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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	Lignin	LIGNIN	$C_{7.3}H_{13.9}O_{1.3}$
4	Glucose	C6	$C_6H_{12}O_6$
5	Xylose	C5	$C_5H_{10}O_5$
6	Cellobiose	C12	$C_{12}H_{22}O_{11}$
7	Ethanol	ETHANOL	C_2H_6O
8	Water	WATER	H_2O
9	Sulfuric Acid	SULFURIC	H_2SO_4
10	Furfural	FURFURAL	$C_5H_4O_2$
11	Ammonia	NH3	NH_3
12	Oxygen	O2	O_2
13	Carbon Dioxide	CO2	CO_2
14	Glycerol	GLYCEROL	$C_3H_8O_3$
15	Succinic Acid	SUCCINIC	$C_4H_6O_4$
16	Lactic Acid	LACTIC	$C_3H_6O_3$
17	Hydroxymethylfurfural	HMF	$C_6H_6O_3$
18	Xylitol	XYLITOL	$C_5H_{12}O_5$
19	Acetic Acid	ACETIC	$C_2H_4O_2$
20	Corn Steep Liquor	CLS	H_2O
21	<i>Zymomonas Mobilis</i> (bacteria)	ZM	$CH_{1.8}O_{0.5}N_{0.2}$
22	Cellulase (enzyme)	CELLULAC	$CH_{1.57}NOS$
23	Calcium Hydroxide	CAHYDROX	$Ca(OH)_2$
24	Calcium Sulphate (Gypsum)	CASO4	$CaSO_4$
25	Ash	ASH	$C_6H_{10}O_5$

Appendix B Chemical Reactions Implemented in PRO/II

Table B1 List of reactions taking place in the pretreatment reactor (Aden *et al.*, 2002)

	Reaction	Conversion	Modeled
1	$\text{Cellulose}_n + n\text{Water} \longrightarrow n\text{Glucose}$ $\text{C}_6\text{H}_{10}\text{O}_5 + \text{H}_2\text{O} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6$	Cellulose	0.070
2	$\text{Cellulose}_n + n/2\text{Water} \longrightarrow n/2\text{Cellobiose}$ $\text{C}_6\text{H}_{10}\text{O}_5 + 1/2\text{H}_2\text{O} \longrightarrow 1/2\text{C}_{12}\text{H}_{22}\text{O}_{11}$	Cellulose	0.007
3	$\text{Hemicellulose}_n + n\text{Water} \longrightarrow n\text{Xylose}$ $\text{C}_5\text{H}_8\text{O}_4 + \text{H}_2\text{O} \longrightarrow \text{C}_5\text{H}_{10}\text{O}_5$	Hemicellulose	0.900
4	$\text{Hemicellulose}_n \longrightarrow n\text{Furfural} + 2n\text{Water}$ $\text{C}_5\text{H}_8\text{O}_4 \longrightarrow \text{C}_5\text{H}_4\text{O}_2 + 2\text{H}_2\text{O}$	Hemicellulose	0.050

Table B2 List of reactions taking place in overliming process (Aden *et al.*, 2002)

	Reaction	Conversion	Modeled
5	Sulfuric Acid + Calcium Hydroxide \longrightarrow Gypsum $\text{H}_2\text{SO}_4 + \text{Ca}(\text{OH})_2 \longrightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	Sulfuric Acid	1.000

Table B3 List of reactions taking place in saccharification process (Aden *et al.*, 2002)

Saccharification Reaction			
	Reaction	Conversion	Modeled
6	$\text{Cellulose}_n + n/2\text{Water} \longrightarrow n/2\text{Cellobiose}$ $\text{C}_6\text{H}_{10}\text{O}_5 + 1/2\text{H}_2\text{O} \longrightarrow 1/2\text{C}_{12}\text{H}_{22}\text{O}_{11}$	Cellulose	0.012
7	$\text{Cellulose}_n + n\text{Water} \longrightarrow n\text{Glucose}$ $\text{C}_6\text{H}_{10}\text{O}_5 + \text{H}_2\text{O} \longrightarrow \text{C}_6\text{H}_{12}\text{O}_6$	Cellulose	0.900
8	$\text{Cellobiose}_n + n\text{Water} \longrightarrow 2n\text{Glucose}$ $\text{C}_{12}\text{H}_{22}\text{O}_{11} + \text{H}_2\text{O} \longrightarrow 2\text{C}_6\text{H}_{12}\text{O}_6$	Cellobiose	1.000

Table B4 List of reactions taking place in seed train process (Aden *et al.*, 2002)

Seed Train Reaction			
	Reaction	Conversion	Modeled
9	Glucose \longrightarrow 2Ethanol + 2Carbon Dioxide $C_6H_{12}O_6 \longrightarrow 2C_2H_6O + 2CO_2$	Glucose	0.900
10	Glucose+1.2Ammonia \longrightarrow 6 <i>Z. mobilis</i> +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
11	Glucose + 2Water \longrightarrow 2Glycerol + Oxygen $C_6H_{12}O_6 + 2H_2O \longrightarrow 2C_3H_8O_3 + O_2$	Glucose	0.004
12	Glucose+2Carbon Dioxide \longrightarrow 2Succinic Acid+Oxygen $C_6H_{12}O_6 + 2CO_2 \longrightarrow 2C_4H_6O_4 + O_2$	Glucose	0.006
13	Glucose \longrightarrow 3Acetic Acid $C_6H_{12}O_6 \longrightarrow 3CH_3COOH$	Glucose	0.015
14	Glucose \longrightarrow 2Lactic Acid $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Glucose	0.002
15	3Xylose \longrightarrow 5Ethanol + 5Carbon Dioxide $3C_5H_{10}O_5 \longrightarrow 5C_2H_6O + 5CO_2$	Xylose	0.800
16	Xylose+Ammonia \longrightarrow 5 <i>Z. mobilis</i> +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
17	3Xylose + 5Water \longrightarrow 5Glycerol + 2.5Oxygen $3C_5H_{10}O_5 + 5H_2O \longrightarrow 5C_3H_8O_3 + 2.5O_2$	Xylose	0.003
18	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
19	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
20	2Xylose \longrightarrow 5Acetic Acid $2C_5H_{10}O_5 \longrightarrow 5CH_3COOH$	Xylose	0.014
21	3Xylose \longrightarrow 5Lactic Acid $3C_5H_{10}O_5 \longrightarrow 5CH_3CHOHCOOH$	Xylose	0.002

Table B5 List of reactions taking place in Co-Fermentation (Aden *et al.*, 2002)

Co-Fermentation Reaction			
	Reaction	Conversion	Modeled
22	Glucose \longrightarrow 2Ethanol + 2Carbon Dioxide $C_6H_{12}O_6 \longrightarrow 2C_2H_6O + 2CO_2$	Glucose	0.950
23	Glucose+1.2Ammonia \longrightarrow 6 <i>Z. mobilis</i> +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
24	Glucose + 2Water \longrightarrow 2Glycerol + Oxygen $C_6H_{12}O_6 + 2H_2O \longrightarrow 2C_3H_8O_3 + O_2$	Glucose	0.004
25	Glucose+2Carbon Dioxide \longrightarrow 2Succinic Acid+Oxygen $C_6H_{12}O_6 + 2CO_2 \longrightarrow 2C_4H_6O_4 + O_2$	Glucose	0.006
26	Glucose \longrightarrow 3Acetic Acid $C_6H_{12}O_6 \longrightarrow 3CH_3COOH$	Glucose	0.015
27	Glucose \longrightarrow 2Lactic Acid $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Glucose	0.002
28	3Xylose \longrightarrow 5Ethanol + 5Carbon Dioxide $3C_5H_{10}O_5 \longrightarrow 5C_2H_6O + 5CO_2$	Xylose	0.850
29	Xylose+Ammonia \longrightarrow 5 <i>Z. mobilis</i> +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
30	3Xylose + 5Water \longrightarrow 5Glycerol + 2.5Oxygen $3C_5H_{10}O_5 + 5H_2O \longrightarrow 5C_3H_8O_3 + 2.5O_2$	Xylose	0.003
31	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
32	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
33	2Xylose \longrightarrow 5Acetic Acid $2C_5H_{10}O_5 \longrightarrow 5CH_3COOH$	Xylose	0.014
34	3Xylose \longrightarrow 5Lactic Acid $3C_5H_{10}O_5 \longrightarrow 5CH_3CHOHCOOH$	Xylose	0.002

