292,026	0	292,026	0	205,382
Arabinose	0	0	0	0	0	0	0	0	38,346	0	38,346	0	38,346	0	26,965
Cellobiose	0	0	0	0	0	0	0	0	3,159	0	3,159	0	3,159	0	2,224
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	170,459	114,336	284,794	682,615	0	682,615	397,914	1,365,324	1,316,634	312,335	1,004,299	0	1,004,299	1,343,116	1,650,937
Sulfuric Acid	0	0	0	0	13,653	13,653	0	13,653	13,653	0	13,653	0	13,653	0	9,597
Furfural	0	0	0	0	0	0	0	0	1,851	1,108	743	0	743	0	522
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	0	0	0	0	0	0	0	0	235	10	225	0	225	0	159
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	234,963	0	234,963	0	0	0	0	234,963	234,963	0	0	234,963	234,963	0	0

Table D2 Stream table of the bioethanol process from rice straw for alternative 1 design (continue)

Stream Name	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
Stream Phase	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature (°C)	70	50	30	50	30	50	50	30	50	50	50	50	59	59	59
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	3,736	n/a	n/a	n/a	n/a	3,839	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Mass Rate (kg/day)	1,691,746	1,966,697	6,864	1,973,561	17,765	1,991,326	1,991,326	7,055	1,998,381	1,998,381	35,542	1,962,839	3,654,585	365,459	3,289,127
Total Molar Rate (kmol/day)	57,937	93,697	70	93,767	240	94,007	94,174	72	94,246	94,318	258	94,060	151,998	15,200	136,798
Total Solid Mass Rate (kg/day)	863,356	3,105	n/a	3,105	17,765	20,869	31,283	n/a	31,283	35,747	34,940	806	864,162	86,416	777,746
Total Enthalpy (GJ/day)	-25.43	18.95	0.01	18.96	-1.98	16.98	18.33	0.01	18.34	18.92	-0.20	19.12	-6.31	-0.63	-5.68
Component	**Mass Flow (kg/day)**														
Cellulose	422,405	2,123	0	2,123	0	2,123	2,123	0	2,123	2,123	2,123	0	422,405	42,240	380,164
Hemicellulose	28,468	143	0	143	0	143	143	0	143	143	143	0	28,468	2,847	25,622
Galactan	1,189	6	0	6	0	6	6	0	6	6	6	0	1,189	119	1,070
Mannan	5,350	27	0	27	0	27	27	0	27	27	27	0	5,350	535	4,815
Arabinan	10,562	0	0	0	0	0	0	0	0	0	0	0	10,562	1,056	9,506
Lignin	160,419	806	0	806	0	806	806	0	806	806	0	806	161,225	16,122	145,102
Glucose	21,808	51,694	0	51,694	0	51,694	51,694	0	51,694	51,694	103	51,591	73,399	7,340	66,059
Mannose	5,564	13,183	0	13,183	0	13,183	13,183	0	13,183	13,183	26	13,157	18,721	1,872	16,849
Galactose	1,236	2,930	0	2,930	0	2,930	2,930	0	2,930	2,930	6	2,924	4,160	416	3,744
Xylose	86,644	205,382	0	205,382	0	205,382	205,382	0	205,382	205,382	411	204,971	291,615	29,162	262,454
Arabinose	11,381	26,965	0	26,965	0	26,965	26,965	0	26,965	26,965	54	26,911	38,292	3,829	34,463
Cellobiose	935	2,224	0	2,224	0	2,224	2,224	0	2,224	2,224	0	2,224	3,159	316	2,843
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	696,478	1,650,937	0	1,650,937	0	1,650,937	1,656,984	0	1,656,984	1,659,576	0	1,659,576	2,356,054	235,605	2,120,448
Sulfuric Acid	4,056	9,597	6,864	16,461	0	16,461	0	7,055	7,055	0	0	0	4,056	406	3,651
Furfural	221	522	0	522	0	522	522	0	522	522	1	521	742	74	668
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	67	159	0	159	0	159	159	0	159	159	0	158	225	23	203
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	17,765	17,765	5,329	0	5,329	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	22,849	0	22,849	32,642	32,642	0	0	0	0
Ash	234,963	0	0	0	0	0	0	0	0	0	0	0	234,963	23,496	211,467

Table D2 Stream table of the bioethanol process from rice straw for alternative 1 design (continue)

Stream Name	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45	S46	S47
Stream Phase	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Liquid	Mixed
Temperature (°C)	41	42	30	30	30	40	40	40	40	41	30	30	30	40	40	40	40
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	269	6,219	42,751	n/a	n/a	18,687	n/a	n/a	1,178	9,146	417,431	n/a	n/a	7,865	n/a
Total Mass Rate (kg/day)	365,459	3,289,127	166	6,213	42,991	414,829	414,828	15,334	399,494	3,688,621	726	9,137	419,771	4,118,254	4,106,129	12,125	4,106,130
Total Molar Rate (kmol/day)	15,200	136,798	10	345	2,376	17,931	18,390	354	18,036	154,834	43	507	23,204	178,588	178,511	77	181,021
Total Solid Mass Rate (kg/day)	86,416	777,746	n/a	n/a	845	87,261	77,898	n/a	77,898	855,644	n/a	n/a	8,237	863,881	863,881	n/a	493,525
Total Enthalpy (GJ/day)	-1.56	-13.99	0.01	0.03	0.18	-1.33	-0.76	0.13	-0.89	-14.88	0.04	0.05	1.79	-13.01	-13.19	0.18	17.85
Component	**Mass Flow (kg/day)**																
Cellulose	42,240	380,164	0	0	0	42,240	31,680	0	31,680	411,845	0	0	0	411,845	411,845	0	36,242
Hemicellulose	2,847	25,622	0	0	0	2,847	2,847	0	2,847	28,468	0	0	0	28,468	28,468	0	28,468
Galactan	119	1,070	0	0	0	119	119	0	119	1,189	0	0	0	1,189	1,189	0	1,189
Mannan	535	4,815	0	0	0	535	535	0	535	5,350	0	0	0	5,350	5,350	0	5,350
Arabinan	1,056	9,506	0	0	0	1,056	1,056	0	1,056	10,562	0	0	0	10,562	10,562	0	10,562
Lignin	16,122	145,102	0	0	0	16,122	16,122	0	16,122	161,225	0	0	0	161,225	161,225	0	161,225
Glucose	7,340	66,059	0	0	0	7,340	11,976	0	11,976	78,035	0	0	0	78,035	75,694	2,341	415,398
Mannose	1,872	16,849	0	0	0	1,872	1,872	0	1,872	18,721	0	0	0	18,721	18,159	562	18,159
Galactose	416	3,744	0	0	0	416	416	0	416	4,160	0	0	0	4,160	4,035	125	4,035
Xylose	29,162	262,454	0	0	0	29,162	2,508	0	2,508	264,962	0	0	0	264,962	257,013	7,949	14,650
Arabinose	3,829	34,463	0	0	0	3,829	3,829	0	3,829	38,292	0	0	0	38,292	37,143	1,149	37,143
Cellobiose	316	2,843	0	0	0	316	316	0	316	3,159	0	0	0	3,159	3,159	0	5,217
Ethanol	0	0	0	0	0	0	15,310	1,148	14,161	14,161	0	0	0	14,161	14,161	0	162,665
Water	235,605	2,120,448	0	0	42,147	277,752	276,745	138	276,606	2,397,055	0	0	411,534	2,808,589	2,808,589	0	2,766,867
Sulfuric Acid	406	3,651	0	0	0	406	406	0	406	4,056	0	0	0	4,056	4,056	0	4,056
Furfural	74	668	0	0	0	74	74	0	74	742	0	0	0	742	742	0	742
Ammonia	0	0	166	0	0	166	0	0	0	0	726	0	0	726	726	0	0
Oxygen	0	0	0	0	0	0	296	296	0	0	0	0	0	0	0	0	2,283
Carbon Dioxide	0	0	0	0	0	0	14,476	13,752	724	724	0	0	0	724	724	0	141,237
Glycerol	0	0	0	0	0	0	119	0	119	119	0	0	0	119	119	0	1,217
Succinic Acid	0	0	0	0	0	0	402	0	402	402	0	0	0	402	402	0	4,030
Lactic Acid	0	0	0	0	0	0	73	0	73	73	0	0	0	73	73	0	738
HMF	23	203	0	0	0	23	23	0	23	225	0	0	0	225	225	0	225
Xylitol	0	0	0	0	0	0	1,359	0	1,359	1,359	0	0	0	1,359	1,359	0	13,341
Acetic Acid	0	0	0	0	0	0	518	0	518	518	0	0	0	518	518	0	5,252
Corn Steep Liquor	0	0	0	6,213	0	6,213	6,213	0	6,213	6,213	0	9,137	0	15,350	15,350	0	15,350
ZM	0	0	0	0	0	0	1,197	0	1,197	1,197	0	0	0	1,197	1,197	0	6,444
Cellulase	0	0	0	0	845	845	845	0	845	845	0	0	8,237	9,082	9,082	0	9,082
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	23,496	211,467	0	0	0	23,496	23,496	0	23,496	234,963	0	0	0	234,963	234,963	0	234,963

Table D2 Stream table of the bioethanol process from rice straw for alternative 1 design (continue)

Stream Name	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60	S61	S62	S63
Stream Phase	Liquid	Mixed	Vapor	Mixed	Liquid	Solid	Liquid	Liquid	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Vapor	Vapor
Temperature (°C)	40	40	40	40	40	40	40	100	100	100	94	117	93	112	100	100
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	4.76	4.76	4.76	4.76	1.77	1.77	1.77	1.77	1.77	1.00
Total Std. Liq. Rate (L/day)	9,861	n/a	87,565	n/a	3,425,493	n/a	3,425,493	3,425,493	94,263	3,331,229	228,418	3,102,811	209,392	19,026	209,392	200,000
Total Mass Rate (kg/day)	12,125	4,118,255	72,440	4,045,815	3,552,290	493,525	3,552,290	3,552,290	77,469	3,474,821	187,205	3,287,615	168,399	18,807	168,399	159,016
Total Molar Rate (kmol/day)	135	181,156	1,733	179,423	162,720	16,702	162,720	162,720	1,844	160,877	5,015	155,862	3,999	1,016	3,999	3,479
Total Solid Mass Rate (kg/day)	n/a	493,525	n/a	493,525	n/a	493,525	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	0.05	17.89	0.63	17.27	27.95	-10.68	28.05	60.55	1.01	59.54	10.18	66.23	1.81	0.36	8.19	7.14
Component	**Mass Flow (kg/day)**															
Cellulose	0	36,242	0	36,242	0	36,242	0	0	0	0	0	0	0	0	0	0
Hemicellulose	0	28,468	0	28,468	0	28,468	0	0	0	0	0	0	0	0	0	0
Galactan	0	1,189	0	1,189	0	1,189	0	0	0	0	0	0	0	0	0	0
Mannan	0	5,350	0	5,350	0	5,350	0	0	0	0	0	0	0	0	0	0
Arabinan	0	10,562	0	10,562	0	10,562	0	0	0	0	0	0	0	0	0	0
Lignin	0	161,225	0	161,225	0	161,225	0	0	0	0	0	0	0	0	0	0
Glucose	0	415,398	0	415,398	415,398	0	415,398	415,398	0	415,398	0	415,398	0	0	0	0
Mannose	0	18,159	0	18,159	18,159	0	18,159	18,159	0	18,159	0	18,159	0	0	0	0
Galactose	0	4,035	0	4,035	4,035	0	4,035	4,035	0	4,035	0	4,035	0	0	0	0
Xylose	0	14,650	0	14,650	14,650	0	14,650	14,650	0	14,650	0	14,650	0	0	0	0
Arabinose	0	37,143	0	37,143	37,143	0	37,143	37,143	0	37,143	0	37,143	0	0	0	0
Cellobiose	0	5,217	0	5,217	5,217	0	5,217	5,217	0	5,217	0	5,217	0	0	0	0
Ethanol	0	162,665	1,226	161,438	161,438	0	161,438	161,438	484	160,954	159,017	1,937	158,222	795	158,222	158,222
Water	0	2,766,867	2,152	2,764,714	2,764,714	0	2,764,714	2,764,714	2,488	2,762,226	28,150	2,734,076	10,177	17,974	10,177	794
Sulfuric Acid	0	4,056	0	4,056	4,056	0	4,056	4,056	0	4,056	0	4,056	0	0	0	0
Furfural	0	742	2	740	740	0	740	740	4	735	27	708	0	27	0	0
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	2,283	2,058	225	225	0	225	225	225	0	0	0	0	0	0	0
Carbon Dioxide	0	141,237	66,986	74,251	74,251	0	74,251	74,251	74,251	0	0	0	0	0	0	0
Glycerol	0	1,217	0	1,217	1,217	0	1,217	1,217	0	1,217	0	1,217	0	0	0	0
Succinic Acid	0	4,030	0	4,030	4,030	0	4,030	4,030	0	4,030	0	4,030	0	0	0	0
Lactic Acid	12,125	12,863	0	12,863	12,863	0	12,863	12,863	0	12,863	0	12,863	0	0	0	0
HMF	0	225	0	225	225	0	225	225	1	224	0	224	0	0	0	0
Xylitol	0	13,341	0	13,341	13,341	0	13,341	13,341	0	13,341	0	13,341	0	0	0	0
Acetic Acid	0	5,252	7	5,245	5,245	0	5,245	5,245	2	5,243	8	5,235	0	8	0	0
Corn Steep Liquor	0	15,350	8	15,342	15,342	0	15,342	15,342	13	15,329	3	15,326	0	3	0	0
ZM	0	6,444	0	6,444	0	6,444	0	0	0	0	0	0	0	0	0	0
Cellulase	0	9,082	0	9,082	0	9,082	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	234,963	0	234,963	0	234,963	0	0	0	0	0	0	0	0	0	0

Table D2 Stream table of the bioethanol process from rice straw for alternative 1 design (continue)

Stream Name	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73	S74	S75	S76	S77	S78
Stream Phase	Vapor	Liquid	Liquid	Liquid	Liquid	Mixed	Liquid	Mixed	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Mixed
Temperature (°C)	100	40	40	40	50	59	48	55	49	49	49	86	57	64	78
Pressure (atm)	1.00	1.00	4.76	4.76	4.76	1.00	4.76	1.00	4.76	4.76	4.76	4.76	4.76	4.76	1.00
Total Std. Liq. Rate (L/day)	9,392	200,000	1,791,533	1,633,960	1,791,533	n/a	1,633,960	n/a	3,425,493	774,161	2,651,331	774,161	2,651,331	3,425,493	200,000
Total Mass Rate (kg/day)	9,383	159,016	1,857,848	1,694,442	1,857,848	1,966,697	1,694,442	3,289,127	3,552,290	802,818	2,749,472	802,818	2,749,472	3,552,290	159,016
Total Molar Rate (kmol/day)	521	3,479	85,103	77,618	85,103	93,697	77,618	136,798	162,720	36,775	125,945	36,775	125,945	162,720	3,479
Total Solid Mass Rate (kg/day)	n/a	n/a	n/a	n/a	n/a	3,105	n/a	777,746	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	1.05	0.64	14.67	13.38	17.29	21.57	15.43	-7.72	32.72	7.40	25.33	11.86	28.84	40.70	2.68
Component	**Mass Flow (kg/day)**														
Cellulose	0	0	0	0	0	2,123	0	380,164	0	0	0	0	0	0	0
Hemicellulose	0	0	0	0	0	143	0	25,622	0	0	0	0	0	0	0
Galactan	0	0	0	0	0	6	0	1,070	0	0	0	0	0	0	0
Mannan	0	0	0	0	0	27	0	4,815	0	0	0	0	0	0	0
Arabinan	0	0	0	0	0	0	0	9,506	0	0	0	0	0	0	0
Lignin	0	0	0	0	0	806	0	145,102	0	0	0	0	0	0	0
Glucose	0	0	217,253	198,145	217,253	51,694	198,145	66,059	415,398	93,880	321,518	93,880	321,518	415,398	0
Mannose	0	0	9,497	8,662	9,497	13,183	8,662	16,849	18,159	4,104	14,055	4,104	14,055	18,159	0
Galactose	0	0	2,110	1,925	2,110	2,930	1,925	3,744	4,035	912	3,123	912	3,123	4,035	0
Xylose	0	0	7,662	6,988	7,662	205,382	6,988	262,454	14,650	3,311	11,339	3,311	11,339	14,650	0
Arabinose	0	0	19,426	17,717	19,426	26,965	17,717	34,463	37,143	8,394	28,749	8,394	28,749	37,143	0
Cellobiose	0	0	2,728	2,488	2,728	2,224	2,488	2,843	5,217	1,179	4,038	1,179	4,038	5,217	0
Ethanol	0	158,222	84,432	77,006	84,432	0	77,006	0	161,438	36,485	124,953	36,485	124,953	161,438	158,222
Water	9,383	794	1,445,946	1,318,769	1,445,946	1,650,937	1,318,769	2,120,448	2,764,714	624,825	2,139,889	624,825	2,139,889	2,764,714	794
Sulfuric Acid	0	0	2,121	1,935	2,121	9,597	1,935	3,651	4,056	917	3,140	917	3,140	4,056	0
Furfural	0	0	387	353	387	522	353	668	740	167	572	167	572	740	0
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	118	107	118	0	107	0	225	51	174	51	174	225	0
Carbon Dioxide	0	0	38,833	35,418	38,833	0	35,418	0	74,251	16,781	57,470	16,781	57,470	74,251	0
Glycerol	0	0	637	581	637	0	581	0	1,217	275	942	275	942	1,217	0
Succinic Acid	0	0	2,107	1,922	2,107	0	1,922	0	4,030	911	3,119	911	3,119	4,030	0
Lactic Acid	0	0	6,728	6,136	6,728	0	6,136	0	12,863	2,907	9,956	2,907	9,956	12,863	0
HMF	0	0	118	107	118	159	107	203	225	51	174	51	174	225	0
Xylitol	0	0	6,977	6,364	6,977	0	6,364	0	13,341	3,015	10,326	3,015	10,326	13,341	0
Acetic Acid	0	0	2,743	2,502	2,743	0	2,502	0	5,245	1,185	4,060	1,185	4,060	5,245	0
Corn Steep Liquor	0	0	8,024	7,318	8,024	0	7,318	0	15,342	3,467	11,875	3,467	11,875	15,342	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	211,467	0	0	0	0	0	0	0

D.2.3 Alternative 2 Design

Table D3 Stream table of the bioethanol process from rice straw for alternative 2 design

Stream Name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Stream Phase	Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid	Mixed
Temperature (°C)	30	160	100	30	30	30	268	180	180	101	101	101	101	30	70
Pressure (atm)	1.00	6.00	1.00	1.00	1.00	1.00	13.00	10.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	114,448	n/a	682,848	7,427	690,275	398,163	n/a	n/a	313,510	1,292,013	n/a	n/a	1,344,142	n/a
Total Mass Rate (kg/day)	1,420,254	114,336	1,534,589	682,174	13,647	695,822	397,771	2,628,182	2,628,182	313,360	1,448,366	866,455	2,314,821	1,342,817	1,966,134
Total Molar Rate (kmol/day)	30,676	6,347	37,023	37,866	139	38,006	22,080	97,108	94,396	17,344	58,613	18,439	77,052	74,538	93,666
Total Solid Mass Rate (kg/day)	1,249,796	n/a	1,249,796	n/a	n/a	n/a	n/a	1,249,796	866,455	n/a	n/a	866,455	866,455	n/a	3,105
Total Enthalpy (GJ/day)	-68.77	13.16	-55.61	3.58	0.02	3.60	46.13	-5.88	27.58	34.98	25.59	-32.99	-7.40	7.05	25.08
Component	**Mass Flow (kg/day)**														
Cellulose	493,669	0	493,669	0	0	0	0	493,669	424,525	0	0	424,525	424,525	0	2,123
Hemicellulose	287,453	0	287,453	0	0	0	0	287,453	28,611	0	0	28,611	28,611	0	143
Galactan	4,999	0	4,999	0	0	0	0	4,999	1,195	0	0	1,195	1,195	0	6
Mannan	22,496	0	22,496	0	0	0	0	22,496	5,377	0	0	5,377	5,377	0	27
Arabinan	44,993	0	44,993	0	0	0	0	44,993	10,562	0	0	10,562	10,562	0	0
Lignin	161,224	0	161,224	0	0	0	0	161,224	161,224	0	0	161,224	161,224	0	806
Glucose	0	0	0	0	0	0	0	0	73,502	0	73,502	0	73,502	0	51,694
Mannose	0	0	0	0	0	0	0	0	18,747	0	18,747	0	18,747	0	13,183
Galactose	0	0	0	0	0	0	0	0	4,166	0	4,166	0	4,166	0	2,930
Xylose	0	0	0	0	0	0	0	0	292,024	0	292,024	0	292,024	0	205,381
Arabinose	0	0	0	0	0	0	0	0	38,346	0	38,346	0	38,346	0	26,965
Cellobiose	0	0	0	0	0	0	0	0	3,159	0	3,159	0	3,159	0	2,224
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	170,458	114,336	284,793	682,174	0	682,174	397,771	1,364,738	1,316,049	312,242	1,003,806	0	1,003,806	1,342,817	1,650,380
Sulfuric Acid	0	0	0	0	13,647	13,647	0	13,647	13,647	0	13,647	0	13,647	0	9,593
Furfural	0	0	0	0	0	0	0	0	1,851	1,108	743	0	743	0	522
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	0	0	0	0	0	0	0	0	235	10	225	0	225	0	159
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	234,962	0	234,962	0	0	0	0	234,962	234,962	0	0	234,962	234,962	0	0

Table D3 Stream table of the bioethanol process from rice straw for alternative 2 design (continue)

Stream Name	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
Stream Phase	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature (°C)	70	50	30	50	30	50	50	30	50	50	50	50	59	59	59
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	3,735	n/a	n/a	n/a	n/a	3,838	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Mass Rate (kg/day)	1,691,504	1,966,134	6,864	1,972,998	17,760	1,990,757	1,990,757	7,053	1,997,810	1,997,810	35,533	1,962,278	3,653,782	365,378	3,288,403
Total Molar Rate (kmol/day)	57,924	93,666	70	93,736	240	93,976	94,143	72	94,215	94,287	258	94,029	151,953	15,195	136,758
Total Solid Mass Rate (kg/day)	863,351	3,105	n/a	3,105	17,760	20,864	31,275	n/a	31,275	35,737	34,931	806	864,157	86,416	777,741
Total Enthalpy (GJ/day)	-25.43	18.92	0.01	18.93	-1.98	16.95	18.30	0.01	18.31	18.89	-0.20	19.09	-6.34	-0.63	-5.71
Component	**Mass Flow (kg/day)**														
Cellulose	422,403	2,123	0	2,123	0	2,123	2,123	0	2,123	2,123	2,123	0	422,403	42,240	380,162
Hemicellulose	28,468	143	0	143	0	143	143	0	143	143	143	0	28,468	2,847	25,621
Galactan	1,189	6	0	6	0	6	6	0	6	6	6	0	1,189	119	1,070
Mannan	5,350	27	0	27	0	27	27	0	27	27	27	0	5,350	535	4,815
Arabinan	10,562	0	0	0	0	0	0	0	0	0	0	0	10,562	1,056	9,506
Lignin	160,418	806	0	806	0	806	806	0	806	806	0	806	161,224	16,122	145,101
Glucose	21,808	51,694	0	51,694	0	51,694	51,694	0	51,694	51,694	103	51,591	73,399	7,340	66,059
Mannose	5,564	13,183	0	13,183	0	13,183	13,183	0	13,183	13,183	26	13,157	18,721	1,872	16,849
Galactose	1,236	2,930	0	2,930	0	2,930	2,930	0	2,930	2,930	6	2,924	4,160	416	3,744
Xylose	86,644	205,381	0	205,381	0	205,381	205,381	0	205,381	205,381	411	204,970	291,614	29,161	262,452
Arabinose	11,381	26,965	0	26,965	0	26,965	26,965	0	26,965	26,965	54	26,911	38,292	3,829	34,463
Cellobiose	935	2,224	0	2,224	0	2,224	2,224	0	2,224	2,224	0	2,224	3,159	316	2,843
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	696,243	1,650,380	0	1,650,380	0	1,650,380	1,656,426	0	1,656,426	1,659,016	0	1,659,016	2,355,259	235,526	2,119,734
Sulfuric Acid	4,055	9,593	6,864	16,456	0	16,456	0	7,053	7,053	0	0	0	4,055	405	3,649
Furfural	221	522	0	522	0	522	522	0	522	522	1	521	742	74	668
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	67	159	0	159	0	159	159	0	159	159	0	158	225	23	203
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	17,760	17,760	5,328	0	5,328	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	22,843	0	22,843	32,633	32,633	0	0	0	0
Ash	234,962	0	0	0	0	0	0	0	0	0	0	0	234,962	23,496	211,466