Table B6 List of reactions taking place in SSCF contamination loss (Aden *et al.*, 2002)

	Reaction	Conversion	Modeled
35	Glucose \longrightarrow 2Lactic Acid $C_6H_{12}O_6 \longrightarrow 2CH_3CHOHCOOH$	Glucose	1.000
36	3Xylose \longrightarrow 5Lactic Acid $3C_5H_{10}O_5 \longrightarrow 5CH_3CHOHCOOH$	Xylose	1.000

Table B7 List of reactions taking place in combustion process

	Reaction	Conversion	Modeled
37	Cellulose _n + 6nOxygen \longrightarrow 5nWater + 6nCarbon Dioxide $C_6H_{10}O_5 + 6O_2 \longrightarrow 5H_2O + 6CO_2$	Cellulose	0.800
38	Hemicellulose _n +5nOxygen \longrightarrow 4nWater+5nCarbon Dioxide $C_5H_8O_4 + 5O_2 \longrightarrow 4H_2O + 5CO_2$	Hemicellulose	0.800
39	Lignin _n +10.13nOxygen \longrightarrow 6.95nWater+7.30nCarbon Dioxide $C_{7.3}H_{13.9}O_{1.3} + 10.13O_2 \longrightarrow 6.95H_2O + 7.30CO_2$	Lignin	0.800

Appendix C Main Process Condition for Base Case Design

Table C1 Pretreatment Hydrolyzer Conditions

Agent	Dilute sulfuric acid
Acid concentration (w/w)	1.1 %
Residence time	2 minutes
Temperature	190 °C
Pressure	12.1 atm
Solids in the reactor (w/w)	30 %

Table C2 Blowdown tank

Temperature	100 °C
Pressure	1 atm

Table C3 Detoxification Conditions

Type	Overliming (50 °C)
Alkali	Calcium hydroxide
Residence time	1 hour for overliming and 4 hours for reacidification

Table C4 Saccharification Conditions

Temperature	65 °C
Initial solids level (w/w)	20 %
Residence time	36 hours
Enzyme	Cellulase
Biocatalyst	<i>Zymomonas Mobilis</i>
Enzyme level (w/w)	2 % of cellulose
Corn steep liquor level (w/w)	0.25 %
Pressure	1 atm

Table C5 SSCF seed fermenter Conditions

Temperature	41 °C
Initial solids level (w/w)	10 %
Residence time	24 hours
Enzyme	Cellulase
Biocatalyst	<i>Zymomonas Mobilis</i>
Enzyme level (w/w)	2 % of cellulose
Corn steep liquor level (w/w)	0.5 %
Pressure	1 atm

Table C6 SSCF fermenter Conditions

Temperature	41 °C
Initial solids level (w/w)	20 %
Residence time	1.5 days
Enzyme	Cellulase
Biocatalyst	<i>Zymomonas Mobilis</i>
Enzyme level	2 % of cellulose
Inoculum level (w/w)	10 % of hydrolyzate
Corn steep liquor level (w/w)	0.25 %
Pressure	1 atm

Table C7 Beer distillation

Pressure	1.77 atm
Stages	32
Feed stage	4
Reflux ratio	3.2

Table C8 Rectification column

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

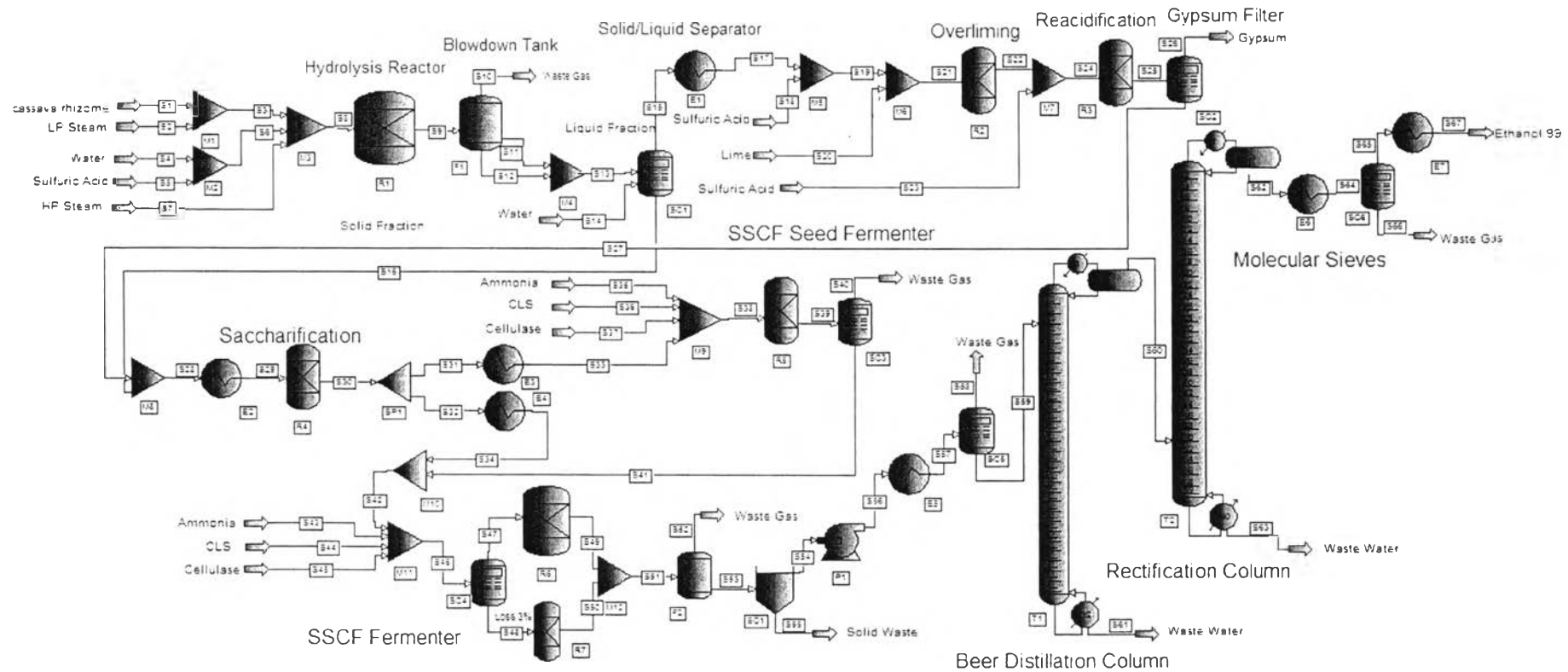


Figure D1 Flowsheet of the bioethanol production process from cassava rhizome for base case design.