Table D3 Stream table of the bioethanol process from rice straw for alternative 2 design (continue)

Stream Name	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45
Stream Phase	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed
Temperature (°C)	41	42	30	30	30	40	40	40	40	41	30	30	30	40	40
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	269	6,218	42,750	n/a	n/a	18,687	n/a	n/a	1,178	9,144	417,423	n/a	n/a
Total Mass Rate (kg/day)	365,378	3,288,403	166	6,212	42,990	414,745	414,745	15,334	399,411	3,687,814	726	9,135	419,762	4,117,437	4,105,312
Total Molar Rate (kmol/day)	15,195	136,758	10	345	2,376	17,926	18,386	354	18,032	154,790	43	507	23,204	178,543	178,466
Total Solid Mass Rate (kg/day)	86,416	777,741	n/a	n/a	845	87,260	77,898	n/a	77,898	855,639	n/a	n/a	8,237	863,876	863,876
Total Enthalpy (GJ/day)	-1.56	-13.99	0.01	0.03	0.18	-1.33	-0.76	0.13	-0.89	-14.89	0.04	0.05	1.79	-13.01	-13.19
Component	**Mass Flow (kg/day)**														
Cellulose	42,240	380,162	0	0	0	42,240	31,680	0	31,680	411,842	0	0	0	411,842	411,842
Hemicellulose	2,847	25,621	0	0	0	2,847	2,847	0	2,847	28,468	0	0	0	28,468	28,468
Galactan	119	1,070	0	0	0	119	119	0	119	1,189	0	0	0	1,189	1,189
Mannan	535	4,815	0	0	0	535	535	0	535	5,350	0	0	0	5,350	5,350
Arabinan	1,056	9,506	0	0	0	1,056	1,056	0	1,056	10,562	0	0	0	10,562	10,562
Lignin	16,122	145,101	0	0	0	16,122	16,122	0	16,122	161,224	0	0	0	161,224	161,224
Glucose	7,340	66,059	0	0	0	7,340	11,976	0	11,976	78,034	0	0	0	78,034	75,693
Mannose	1,872	16,849	0	0	0	1,872	1,872	0	1,872	18,721	0	0	0	18,721	18,159
Galactose	416	3,744	0	0	0	416	416	0	416	4,160	0	0	0	4,160	4,035
Xylose	29,161	262,452	0	0	0	29,161	2,508	0	2,508	264,960	0	0	0	264,960	257,011
Arabinose	3,829	34,463	0	0	0	3,829	3,829	0	3,829	38,292	0	0	0	38,292	37,143
Cellobiose	316	2,843	0	0	0	316	316	0	316	3,159	0	0	0	3,159	3,159
Ethanol	0	0	0	0	0	0	15,310	1,148	14,161	14,161	0	0	0	14,161	14,161
Water	235,526	2,119,734	0	0	42,145	277,671	276,664	138	276,526	2,396,259	0	0	411,525	2,807,785	2,807,785
Sulfuric Acid	405	3,649	0	0	0	405	405	0	405	4,055	0	0	0	4,055	4,055
Furfural	74	668	0	0	0	74	74	0	74	742	0	0	0	742	742
Ammonia	0	0	166	0	0	166	0	0	0	0	726	0	0	726	726
Oxygen	0	0	0	0	0	0	296	296	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	14,475	13,752	724	724	0	0	0	724	724
Glycerol	0	0	0	0	0	0	119	0	119	119	0	0	0	119	119
Succinic Acid	0	0	0	0	0	0	402	0	402	402	0	0	0	402	402
Lactic Acid	0	0	0	0	0	0	73	0	73	73	0	0	0	73	73
HMF	23	203	0	0	0	23	23	0	23	225	0	0	0	225	225
Xylitol	0	0	0	0	0	0	1,359	0	1,359	1,359	0	0	0	1,359	1,359
Acetic Acid	0	0	0	0	0	0	518	0	518	518	0	0	0	518	518
Corn Steep Liquor	0	0	0	6,212	0	6,212	6,212	0	6,212	6,212	0	9,135	0	15,346	15,346
ZM	0	0	0	0	0	0	1,197	0	1,197	1,197	0	0	0	1,197	1,197
Cellulase	0	0	0	0	845	845	845	0	845	845	0	0	8,237	9,082	9,082
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	23,496	211,466	0	0	0	23,496	23,496	0	23,496	234,962	0	0	0	234,962	234,962

Table D3 Stream table of the bioethanol process from rice straw for alternative 2 design (continue)

Stream Name	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56
Stream Phase	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid	Solid	Liquid	Liquid	Vapor
Temperature (°C)	40	40	40	40	40	40	40	40	40	100	100
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4.76	4.76	4.76
Total Std. Liq. Rate (L/day)	7,865	n/a	9,861	n/a	87,588	n/a	3,424,656	n/a	3,424,656	3,424,656	94,239
Total Mass Rate (kg/day)	12,125	4,105,313	12,125	4,117,438	72,459	4,044,979	3,551,457	493,522	3,551,457	3,551,457	77,449
Total Molar Rate (kmol/day)	77	180,976	135	181,111	1,734	179,377	162,675	16,702	162,675	162,675	1,843
Total Solid Mass Rate (kg/day)	n/a	493,522	n/a	493,522	n/a	493,522	n/a	493,522	n/a	n/a	n/a
Total Enthalpy (GJ/day)	0.18	17.84	0.05	17.89	0.63	17.26	27.94	-10.68	28.05	60.54	1.01
Component	**Mass Flow (kg/day)**										
Cellulose	0	36,242	0	36,242	0	36,242	0	36,242	0	0	0
Hemicellulose	0	28,468	0	28,468	0	28,468	0	28,468	0	0	0
Galactan	0	1,189	0	1,189	0	1,189	0	1,189	0	0	0
Mannan	0	5,350	0	5,350	0	5,350	0	5,350	0	0	0
Arabinan	0	10,562	0	10,562	0	10,562	0	10,562	0	0	0
Lignin	0	161,224	0	161,224	0	161,224	0	161,224	0	0	0
Glucose	2,341	415,396	0	415,396	0	415,396	415,396	0	415,396	415,396	0
Mannose	562	18,159	0	18,159	0	18,159	18,159	0	18,159	18,159	0
Galactose	125	4,035	0	4,035	0	4,035	4,035	0	4,035	4,035	0
Xylose	7,949	14,650	0	14,650	0	14,650	14,650	0	14,650	14,650	0
Arabinose	1,149	37,143	0	37,143	0	37,143	37,143	0	37,143	37,143	0
Cellobiose	0	5,217	0	5,217	0	5,217	5,217	0	5,217	5,217	0
Ethanol	0	162,664	0	162,664	1,227	161,437	161,437	0	161,437	161,437	484
Water	0	2,766,063	0	2,766,063	2,153	2,763,910	2,763,910	0	2,763,910	2,763,910	2,488
Sulfuric Acid	0	4,055	0	4,055	0	4,055	4,055	0	4,055	4,055	0
Furfural	0	742	0	742	2	740	740	0	740	740	4
Ammonia	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	2,283	0	2,283	2,058	225	225	0	225	225	225
Carbon Dioxide	0	141,236	0	141,236	67,004	74,232	74,232	0	74,232	74,232	74,232
Glycerol	0	1,217	0	1,217	0	1,217	1,217	0	1,217	1,217	0
Succinic Acid	0	4,030	0	4,030	0	4,030	4,030	0	4,030	4,030	0
Lactic Acid	0	738	12,125	12,863	0	12,863	12,863	0	12,863	12,863	0
HMF	0	225	0	225	0	225	225	0	225	225	1
Xylitol	0	13,341	0	13,341	0	13,341	13,341	0	13,341	13,341	0
Acetic Acid	0	5,252	0	5,252	7	5,245	5,245	0	5,245	5,245	2
Corn Steep Liquor	0	15,346	0	15,346	8	15,339	15,339	0	15,339	15,339	13
ZM	0	6,444	0	6,444	0	6,444	0	6,444	0	0	0
Cellulase	0	9,082	0	9,082	0	9,082	0	9,082	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0
Ash	0	234,962	0	234,962	0	234,962	0	234,962	0	0	0

Table D3 Stream table of the bioethanol process from rice straw for alternative 2 design (continue)

Stream Name	S57	S58	S59	S60	S61	S62	S63	S64	S65	S66	S67
Stream Phase	Liquid	Vapor	Liquid	Liquid	Liquid	Vapor	Vapor	Vapor	Liquid	Mixed	Liquid
Temperature (°C)	100	94	117	93	112	100	100	100	40	117	54
Pressure (atm)	4.76	1.77	1.77	1.77	1.77	1.77	1.00	1.00	1.00	1.77	1.77
Total Std. Liq. Rate (L/day)	3,330,417	228,420	3,101,996	209,423	18,997	209,423	200,000	9,422	200,000	3,120,994	3,120,994
Total Mass Rate (kg/day)	3,474,007	187,208	3,286,800	168,430	18,778	168,430	159,017	9,413	159,017	3,305,578	3,305,578
Total Molar Rate (kmol/day)	160,832	5,015	155,817	4,001	1,014	4,001	3,479	523	3,479	156,831	156,831
Total Solid Mass Rate (kg/day)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	59.53	10.18	66.21	1.81	0.36	8.20	7.15	1.05	0.64	66.57	34.08
Component	**Mass Flow (kg/day)**										
Cellulose	0	0	0	0	0	0	0	0	0	0	0
Hemicellulose	0	0	0	0	0	0	0	0	0	0	0
Galactan	0	0	0	0	0	0	0	0	0	0	0
Mannan	0	0	0	0	0	0	0	0	0	0	0
Arabinan	0	0	0	0	0	0	0	0	0	0	0
Lignin	0	0	0	0	0	0	0	0	0	0	0
Glucose	415,396	0	415,396	0	0	0	0	0	0	415,396	415,396
Mannose	18,159	0	18,159	0	0	0	0	0	0	18,159	18,159
Galactose	4,035	0	4,035	0	0	0	0	0	0	4,035	4,035
Xylose	14,650	0	14,650	0	0	0	0	0	0	14,650	14,650
Arabinose	37,143	0	37,143	0	0	0	0	0	0	37,143	37,143
Cellobiose	5,217	0	5,217	0	0	0	0	0	0	5,217	5,217
Ethanol	160,953	159,015	1,937	158,220	795	158,220	158,220	0	158,220	2,732	2,732
Water	2,761,422	28,154	2,733,268	10,209	17,945	10,209	796	9,413	796	2,751,213	2,751,213
Sulfuric Acid	4,055	0	4,055	0	0	0	0	0	0	4,055	4,055
Furfural	735	27	709	0	27	0	0	0	0	735	735
Ammonia	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0
Glycerol	1,217	0	1,217	0	0	0	0	0	0	1,217	1,217
Succinic Acid	4,030	0	4,030	0	0	0	0	0	0	4,030	4,030
Lactic Acid	12,863	0	12,863	0	0	0	0	0	0	12,863	12,863
HMF	224	0	224	0	0	0	0	0	0	224	224
Xylitol	13,341	0	13,341	0	0	0	0	0	0	13,341	13,341
Acetic Acid	5,243	8	5,235	0	8	0	0	0	0	5,243	5,243
Corn Steep Liquor	15,326	3	15,323	0	3	0	0	0	0	15,326	15,326
ZM	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0

D.2.4 Alternative 3 Design

Table D4 Stream table of the bioethanol process from rice straw for alternative 3 design

Stream Name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Stream Phase	Mixed	Vapor	Mixed	Liquid	Liquid	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid	Mixed
Temperature (°C)	30	160	100	30	30	100	268	180	180	102	102	102	102	30	74
Pressure (atm)	1.00	6.00	1.00	1.00	1.00	1.00	13.00	10.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	104,536	n/a	175,367	5,572	694,711	74,570	n/a	n/a	256,334	996,420	n/a	n/a	860,824	n/a
Total Mass Rate (kg/day)	1,336,730	104,433	1,441,163	175,194	10,238	698,739	74,496	2,214,398	2,214,398	256,189	1,142,691	815,518	1,958,208	859,976	1,750,598
Total Molar Rate (kmol/day)	28,871	5,797	34,668	9,725	104	38,185	4,135	76,988	74,436	14,114	42,967	17,355	60,322	47,736	81,762
Total Solid Mass Rate (kg/day)	1,176,322	n/a	1,176,322	n/a	n/a	n/a	n/a	1,176,322	815,518	n/a	n/a	815,518	815,518	n/a	2,922
Total Enthalpy (GJ/day)	-64.73	12.02	-52.71	0.92	0.02	30.29	8.64	-13.78	17.71	28.47	20.25	-31.01	-10.76	4.51	23.35
Component	**Mass Flow (kg/day)**														
Cellulose	464,647	0	464,647	0	0	0	0	464,647	399,568	0	0	399,568	399,568	0	1,998
Hemicellulose	270,554	0	270,554	0	0	0	0	270,554	26,929	0	0	26,929	26,929	0	135
Galactan	4,705	0	4,705	0	0	0	0	4,705	1,125	0	0	1,125	1,125	0	6
Mannan	21,174	0	21,174	0	0	0	0	21,174	5,061	0	0	5,061	5,061	0	25
Arabinan	42,348	0	42,348	0	0	0	0	42,348	9,941	0	0	9,941	9,941	0	0
Lignin	151,746	0	151,746	0	0	0	0	151,746	151,746	0	0	151,746	151,746	0	759
Glucose	0	0	0	0	0	0	0	0	69,181	0	69,181	0	69,181	0	60,370
Mannose	0	0	0	0	0	0	0	0	17,645	0	17,645	0	17,645	0	12,942
Galactose	0	0	0	0	0	0	0	0	3,921	0	3,921	0	3,921	0	2,876
Xylose	0	0	0	0	0	0	0	0	274,857	0	274,857	0	274,857	0	193,720
Arabinose	0	0	0	0	0	0	0	0	36,091	0	36,091	0	36,091	0	26,471
Cellobiose	0	0	0	0	0	0	0	0	2,973	0	2,973	0	2,973	0	2,240
Ethanol	0	0	0	0	0	586	0	586	586	464	122	0	122	0	1,261
Water	160,408	104,433	264,840	175,194	0	681,971	74,496	1,021,308	975,481	253,081	722,399	0	722,399	859,976	1,431,788
Sulfuric Acid	0	0	0	0	10,238	10,238	0	10,238	10,238	0	10,238	0	10,238	0	7,289
Furfural	0	0	0	0	0	466	0	466	2,208	1,295	913	0	913	0	1,208
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	1	0	1	1	0	1	0	1	0	39
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	123
Lactic Acid	0	0	0	0	0	5	0	5	5	0	5	0	5	0	403
HMF	0	0	0	0	0	9	0	9	230	11	219	0	219	0	165
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	394
Acetic Acid	0	0	0	0	0	2,454	0	2,454	2,454	828	1,626	0	1,626	0	2,794
Corn Steep Liquor	0	0	0	0	0	3,008	0	3,008	3,008	511	2,498	0	2,498	0	3,592
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	221,149	0	221,149	0	0	0	0	221,149	221,149	0	0	221,149	221,149	0	0

Table D4 Stream table of the bioethanol process from rice straw for alternative 3 design (continue)

Stream Name	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
Stream Phase	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature (°C)	74	50	30	50	30	50	50	30	50	50	50	50	61	61	61
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	4,039	n/a	n/a	n/a	n/a	3,411	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Mass Rate (kg/day)	1,549,894	1,750,598	7,422	1,758,020	15,848	1,773,868	1,773,868	6,267	1,780,135	1,780,135	31,885	1,748,250	3,298,144	329,814	2,968,329
Total Molar Rate (kmol/day)	51,820	81,762	76	81,838	214	82,052	82,202	64	82,266	82,329	232	82,098	133,918	13,392	120,526
Total Solid Mass Rate (kg/day)	812,595	2,922	n/a	2,922	15,848	18,770	28,077	n/a	28,077	32,041	31,283	759	813,354	81,335	732,019
Total Enthalpy (GJ/day)	-23.69	17.01	0.01	17.02	-1.76	15.26	16.46	0.01	16.48	16.99	-0.19	17.18	-6.52	-0.65	-5.86
Component	**Mass Flow (kg/day)**														
Cellulose	397,570	1,998	0	1,998	0	1,998	1,998	0	1,998	1,998	1,998	0	397,570	39,757	357,813
Hemicellulose	26,795	135	0	135	0	135	135	0	135	135	135	0	26,795	2,679	24,115
Galactan	1,119	6	0	6	0	6	6	0	6	6	6	0	1,119	112	1,007
Mannan	5,035	25	0	25	0	25	25	0	25	25	25	0	5,035	504	4,532
Arabinan	9,941	0	0	0	0	0	0	0	0	0	0	0	9,941	994	8,947
Lignin	150,987	759	0	759	0	759	759	0	759	759	0	759	151,746	15,175	136,571
Glucose	25,468	60,370	0	60,370	0	60,370	60,370	0	60,370	60,370	121	60,250	85,718	8,572	77,146
Mannose	5,462	12,942	0	12,942	0	12,942	12,942	0	12,942	12,942	26	12,916	18,378	1,838	16,540
Galactose	1,214	2,876	0	2,876	0	2,876	2,876	0	2,876	2,876	6	2,870	4,084	408	3,676
Xylose	81,725	193,720	0	193,720	0	193,720	193,720	0	193,720	193,720	387	193,333	275,058	27,506	247,552
Arabinose	11,173	26,471	0	26,471	0	26,471	26,471	0	26,471	26,471	53	26,418	37,591	3,759	33,832
Cellobiose	942	2,240	0	2,240	0	2,240	2,240	0	2,240	2,240	0	2,240	3,182	318	2,864
Ethanol	531	1,261	0	1,261	0	1,261	1,261	0	1,261	1,261	0	1,261	1,792	179	1,613
Water	604,026	1,431,788	0	1,431,788	0	1,431,788	1,437,192	0	1,437,192	1,439,494	0	1,439,494	2,043,520	204,352	1,839,168
Sulfuric Acid	3,081	7,289	7,422	14,711	0	14,711	0	6,267	6,267	0	0	0	3,081	308	2,773
Furfural	510	1,208	0	1,208	0	1,208	1,208	0	1,208	1,208	2	1,206	1,716	172	1,544
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	17	39	0	39	0	39	39	0	39	39	0	39	56	6	50
Succinic Acid	52	123	0	123	0	123	123	0	123	123	0	123	175	17	157
Lactic Acid	170	403	0	403	0	403	403	0	403	403	0	403	573	57	516
HMF	69	165	0	165	0	165	165	0	165	165	0	164	234	23	210
Xylitol	166	394	0	394	0	394	394	0	394	394	0	394	560	56	504
Acetic Acid	1,179	2,794	0	2,794	0	2,794	2,794	0	2,794	2,794	0	2,794	3,974	397	3,576
Corn Steep Liquor	1,515	3,592	0	3,592	0	3,592	3,592	0	3,592	3,592	7	3,585	5,099	510	4,589
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	15,848	15,848	4,734	0	4,734	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	20,420	0	20,420	29,119	29,119	0	0	0	0
Ash	221,149	0	0	0	0	0	0	0	0	0	0	0	221,149	22,115	199,034

Table D4 Stream table of the bioethanol process from rice straw for alternative 3 design (continue)

Stream Name	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45
Stream Phase	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed
Temperature (°C)	42	42	30	30	30	40	40	40	40	41	30	30	30	40	40
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	265	5,620	40,319	n/a	n/a	18,549	n/a	n/a	1,163	8,264	392,900	n/a	n/a
Total Mass Rate (kg/day)	329,814	2,968,329	163	5,614	40,545	376,137	376,137	15,216	360,921	3,329,250	716	8,256	395,102	3,733,325	3,721,371
Total Molar Rate (kmol/day)	13,392	120,526	10	312	2,241	15,954	16,415	351	16,064	136,590	42	458	21,841	158,931	158,855
Total Solid Mass Rate (kg/day)	81,335	732,019	n/a	n/a	795	82,131	73,375	n/a	73,375	805,394	n/a	n/a	7,753	813,146	813,146
Total Enthalpy (GJ/day)	-1.55	-13.94	0.01	0.03	0.17	-1.34	-0.82	0.13	-0.95	-14.89	0.04	0.04	1.68	-13.13	-13.31
Component	**Mass Flow (kg/day)**														
Cellulose	39,757	357,813	0	0	0	39,757	29,818	0	29,818	387,631	0	0	0	387,631	387,631
Hemicellulose	2,679	24,115	0	0	0	2,679	2,679	0	2,679	26,795	0	0	0	26,795	26,795
Galactan	112	1,007	0	0	0	112	112	0	112	1,119	0	0	0	1,119	1,119
Mannan	504	4,532	0	0	0	504	504	0	504	5,035	0	0	0	5,035	5,035
Arabinan	994	8,947	0	0	0	994	994	0	994	9,941	0	0	0	9,941	9,941
Lignin	15,175	136,571	0	0	0	15,175	15,175	0	15,175	151,746	0	0	0	151,746	151,746
Glucose	8,572	77,146	0	0	0	8,572	11,327	0	11,327	88,473	0	0	0	88,473	85,819
Mannose	1,838	16,540	0	0	0	1,838	1,838	0	1,838	18,378	0	0	0	18,378	17,827
Galactose	408	3,676	0	0	0	408	408	0	408	4,084	0	0	0	4,084	3,961
Xylose	27,506	247,552	0	0	0	27,506	2,365	0	2,365	249,917	0	0	0	249,917	242,420
Arabinose	3,759	33,832	0	0	0	3,759	3,759	0	3,759	37,591	0	0	0	37,591	36,463
Cellobiose	318	2,864	0	0	0	318	318	0	318	3,182	0	0	0	3,182	3,182
Ethanol	179	1,613	0	0	0	179	15,378	1,153	14,225	15,838	0	0	0	15,838	15,838
Water	204,352	1,839,168	0	0	39,749	244,101	243,168	122	243,047	2,082,215	0	0	387,349	2,469,564	2,469,564
Sulfuric Acid	308	2,773	0	0	0	308	308	0	308	3,081	0	0	0	3,081	3,081
Furfural	172	1,544	0	0	0	172	172	0	172	1,716	0	0	0	1,716	1,716
Ammonia	0	0	163	0	0	163	0	0	0	0	716	0	0	716	716
Oxygen	0	0	0	0	0	0	286	286	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	14,374	13,655	719	719	0	0	0	719	719
Glycerol	6	50	0	0	0	6	125	0	125	175	0	0	0	175	175
Succinic Acid	17	157	0	0	0	17	409	0	409	567	0	0	0	567	567
Lactic Acid	57	516	0	0	0	57	129	0	129	645	0	0	0	645	645
HMF	23	210	0	0	0	23	23	0	23	234	0	0	0	234	234
Xylitol	56	504	0	0	0	56	1,338	0	1,338	1,842	0	0	0	1,842	1,842
Acetic Acid	397	3,576	0	0	0	397	911	0	911	4,487	0	0	0	4,487	4,487
Corn Steep Liquor	510	4,589	0	5,614	0	6,124	6,124	0	6,124	10,713	0	8,256	0	18,970	18,970
ZM	0	0	0	0	0	0	1,184	0	1,184	1,184	0	0	0	1,184	1,184
Cellulase	0	0	0	0	795	795	795	0	795	795	0	0	7,753	8,548	8,548
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	22,115	199,034	0	0	0	22,115	22,115	0	22,115	221,149	0	0	0	221,149	221,149