D.1.2 Alternative 1: Base Case with Heat Integration

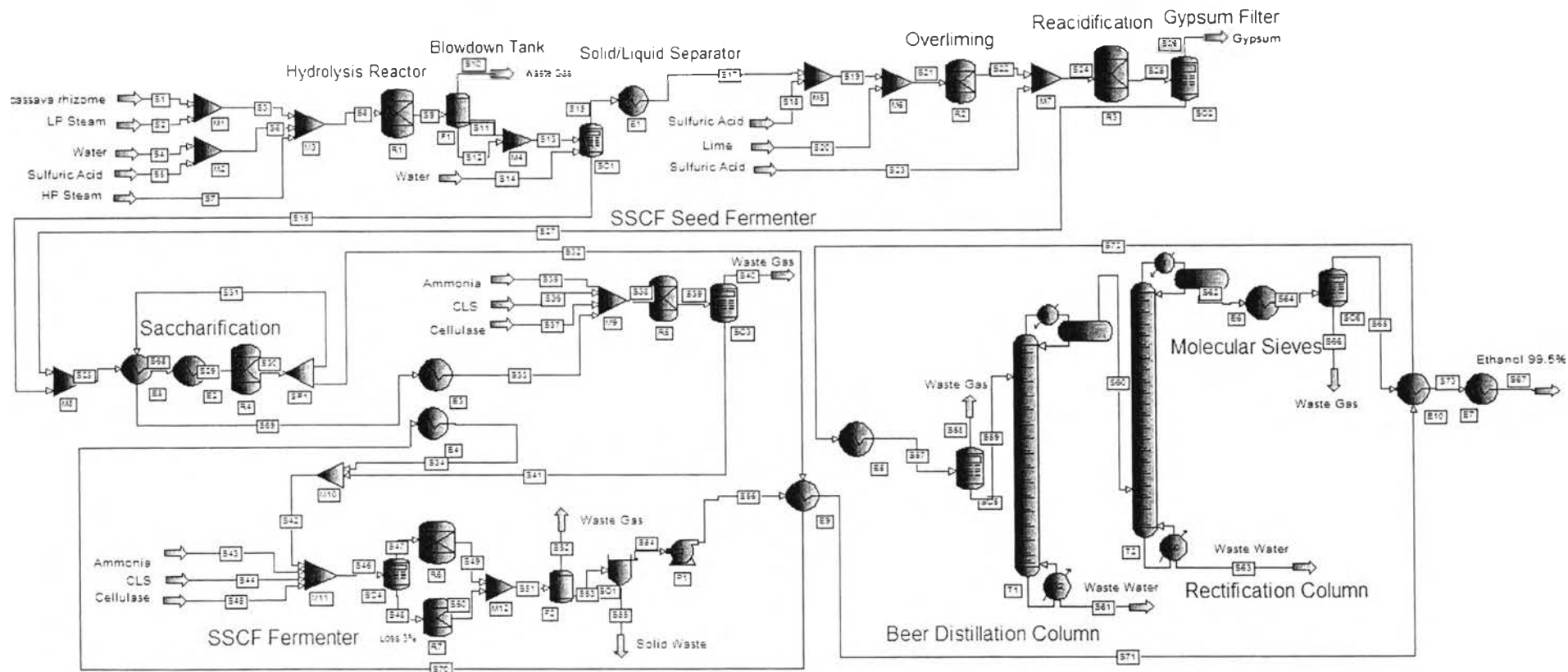


Figure D2 Flowsheet of the bioethanol production process from cassava rhizome for alternative 1 design.

D.1.3 Alternative 2: Wastewater Recover by Membranes

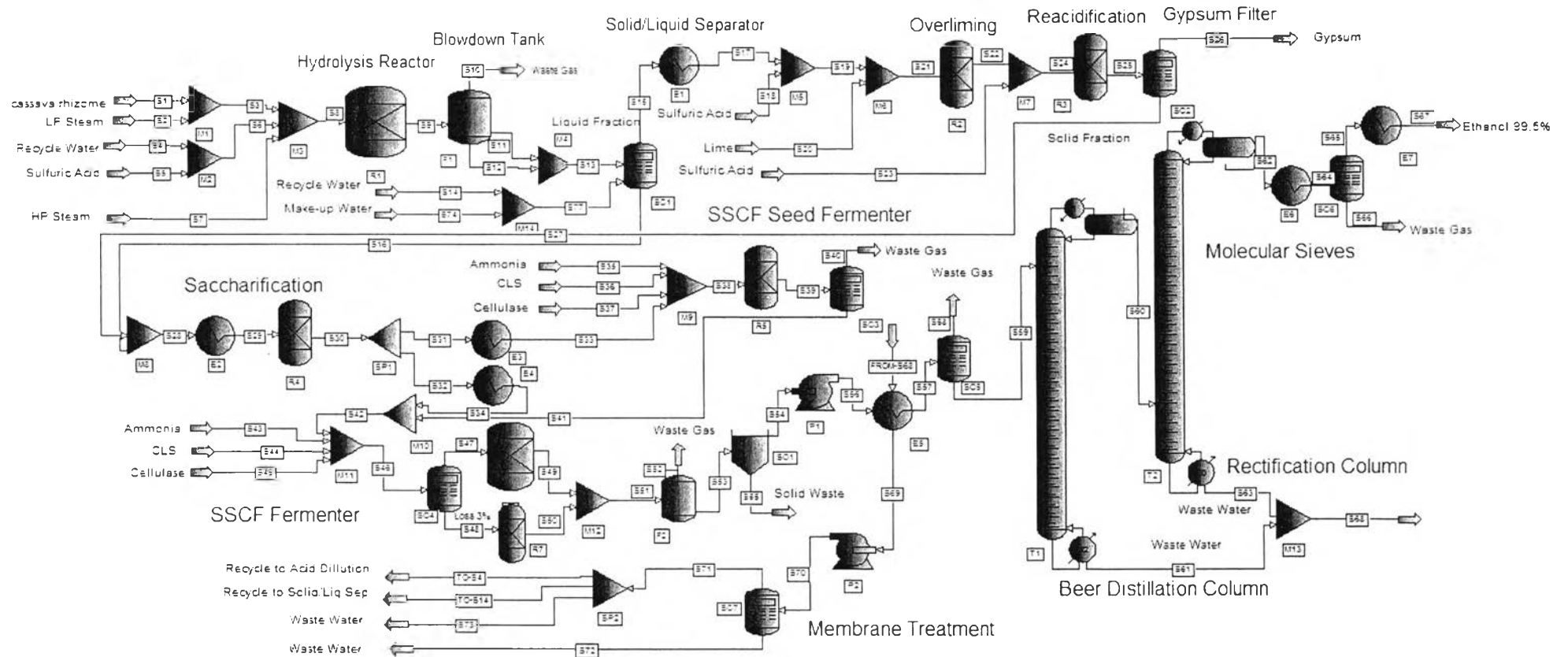


Figure D3 Flowsheet of the bioethanol production process from cassava rhizome for alternative 2 design.