Table D4 Stream table of the bioethanol process from rice straw for alternative 3 design (continue)

Stream Name	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
Stream Phase	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid	Solid	Liquid	Liquid	Vapor	Liquid	Vapor	Liquid	Liquid
Temperature (°C)	40	40	40	40	40	40	40	40	40	90	100	100	94	118	93
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4.76	4.76	4.76	4.76	1.77	1.77	1.77
Total Std. Liq. Rate (L/day)	7,750	n/a	9,721	n/a	95,992	n/a	3,069,849	n/a	3,069,849	3,069,849	84,352	2,985,497	227,448	2,758,049	209,406
Total Mass Rate (kg/day)	11,953	3,721,373	11,953	3,733,326	79,338	3,653,988	3,189,176	464,812	3,189,176	3,189,176	69,312	3,119,864	186,239	2,933,625	168,413
Total Molar Rate (kmol/day)	76	161,469	133	161,602	1,895	159,706	143,974	15,733	143,974	143,974	1,648	142,326	4,960	137,365	4,000
Total Solid Mass Rate (kg/day)	n/a	464,812	n/a	464,812	n/a	464,812	n/a	464,812	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	0.18	15.78	0.05	15.83	0.69	15.14	25.20	-10.07	25.29	49.13	0.90	53.30	10.07	58.99	1.81
Component	**Mass Flow (kg/day)**														
Cellulose	0	34,112	0	34,112	0	34,112	0	34,112	0	0	0	0	0	0	0
Hemicellulose	0	26,795	0	26,795	0	26,795	0	26,795	0	0	0	0	0	0	0
Galactan	0	1,119	0	1,119	0	1,119	0	1,119	0	0	0	0	0	0	0
Mannan	0	5,035	0	5,035	0	5,035	0	5,035	0	0	0	0	0	0	0
Arabinan	0	9,941	0	9,941	0	9,941	0	9,941	0	0	0	0	0	0	0
Lignin	0	151,746	0	151,746	0	151,746	0	151,746	0	0	0	0	0	0	0
Glucose	2,654	391,239	0	391,239	0	391,239	391,239	0	391,239	391,239	0	391,239	0	391,239	0
Mannose	551	17,827	0	17,827	0	17,827	17,827	0	17,827	17,827	0	17,827	0	17,827	0
Galactose	123	3,961	0	3,961	0	3,961	3,961	0	3,961	3,961	0	3,961	0	3,961	0
Xylose	7,498	13,818	0	13,818	0	13,818	13,818	0	13,818	13,818	0	13,818	0	13,818	0
Arabinose	1,128	36,463	0	36,463	0	36,463	36,463	0	36,463	36,463	0	36,463	0	36,463	0
Cellobiose	0	4,910	0	4,910	0	4,910	4,910	0	4,910	4,910	0	4,910	0	4,910	0
Ethanol	0	162,916	0	162,916	1,478	161,438	161,438	0	161,438	161,438	484	160,954	159,017	1,937	158,221
Water	0	2,430,342	0	2,430,342	2,338	2,428,003	2,428,003	0	2,428,003	2,428,003	2,185	2,425,818	27,166	2,398,652	10,191
Sulfuric Acid	0	3,081	0	3,081	0	3,081	3,081	0	3,081	3,081	0	3,081	0	3,081	0
Furfural	0	1,716	0	1,716	6	1,710	1,710	0	1,710	1,710	10	1,700	40	1,660	0
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	2,194	0	2,194	2,015	180	180	0	180	180	180	0	0	0	0
Carbon Dioxide	0	139,905	0	139,905	73,474	66,431	66,431	0	66,431	66,431	66,431	0	0	0	0
Glycerol	0	1,270	0	1,270	0	1,270	1,270	0	1,270	1,270	0	1,270	0	1,270	0
Succinic Acid	0	4,102	0	4,102	0	4,102	4,102	0	4,102	4,102	0	4,102	0	4,102	0
Lactic Acid	0	1,302	11,953	13,255	0	13,255	13,255	0	13,255	13,255	0	13,255	0	13,255	0
HMF	0	234	0	234	0	234	234	0	234	234	1	232	0	232	0
Xylitol	0	13,143	0	13,143	0	13,143	13,143	0	13,143	13,143	0	13,143	0	13,143	0
Acetic Acid	0	9,168	0	9,168	15	9,154	9,154	0	9,154	9,154	4	9,150	12	9,138	0
Corn Steep Liquor	0	18,970	0	18,970	11	18,958	18,958	0	18,958	18,958	16	18,942	4	18,938	0
ZM	0	6,369	0	6,369	0	6,369	0	6,369	0	0	0	0	0	0	0
Cellulase	0	8,548	0	8,548	0	8,548	0	8,548	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	221,149	0	221,149	0	221,149	0	221,149	0	0	0	0	0	0	0

Table D4 Stream table of the bioethanol process from rice straw for alternative 3 design (continue)

Stream Name	S61	S62	S63	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73	S74	S75
Stream Phase	Liquid	Vapor	Vapor	Vapor	Liquid	Liquid	Mixed	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Liquid	Vapor
Temperature (°C)	112	100	100	100	40	100	117	72	72	72	72	61	61	71	61
Pressure (atm)	1.77	1.77	1.00	1.00	1.00	4.76	1.77	0.33	0.33	0.33	0.33	0.20	0.20	0.33	0.20
Total Std. Liq. Rate (L/day)	18,042	209,406	200,000	9,406	200,000	3,069,849	2,776,091	2,776,091	2,776,091	478,617	2,297,474	2,297,474	2,297,474	478,617	513,805
Total Mass Rate (kg/day)	17,826	168,413	159,016	9,396	159,016	3,189,176	2,951,451	2,951,451	2,951,451	477,899	2,473,552	2,473,552	2,473,552	477,899	513,339
Total Molar Rate (kmol/day)	960	4,000	3,479	522	3,479	143,974	138,326	138,326	138,326	26,315	112,010	112,010	112,010	26,315	28,358
Total Solid Mass Rate (kg/day)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	0.34	8.20	7.14	1.05	0.64	54.20	59.33	59.33	84.70	52.04	32.66	32.66	78.81	5.89	55.63
Component	**Mass Flow (kg/day)**														
Cellulose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemicellulose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galactan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mannan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabinan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lignin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glucose	0	0	0	0	0	391,239	391,239	391,239	391,239	0	391,239	391,239	391,239	0	0
Mannose	0	0	0	0	0	17,827	17,827	17,827	17,827	0	17,827	17,827	17,827	0	0
Galactose	0	0	0	0	0	3,961	3,961	3,961	3,961	0	3,961	3,961	3,961	0	0
Xylose	0	0	0	0	0	13,818	13,818	13,818	13,818	0	13,818	13,818	13,818	0	0
Arabinose	0	0	0	0	0	36,463	36,463	36,463	36,463	0	36,463	36,463	36,463	0	0
Cellobiose	0	0	0	0	0	4,910	4,910	4,910	4,910	0	4,910	4,910	4,910	0	0
Ethanol	795	158,221	158,221	0	158,221	161,438	2,732	2,732	2,732	1,993	739	739	739	1,993	586
Water	16,975	10,191	795	9,396	795	2,428,003	2,415,627	2,415,627	2,415,627	469,902	1,945,725	1,945,725	1,945,725	469,902	506,809
Sulfuric Acid	0	0	0	0	0	3,081	3,081	3,081	3,081	0	3,081	3,081	3,081	0	0
Furfural	40	0	0	0	0	1,710	1,700	1,700	1,700	950	749	749	749	950	467
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	180	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	66,431	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	1,270	1,270	1,270	1,270	1	1,269	1,269	1,269	1	1
Succinic Acid	0	0	0	0	0	4,102	4,102	4,102	4,102	0	4,102	4,102	4,102	0	0
Lactic Acid	0	0	0	0	0	13,255	13,255	13,255	13,255	5	13,250	13,250	13,250	5	5
HMF	0	0	0	0	0	234	232	232	232	7	226	226	226	7	9
Xylitol	0	0	0	0	0	13,143	13,143	13,143	13,143	0	13,143	13,143	13,143	0	0
Acetic Acid	12	0	0	0	0	9,154	9,150	9,150	9,150	2,604	6,546	6,546	6,546	2,604	2,454
Corn Steep Liquor	4	0	0	0	0	18,958	18,942	18,942	18,942	2,437	16,504	16,504	16,504	2,437	3,009
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D4 Stream table of the bioethanol process from rice straw for alternative 3 design (continue)

Stream Name	S76	S77	S78	S79	S80	S81	S82	S83	S84	S85	S86	S87
Stream Phase	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Mixed	Liquid
Temperature (°C)	61	61	61	70	70	70	70	220	100	100	100	44
Pressure (atm)	0.20	0.20	0.20	0.31	0.31	0.31	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	1,783,669	90,994	1,692,675	569,611	475,402	94,209	475,402	513,805	513,805	513,795	689,139	1,336,215
Total Mass Rate (kg/day)	1,960,213	100,000	1,860,213	577,899	482,320	95,580	482,320	513,339	513,339	513,329	688,500	1,342,284
Total Molar Rate (kmol/day)	83,652	4,268	79,385	30,583	25,525	5,058	25,525	28,358	28,358	28,357	38,081	73,260
Total Solid Mass Rate (kg/day)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	23.18	1.18	22.00	7.07	5.90	1.17	5.90	59.59	53.20	29.36	30.27	10.42
Component	**Mass Flow (kg/day)**											
Cellulose	0	0	0	0	0	0	0	0	0	0	0	0
Hemicellulose	0	0	0	0	0	0	0	0	0	0	0	0
Galactan	0	0	0	0	0	0	0	0	0	0	0	0
Mannan	0	0	0	0	0	0	0	0	0	0	0	0
Arabinan	0	0	0	0	0	0	0	0	0	0	0	0
Lignin	0	0	0	0	0	0	0	0	0	0	0	0
Glucose	391,239	19,959	371,280	19,959	16,658	3,301	16,658	0	0	0	0	16,658
Mannose	17,827	909	16,917	909	759	150	759	0	0	0	0	759
Galactose	3,961	202	3,759	202	169	33	169	0	0	0	0	169
Xylose	13,818	705	13,113	705	588	117	588	0	0	0	0	588
Arabinose	36,463	1,860	34,603	1,860	1,553	308	1,553	0	0	0	0	1,553
Cellobiose	4,910	250	4,659	250	209	41	209	0	0	0	0	209
Ethanol	154	8	146	2,001	1,670	331	1,670	586	586	586	586	1,670
Water	1,438,915	73,406	1,365,509	543,308	453,449	89,859	453,449	506,809	506,809	506,800	681,971	1,313,414
Sulfuric Acid	3,081	157	2,924	157	131	26	131	0	0	0	0	131
Furfural	283	14	268	965	805	160	805	467	467	467	466	805
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	1,268	65	1,203	66	55	11	55	1	1	1	1	55
Succinic Acid	4,102	209	3,893	209	175	35	175	0	0	0	0	175
Lactic Acid	13,245	676	12,569	681	568	113	568	5	5	5	5	568
HMF	217	11	206	18	15	3	15	9	9	9	9	15
Xylitol	13,143	670	12,473	671	560	111	560	0	0	0	0	560
Acetic Acid	4,092	209	3,883	2,813	2,348	465	2,348	2,454	2,454	2,454	2,454	2,347
Corn Steep Liquor	13,496	688	12,807	3,126	2,609	517	2,609	3,009	3,009	3,008	3,008	2,609
ZM	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0	0

D.2.5 Alternative 4 Design

Table D5 Stream table of the bioethanol process from rice straw for alternative 4 design

Stream Name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Stream Phase	Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid	Mixed
Temperature (°C)	30	160	100	55	30	55	268	180	180	102	102	102	102	55	81
Pressure (atm)	1.00	6.00	1.00	1.00	1.00	1.00	13.00	10.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	114,448	n/a	659,721	6,884	666,614	341,124	n/a	n/a	294,543	1,210,022	n/a	n/a	1,349,046	n/a
Total Mass Rate (kg/day)	1,348,792	114,336	1,463,127	661,346	12,649	674,004	340,788	2,477,919	2,477,919	294,326	1,360,734	822,858	2,183,593	1,352,367	1,911,078
Total Molar Rate (kmol/day)	29,133	6,347	35,479	36,356	129	36,485	18,917	90,881	88,306	16,275	54,519	17,511	72,031	74,343	90,649
Total Solid Mass Rate (kg/day)	1,186,911	n/a	1,186,911	n/a	n/a	n/a	n/a	1,186,911	822,858	n/a	n/a	822,858	822,858	n/a	2,948
Total Enthalpy (GJ/day)	-65.31	13.16	-52.15	6.38	0.02	6.40	39.52	-6.23	25.54	32.83	24.05	-31.33	-7.28	13.05	27.39
Component	**Mass Flow (kg/day)**														
Cellulose	468,830	0	468,830	0	0	0	0	468,830	403,164	0	0	403,164	403,164	0	2,016
Hemicellulose	272,989	0	272,989	0	0	0	0	272,989	27,172	0	0	27,172	27,172	0	136
Galactan	4,748	0	4,748	0	0	0	0	4,748	1,135	0	0	1,135	1,135	0	6
Mannan	21,364	0	21,364	0	0	0	0	21,364	5,106	0	0	5,106	5,106	0	26
Arabinan	42,729	0	42,729	0	0	0	0	42,729	10,031	0	0	10,031	10,031	0	0
Lignin	153,111	0	153,111	0	0	0	0	153,111	153,111	0	0	153,111	153,111	0	766
Glucose	0	0	0	4,927	0	4,927	0	4,927	74,731	0	74,731	0	74,731	10,075	59,644
Mannose	0	0	0	282	0	282	0	282	18,086	0	18,086	0	18,086	577	13,123
Galactose	0	0	0	63	0	63	0	63	4,019	0	4,019	0	4,019	128	2,916
Xylose	0	0	0	218	0	218	0	218	277,548	0	277,548	0	277,548	445	195,513
Arabinose	0	0	0	577	0	577	0	577	36,993	0	36,993	0	36,993	1,180	26,843
Cellobiose	0	0	0	77	0	77	0	77	3,077	0	3,077	0	3,077	158	2,278
Ethanol	0	0	0	426	0	426	0	426	426	333	93	0	93	872	679
Water	161,881	114,336	276,216	653,791	0	653,800	340,788	1,270,805	1,224,565	292,819	931,746	0	931,746	1,336,919	1,595,566
Sulfuric Acid	0	0	0	59	12,649	12,708	0	12,708	12,708	0	12,708	0	12,708	122	9,018
Furfural	0	0	0	85	0	85	0	85	1,843	1,099	744	0	744	174	645
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	20	0	20	0	20	20	0	20	0	20	41	43
Succinic Acid	0	0	0	65	0	65	0	65	65	0	65	0	65	132	139
Lactic Acid	0	0	0	209	0	209	0	209	209	0	209	0	209	427	447
HMF	0	0	0	12	0	12	0	12	235	10	225	0	225	24	175
Xylitol	0	0	0	208	0	208	0	208	208	0	208	0	208	425	446
Acetic Acid	0	0	0	85	0	85	0	85	85	27	58	0	58	173	163
Corn Steep Liquor	0	0	0	243	0	243	0	243	243	38	205	0	205	496	493
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	223,139	0	223,139	0	0	0	0	223,139	223,139	0	0	223,139	223,139	0	0

Table D5 Stream table of the bioethanol process from rice straw for alternative 4 design (continue)

Stream Name	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
Stream Phase	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature (°C)	81	50	30	50	30	50	50	30	50	50	50	50	63	63	63
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	3,808	n/a	n/a	n/a	n/a	3,752	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Mass Rate (kg/day)	1,624,901	1,911,078	6,998	1,918,076	17,308	1,935,384	1,935,384	6,895	1,942,278	1,942,279	34,584	1,907,695	3,532,595	353,260	3,179,336
Total Molar Rate (kmol/day)	55,725	90,649	71	90,721	234	90,954	91,118	70	91,188	91,258	251	91,007	146,732	14,673	132,059
Total Solid Mass Rate (kg/day)	819,910	2,948	n/a	2,948	17,308	20,256	30,389	n/a	30,389	34,751	33,985	766	820,675	82,068	738,608
Total Enthalpy (GJ/day)	-21.62	18.43	0.01	18.44	-1.93	16.51	17.83	0.01	17.84	18.40	-0.19	18.60	-3.03	-0.30	-2.73
Component	**Mass Flow (kg/day)**														
Cellulose	401,149	2,016	0	2,016	0	2,016	2,016	0	2,016	2,016	2,016	0	401,149	40,115	361,034
Hemicellulose	27,036	136	0	136	0	136	136	0	136	136	136	0	27,036	2,704	24,332
Galactan	1,129	6	0	6	0	6	6	0	6	6	6	0	1,129	113	1,016
Mannan	5,081	26	0	26	0	26	26	0	26	26	26	0	5,081	508	4,573
Arabinan	10,031	0	0	0	0	0	0	0	0	0	0	0	10,031	1,003	9,028
Lignin	152,346	766	0	766	0	766	766	0	766	766	0	766	153,111	15,311	137,800
Glucose	25,162	59,644	0	59,644	0	59,644	59,644	0	59,644	59,644	119	59,524	84,686	8,469	76,218
Mannose	5,539	13,123	0	13,123	0	13,123	13,123	0	13,123	13,123	26	13,097	18,636	1,864	16,773
Galactose	1,231	2,916	0	2,916	0	2,916	2,916	0	2,916	2,916	6	2,910	4,141	414	3,727
Xylose	82,481	195,513	0	195,513	0	195,513	195,513	0	195,513	195,513	391	195,122	277,602	27,760	249,842
Arabinose	11,330	26,843	0	26,843	0	26,843	26,843	0	26,843	26,843	54	26,789	38,119	3,812	34,307
Cellobiose	958	2,278	0	2,278	0	2,278	2,278	0	2,278	2,278	0	2,278	3,235	324	2,912
Ethanol	286	679	0	679	0	679	679	0	679	679	0	679	965	96	868
Water	673,119	1,595,566	0	1,595,566	0	1,595,566	1,601,449	0	1,601,449	1,603,982	0	1,603,982	2,277,101	227,710	2,049,391
Sulfuric Acid	3,812	9,018	6,998	16,016	0	16,016	0	6,895	6,895	0	0	0	3,812	381	3,431
Furfural	273	645	0	645	0	645	645	0	645	645	1	644	917	92	825
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	18	43	0	43	0	43	43	0	43	43	0	43	61	6	55
Succinic Acid	58	139	0	139	0	139	139	0	139	139	0	139	197	20	177
Lactic Acid	188	447	0	447	0	447	447	0	447	447	0	447	636	64	572
HMF	74	175	0	175	0	175	175	0	175	175	0	175	248	25	223
Xylitol	188	446	0	446	0	446	446	0	446	446	0	446	633	63	570
Acetic Acid	69	163	0	163	0	163	163	0	163	163	0	163	231	23	208
Corn Steep Liquor	208	493	0	493	0	493	493	0	493	493	1	492	700	70	630
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	17,308	17,308	5,208	0	5,208	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	22,232	0	22,232	31,802	31,802	0	0	0	0
Ash	223,139	0	0	0	0	0	0	0	0	0	0	0	223,139	22,314	200,825

Table D5 Stream table of the bioethanol process from rice straw for alternative 4 design (continue)

Stream Name	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45
Stream Phase	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed
Temperature (°C)	41	42	30	30	30	40	40	40	40	41	30	30	30	40	40
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	267	6,024	40,600	n/a	n/a	18,622	n/a	n/a	1,169	8,858	396,425	n/a	n/a
Total Mass Rate (kg/day)	353,260	3,179,336	164	6,018	40,828	400,270	400,270	15,278	384,992	3,564,327	720	8,850	398,647	3,972,544	3,960,521
Total Molar Rate (kmol/day)	14,673	132,059	10	334	2,257	17,274	17,736	353	17,383	149,442	42	491	22,037	172,013	171,936
Total Solid Mass Rate (kg/day)	82,068	738,608	n/a	n/a	802	82,870	74,030	n/a	74,030	812,638	n/a	n/a	7,822	820,460	820,460
Total Enthalpy (GJ/day)	-1.42	-12.77	0.01	0.03	0.17	-1.21	-0.68	0.13	-0.81	-13.58	0.04	0.05	1.70	-11.80	-11.98
Component	**Mass Flow (kg/day)**														
Cellulose	40,115	361,034	0	0	0	40,115	30,086	0	30,086	391,120	0	0	0	391,120	391,120
Hemicellulose	2,704	24,332	0	0	0	2,704	2,704	0	2,704	27,036	0	0	0	27,036	27,036
Galactan	113	1,016	0	0	0	113	113	0	113	1,129	0	0	0	1,129	1,129
Mannan	508	4,573	0	0	0	508	508	0	508	5,081	0	0	0	5,081	5,081
Arabinan	1,003	9,028	0	0	0	1,003	1,003	0	1,003	10,031	0	0	0	10,031	10,031
Lignin	15,311	137,800	0	0	0	15,311	15,311	0	15,311	153,111	0	0	0	153,111	153,111
Glucose	8,469	76,218	0	0	0	8,469	11,423	0	11,423	87,640	0	0	0	87,640	85,011
Mannose	1,864	16,773	0	0	0	1,864	1,864	0	1,864	18,636	0	0	0	18,636	18,077
Galactose	414	3,727	0	0	0	414	414	0	414	4,141	0	0	0	4,141	4,017
Xylose	27,760	249,842	0	0	0	27,760	2,387	0	2,387	252,229	0	0	0	252,229	244,662
Arabinose	3,812	34,307	0	0	0	3,812	3,812	0	3,812	38,119	0	0	0	38,119	36,975
Cellobiose	324	2,912	0	0	0	324	324	0	324	3,235	0	0	0	3,235	3,235
Ethanol	96	868	0	0	0	96	15,352	1,151	14,201	15,069	0	0	0	15,069	15,069
Water	227,710	2,049,391	0	0	40,026	267,736	266,793	133	266,659	2,316,050	0	0	390,824	2,706,875	2,706,875
Sulfuric Acid	381	3,431	0	0	0	381	381	0	381	3,812	0	0	0	3,812	3,812
Furfural	92	825	0	0	0	92	92	0	92	917	0	0	0	917	917
Ammonia	0	0	164	0	0	164	0	0	0	0	720	0	0	720	720
Oxygen	0	0	0	0	0	0	288	288	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	14,427	13,706	721	721	0	0	0	721	721
Glycerol	6	55	0	0	0	6	126	0	126	180	0	0	0	180	180
Succinic Acid	20	177	0	0	0	20	414	0	414	591	0	0	0	591	591
Lactic Acid	64	572	0	0	0	64	136	0	136	708	0	0	0	708	708
HMF	25	223	0	0	0	25	25	0	25	248	0	0	0	248	248
Xylitol	63	570	0	0	0	63	1,357	0	1,357	1,927	0	0	0	1,927	1,927
Acetic Acid	23	208	0	0	0	23	539	0	539	747	0	0	0	747	747
Corn Steep Liquor	70	630	0	6,018	0	6,088	6,088	0	6,088	6,718	0	8,850	0	15,567	15,567
ZM	0	0	0	0	0	0	1,189	0	1,189	1,189	0	0	0	1,189	1,189
Cellulase	0	0	0	0	802	802	802	0	802	802	0	0	7,822	8,625	8,625
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	22,314	200,825	0	0	0	22,314	22,314	0	22,314	223,139	0	0	0	223,139	223,139

Table D5 Stream table of the bioethanol process from rice straw for alternative 4 design (continue)

Stream Name	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
Stream Phase	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid	Solid	Liquid	Liquid	Vapor	Liquid	Vapor	Liquid	Liquid
Temperature (°C)	40	40	40	40	40	40	40	40	40	100	100	100	94	117	93
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4.76	4.76	4.76	4.76	1.77	1.77	1.77
Total Std Liq Rate (L/day)	7,795	n/a	9,778	n/a	89,557	n/a	3,309,884	n/a	3,309,884	3,309,884	91,293	3,218,591	228,070	2,990,521	209,405
Total Mass Rate (kg/day)	12,023	3,960,522	12,023	3,972,545	74,057	3,898,488	3,429,522	468,966	3,429,522	3,429,522	75,023	3,354,499	186,858	3,167,641	168,412
Total Molar Rate (kmol/day)	76	174,548	133	174,681	1,771	172,911	157,037	15,873	157,037	157,037	1,785	155,252	4,995	150,257	4,000
Total Solid Mass Rate (kg/day)	n/a	468,966	n/a	468,966	n/a	468,966	n/a	468,966	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	0.18	17.36	0.05	17.41	0.64	16.76	26.92	-10.16	27.02	58.40	0.98	57.43	10.14	63.80	1.81
Component	**Mass Flow (kg/day)**														
Cellulose	0	34,419	0	34,419	0	34,419	0	34,419	0	0	0	0	0	0	0
Hemicellulose	0	27,036	0	27,036	0	27,036	0	27,036	0	0	0	0	0	0	0
Galactan	0	1,129	0	1,129	0	1,129	0	1,129	0	0	0	0	0	0	0
Mannan	0	5,081	0	5,081	0	5,081	0	5,081	0	0	0	0	0	0	0
Arabinan	0	10,031	0	10,031	0	10,031	0	10,031	0	0	0	0	0	0	0
Lignin	0	153,111	0	153,111	0	153,111	0	153,111	0	0	0	0	0	0	0
Glucose	2,629	394,781	0	394,781	0	394,781	394,781	0	394,781	394,781	0	394,781	0	394,781	0
Mannose	559	18,077	0	18,077	0	18,077	18,077	0	18,077	18,077	0	18,077	0	18,077	0
Galactose	124	4,017	0	4,017	0	4,017	4,017	0	4,017	4,017	0	4,017	0	4,017	0
Xylose	7,567	13,946	0	13,946	0	13,946	13,946	0	13,946	13,946	0	13,946	0	13,946	0
Arabinose	1,144	36,975	0	36,975	0	36,975	36,975	0	36,975	36,975	0	36,975	0	36,975	0
Cellobiose	0	4,954	0	4,954	0	4,954	4,954	0	4,954	4,954	0	4,954	0	4,954	0
Ethanol	0	162,730	0	162,730	1,292	161,438	161,438	0	161,438	161,438	484	160,954	159,016	1,937	158,221
Water	0	2,667,291	0	2,667,291	2,197	2,665,094	2,665,094	0	2,665,094	2,665,094	2,399	2,662,696	27,801	2,634,895	10,191
Sulfuric Acid	0	3,812	0	3,812	0	3,812	3,812	0	3,812	3,812	0	3,812	0	3,812	0
Furfural	0	917	0	917	3	914	914	0	914	914	5	908	29	879	0
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	2,210	0	2,210	2,003	207	207	0	207	207	207	0	0	0	0
Carbon Dioxide	0	140,457	0	140,457	68,546	71,911	71,911	0	71,911	71,911	71,911	0	0	0	0
Glycerol	0	1,278	0	1,278	0	1,278	1,278	0	1,278	1,278	0	1,278	0	1,278	0
Succinic Acid	0	4,146	0	4,146	0	4,146	4,146	0	4,146	4,146	0	4,146	0	4,146	0
Lactic Acid	0	1,368	12,023	13,390	0	13,390	13,390	0	13,390	13,390	0	13,390	0	13,390	0
HMF	0	248	0	248	0	248	248	0	248	248	1	247	0	247	0
Xylitol	0	13,333	0	13,333	0	13,333	13,333	0	13,333	13,333	0	13,333	0	13,333	0
Acetic Acid	0	5,447	0	5,447	8	5,439	5,439	0	5,439	5,439	2	5,437	8	5,429	0
Corn Steep Liquor	0	15,567	0	15,567	8	15,559	15,559	0	15,559	15,559	13	15,546	3	15,543	0
ZM	0	6,396	0	6,396	0	6,396	0	6,396	0	0	0	0	0	0	0
Cellulase	0	8,625	0	8,625	0	8,625	0	8,625	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	223,139	0	223,139	0	223,139	0	223,139	0	0	0	0	0	0	0

Table D5 Stream table of the bioethanol process from rice straw for alternative 4 design (continue)

Stream Name	S61	S62	S63	S64	S65	S66	S67	S68	S69	S70	S71
Stream Phase	Liquid	Vapor	Vapor	Vapor	Liquid	Mixed	Liquid	Liquid	Liquid	Liquid	Liquid
Temperature (°C)	112	100	100	100	40	117	54	55	55	55	55
Pressure (atm)	1.77	1.77	1.00	1.00	1.00	1.77	1.77	21.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	18,665	209,405	200,000	9,405	200,000	3,009,186	3,009,195	3,009,195	2,114,491	894,704	105,725
Total Mass Rate (kg/day)	18,446	168,412	159,016	9,396	159,016	3,186,087	3,186,097	3,186,097	2,119,698	1,066,399	105,985
Total Molar Rate (kmol/day)	995	4,000	3,479	522	3,479	151,252	151,253	151,253	116,525	34,728	5,826
Total Solid Mass Rate (kg/day)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	0.35	8.20	7.14	1.05	0.64	64.15	32.77	33.22	20.45	12.76	1.02
Component	**Mass Flow (kg/day)**										
Cellulose	0	0	0	0	0	0	0	0	0	0	0
Hemicellulose	0	0	0	0	0	0	0	0	0	0	0
Galactan	0	0	0	0	0	0	0	0	0	0	0
Mannan	0	0	0	0	0	0	0	0	0	0	0
Arabinan	0	0	0	0	0	0	0	0	0	0	0
Lignin	0	0	0	0	0	0	0	0	0	0	0
Glucose	0	0	0	0	0	394,781	394,783	394,783	15,791	378,992	790
Mannose	0	0	0	0	0	18,077	18,077	18,077	904	17,173	45
Galactose	0	0	0	0	0	4,017	4,017	4,017	201	3,816	10
Xylose	0	0	0	0	0	13,946	13,946	13,946	697	13,249	35
Arabinose	0	0	0	0	0	36,975	36,976	36,976	1,849	35,127	92
Cellobiose	0	0	0	0	0	4,954	4,954	4,954	248	4,706	12
Ethanol	795	158,221	158,221	0	158,221	2,732	2,732	2,732	1,366	1,366	68
Water	17,611	10,191	795	9,396	795	2,652,505	2,652,513	2,652,513	2,095,485	557,028	104,774
Sulfuric Acid	0	0	0	0	0	3,812	3,812	3,812	191	3,621	10
Furfural	29	0	0	0	0	908	910	910	273	637	14
Ammonia	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	1,278	1,279	1,279	64	1,215	3
Succinic Acid	0	0	0	0	0	4,146	4,146	4,146	207	3,939	10
Lactic Acid	0	0	0	0	0	13,390	13,390	13,390	670	12,721	33
HMF	0	0	0	0	0	247	247	247	37	210	2
Xylitol	0	0	0	0	0	13,333	13,333	13,333	667	12,667	33
Acetic Acid	8	0	0	0	0	5,437	5,437	5,437	272	5,166	14
Corn Steep Liquor	3	0	0	0	0	15,546	15,546	15,546	777	14,768	39
ZM	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0

D.2.6 Alternative 5 Design

Table D6 Stream table of the bioethanol process from rice straw for alternative 5 design

Stream Name	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Stream Phase	Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid	Mixed
Temperature (°C)	30	160	100	30	30	30	268	180	180	101	101	101	101	30	70
Pressure (atm)	1.00	6.00	1.00	1.00	1.00	1.00	13.00	10.00	10.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq Rate (L/day)	n/a	114,448	n/a	683,020	7,428	690,448	398,219	n/a	n/a	313,546	1,292,206	n/a	n/a	1,344,259	n/a
Total Mass Rate (kg/day)	1,420,253	114,336	1,534,588	682,346	13,650	695,996	397,826	2,628,410	2,628,410	313,396	1,448,559	866,455	2,315,014	1,342,933	1,966,352
Total Molar Rate (kmol/day)	30,676	6,347	37,023	37,876	139	38,015	22,083	97,121	94,409	17,346	58,624	18,439	77,063	74,544	93,678
Total Solid Mass Rate (kg/day)	1,249,795	n/a	1,249,795	n/a	n/a	n/a	n/a	1,249,795	866,455	n/a	n/a	866,455	866,455	n/a	3,105
Total Enthalpy (GJ/day)	-68.77	13.16	-55.61	3.58	0.02	3.61	46.13	-5.87	27.58	34.98	25.59	-32.99	-7.40	7.05	25.08
Component	**Mass Flow (kg/day)**														
Cellulose	493,669	0	493,669	0	0	0	0	493,669	424,525	0	0	424,525	424,525	0	2,123
Hemicellulose	287,453	0	287,453	0	0	0	0	287,453	28,611	0	0	28,611	28,611	0	143
Galactan	4,999	0	4,999	0	0	0	0	4,999	1,195	0	0	1,195	1,195	0	6
Mannan	22,496	0	22,496	0	0	0	0	22,496	5,377	0	0	5,377	5,377	0	27
Arabinan	44,993	0	44,993	0	0	0	0	44,993	10,562	0	0	10,562	10,562	0	0
Lignin	161,224	0	161,224	0	0	0	0	161,224	161,224	0	0	161,224	161,224	0	806
Glucose	0	0	0	0	0	0	0	0	73,502	0	73,502	0	73,502	0	51,694
Mannose	0	0	0	0	0	0	0	0	18,747	0	18,747	0	18,747	0	13,183
Galactose	0	0	0	0	0	0	0	0	4,166	0	4,166	0	4,166	0	2,930
Xylose	0	0	0	0	0	0	0	0	292,024	0	292,024	0	292,024	0	205,381
Arabinose	0	0	0	0	0	0	0	0	38,346	0	38,346	0	38,346	0	26,965
Cellobiose	0	0	0	0	0	0	0	0	3,159	0	3,159	0	3,159	0	2,224
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	170,458	114,336	284,793	682,346	0	682,346	397,826	1,364,965	1,316,276	312,278	1,003,998	0	1,003,998	1,342,933	1,650,597
Sulfuric Acid	0	0	0	0	13,650	13,650	0	13,650	13,650	0	13,650	0	13,650	0	9,594
Furfural	0	0	0	0	0	0	0	0	1,851	1,108	743	0	743	0	522
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	0	0	0	0	0	0	0	0	235	10	225	0	225	0	159
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	234,961	0	234,961	0	0	0	0	234,961	234,961	0	0	234,961	234,961	0	0
Nitrogen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D6 Stream table of the bioethanol process from rice straw for alternative 5 design (continue)

Stream Name	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
Stream Phase	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature (°C)	70	50	30	50	30	50	50	30	50	50	50	50	59	59	59
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	3,735	n/a	n/a	n/a	n/a	3,839	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Mass Rate (kg/day)	1,691,595	1,966,352	6,864	1,973,216	17,762	1,990,978	1,990,978	7,054	1,998,031	1,998,031	35,536	1,962,495	3,654,090	365,409	3,288,681
Total Molar Rate (kmol/day)	57,929	93,678	70	93,748	240	93,988	94,155	72	94,227	94,299	258	94,041	151,971	15,197	136,773
Total Solid Mass Rate (kg/day)	863,350	3,105	n/a	3,105	17,762	20,866	31,278	n/a	31,278	35,741	34,935	806	864,156	86,416	777,740
Total Enthalpy (GJ/day)	-25.43	18.92	0.01	18.93	-1.98	16.95	18.30	0.01	18.31	18.89	-0.20	19.09	-6.34	-0.63	-5.70
Component	**Mass Flow (kg/day)**														
Cellulose	422,402	2,123	0	2,123	0	2,123	2,123	0	2,123	2,123	2,123	0	422,402	42,240	380,162
Hemicellulose	28,468	143	0	143	0	143	143	0	143	143	143	0	28,468	2,847	25,621
Galactan	1,189	6	0	6	0	6	6	0	6	6	6	0	1,189	119	1,070
Mannan	5,350	27	0	27	0	27	27	0	27	27	27	0	5,350	535	4,815
Arabinan	10,562	0	0	0	0	0	0	0	0	0	0	0	10,562	1,056	9,506
Lignin	160,417	806	0	806	0	806	806	0	806	806	0	806	161,224	16,122	145,101
Glucose	21,808	51,694	0	51,694	0	51,694	51,694	0	51,694	51,694	103	51,591	73,399	7,340	66,059
Mannose	5,564	13,183	0	13,183	0	13,183	13,183	0	13,183	13,183	26	13,157	18,721	1,872	16,849
Galactose	1,236	2,930	0	2,930	0	2,930	2,930	0	2,930	2,930	6	2,924	4,160	416	3,744
Xylose	86,644	205,381	0	205,381	0	205,381	205,381	0	205,381	205,381	411	204,970	291,613	29,161	262,452
Arabinose	11,381	26,965	0	26,965	0	26,965	26,965	0	26,965	26,965	54	26,911	38,292	3,829	34,463
Cellobiose	935	2,224	0	2,224	0	2,224	2,224	0	2,224	2,224	0	2,224	3,159	316	2,843
Ethanol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	696,334	1,650,597	0	1,650,597	0	1,650,597	1,656,643	0	1,656,643	1,659,234	0	1,659,234	2,355,568	235,557	2,120,012
Sulfuric Acid	4,055	9,594	6,864	16,458	0	16,458	0	7,054	7,054	0	0	0	4,055	406	3,650
Furfural	221	522	0	522	0	522	522	0	522	522	1	521	742	74	668
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	67	159	0	159	0	159	159	0	159	159	0	158	225	23	203
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellulase	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	17,762	17,762	5,329	0	5,329	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	22,845	0	22,845	32,636	32,636	0	0	0	0
Ash	234,961	0	0	0	0	0	0	0	0	0	0	0	234,961	23,496	211,465
Nitrogen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D6 Stream table of the bioethanol process from rice straw for alternative 5 design (continue)

Stream Name	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45	S46
Stream Phase	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Liquid
Temperature (°C)	41	42	30	30	30	40	40	40	40	41	30	30	30	40	40	40
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total Std. Liq. Rate (L/day)	n/a	n/a	269	6,218	42,750	n/a	n/a	18,687	n/a	n/a	1,178	9,145	417,424	n/a	n/a	7,865
Total Mass Rate (kg/day)	365,409	3,288,681	166	6,212	42,990	414,777	414,777	15,334	399,443	3,688,124	726	9,136	419,764	4,117,748	4,105,623	12,125
Total Molar Rate (kmol/day)	15,197	136,773	10	345	2,376	17,928	18,388	354	18,033	154,807	43	507	23,204	178,560	178,483	77
Total Solid Mass Rate (kg/day)	86,416	777,740	n/a	n/a	845	87,260	77,898	n/a	77,898	855,638	n/a	n/a	8,237	863,875	863,875	n/a
Total Enthalpy (GJ/day)	-1.56	-13.99	0.01	0.03	0.18	-1.33	-0.76	0.13	-0.89	-14.88	0.04	0.05	1.79	-13.01	-13.19	0.18
Component	**Mass Flow (kg/day)**															
Cellulose	42,240	380,162	0	0	0	42,240	31,680	0	31,680	411,842	0	0	0	411,842	411,842	0
Hemicellulose	2,847	25,621	0	0	0	2,847	2,847	0	2,847	28,468	0	0	0	28,468	28,468	0
Galactan	119	1,070	0	0	0	119	119	0	119	1,189	0	0	0	1,189	1,189	0
Mannan	535	4,815	0	0	0	535	535	0	535	5,350	0	0	0	5,350	5,350	0
Arabinan	1,056	9,506	0	0	0	1,056	1,056	0	1,056	10,562	0	0	0	10,562	10,562	0
Lignin	16,122	145,101	0	0	0	16,122	16,122	0	16,122	161,224	0	0	0	161,224	161,224	0
Glucose	7,340	66,059	0	0	0	7,340	11,976	0	11,976	78,034	0	0	0	78,034	75,693	2,341
Mannose	1,872	16,849	0	0	0	1,872	1,872	0	1,872	18,721	0	0	0	18,721	18,159	562
Galactose	416	3,744	0	0	0	416	416	0	416	4,160	0	0	0	4,160	4,035	125
Xylose	29,161	262,452	0	0	0	29,161	2,508	0	2,508	264,960	0	0	0	264,960	257,011	7,949
Arabinose	3,829	34,463	0	0	0	3,829	3,829	0	3,829	38,292	0	0	0	38,292	37,143	1,149
Cellobiose	316	2,843	0	0	0	316	316	0	316	3,159	0	0	0	3,159	3,159	0
Ethanol	0	0	0	0	0	0	15,310	1,148	14,161	14,161	0	0	0	14,161	14,161	0
Water	235,557	2,120,012	0	0	42,145	277,702	276,695	138	276,557	2,396,568	0	0	411,527	2,808,095	2,808,095	0
Sulfuric Acid	406	3,650	0	0	0	406	406	0	406	4,055	0	0	0	4,055	4,055	0
Furfural	74	668	0	0	0	74	74	0	74	742	0	0	0	742	742	0
Ammonia	0	0	166	0	0	166	0	0	0	0	726	0	0	726	726	0
Oxygen	0	0	0	0	0	0	296	296	0	0	0	0	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	14,475	13,752	724	724	0	0	0	724	724	0
Glycerol	0	0	0	0	0	0	119	0	119	119	0	0	0	119	119	0
Succinic Acid	0	0	0	0	0	0	402	0	402	402	0	0	0	402	402	0
Lactic Acid	0	0	0	0	0	0	73	0	73	73	0	0	0	73	73	0
HMF	23	203	0	0	0	23	23	0	23	225	0	0	0	225	225	0
Xylitol	0	0	0	0	0	0	1,359	0	1,359	1,359	0	0	0	1,359	1,359	0
Acetic Acid	0	0	0	0	0	0	518	0	518	518	0	0	0	518	518	0
Corn Steep Liquor	0	0	0	6,212	0	6,212	6,212	0	6,212	6,212	0	9,136	0	15,348	15,348	0
ZM	0	0	0	0	0	0	1,197	0	1,197	1,197	0	0	0	1,197	1,197	0
Cellulase	0	0	0	0	845	845	845	0	845	845	0	0	8,237	9,082	9,082	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	23,496	211,465	0	0	0	23,496	23,496	0	23,496	234,961	0	0	0	234,961	234,961	0
Nitrogen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D6 Stream table of the bioethanol process from rice straw for alternative 5 design (continue)

Stream Name	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60	S61	S62
Stream Phase	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid	Solid	Liquid	Liquid	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Vapor
Temperature (°C)	40	40	40	40	40	40	40	40	100	100	100	94	117	93	112	100
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4.76	4.76	4.76	4.76	1.77	1.77	1.77	1.77	1.77
Total Std. Liq. Rate (L/day)	n/a	9,861	n/a	87,578	n/a	n/a	n/a	n/a	n/a	94,249	n/a	228,415	3,102,314	209,415	19,000	209,415
Total Mass Rate (kg/day)	4,105,624	12,125	4,117,749	72,451	4,045,299	3,551,777	493,522	3,551,777	3,551,777	77,457	3,474,320	187,203	3,287,117	168,422	18,781	168,422
Total Molar Rate (kmol/day)	180,993	135	181,128	1,733	179,395	162,692	16,702	162,692	162,692	1,843	160,849	5,015	155,834	4,001	1,014	4,001
Total Solid Mass Rate (kg/day)	493,522	n/a	493,522	n/a	493,522	n/a	493,522	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	17.84	0.05	17.89	0.63	17.27	27.95	-10.68	28.05	60.54	1.01	59.53	10.18	66.22	1.81	0.36	8.20
Component	**Mass Flow (kg/day)**															
Cellulose	36,242	0	36,242	0	36,242	0	36,242	0	0	0	0	0	0	0	0	0
Hemicellulose	28,468	0	28,468	0	28,468	0	28,468	0	0	0	0	0	0	0	0	0
Galactan	1,189	0	1,189	0	1,189	0	1,189	0	0	0	0	0	0	0	0	0
Mannan	5,350	0	5,350	0	5,350	0	5,350	0	0	0	0	0	0	0	0	0
Arabinan	10,562	0	10,562	0	10,562	0	10,562	0	0	0	0	0	0	0	0	0
Lignin	161,224	0	161,224	0	161,224	0	161,224	0	0	0	0	0	0	0	0	0
Glucose	415,395	0	415,395	0	415,395	415,395	0	415,395	415,395	0	415,395	0	415,395	0	0	0
Mannose	18,159	0	18,159	0	18,159	18,159	0	18,159	18,159	0	18,159	0	18,159	0	0	0
Galactose	4,035	0	4,035	0	4,035	4,035	0	4,035	4,035	0	4,035	0	4,035	0	0	0
Xylose	14,650	0	14,650	0	14,650	14,650	0	14,650	14,650	0	14,650	0	14,650	0	0	0
Arabinose	37,143	0	37,143	0	37,143	37,143	0	37,143	37,143	0	37,143	0	37,143	0	0	0
Cellobiose	5,217	0	5,217	0	5,217	5,217	0	5,217	5,217	0	5,217	0	5,217	0	0	0
Ethanol	162,663	0	162,663	1,226	161,437	161,437	0	161,437	161,437	484	160,953	159,016	1,937	158,221	795	158,221
Water	2,766,373	0	2,766,373	2,153	2,764,221	2,764,221	0	2,764,221	2,764,221	2,488	2,761,733	28,149	2,733,584	10,201	17,948	10,201
Sulfuric Acid	4,055	0	4,055	0	4,055	4,055	0	4,055	4,055	0	4,055	0	4,055	0	0	0
Furfural	742	0	742	2	740	740	0	740	740	4	735	27	709	0	27	0
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	2,283	0	2,283	2,058	225	225	0	225	225	225	0	0	0	0	0	0
Carbon Dioxide	141,236	0	141,236	66,996	74,240	74,240	0	74,240	74,240	74,240	0	0	0	0	0	0
Glycerol	1,217	0	1,217	0	1,217	1,217	0	1,217	1,217	0	1,217	0	1,217	0	0	0
Succinic Acid	4,030	0	4,030	0	4,030	4,030	0	4,030	4,030	0	4,030	0	4,030	0	0	0
Lactic Acid	738	12,125	12,863	0	12,863	12,863	0	12,863	12,863	0	12,863	0	12,863	0	0	0
HMF	225	0	225	0	225	225	0	225	225	1	224	0	224	0	0	0
Xylitol	13,341	0	13,341	0	13,341	13,341	0	13,341	13,341	0	13,341	0	13,341	0	0	0
Acetic Acid	5,252	0	5,252	7	5,245	5,245	0	5,245	5,245	2	5,243	8	5,235	0	8	0
Corn Steep Liquor	15,348	0	15,348	8	15,340	15,340	0	15,340	15,340	13	15,327	3	15,324	0	3	0
ZM	6,444	0	6,444	0	6,444	0	6,444	0	0	0	0	0	0	0	0	0
Cellulase	9,082	0	9,082	0	9,082	0	9,082	0	0	0	0	0	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	234,961	0	234,961	0	234,961	0	234,961	0	0	0	0	0	0	0	0	0
Nitrogen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table D6 Stream table of the bioethanol process from rice straw for alternative 5 design (continue)