D.1.4 Alternative 3: Lignin Combustion

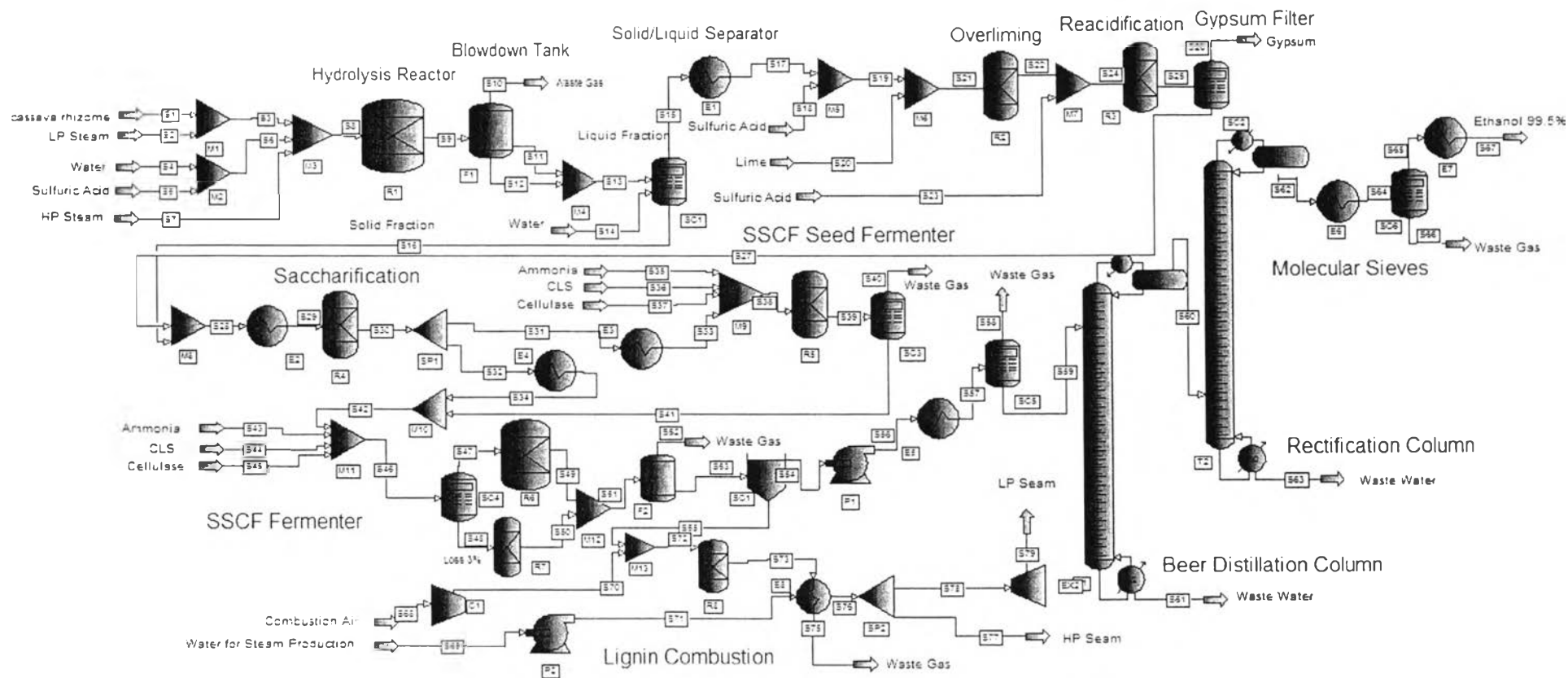


Figure D4 Flowsheet of the bioethanol production process from cassava rhizome for alternative 3 design.

D.1.5 Alternative 4: Wastewater Recover by Membranes and Lignin Combustion

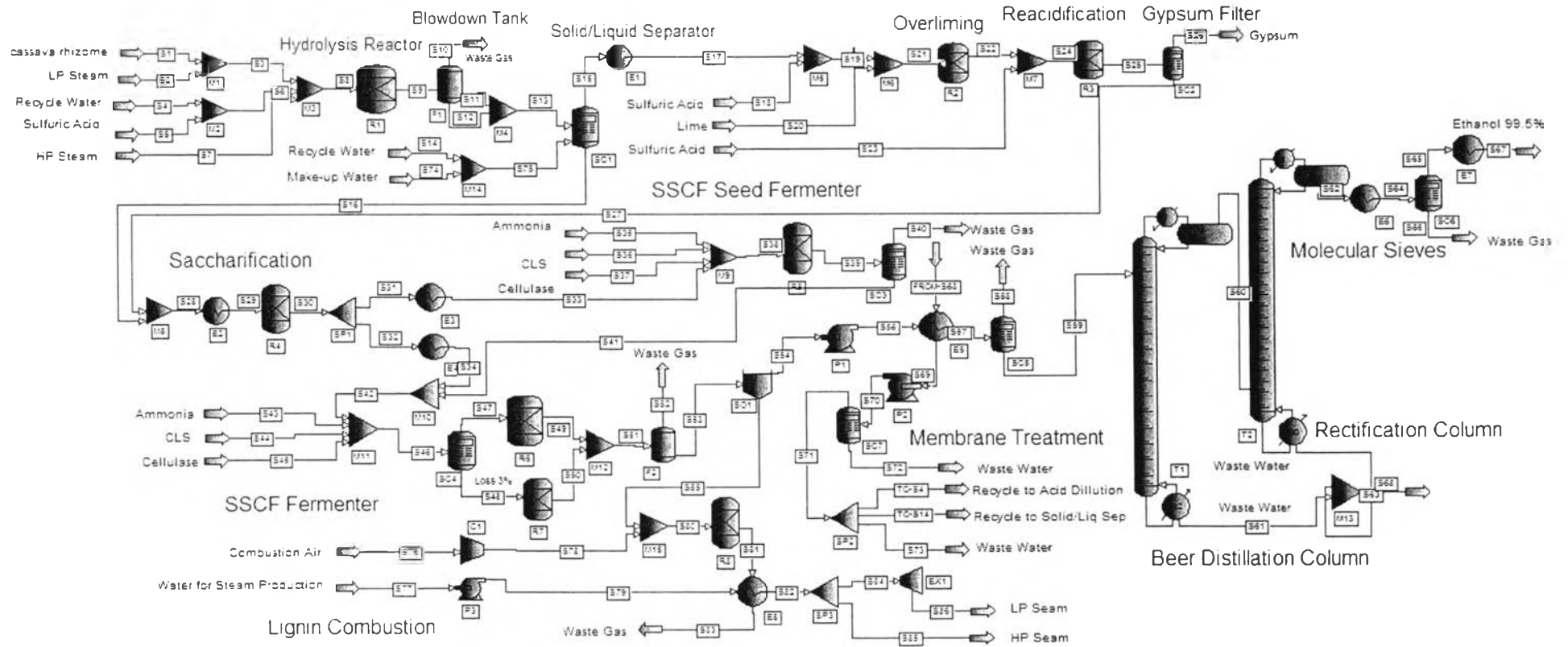


Figure D5 Flowsheet of the bioethanol production process from cassava rhizome for alternative 4 design.

D.1.6 Alternative 5: Wastewater Recover by Membranes with Heat Integration

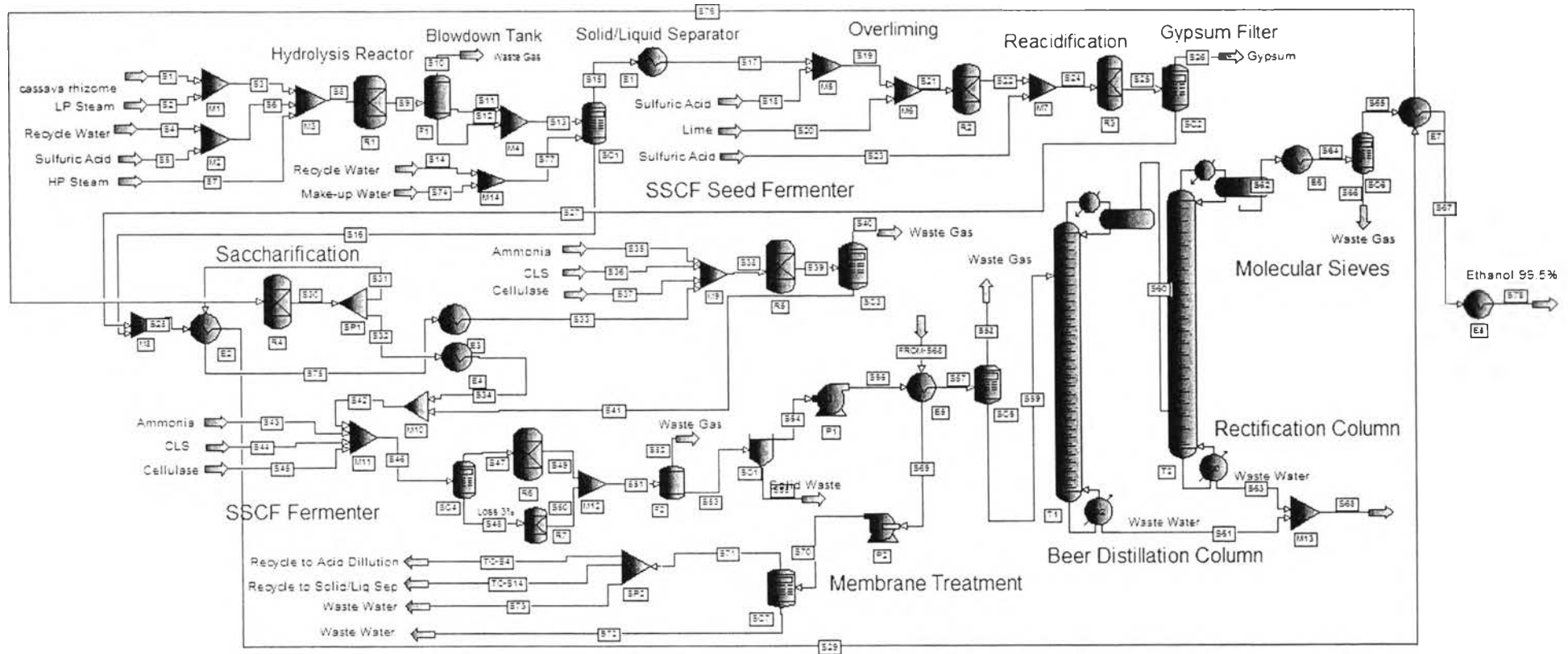


Figure D6 Flowsheet of the bioethanol production process from cassava rhizome for alternative 5 design.

D.1.7 Alternative 6: Lignin Combustion with Heat Integration

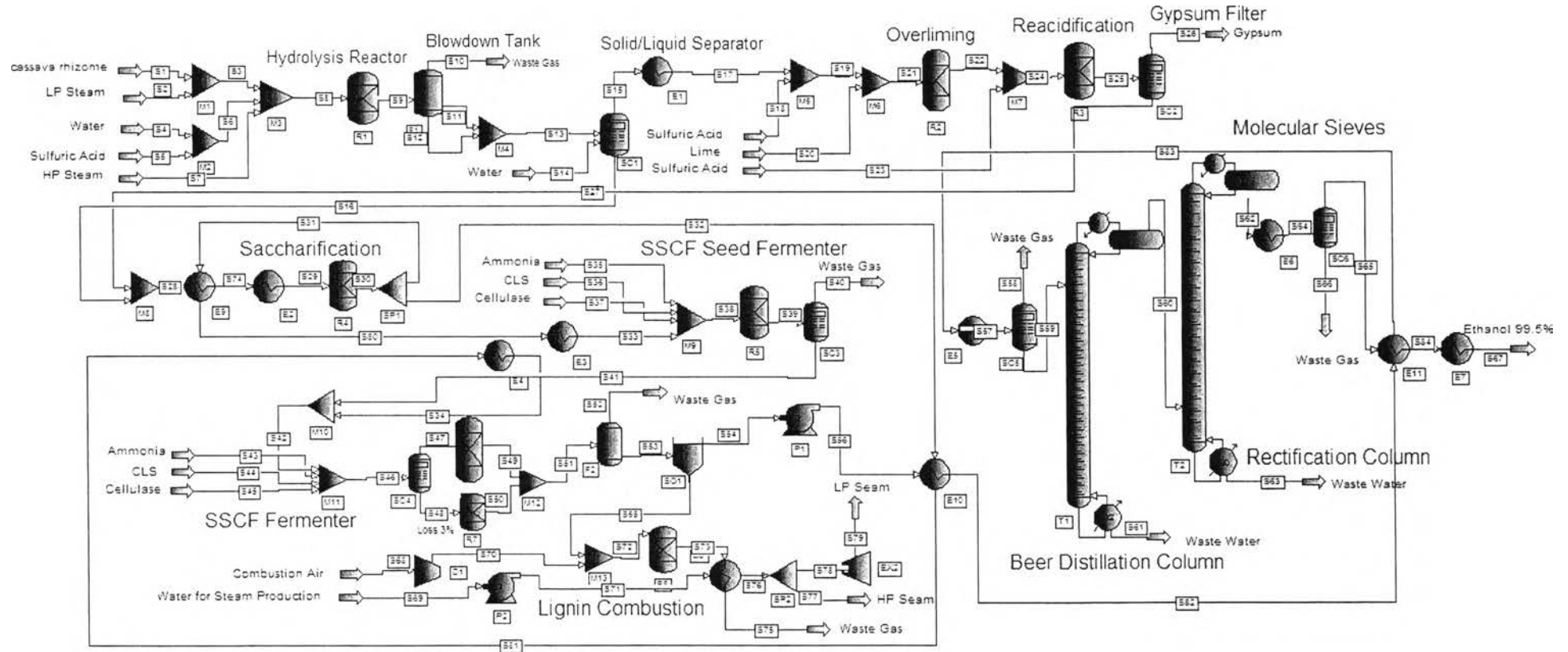


Figure D7 Flowsheet of the bioethanol production process from cassava rhizome for alternative 6 design.

D.1.8 Alternative 7: Wastewater Recover by Membranes and Lignin Combustion with Heat Integration

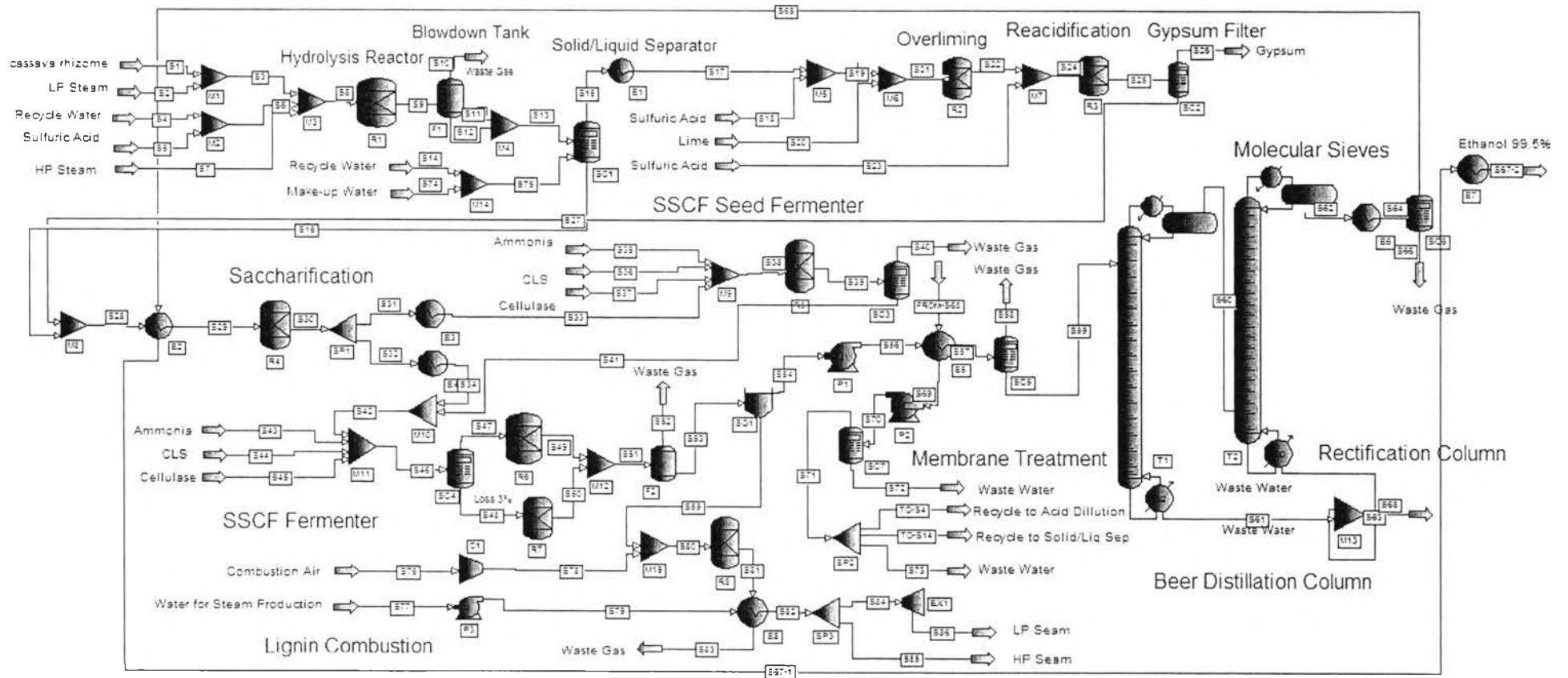


Figure D8 Flowsheet of the bioethanol production process from cassava rhizome for alternative 7 design.