Stream Name	S63	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73	S74	S75	S76	S77
Stream Phase	Vapor	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Mixed	Mixed	Vapor	Mixed	Vapor	Vapor	Vapor	Vapor
Temperature (°C)	100	100	40	30	30	47	35	45	650	600	43	268	268	268	160
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.10	100.00	1.00	1.00	100.00	1.00	13.00	13.00	13.00	5.23
Total Std. Liq. Rate (L/day)	200,000	9,415	200,000	2,596,510	1,749,325	2,596,510	1,749,325	n/a	n/a	1,749,325	n/a	1,749,325	413,243	1,336,082	1,336,082
Total Mass Rate (kg/day)	159,017	9,405	159,017	2,251,222	1,747,600	2,251,222	1,747,600	2,744,744	2,744,740	1,747,600	2,744,740	1,747,600	412,836	1,334,764	1,334,764
Total Molar Rate (kmol/day)	3,479	522	3,479	78,031	97,007	78,031	97,007	94,733	99,577	97,007	99,577	97,007	22,916	74,091	74,091
Total Solid Mass Rate (kg/day)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	493,522	299,094	n/a	299,094	n/a	n/a	n/a	n/a
Total Enthalpy (GJ/day)	7.15	1.05	0.64	3.78	9.17	6.86	10.64	-3.82	206.88	193.03	24.49	202.66	47.87	154.78	153.68
Component	**Mass Flow (kg/day)**														
Cellulose	0	0	0	0	0	0	0	36,242	7,248	0	7,248	0	0	0	0
Hemicellulose	0	0	0	0	0	0	0	28,468	5,694	0	5,694	0	0	0	0
Galactan	0	0	0	0	0	0	0	1,189	238	0	238	0	0	0	0
Mannan	0	0	0	0	0	0	0	5,350	1,070	0	1,070	0	0	0	0
Arabinan	0	0	0	0	0	0	0	10,562	2,112	0	2,112	0	0	0	0
Lignin	0	0	0	0	0	0	0	161,224	32,245	0	32,245	0	0	0	0
Glucose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mannose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galactose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xylose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabinose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellobiose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ethanol	158,221	0	158,221	0	0	0	0	0	0	0	0	0	0	0	0
Water	796	9,405	796	0	1,747,600	0	1,747,600	0	167,879	1,747,600	167,879	1,747,600	412,836	1,334,764	1,334,764
Sulfuric Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Furfural	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen	0	0	0	524,348	0	524,348	0	524,348	104,868	0	104,868	0	0	0	0
Carbon Dioxide	0	0	0	0	0	0	0	0	446,025	0	446,025	0	0	0	0
Glycerol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Succinic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HMF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xylitol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acetic Acid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corn Steep Liquor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ZM	0	0	0	0	0	0	0	6,444	6,444	0	6,444	0	0	0	0
Cellulase	0	0	0	0	0	0	0	9,082	9,082	0	9,082	0	0	0	0
Lime	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$CASO_4$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	234,961	234,961	0	234,961	0	0	0	0
Nitrogen	0	0	0	1,726,874	0	1,726,874	0	1,726,874	1,726,874	0	1,726,874	0	0	0	0

Appendix E Economic Evaluation for Base Case Design

E.1 Price

E.1.1 Exchange Rate

1 Dollar US was equal to approximate 30 Baht (2011-2012).

E.1.2 Raw Material, Product and Utility Prices

Table E1.2.1 Raw material and product prices

Raw Material Price				
Raw Material	Price from Literature		Price from Calculation	
	Value	Unit	Value	Unit
Rice straw [1]	30	Baht/ton	0.001	$/kg
Water [2]	23.5	Baht/m^3	0.000783	$/kg
Sulfuric acid [3]	18	Baht/kg	0.6	$/kg
Lime [3]	12	Baht/kg	0.4	$/kg
Ammonia [4]	565	$/ton	0.565	$/kg
CLS [5]	800	$/ton	0.8	$/kg
Cellulase [5]	5	$/kg	5	$/kg
Product Price				
Product	Price from Literature		Price from Calculation	
	Value	Unit	Value	Unit
Ethanol [6]	27.17	Baht/L	1.14	$/kg

References: [1] Niracharopas, 2011
[2] Provincial Waterworks Authority (PWA)
[3] www.clickchemical.com
[4] www.icis.com
[5] www.alibaba.com
[6] EPPO

Table E1.2.2 Utility price

Cooling Water						
Cooling Water*	Price from Literature		Price from Calculation		Volume per Energy	
	Value	Unit	Value	Unit	Value	Unit
CW 30-45 °C**	2	Baht/m^3	1	$/GJ	15.97	m^3/GJ
CW 30-40 °C	2	Baht/m^3	1.6	$/GJ	24.00	m^3/GJ
CW 30-39 °C	2	Baht/m^3	1.778	$/GJ	26.67	m^3/GJ
CW 30-38 °C	2	Baht/m^3	2	$/GJ	30.00	m^3/GJ

Table E1.2.2 Utility price (continue)

Steam						
Steam	**Price from Literature**		**Price from Calculation**		**Mass per Energy**	
	Value	**Unit**	**Value**	**Unit**	**Value**	**Unit**
LP steam	0.73	Baht/kg	11.68	$/GJ	480.00	kg/GJ
HP steam	0.75	Baht/kg	14.77	$/GJ	590.60	kg/GJ
Electricity						
Electricity	**Price from Literature**		**Price from Calculation**		**Convert Factor**	
	Value	**Unit**	**Value**	**Unit**	**Value**	**Unit**
Electricity***	1.7	Baht/kWh	15.83	$/GJ	0.0036	GJ/kWh

* Assume that cooling water recycle 12 times in cooling tower.

** Temperature of cooling water (inlet – outlet) from heat exchanger.

*** Average value from EPPO

E.2 Raw Materials and Products Annual Price

Table E2.1 Raw materials annual price

Raw Material	Quantity (kg/year)	Annual Price	Cost per Ethanol ($/L)
Rice Straw	473,419,251	$473,419	0.0071
Sulfuric Acid	9,190,757	$5,514,454	0.0827
Lime	5,921,578	$2,368,631	0.0355
Ammonia	297,078	$167,849	0.0025
Corn Steep Liquor	5,116,615	$4,093,292	0.0614
Cellulase	3,027,252	$15,136,261	0.2270
Water	826,469,722	$647,126	0.0097
LP steam (Prehydrolysis)	38,111,864	$926,118	0.0139
HP steam (Prehydrolysis)	132,638,022	$3,315,951	0.0497
Total		**$29,897,785**	**0.4896**

Table E2.2 Products annual price

Product	Quantity (kg/year)	Annual Price
Ethanol	53,005,280	$60,426,019
Total		**$60,426,019**

E3 Annual Utility Cost for Base Case Design

Table E3.1 Annual cooling water cost for the base case design

Unit	Quantity (MJ/hr)	Price ($/GJ)	Utility Cost	Cost per Ethanol ($/L)
E1	6,163	1	$48,811	0.0007
E2	926	1	$7,334	0.0001
E3	8,291	1	$65,665	0.0010
E6	6,506	1	$51,528	0.0008
R2	1,437	1.6	$18,210	0.0003
R3	616	1.6	$7,802	0.0001
R4	597	1.78	$8,407	0.0001
R5	5,407	2	$85,647	0.0013
Condenser T1	26,051	1	$206,324	0.0031
Condenser T2	26,549	1	$210,268	0.0032
Total			**$709,995**	**0.0106**

Table E3.2 Annual LP steam cost for the base case design

Unit	Quantity (MJ/hr)	Price ($/GJ)	Utility Cost	Cost per Ethanol ($/L)
E4	32,499	11.68	$3,006,340	0.0451
E5	6,386	11.68	$590,741	0.0089
Reboiler T1	42,917	11.68	$3,970,063	0.0596
Reboiler T2	18,541	11.68	$1,715,146	0.0257
Total			**$9,282,290**	**0.1392**

Table E3.3 Annual HP steam cost for the base case design

Unit	Quantity (MJ/hr)	Price ($/GJ)	Utility Cost	Cost per Ethanol ($/L)
R1	5,595	14.77	$654,494	0.0098
Total			**$654,494**	**0.0098**

Table E3.4 Annual electricity cost for the base case design

Unit	Quantity (kW)	Price ($/kWh)	Utility Cost	Cost per Ethanol ($/L)
Feed Handling	270	0.057	$121,863	0.0018
P1	28	0.057	$12,787	0.0002
Cooling Tower	380	0.057	$171,511	0.0026
Total			**$306,161**	**0.0046**

Therefore, total annual utility cost for the base case design was **$10,952,940** and cost per ethanol production for the base case design was **0.1642 $/L**

E.4 Equipment Sizing and Purchase Cost for Base Case Design

Table E4.1 Mixer sizing and purchase cost for the base case design

Unit	Material	Capacity (m^3)	Purchase Cost
M1	CS	2.04	$16,307
M2	SS	4.82	$38,150
M3	SS	10.73	$59,160
M4	SS	7.56	$48,827
M5	SS	11.84	$62,440
M6	SS	11.84	$62,440
M7	SS	11.85	$62,469
M8	SS	16.9	$75,889
M9	SS	2.02	$23,684
M10	SS	17.22	$76,674
M11	SS	20.18	$83,639
Total			**$609,679**

Table E4.2 Pump sizing and purchase cost for the base case design

Unit	Type	Material	Efficiency	Flow Rate (m^3/h)	ΔP (atm)	Purchase Cost
P1	Centrifugal	SS	50 %	133.86	3.76	$21,237
Total						**$21,237**

Table E4.3 Flash sizing and purchase cost for the base case design

Unit	Type	Material	Liq. Rate (m^3/h)	Height (m)	Diameter (m)	Purchase Cost
F1	Vertical	316 SS	63.55	6.00	1.50	$162,230
Total						**$162,230**

Table E4.4 Heat exchanger sizing and purchase cost for the base case design

Unit	Type	Material	U Value ($kW/m^2/K$)	Area (m^2)	Purchase Cost
E1	Floating shell & tube	304 SS	1.4196	53.16	$41,753
E2	Floating shell & tube	304 SS	1.4196	14.36	$22,938
E3	Floating shell & tube	304 SS	1.4196	128.14	$75,150
E4	Floating shell & tube	304 SS	1.4196	73.78	$51,313
E5	Floating shell & tube	CS	1.4196	19.75	$8,540
E6	Floating shell & tube	CS	2.2713	30.14	$10,241
Total					**$209,935**

Table E4.5 Reactors sizing and purchase cost for the base case design

Unit	Type	Material	Capacity (m^3)	Height (m)	Dia. (m)	Purchase Cost
R1	Plug Flow	SS	2.58	5.00	0.81	$2,219,716
R2	Vertical	316 SS	71.46	10.00	3.02	$331,996
R3	Horizontal	316 SS	286.38	10.00	6.04	$716,021
R4-1	Vertical	316 SS	0.12	1.20	0.35	$19,994
R4-2	Vertical	316 SS	0.94	2.80	0.65	$48,416
R4-3	Vertical	316 SS	7.54	5.00	1.39	$115,518
R4-4	Horizontal	316 SS	60.31	5.00	3.92	$19,994
R4-5	Horizontal	316 SS	482.46	10.00	7.84	$102,455
R5 (17 vessels)	Horizontal	316 SS	1,984.88 (each)	14.00 (each)	13.44 (each)	$1,664,699
Total						**$5,238,809**

* SSCF Seed Fermenter (R4) has 5 vessels. It is more precisely for economic analysis if we calculate them individual.

**SSCF Fermenter (R5 and R6) has 17 vessels which separate to three continuous trains. The table shows sizing of each of vessel. So, the total capacity of SSCF fermenter is 33,743 m^3.

Table E4.6 Tower unit sizing and purchase cost for the base case design

Unit	Detail	Quantity
T1	**Tower**	
	Material	316 SS
	Height (m)	24.9
	Diameter (m)	1.83
	Purchase Cost	$437,706
	Tray	
	Type	Valve
	Material	SS
	No. of Trays	32
	Diameter (mm)	47.63
	Purchase Cost	$40,930
	Vessel	
	Type	Horizontal
	Material	316 SS
	Length (m)	4.69
	Diameter (m)	1.17
	Purchase Cost	$53,315
	Condenser	
	Type	Fixed tube
	Material	316 SS
	Area (m^2)	88.91
	Purchase Cost	$30,411
	Reboiler	
	Type	Floating shell & tube
	Material	316 SS
	Area (m^2)	112.51
	Purchase Cost	$68,493
	Total Purchase Cost of T1	**$630,855**
T2	**Tower**	
	Material	316 SS
	Height (m)	41.97
	Diameter (m)	1.68
	Purchase Cost	$424,449

Table E4.6 Tower unit sizing and purchase cost for the base case design (continue)

Unit	Detail	Quantity
T2	**Tray**	
	Type	Valve
	Material	SS
	No. of Trays	60
	Diameter (mm)	47.63
	Purchase Cost	$76,744
	Vessel	
	Type	Horizontal
	Material	316 SS
	Length (m)	4.71
	Diameter (m)	1.18
	Purchase Cost	$53,845
	Condenser	
	Type	Fixed tube
	Material	316 SS
	Area (m^2)	93.66
	Purchase Cost	$31,707
	Reboiler	
	Type	Floating shell & tube
	Material	316 SS
	Area (m^2)	39.04
	Purchase Cost	$35,034
	Total Purchase Cost of T2	**$621,779**
Total Tower Cost		**$1,252,634**

Table E4.7 Additional unit purchase cost for the base case design (Wooley *et al.*, 1999)

Unit	Equipment	Purchase Cost
-	Feed Handling Unit	$856,000
SC1	Solid/Liquid Filter	$320,000
SC2	Gypsum Filter	$30,120
SC3	Seed Hold Tank	$33,000
SC6	Molecular Sieve	$475,000
Total		**$1,714,120**

Table E4.8 Utility unit sizing and purchase cost for the base case design

Equipment	Capacity (m^3/h)	Purchase Cost
Cooling Tower	1,416.9	$1,019,412
Total		**$1,019,412**

Table E4.9 Storage unit sizing and purchase cost for the base case design

Equipment	Type	Mat.	Capacity (m^3)	Height (m)	Dia. (m)	Purchase Cost
H_2SO_4 Storage	Cone Roof Tank	SS	151.18	14.55	3.64	$66,103
NH_3 Storage	Cone Roof Tank	SS	12.60	6.35	1.59	$50,485
CLS Storage	Cone Roof Tank	CS	154.55	14.66	3.66	$44,707
Ethanol Storage	Floating Roof Tank	CS	2,879.47	38.86	9.71	$497,173
Total						**$658,468**

Therefore, Total Purchase Equipment Cost for the base case design was **$10,886,524**

E.5 Capital Cost Analysis for Base Case Design

Table E5.1 Breakdown of capital cost for the base case design

Description	%	Result
I. Direct costs (65-85 % of Fixed-capital investment)		
Purchased Equipment Delivered (15-40 % of fixed-capital investment)	19.8	$11,975,176
Purchased Equipment Installation (6-14 % of fixed-capital investment)	9.3	$5,628,333
Instrumentation and Controls (installed) (2-12 % of fixed-capital investment)	7.1	$4,311,063
Piping (Installed) (4-17 % of fixed-capital investment)	13.5	$8,143,120
Electrical Systems (Installed) (2-10 % of fixed-capital investment)	2.2	$1,317,269
Buildings (Including Services) (2-18 % of fixed-capital investment)	3.6	$2,155,532
Yard Improvement (2-5 % of fixed-capital investment)	2.0	$1,197,518
Service Facilities (Installed) (8-30 % of fixed-capital investment)	13.9	$8,382,623
Land Cost (1-2 % of fixed-capital investment)	1.0	$603,549
Total Direct Cost		**$43,714,182**

Table E5.1 Breakdown of capital cost for the base case design (continue)

Description	%	Result
II. Indirect costs (15-35 % of Fixed-capital investment)		
Engineering and Supervision (4-20 % of fixed-capital investment)	6.5	$3,951,808
Construction Expenses (4-17 % of fixed-capital investment)	8.1	$4,909,822
Legal Expenses (0.5-3 % of fixed-capital investment)	0.8	$479,007
Contractor's Fees (2-6 % of fixed-capital investment)	4.4	$2,634,539
Contingency (5-15 % of fixed-capital investment)	8.7	$5,269,077
Total Indirect Cost		**$22,450,409**
III. Fixed-capital Investment (FCI) = Direct cost + Indirect cost		$60,354,887
IV. Working capital Investments (WC) (5-20 % of Total capital investment)	5.0	$3,179,409
V. Total Capital Investment (TCI) = Fixed-capital investment + Working capital		**$63,534,296**

E.6 Operating Cost Analysis for Base Case

Table E6.1 Breakdown of operating cost for the base case design

Items of Operating Cost	% of Basis	Basis	Cost, $/year
I. Variable Cost			
Raw Material	-	-	$32,643,101
Utilities	-	-	$10,952,939
Waste Treatment	-	-	$6,506,293
Operating Labor	2.0 %	Fixed Capital Investment	$1,207,098
Operating Supervision	40.0 %	Operating Labor	$482,839
Maintenance and Repairs	1.0 %	Fixed Capital Investment	$603,549
Operating Supplies	0.75 %	Fixed Capital Investment	$452,662
Laboratory Charges	15.0 %	Operating Labor	$181,065
Royalties	1.0 %	Total Product Cost	$619,552
Total Variable Cost			**$53,649,098**
II. Fixed Charges			
Property Taxes	1.0 %	Fixed Capital Investment	$603,549
Insurance	0.75 %	Fixed Capital Investment	$452,662
Total Fixed Charges			**$1,056,211**

Table E6.1 Breakdown of operating cost for the base case design (continue)

Items of Operating Cost	% of Basis	Basis	Cost, $/year
III. Manufacturing Cost			
Plant Overhead	60.0 %	Labor + Supervision + Maintenance	$1,376,091
		Total Manufacturing Cost	**$56,081,400**
IV. General Expense			
Administration	40.0 %	Labor + Supervision + Maintenance	$917,394
Distribution & selling	4.0 %	Total Product Cost	$2,478,208
Research & Development	4.0 %	Total Product Cost	$2,478,208
		General Expense	**$5,873,811**
V. Total Product Cost with Out Depreciation			**$61,955,212**

Appendix F System Boundary and Environmental Impact Results of New Design Alternatives

F.1 Alternative 1

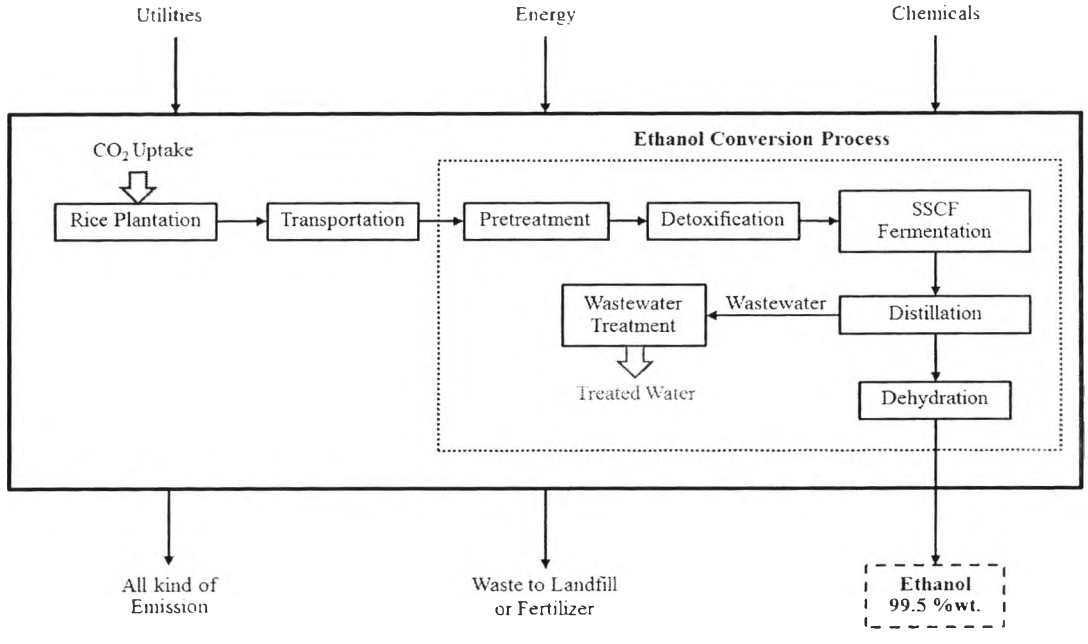

Figure F1.1 System boundary of alternative 1 design.

Table F1.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 1 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.65E-02
Global warming (GWP100)	kg CO_2 eq	6.42E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.66E-07
Human toxicity	kg 1,4-DB eq	1.50E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.24E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.85E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	4.33E-02
Photochemical oxidation	kg C_2H_4	8.34E-03
Acidification	kg SO_2 eq	2.37E-02
Eutrophication	kg PO_4 eq	1.25E-02

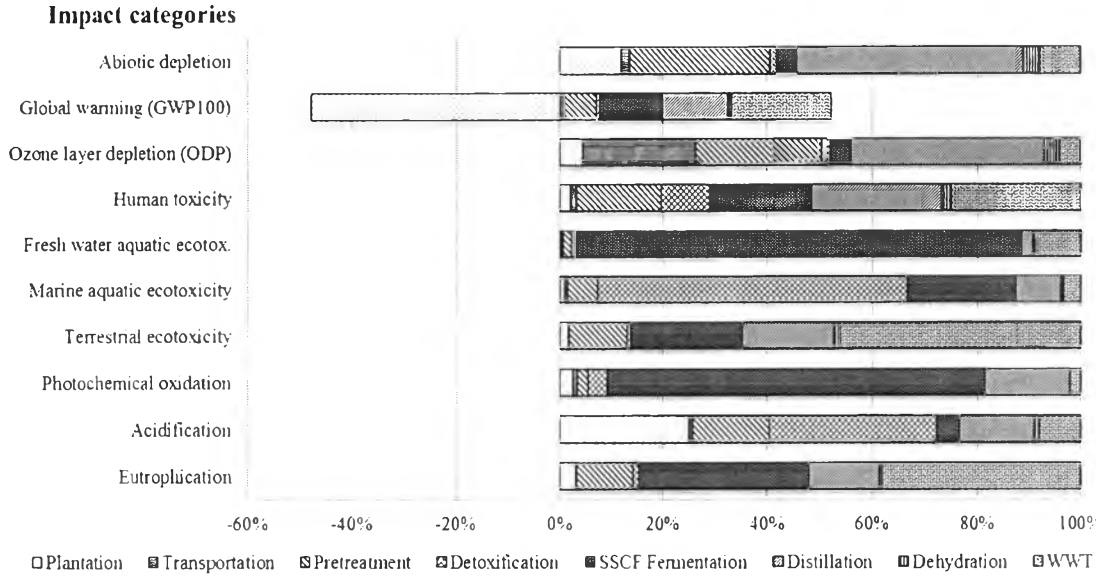

Figure F1.2 Distribution of environmental impacts classified stage by stage of alternative 1 design.