D.2 Stream Table of Three Main Ideas

D.2.1 Base Case Design

Table D1 Stream table of the bioethanol process from cassava rhizome for base case design

Stream Name		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Phase		Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid
Temperature	C	30.0	160.0	100.0	25.0	25.0	25.0	268.0	188.0	190.0	103.9	103.9	103.9	103.9	25.0
Pressure	ATM	1.0	6.0	1.0	1.0	1.0	1.0	13.0	12.1	12.1	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-26.4	2.2	-24.2	0.5	0.0	0.5	8.8	-14.9	-0.8	6.5	5.7	-13.0	-7.3	1.4
Molecular Weight		103.9	18.0	84.7	18.0	98.1	18.3	18.0	38.2	40.9	18.7	35.4	94.7	47.2	18.0
Vapor Weight Fraction		1.0	1.0	0.9	0.0	0.0	0.0	1.0	0.6	0.4	1.0	0.0	1.0	0.4	0.0
Liquid Weight Fraction		0.0	0.0	0.1	1.0	1.0	1.0	0.0	0.4	0.6	0.0	1.0	0.0	0.6	1.0
Total Mass Rate	KG/DAY	377181.3	18842.2	396023.4	119330.6	2386.6	121717.2	75681.1	593421.7	593421.4	59701.8	320465.7	213254.0	533719.6	309557.6
Total Weight Comp. Rates		Mass Flow (KG/DAY)													
Cellulose		112334.0	0.0	112334.0	0.0	0.0	0.0	0.0	112334.0	103684.3	0.0	0.0	103684.3	103684.3	0.0
Hemicellulose		160178.0	0.0	160178.0	0.0	0.0	0.0	0.0	160178.0	8008.9	0.0	0.0	8008.9	8008.9	0.0
Lignin		87682.7	0.0	87682.7	0.0	0.0	0.0	0.0	87682.7	87682.7	0.0	0.0	87682.7	87682.7	0.0
Glucose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8737.1	0.0	8737.1	0.0	8737.1	0.0
Xylose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	163817.3	0.0	163817.3	0.0	163817.3	0.0
Cellobiose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	830.0	0.0	830.0	0.0	830.0	0.0
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water		3108.5	18842.2	21950.7	119330.6	0.0	119330.6	75681.1	216962.4	198571.7	56918.1	141653.6	0.0	141653.6	309557.6
Sulfuric Acid		0.0	0.0	0.0	0.0	2386.6	2386.6	0.0	2386.6	2386.6	0.0	2386.6	0.0	2386.6	0.0
Furfural		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5824.7	2783.6	3041.1	0.0	3041.1	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CornSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13878.1	0.0	13878.1	0.0	0.0	0.0	0.0	13878.1	13878.1	0.0	0.0	13878.1	13878.1	0.0

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

Stream Name		S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28
Phase		Mixed	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature	C	62.7	62.7	50.0	25.0	49.9	25.0	49.9	49.9	25.0	49.8	49.8	49.8	49.8	54.1
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	5.7	-11.6	4.8	0.0	4.8	-0.5	4.3	4.7	0.0	4.7	4.8	0.0	4.9	-6.7
Molecular Weight		23.1	46.5	23.1	98.1	23.2	74.1	23.4	23.3	98.1	23.3	23.3	137.8	23.0	29.5
Vapor Weight Fraction		0.0	0.6	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.3
Liquid Weight Fraction		1.0	0.4	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.7
Total Mass Rate	KG/DAY	475780.8	367496.4	475780.8	2693.7	478474.5	4306.0	482780.4	482780.4	1119.9	483900.4	483900.4	8701.4	475199.0	842695.4
Total Weight Comp. Rates	Mass Flow (KG/DAY)														
Cellulose		518.4	103165.9	518.4	0.0	518.4	0.0	518.4	518.4	0.0	518.4	518.4	518.4	0.0	103165.9
Hemicellulose		40.0	7968.9	40.0	0.0	40.0	0.0	40.0	40.0	0.0	40.0	40.0	40.0	0.0	7968.9
Lignin		438.4	87244.2	438.4	0.0	438.4	0.0	438.4	438.4	0.0	438.4	438.4	0.0	438.4	87682.7
Glucose		6902.3	1834.8	6902.3	0.0	6902.3	0.0	6902.3	6902.3	0.0	6902.3	6902.3	13.8	6888.5	8723.3
Xylose		106481.3	57336.1	106481.3	0.0	106481.3	0.0	106481.3	106481.3	0.0	106481.3	106481.3	213.0	106268.3	163604.4
Cellulobiose		655.7	174.3	655.7	0.0	655.7	0.0	655.7	655.7	0.0	655.7	655.7	0.0	655.7	830.0
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water		356456.8	94754.3	356456.8	0.0	356456.8	0.0	356456.8	358139.0	0.0	358139.0	358550.4	0.0	358550.4	453304.7
Sulfuric Acid		1885.4	501.2	1885.4	2693.7	4579.1	0.0	4579.1	0.0	1119.9	1119.9	0.0	0.0	0.0	501.2
Furfural		2402.4	638.6	2402.4	0.0	2402.4	0.0	2402.4	2402.4	0.0	2402.4	2402.4	4.8	2397.6	3036.2
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CornSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	4306.0	4306.0	846.8	0.0	846.8	0.7	0.7	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	6356.1	0.0	6356.1	7910.6	7910.6	0.0	0.0
Ash		0.0	13878.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13878.1

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

Stream Name		S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42
Phase		Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed
Temperature	C	65.0	65.0	65.0	65.0	41.6	40.9	25.0	25.0	25.0	41.0	41.0	42.5	42.5	41.0
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-5.6	3.0	0.3	2.7	0.1	0.5	0.0	0.0	0.0	0.1	-0.1	0.1	-0.2	0.3
Molecular Weight		29.5	30.1	30.1	30.1	30.1	30.1	17.0	18.0	18.1	29.5	26.2	44.0	24.6	29.5
Vapor Weight Fraction		0.3	0.1	0.1	0.1	0.1	0.1	1.0	0.0	0.0	0.1	0.3	1.0	0.2	0.1
Liquid Weight Fraction		0.7	0.9	0.9	0.9	0.9	0.9	0.0	1.0	1.0	0.9	0.7	0.0	0.8	0.9
Total Mass Rate	KG/DAY	842695.4	842696.0	84269.6	758426.4	84269.6	758426.4	20.0	1432.6	924.0	86646.1	86645.9	11716.7	74929.2	833355.6
Total Weight Comp. Rates		Mass Flow (KG/DAY)													
Cellulose		103165.9	9078.6	907.9	8170.7	907.9	8170.7	0.0	0.0	0.0	907.9	907.9	0.0	907.9	9078.6
Hemicellulose		7968.9	7968.9	796.9	7172.0	796.9	7172.0	0.0	0.0	0.0	796.9	796.9	0.0	796.9	7968.9
Lignin		87682.7	87682.7	8768.3	78914.4	8768.3	78914.4	0.0	0.0	0.0	8768.3	8768.3	0.0	8768.3	87682.7
Glucose		8723.3	112763.2	11276.3	101486.9	11276.3	101486.9	0.0	0.0	0.0	11276.3	1053.5	0.0	1053.5	102540.4
Xylose		163604.4	163604.4	16360.4	147243.9	16360.4	147243.9	0.0	0.0	0.0	16360.4	2913.5	0.0	2913.5	150157.5
Cellulobiose		830.0	1306.8	130.7	1176.1	130.7	1176.1	0.0	0.0	0.0	130.7	130.7	0.0	130.7	1306.8
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11884.0	891.3	10992.7	10992.7
Water		453304.7	442876.1	44287.6	398588.5	44287.6	398588.5	0.0	0.0	905.8	45193.4	45215.6	22.6	45193.0	443781.5
Sulfuric Acid		501.2	501.2	50.1	451.1	50.1	451.1	0.0	0.0	0.0	50.1	50.1	0.0	50.1	501.2
Furfural		3036.2	3036.2	303.6	2732.6	303.6	2732.6	0.0	0.0	0.0	303.6	303.6	0.0	303.6	3036.2
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1	33.1	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11336.5	10769.7	566.8	566.8
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	0.0	14.1	14.1
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.7	0.0	43.7	43.7
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	8.0	8.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	146.0	0.0	146.0	146.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.5	0.0	57.5	57.5
ComSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	1432.6	0.0	1432.6	1432.6	0.0	1432.6	1432.6
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.3	0.0	144.3	144.3
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	18.2	18.2	0.0	18.2	18.2
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13878.1	13878.1	1387.8	12490.3	1387.8	12490.3	0.0	0.0	0.0	1387.8	1387.8	0.0	1387.8	13878.1

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

Stream Name		S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55
Phase		Vapor	Liquid	Solid	Mixed	Mixed	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid	Solid
Temperature	C	25.0	25.0	25.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	0.0	0.0	0.0	0.3	0.1	0.1	-1.0	0.0	-1.0	1.1	-2.1	4.2	-6.2
Molecular Weight		17.0	18.0	22.8	29.4	29.2	161.0	25.9	90.1	26.1	42.3	24.7	22.2	67.4
Vapor Weight Fraction		1.0	0.0	1.0	0.1	0.1	0.0	0.3	0.0	0.3	1.0	0.2	0.0	1.0
Liquid Weight Fraction		0.0	1.0	0.0	0.9	0.9	1.0	0.7	1.0	0.7	0.0	0.8	1.0	0.0
Total Mass Rate	KG/DAY	59.6	2106.7	181.6	835703.5	828122.6	7580.9	828120.8	7580.9	835701.7	107275.2	728426.5	617225.3	111201.3
Total Weight Comp. Rates		Mass Flow (KG/DAY)												
Cellulose		0.0	0.0	0.0	9078.6	9078.6	0.0	897.0	0.0	897.0	0.0	897.0	0.0	897.0
Hemicellulose		0.0	0.0	0.0	7968.9	7968.9	0.0	7968.9	0.0	7968.9	0.0	7968.9	0.0	7968.9
Lignin		0.0	0.0	0.0	87682.7	87682.7	0.0	87682.7	0.0	87682.7	0.0	87682.7	0.0	87682.7
Glucose		0.0	0.0	0.0	102540.4	99464.2	3076.2	5242.4	0.0	5242.4	0.0	5242.4	5242.4	0.0
Xylose		0.0	0.0	0.0	150157.5	145652.7	4504.7	19879.4	0.0	19879.4	0.0	19879.4	19879.4	0.0
Cellobiose		0.0	0.0	0.0	1306.8	1306.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol		0.0	0.0	0.0	10992.7	10992.7	0.0	127720.0	0.0	127720.0	6206.3	121513.7	121513.7	0.0
Water		0.0	0.0	0.0	443781.5	443781.5	0.0	442794.6	0.0	442794.6	3161.1	439633.5	439633.5	0.0
Sulfuric Acid		0.0	0.0	0.0	501.2	501.2	0.0	501.2	0.0	501.2	0.0	501.2	501.2	0.0
Furfural		0.0	0.0	0.0	3036.2	3036.2	0.0	3036.2	0.0	3036.2	52.5	2983.7	2983.7	0.0
Ammonia		59.6	0.0	0.0	59.6	59.6	0.0	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	186.3	0.0	186.3	183.6	2.7	2.7	0.0
Carbon Dioxide		0.0	0.0	0.0	566.8	566.8	0.0	111971.1	0.0	111971.1	97654.4	14316.8	14316.8	0.0
Glycerol		0.0	0.0	0.0	14.1	14.1	0.0	101.8	0.0	101.8	0.0	101.8	101.8	0.0
Succinic Acid		0.0	0.0	0.0	43.7	43.7	0.0	326.5	0.0	326.5	0.0	326.5	326.5	0.0
Lactic Acid		0.0	0.0	0.0	8.0	8.0	0.0	58.3	7580.9	7639.2	0.0	7639.2	7639.2	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	146.0	146.0	0.0	1142.2	0.0	1142.2	0.0	1142.2	1142.2	0.0
Acetic Acid		0.0	0.0	0.0	57.5	57.5	0.0	420.3	0.0	420.3	3.6	416.7	416.7	0.0
ComSteep Liquor		0.0	2106.7	0.0	3539.3	3539.3	0.0	3539.3	0.0	3539.3	13.6	3525.7	3525.7	0.0
ZM		0.0	0.0	0.0	144.3	144.3	0.0	575.0	0.0	575.0	0.0	575.0	0.0	575.0
Cellulase		0.0	0.0	181.6	199.7	199.7	0.0	199.7	0.0	199.7	0.0	199.7	0.0	199.7
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		0.0	0.0	0.0	13878.1	13878.1	0.0	13878.1	0.0	13878.1	0.0	13878.1	0.0	13878.1

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

Stream Name		S56	S57	S58	S59	S60	S61	S62	S63	S64	S65	S66	S67
Phase		Liquid	Liquid	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Vapor	Vapor	Vapor	Liquid
Temperature	C	41.2	100.5	100.0	100.0	93.8	116.7	93.3	110.0	100.0	100.0	100.0	40.0
Pressure	ATM	4.8	4.8	4.8	4.8	1.8	1.8	1.8	1.8	1.8	1.0	1.0	1.0
Enthalpy	M*KJ/HR	4.2	9.9	0.2	9.7	7.1	9.3	1.4	0.2	6.2	5.3	0.8	0.5
Molecular Weight		22.2	22.2	42.5	21.9	38.7	19.4	42.1	18.7	42.1	46.0	18.0	46.0
Vapor Weight Fraction		0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0	0.0
Liquid Weight Fraction		1.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0	1.0
Total Mass Rate	KG/DAY	617225.3	617225.3	15100.6	602124.7	136253.1	465871.6	126727.7	9525.4	126727.7	119152.2	7575.6	119152.2
Total Weight Comp. Rates		Mass Flow (KG/DAY)											
Cellulose		0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0
Lignin		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glucose		5242.4	5242.4	0.0	5242.4	0.0	5242.4	0.0	0.0	0.0	0.0	0.0	0.0
Xylose		19879.4	19879.4	0.0	19879.4	0.0	19879.4	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	0.0	0.0	0.0	0.0	0.0
Ethanol		121513.7	121513.7	364.5	121149.1	119691.1	1458.1	119092.6	598.4	119092.6	119092.6	0.0	119092.6
Water		439633.5	439633.5	395.7	439237.8	16552.2	422685.6	7635.1	8917.1	7635.1	59.6	7575.6	59.6
Sulfuric Acid		501.2	501.2	0.0	501.2	0.0	501.2	0.0	0.0	0.0	0.0	0.0	0.0
Furfural		2983.7	2983.7	17.7	2966.0	8.5	2957.4	0.0	8.5	0.0	0.0	0.0	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		2.7	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		14316.8	14316.8	14316.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		101.8	101.8	0.0	101.8	0.0	101.8	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		326.5	326.5	0.0	326.5	0.0	326.5	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		7639.2	7639.2	0.0	7639.2	0.0	7639.2	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	0.0	0.0	0.0	0.0	0.0
Xylitol		1142.2	1142.2	0.0	1142.2	0.0	1142.2	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		416.7	416.7	0.2	416.5	0.3	416.2	0.0	0.3	0.0	0.0	0.0	0.0
CornSteep Liquor		3525.7	3525.7	3.0	3522.7	1.0	3521.7	0.0	1.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0