F.2 Alternative 2

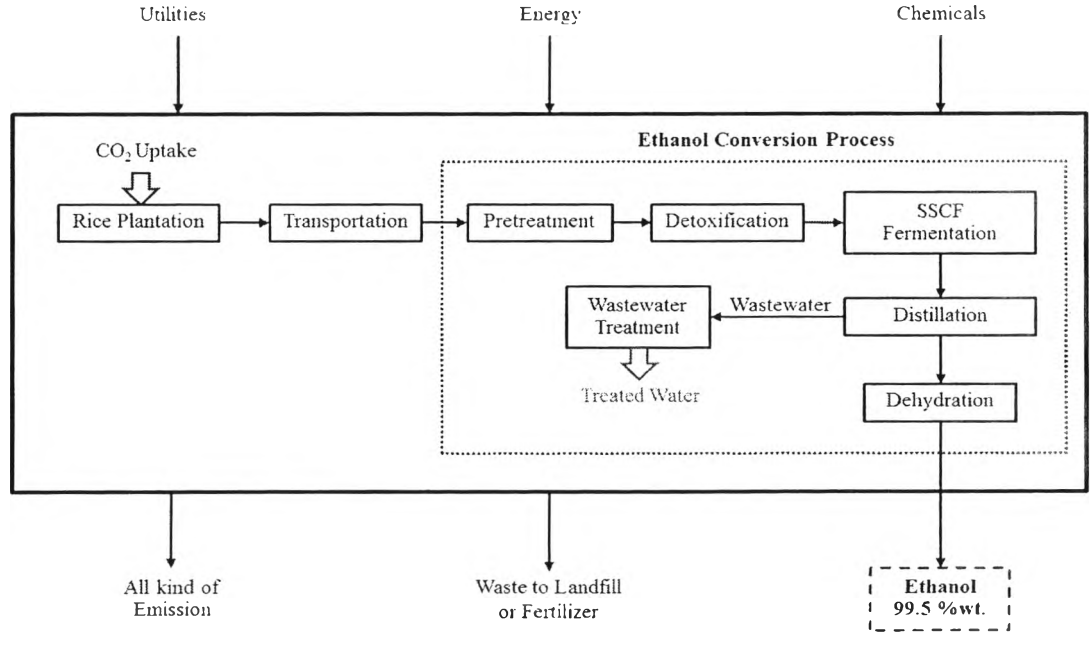

Figure F2.1 System boundary of alternative 2 design.

Table F2.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 2 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.38E-02
Global warming (GWP100)	kg CO_2 eq	3.10E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.25E-07
Human toxicity	kg 1,4-DB eq	1.41E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.24E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.79E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	4.15E-02
Photochemical oxidation	kg C_2H_4	8.30E-03
Acidification	kg SO_2 eq	2.29E-02
Eutrophication	kg PO_4 eq	1.28E-02

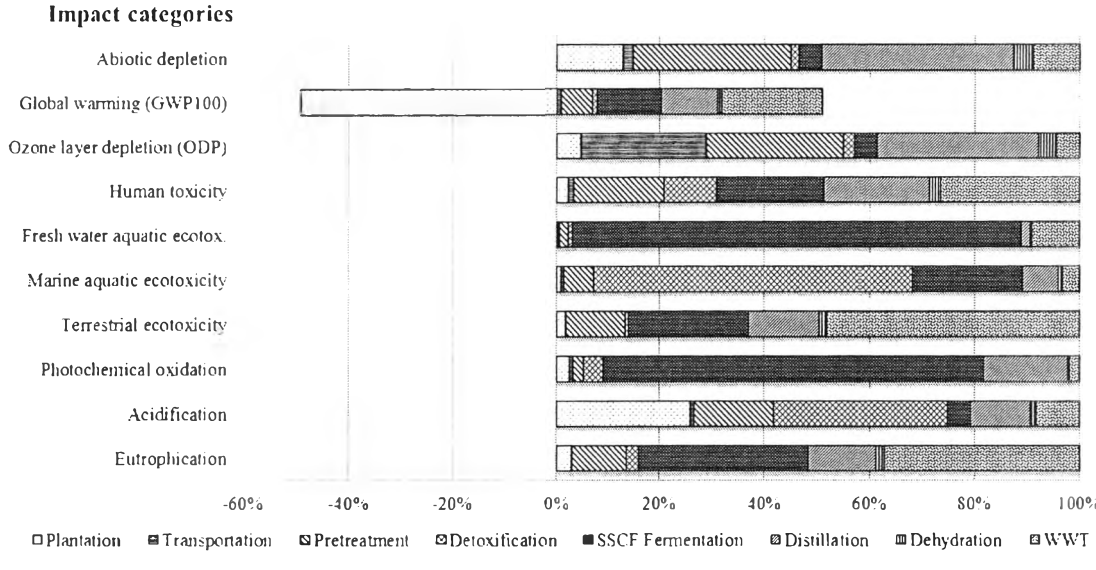

Figure F2.2 Distribution of environmental impacts classified stage by stage of alternative 2 design.

F.3 Alternative 3

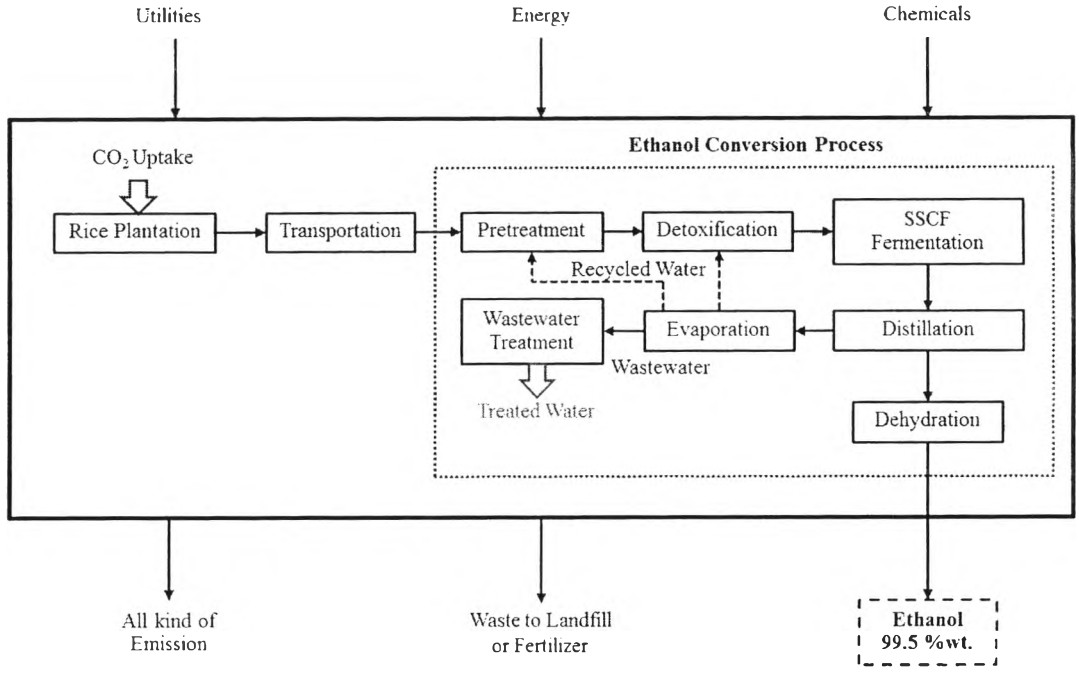

Figure F3.1 System boundary of alternative 3 design.

Table F3.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 3 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.49E-02
Global warming (GWP100)	kg CO_2 eq	5.10E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.01E-07
Human toxicity	kg 1,4-DB eq	1.31E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.16E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.54E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.85E-02
Photochemical oxidation	kg C_2H_4	9.37E-03
Acidification	kg SO_2 eq	2.18E-02
Eutrophication	kg PO_4 eq	1.22E-02

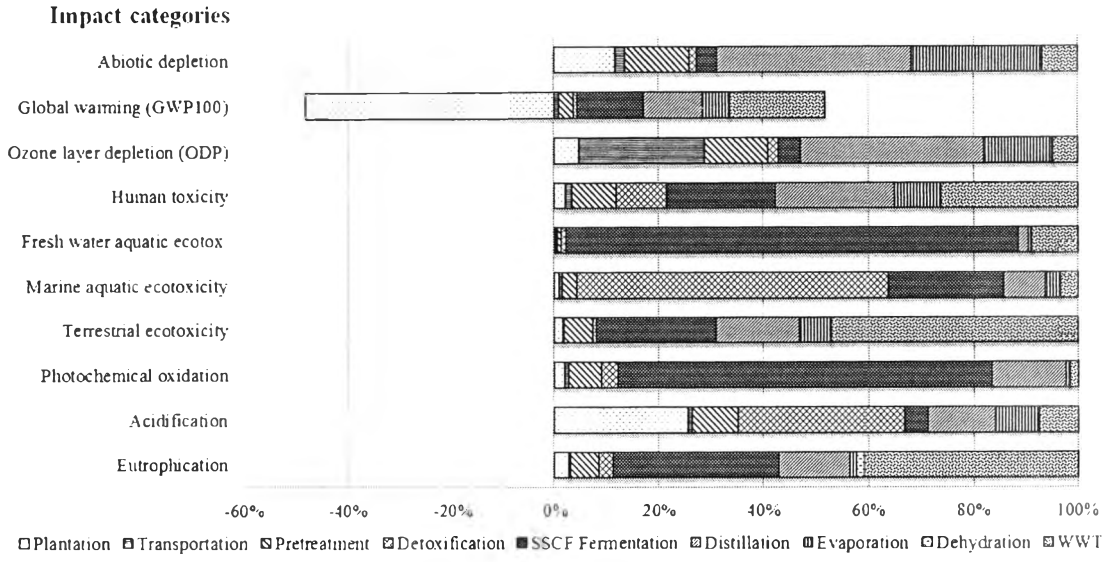

Figure F3.2 Distribution of environmental impacts classified stage by stage of alternative 3 design.

F.4 Alternative 4

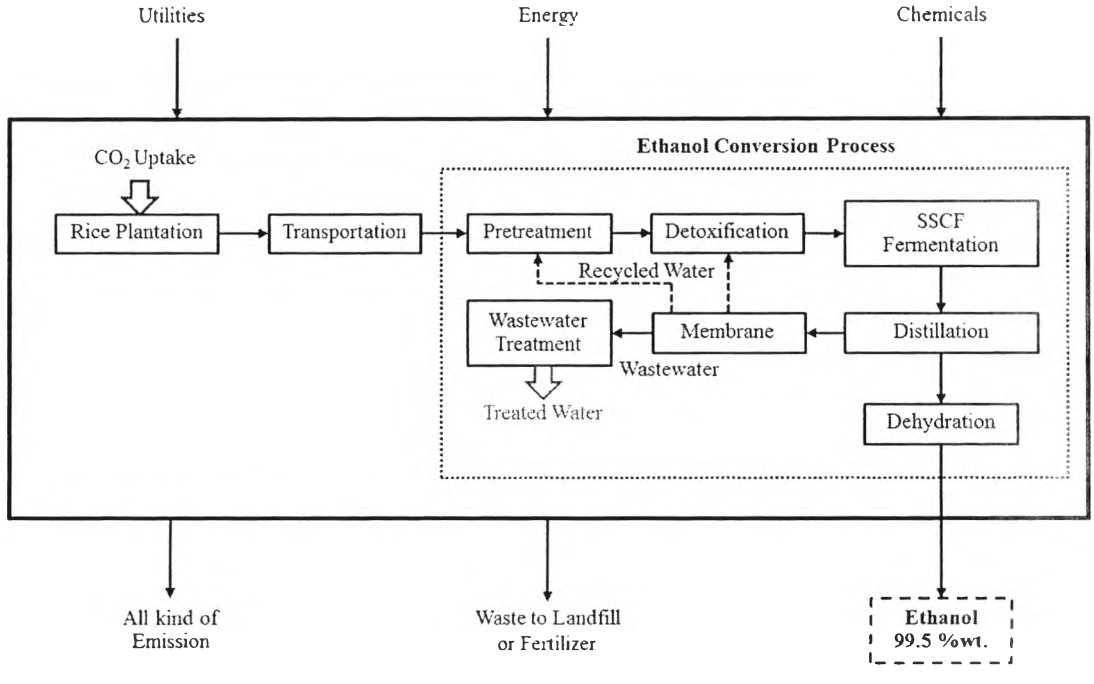

Figure F4.1 System boundary of alternative 4 design.

Table F4.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 4 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.23E-02
Global warming (GWP100)	kg CO_2 eq	2.40E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.05E-07
Human toxicity	kg 1,4-DB eq	1.34E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.17E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.69E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.89E-02
Photochemical oxidation	kg C_2H_4	8.46E-03
Acidification	kg SO_2 eq	2.18E-02
Eutrophication	kg PO_4 eq	1.23E-02

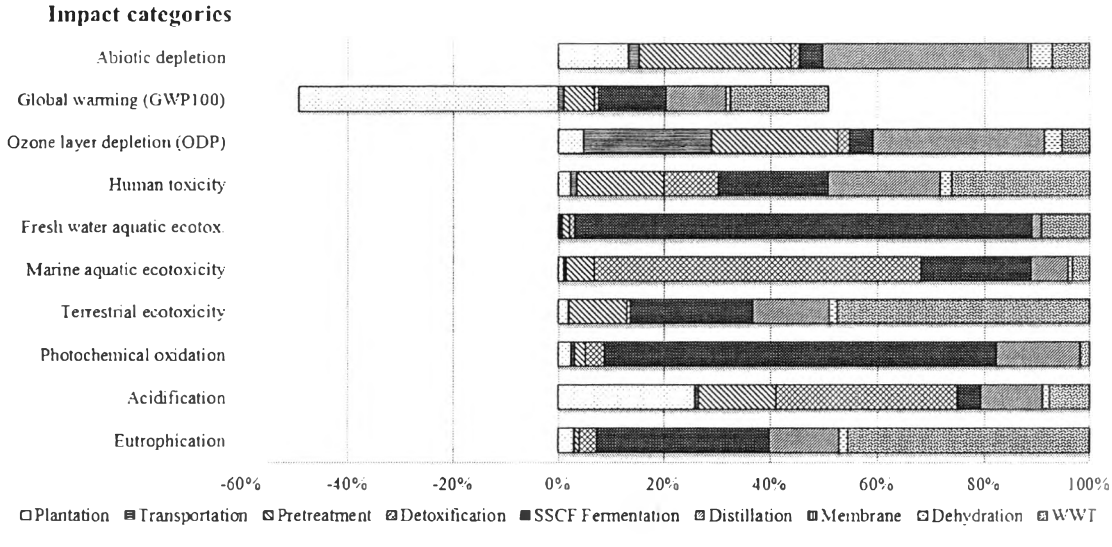

Figure F4.2 Distribution of environmental impacts classified stage by stage of alternative 4 design.

F.5 Alternative 5

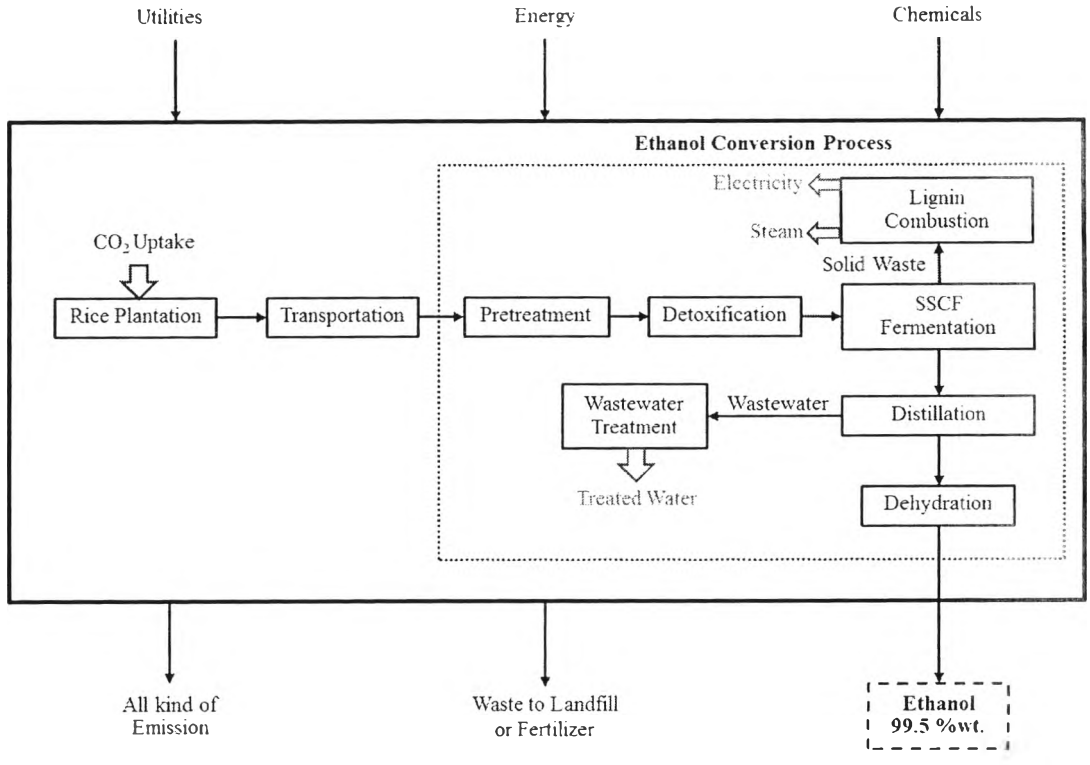

Figure F5.1 System boundary of alternative 5 design.

Table F5.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 5 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.61E-02
Global warming (GWP100)	kg CO_2 eq	5.91E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.85E-07
Human toxicity	kg 1,4-DB eq	1.42E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.21E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.86E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.72E-02
Photochemical oxidation	kg C_2H_4	8.30E-03
Acidification	kg SO_2 eq	2.31E-02
Eutrophication	kg PO_4 eq	1.06E-02

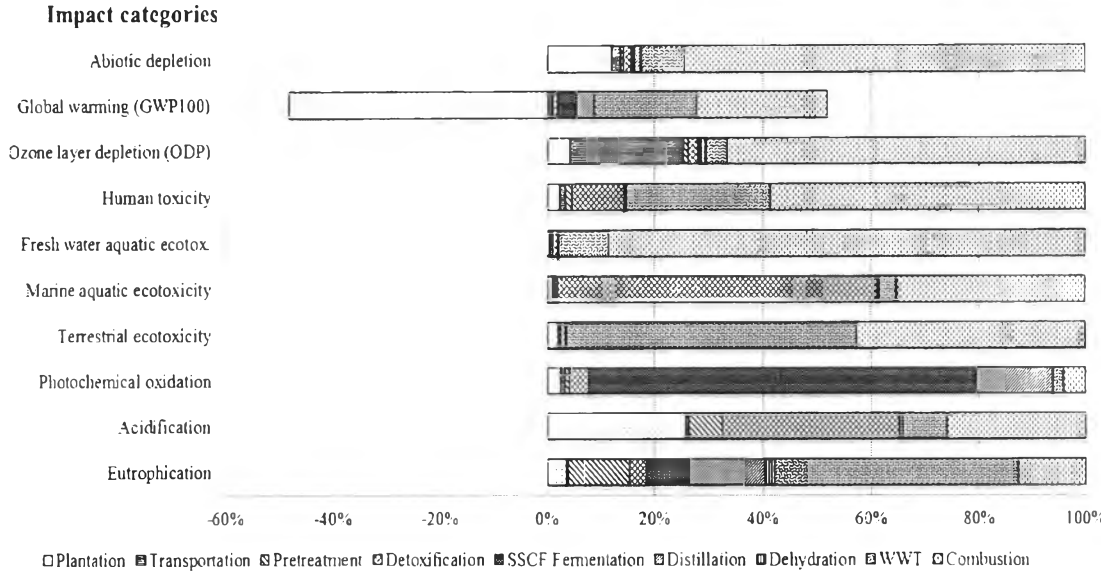

Figure F5.2 Distribution of environmental impacts classified stage by stage of alternative 5 design.

F.6 Alternative 6

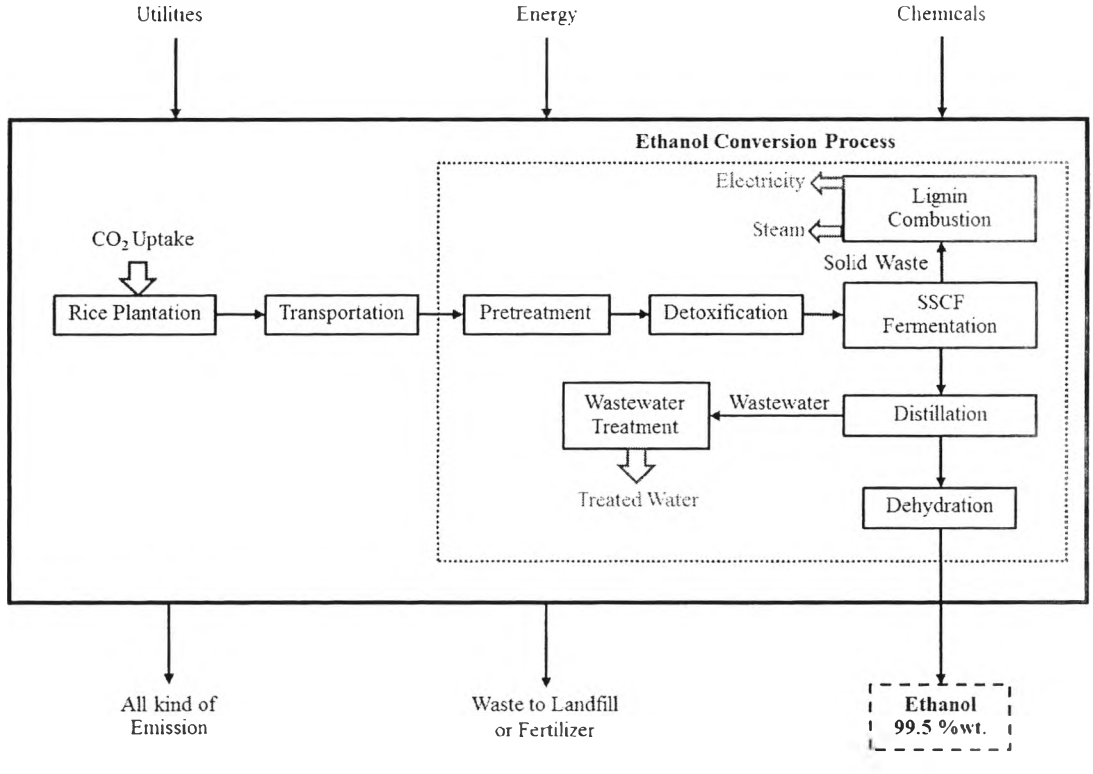

Figure F6.1 System boundary of alternative 6 design.

Table F6.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 6 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.22E-02
Global warming (GWP100)	kg CO_2 eq	6.78E-02
Ozone layer depletion (ODP)	kg CFC-11 eq	4.17E-07
Human toxicity	kg 1,4-DB eq	1.28E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.20E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.76E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.42E-02
Photochemical oxidation	kg C_2H_4	8.23E-03
Acidification	kg SO_2 eq	2.20E-02
Eutrophication	kg PO_4 eq	1.05E-02

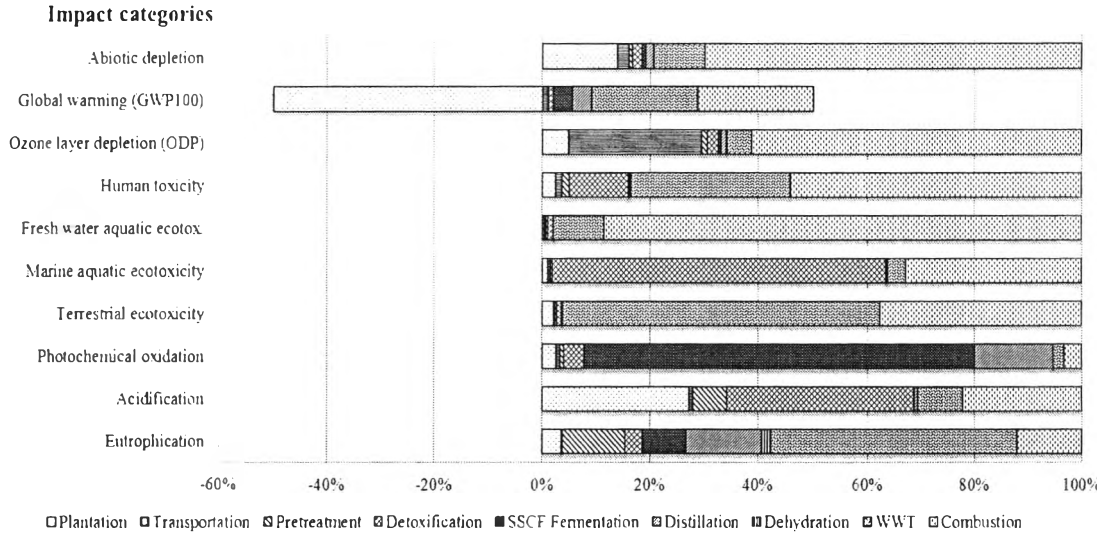

Figure F6.2 Distribution of environmental impacts classified stage by stage of alternative 6 design.

F.7 Alternative 7

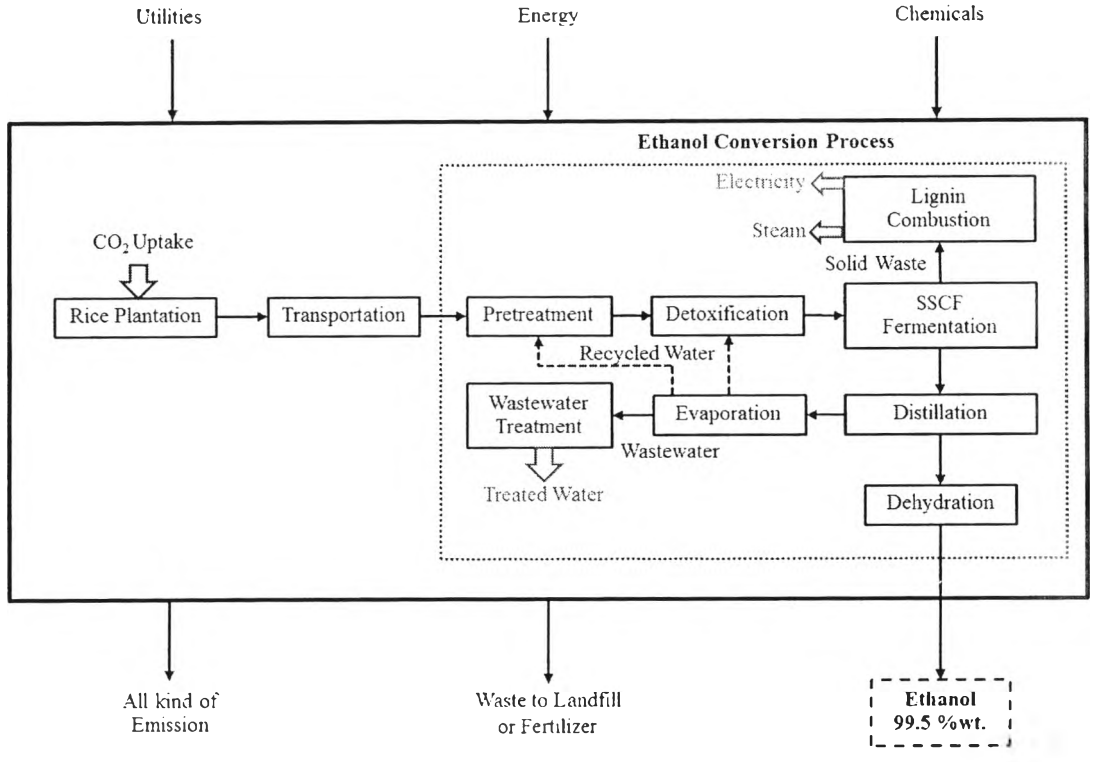

Figure F7.1 System boundary of alternative 7 design.

Table F7.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 7 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.33E-02
Global warming (GWP100)	kg CO_2 eq	2.73E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	3.93E-07
Human toxicity	kg 1,4-DB eq	1.18E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.12E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.51E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.16E-02
Photochemical oxidation	kg C_2H_4	9.31E-03
Acidification	kg SO_2 eq	2.09E-02
Eutrophication	kg PO_4 eq	1.00E-02

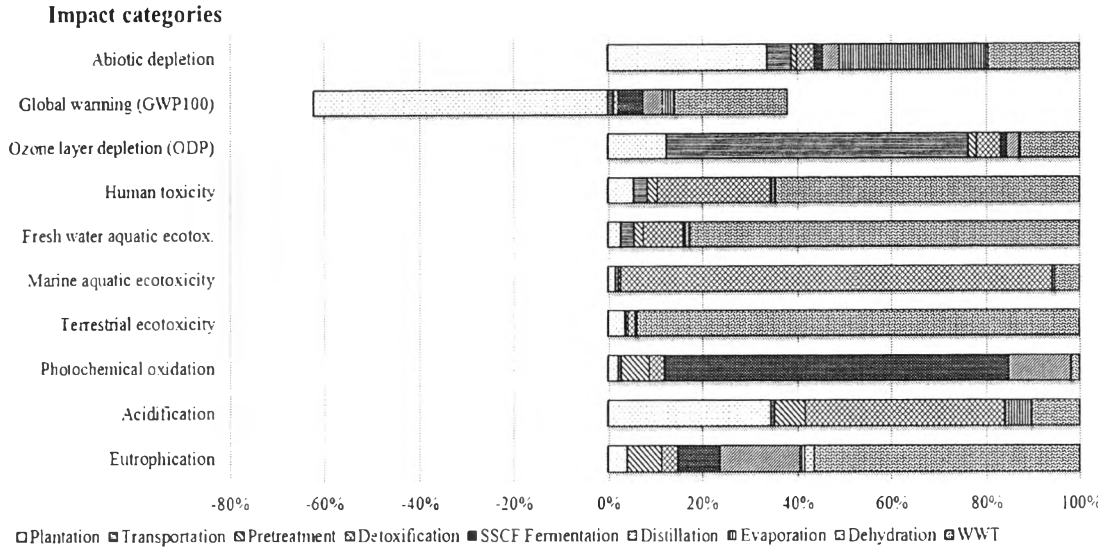

Figure F7.2 Distribution of environmental impacts classified stage by stage of alternative 7 design.

F.8 Alternative 8

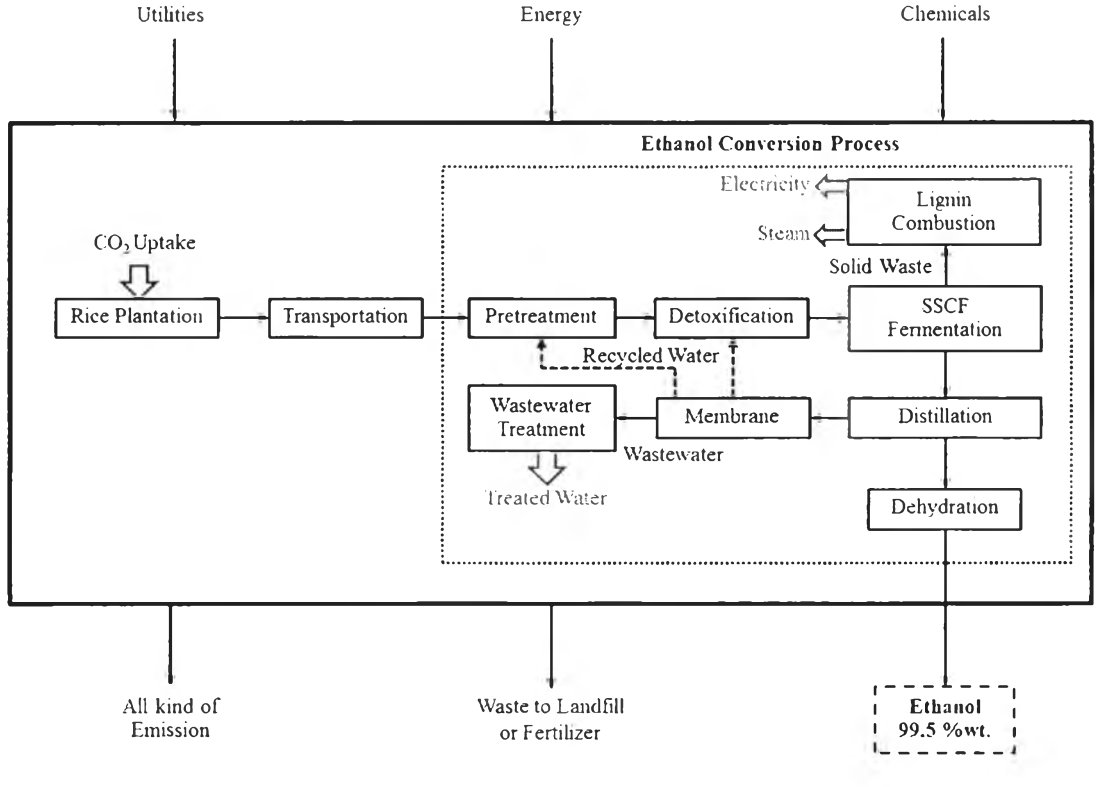

Figure F8.1 System boundary of alternative 8 design.

Table F8.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 8 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.08E-02
Global warming (GWP100)	kg CO_2 eq	7.35E-03
Ozone layer depletion (ODP)	kg CFC-11 eq	3.97E-07
Human toxicity	kg 1,4-DB eq	1.21E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.14E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.66E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.20E-02
Photochemical oxidation	kg C_2H_4	8.40E-03
Acidification	kg SO_2 eq	2.10E-02
Eutrophication	kg PO_4 eq	1.01E-02

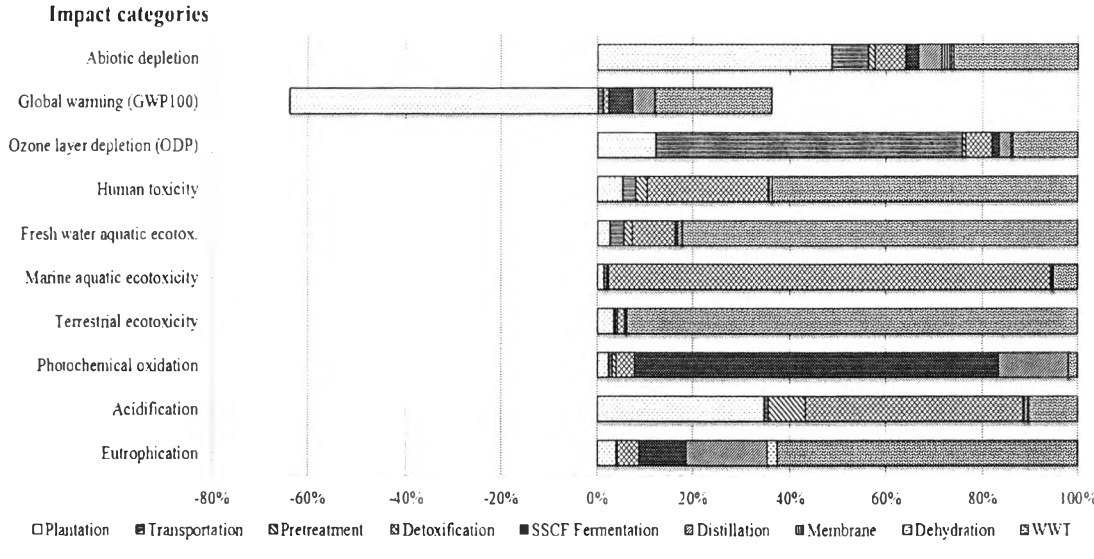

Figure F8.2 Distribution of environmental impacts classified stage by stage of alternative 8 design.

F.9 Alternative 9

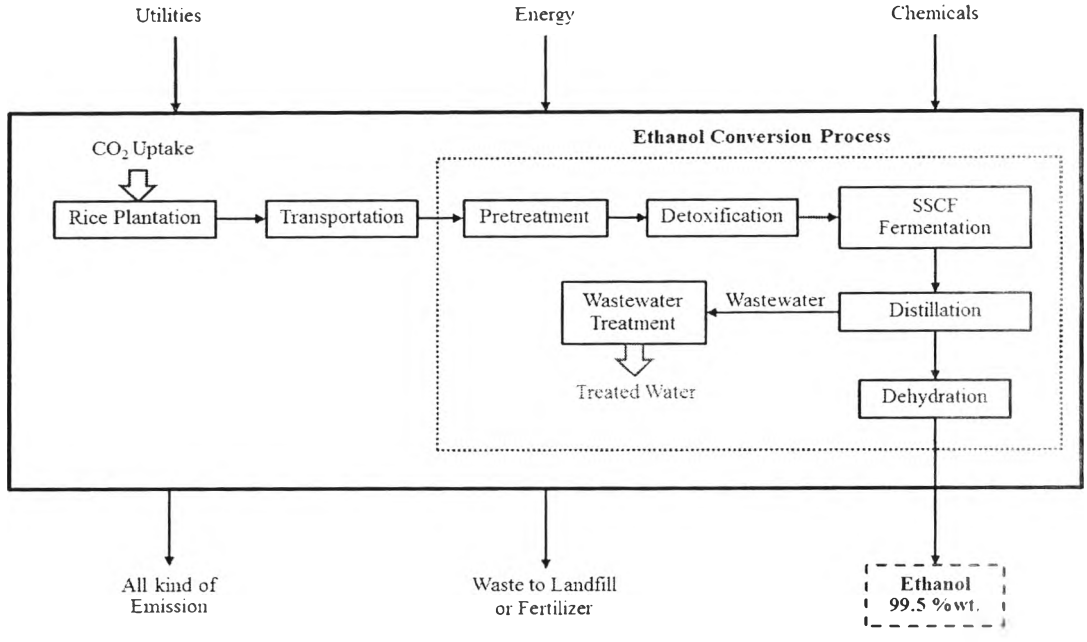

Figure F9.1 System boundary of alternative 9 design.

Table F9.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 9 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.38E-02
Global warming (GWP100)	kg CO_2 eq	3.06E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.24E-07
Human toxicity	kg 1,4-DB eq	1.41E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.24E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.79E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	4.15E-02
Photochemical oxidation	kg C_2H_4	8.30E-03
Acidification	kg SO_2 eq	2.29E-02
Eutrophication	kg PO_4 eq	1.24E-02

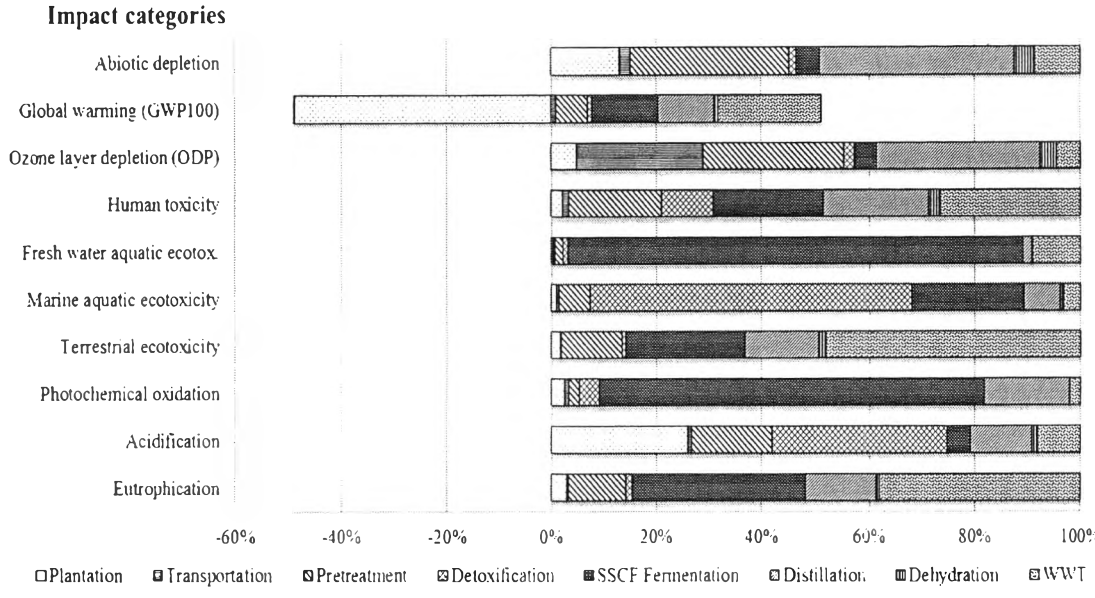

Figure F9.2 Distribution of environmental impacts classified stage by stage of alternative 9 design.

F.10 Alternative 10

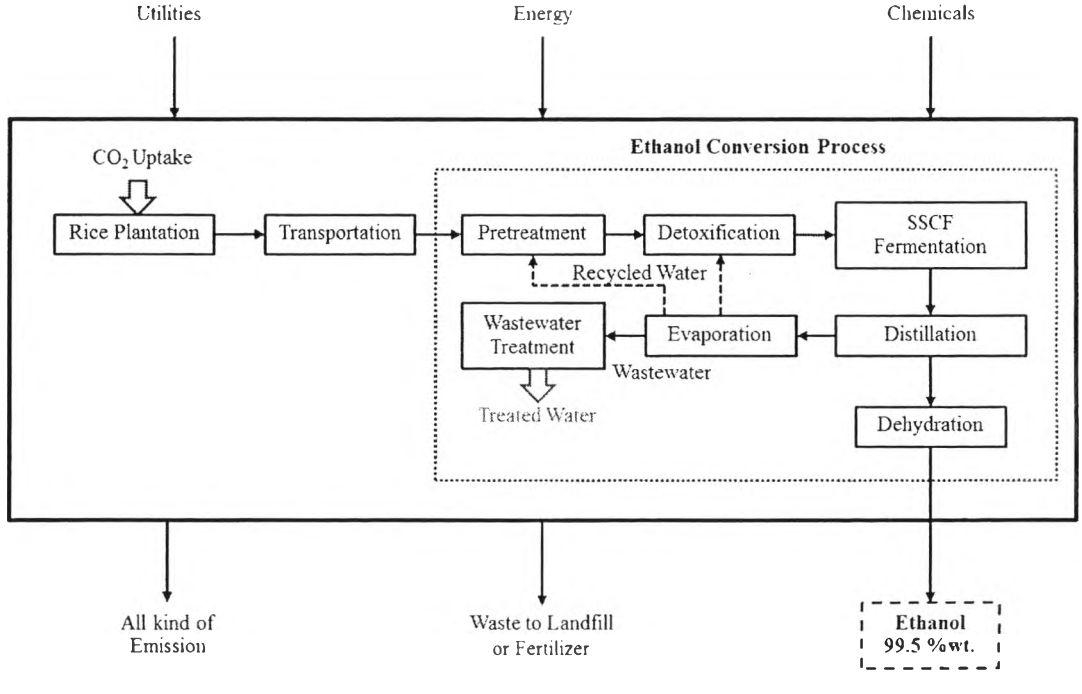

Figure F10.1 System boundary of alternative 10 design.

Table F10.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 10 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.37E-02
Global warming (GWP100)	kg CO_2 eq	3.63E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	3.83E-07
Human toxicity	kg 1,4-DB eq	1.27E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.16E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.52E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.77E-02
Photochemical oxidation	kg C_2H_4	9.35E-03
Acidification	kg SO_2 eq	2.14E-02
Eutrophication	kg PO_4 eq	1.19E-02

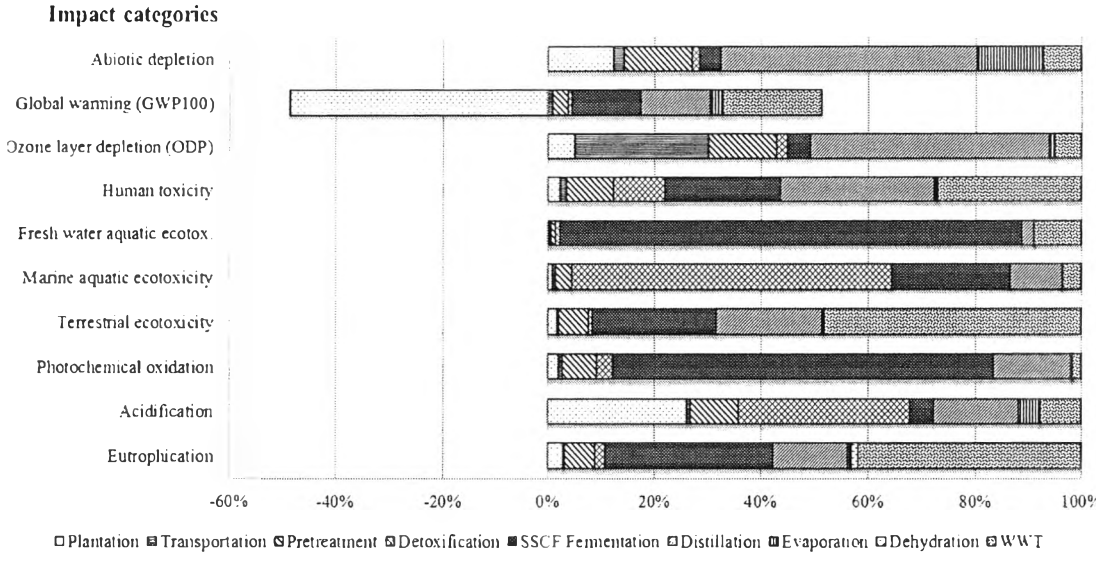

Figure F10.2 Distribution of environmental impacts classified stage by stage of alternative 10 design.

F.11 Alternative 11

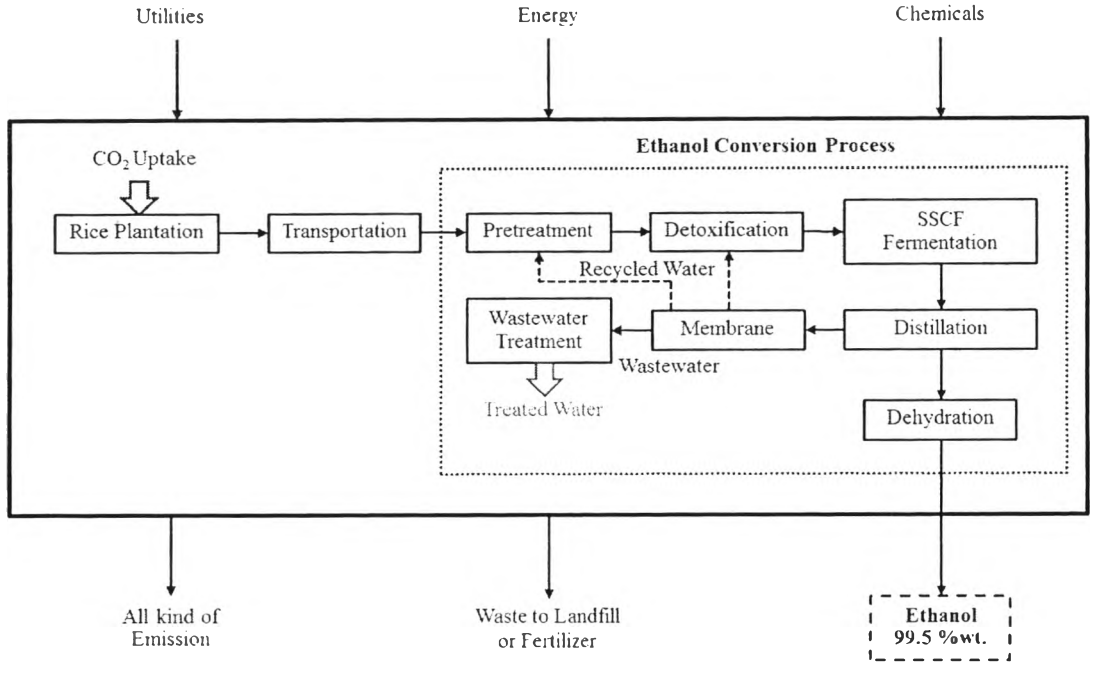

Figure F11.1 System boundary of alternative 11 design.

Table F11.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 11 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.19E-02
Global warming (GWP100)	kg CO_2 eq	1.87E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	3.98E-07
Human toxicity	kg 1,4-DB eq	1.32E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.17E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.68E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.87E-02
Photochemical oxidation	kg C_2H_4	8.42E-03
Acidification	kg SO_2 eq	2.17E-02
Eutrophication	kg PO_4 eq	1.22E-02

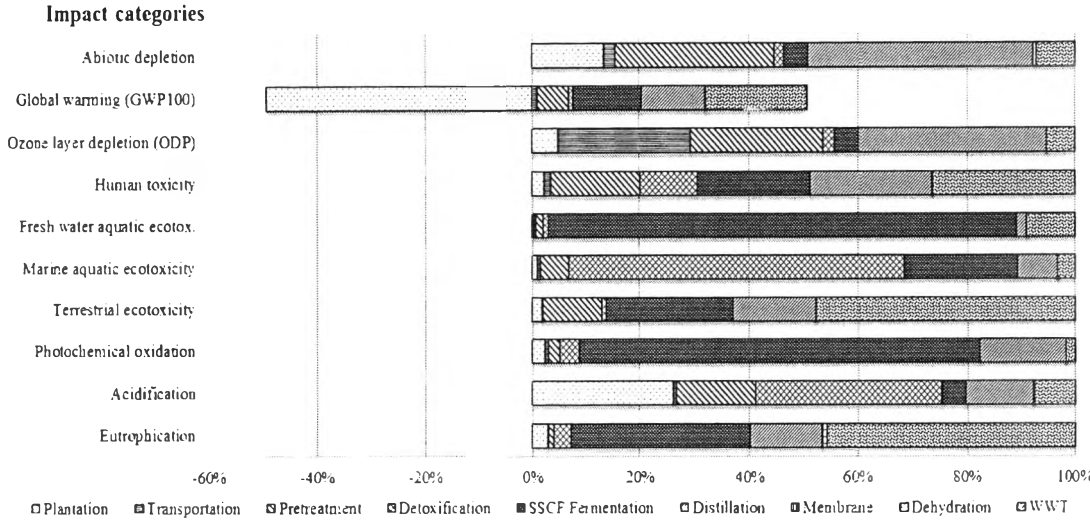

Figure F11.2 Distribution of environmental impacts classified stage by stage of alternative 11 design.

F.12 Alternative 12

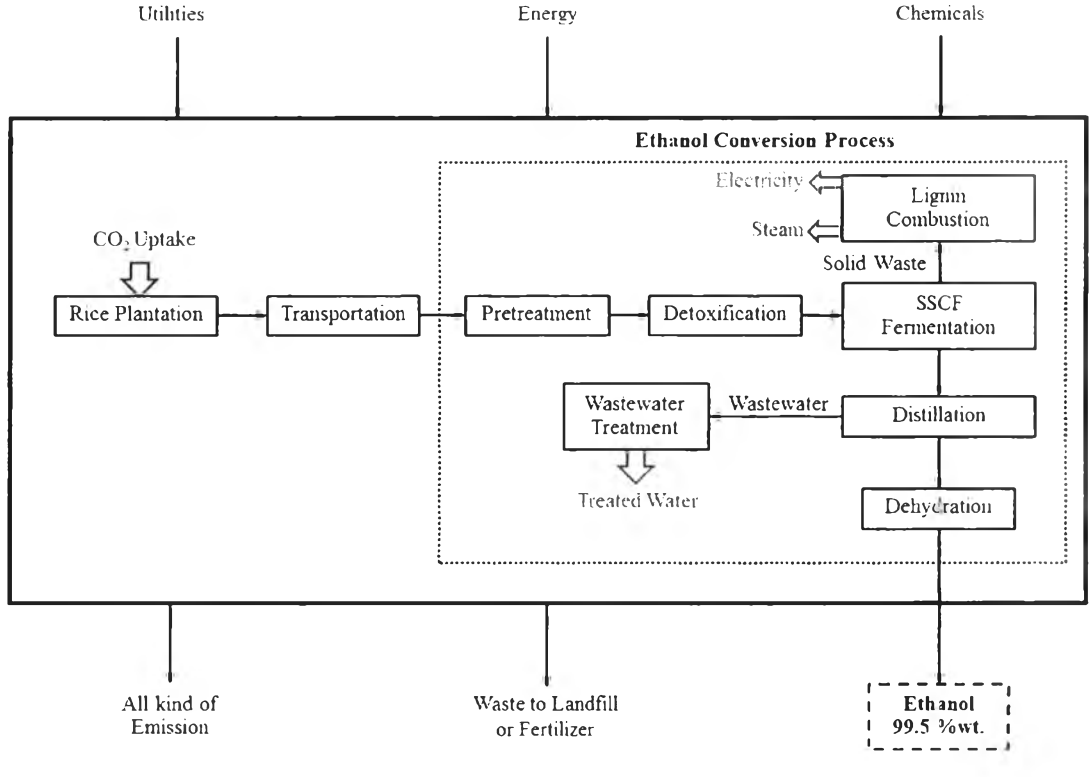

Figure F12.1 System boundary of alternative 12 design.

Table F12.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 12 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.46E-02
Global warming (GWP100)	kg CO_2 eq	3.99E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	4.57E-07
Human toxicity	kg 1,4-DB eq	1.36E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.20E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.82E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.60E-02
Photochemical oxidation	kg C_2H_4	8.27E-03
Acidification	kg SO_2 eq	2.27E-02
Eutrophication	kg PO_4 eq	1.02E-02

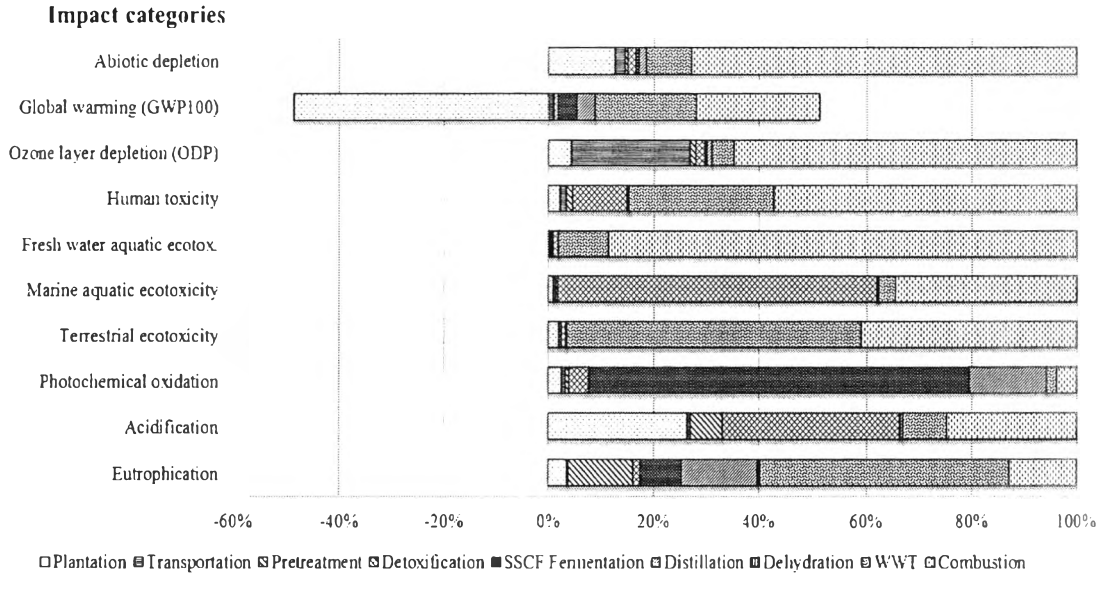

Figure F12.2 Distribution of environmental impacts classified stage by stage of alternative 12 design.

F.13 Alternative 13

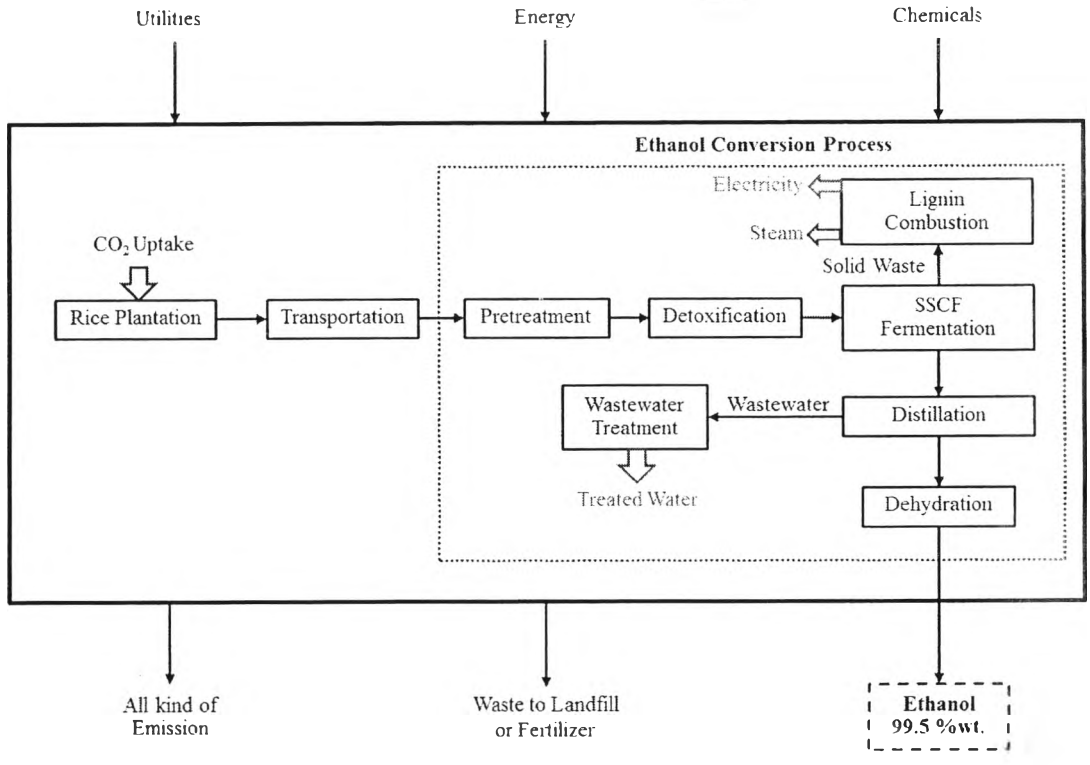

Figure F13.1 System boundary of alternative 13 design.

Table F13.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 13 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.22E-02
Global warming (GWP100)	kg CO_2 eq	6.51E-02
Ozone layer depletion (ODP)	kg CFC-11 eq	4.16E-07
Human toxicity	kg 1,4-DB eq	1.27E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.20E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.76E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.42E-02
Photochemical oxidation	kg C_2H_4	8.23E-03
Acidification	kg SO_2 eq	2.20E-02
Eutrophication	kg PO_4 eq	1.01E-02

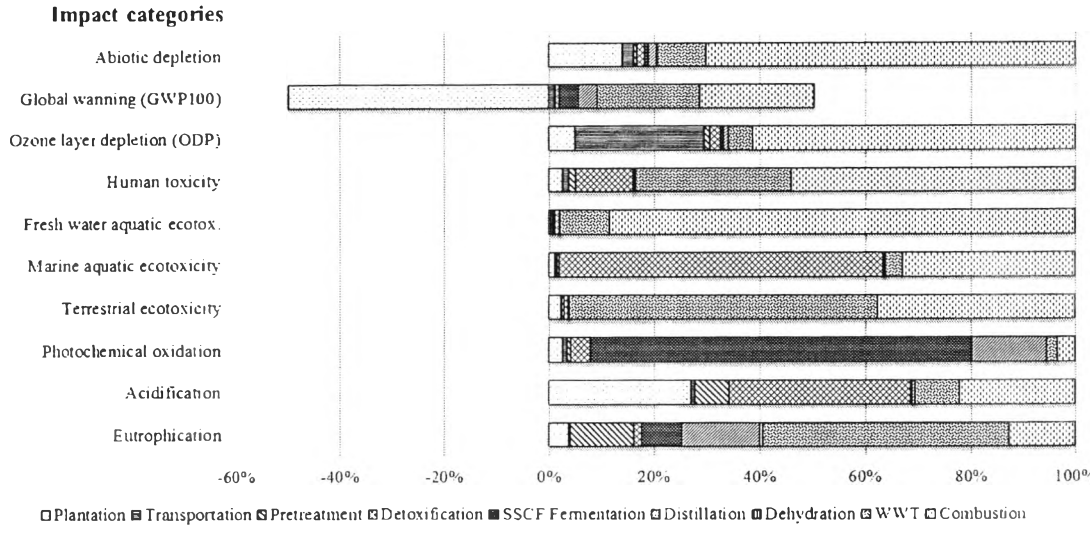

Figure F13.2 Distribution of environmental impacts classified stage by stage of alternative 13 design.

F.14 Alternative 14

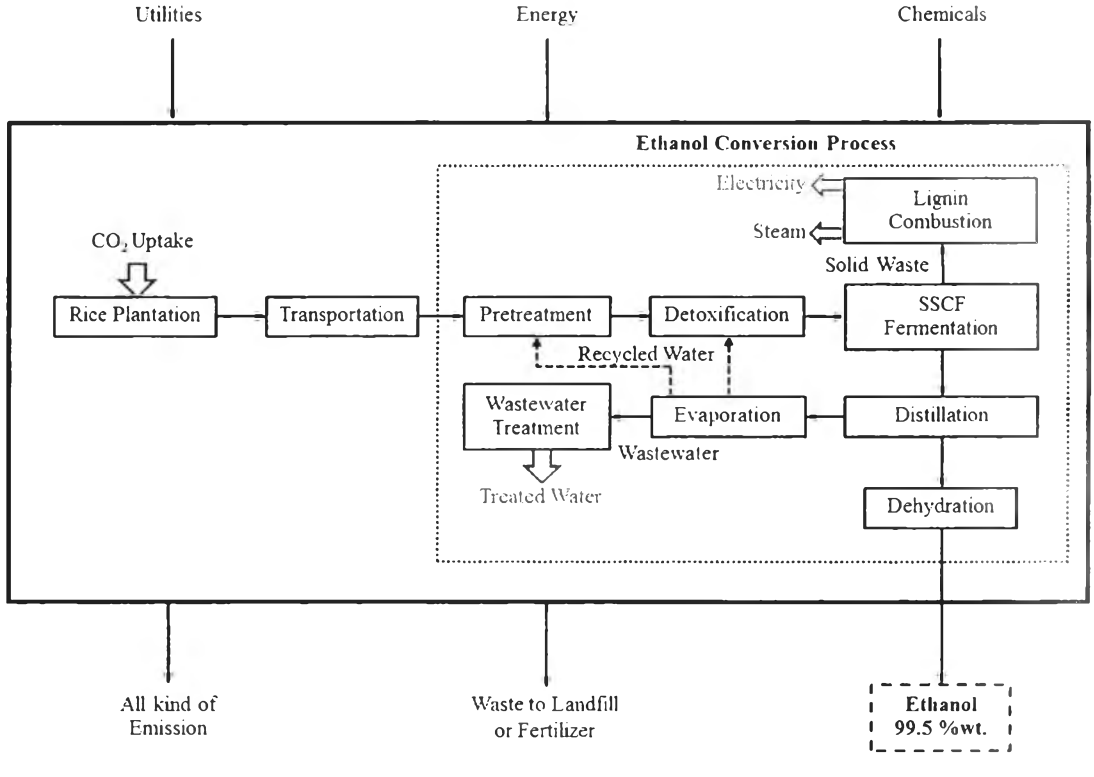

Figure F14.1 System boundary of alternative 14 design.

Table F14.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 14 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.23E-02
Global warming (GWP100)	kg CO_2 eq	2.77E-01
Ozone layer depletion (ODP)	kg CFC-11 eq	3.75E-07
Human toxicity	kg 1,4-DB eq	1.15E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.12E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.49E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.08E-02
Photochemical oxidation	kg C_2H_4	9.29E-03
Acidification	kg SO_2 eq	2.06E-02
Eutrophication	kg PO_4 eq	9.77E-03

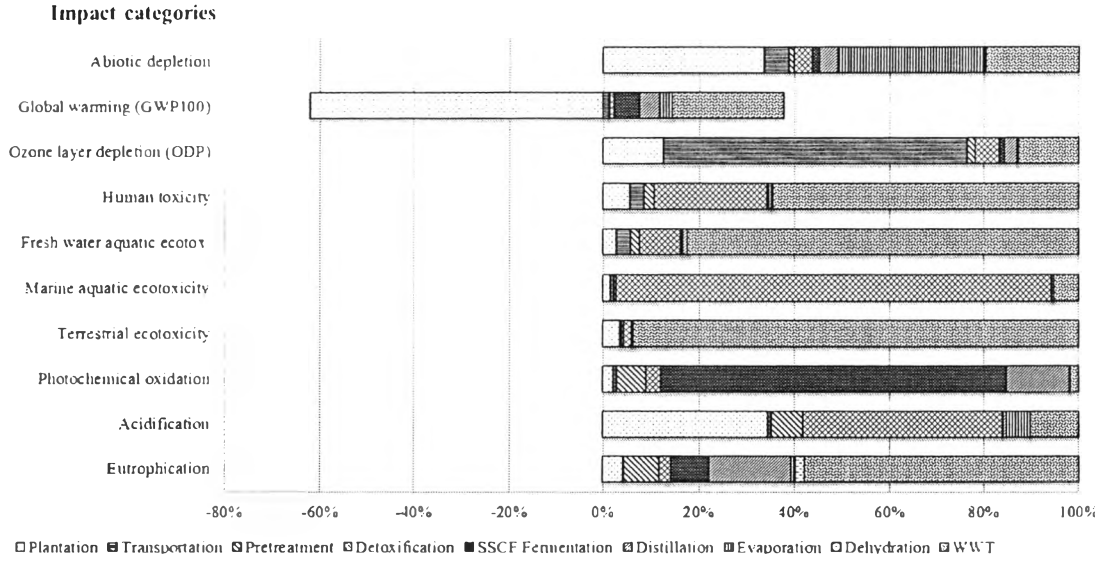

Figure F14.2 Distribution of environmental impacts classified stage by stage of alternative 14 design.

F.15 Alternative 15

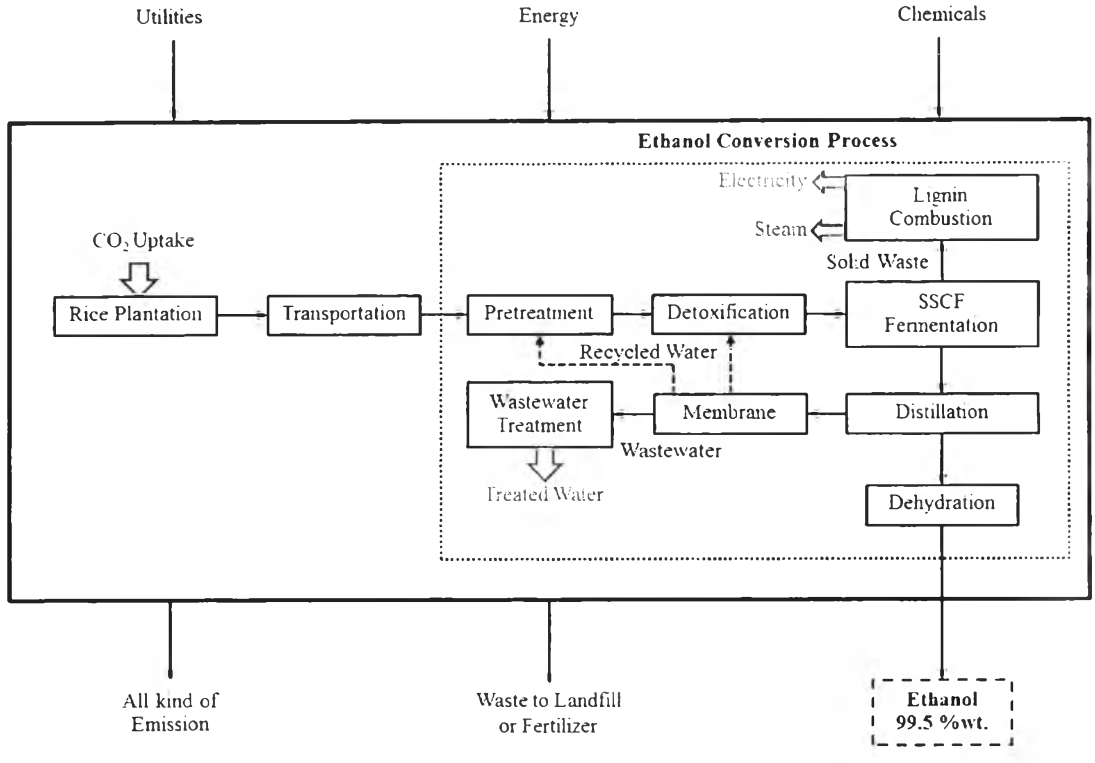

Figure F15.1 System boundary of alternative 15 design.

Table F15.1 Environmental impact of bioethanol conversion process from rice straw per one kilogram ethanol 99.5 wt% of the alternative 15 design

Impact category	Unit	Total
Abiotic depletion	kg Sb eq	2.05E-02
Global warming (GWP100)	kg CO_2 eq	9.35E-03
Ozone layer depletion (ODP)	kg CFC-11 eq	3.90E-07
Human toxicity	kg 1,4-DB eq	1.19E+00
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1.13E+00
Marine aquatic ecotoxicity	kg 1,4-DB eq	2.66E+03
Terrestrial ecotoxicity	kg 1,4-DB eq	3.17E-02
Photochemical oxidation	kg C_2H_4	8.35E-03
Acidification	kg SO_2 eq	2.09E-02
Eutrophication	kg PO_4 eq	1.00E-02

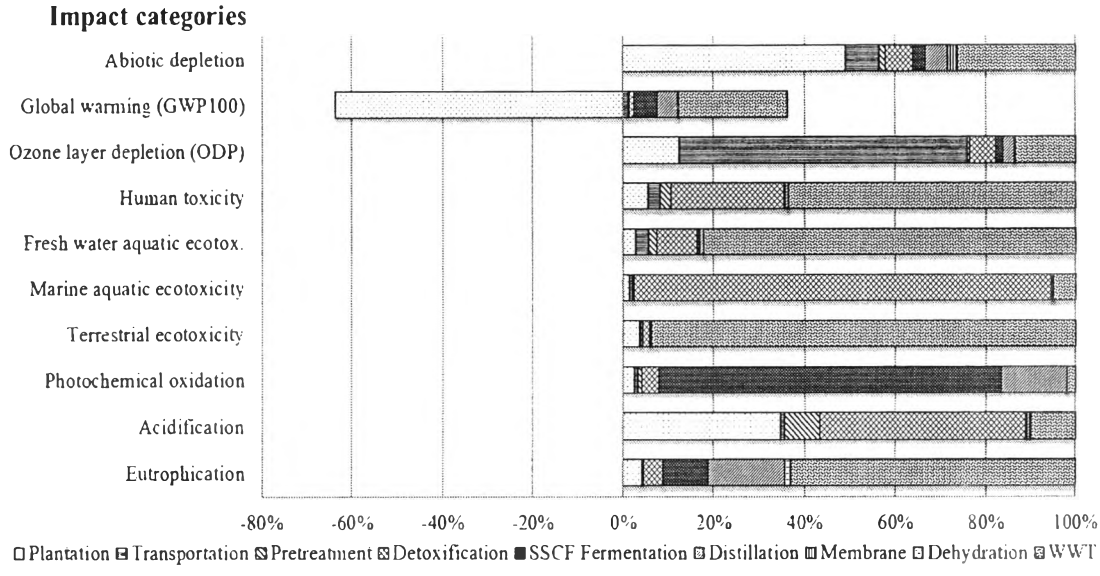

Figure F15.2 Distribution of environmental impacts classified stage by stage of alternative 15 design.

CURRICULUM VITAE

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Proceeding:

Nidhinandana, P.; Malakul, P.; and Gani, R. (2012, April 24) Sustainable Process Design Study of Cellulosic-based Biofuel: Bioethanol Production from Rice Straw. Proceedings of the 3rd Research Symposium on Petrochemical and Materials Technology and the 18th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Ballroom, Queen Sirikit National Convention Center, Bangkok, Thailand.