D.2.2 Alternative 1 Design

Table D2 Stream table of the bioethanol process from cassava rhizome for alternative 1 design

Stream Name		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Phase		Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid	Mixed
Temperature	C	30.0	160.0	100.0	25.0	25.0	25.0	268.0	188.0	190.0	103.9	103.9	103.9	103.9	25.0	62.7
Pressure	ATM	1.0	6.0	1.0	1.0	1.0	1.0	13.0	12.1	12.1	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-26.4	2.1	-24.3	0.5	0.0	0.5	8.9	-14.9	-0.8	6.5	5.7	-13.0	-7.3	1.4	5.7
Molecular Weight		103.9	18.0	85.4	18.0	98.1	18.3	18.0	38.2	40.9	18.7	35.4	94.7	47.2	18.0	23.1
Vapor Weight Fraction		1.0	1.0	0.9	0.0	0.0	0.0	1.0	0.6	0.4	1.0	0.0	1.0	0.4	0.0	0.0
Liquid Weight Fraction		0.0	0.0	0.1	1.0	1.0	1.0	0.0	0.4	0.6	0.0	1.0	0.0	0.6	1.0	1.0
Total Mass Rate	KG/DAY	377191.1	17990.9	395182.1	119490.2	2393.7	121883.9	76553.3	593621.2	593620.9	59735.3	320626.1	213259.5	533885.6	309654.4	475983.5
Total Weight Comp. Rates		KG/DAY														
Cellulose		112337.0	0.0	112337.0	0.0	0.0	0.0	0.0	112337.0	103687.0	0.0	0.0	103687.0	103687.0	0.0	518.4
Hemicellulose		160182.1	0.0	160182.1	0.0	0.0	0.0	0.0	160182.1	8009.1	0.0	0.0	8009.1	8009.1	0.0	40.0
Lignin		87684.9	0.0	87684.9	0.0	0.0	0.0	0.0	87684.9	87684.9	0.0	0.0	87684.9	87684.9	0.0	438.4
Glucose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8737.3	0.0	8737.3	0.0	8737.3	0.0	6902.5
Xylose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	163821.6	0.0	163821.6	0.0	163821.6	0.0	106484.0
Cellobiose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	830.0	0.0	830.0	0.0	830.0	0.0	655.7
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water		3108.6	17990.9	21099.5	119490.2	0.0	119490.2	76553.3	217145.0	198753.8	56950.9	141803.0	0.0	141803.0	309654.4	356651.3
Sulfuric Acid		0.0	0.0	0.0	0.0	2393.7	2393.7	0.0	2393.7	2393.7	0.0	2393.7	0.0	2393.7	0.0	1891.1
Furfural		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5824.8	2784.4	3040.4	0.0	3040.4	0.0	2401.9
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ComSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13878.5	0.0	13878.5	0.0	0.0	0.0	0.0	13878.5	13878.5	0.0	0.0	13878.5	13878.5	0.0	0.0

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

Stream Name		S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
Phase		Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature	C	62.7	50.0	25.0	49.9	25.0	49.9	49.9	25.0	49.8	49.8	49.8	49.8	54.1	65.0	65.0
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-11.6	4.8	0.0	4.8	-0.5	4.3	4.7	0.0	4.7	4.8	0.0	4.9	-6.7	-5.6	3.0
Molecular Weight		46.5	23.1	98.1	23.2	74.1	23.4	23.3	98.1	23.3	23.3	137.8	23.0	29.5	29.5	30.1
Vapor Weight Fraction		0.6	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.3	0.3	0.1
Liquid Weight Fraction		0.4	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.7	0.7	0.9
Total Mass Rate	KG/DAY	367556.6	475983.5	2700.5	478684.0	4308.5	482992.4	482992.4	1111.7	484104.2	484104.2	8706.6	475397.5	842954.1	842954.1	842954.7
Total Weight Comp. Rates		KG/DAY														
Cellulose		103168.6	518.4	0.0	518.4	0.0	518.4	518.4	0.0	518.4	518.4	518.4	0.0	103168.6	103168.6	9078.8
Hemicellulose		7969.1	40.0	0.0	40.0	0.0	40.0	40.0	0.0	40.0	40.0	40.0	0.0	7969.1	7969.1	7969.1
Lignin		87246.5	438.4	0.0	438.4	0.0	438.4	438.4	0.0	438.4	438.4	0.0	438.4	87684.9	87684.9	87684.9
Glucose		1834.8	6902.5	0.0	6902.5	0.0	6902.5	6902.5	0.0	6902.5	6902.5	13.8	6888.7	8723.5	8723.5	112766.1
Xylose		57337.6	106484.0	0.0	106484.0	0.0	106484.0	106484.0	0.0	106484.0	106484.0	213.0	106271.1	163608.6	163608.6	163608.6
Cellobiose		174.3	655.7	0.0	655.7	0.0	655.7	655.7	0.0	655.7	655.7	0.0	655.7	830.0	830.0	1306.8
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water		94806.1	356651.3	0.0	356651.3	0.0	356651.3	358338.1	0.0	358338.1	358746.5	0.0	358746.5	453552.5	453552.5	443123.6
Sulfuric Acid		502.7	1891.1	2700.5	4591.5	0.0	4591.5	0.0	1111.7	1111.7	0.0	0.0	0.0	502.7	502.7	502.7
Furfural		638.5	2401.9	0.0	2401.9	0.0	2401.9	2401.9	0.0	2401.9	2401.9	4.8	2397.1	3035.6	3035.6	3035.6
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ComSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	4308.5	4308.5	839.8	0.0	839.8	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	6373.4	0.0	6373.4	7916.6	7916.6	0.0	0.0	0.0	0.0
Ash		13878.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13878.5	13878.5	13878.5

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

Stream Name		S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41	S42	S43	S44	S45
Phase		Mixed	Mixed	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed	Mixed	Vapor	Liquid	Solid
Temperature	C	65.0	65.0	41.0	41.0	25.0	25.0	25.0	40.4	40.4	41.7	41.7	41.1	25.0	25.0	25.0
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	0.3	2.7	0.1	0.5	0.0	0.0	0.0	0.1	-0.1	0.1	-0.2	0.3	0.0	0.0	0.0
Molecular Weight		30.1	30.1	30.1	30.1	17.0	18.0	18.1	29.5	26.2	44.0	24.6	29.5	17.0	18.0	22.8
Vapor Weight Fraction		0.1	0.1	0.1	0.1	1.0	0.0	0.0	0.1	0.3	1.0	0.2	0.1	1.0	0.0	1.0
Liquid Weight Fraction		0.9	0.9	0.9	0.9	0.0	1.0	1.0	0.9	0.7	0.0	0.8	0.9	0.0	1.0	0.0
Total Mass Rate	KG/DAY	84295.5	758659.3	84295.5	758659.3	5.0	1433.0	924.0	86657.5	86672.3	11717.0	74955.3	833614.5	0.3	2107.4	181.6
Total Weight Comp Rates		KG/DAY														
Cellulose		907.9	8171.0	907.9	8171.0	0.0	0.0	0.0	907.9	907.9	0.0	907.9	9078.8	0.0	0.0	0.0
Hemicellulose		796.9	7172.2	796.9	7172.2	0.0	0.0	0.0	796.9	796.9	0.0	796.9	7969.1	0.0	0.0	0.0
Lignin		8768.5	78916.4	8768.5	78916.4	0.0	0.0	0.0	8768.5	8768.5	0.0	8768.5	87684.9	0.0	0.0	0.0
Glucose		11276.6	101489.5	11276.6	101489.5	0.0	0.0	0.0	11276.6	1053.6	0.0	1053.6	102543.1	0.0	0.0	0.0
Xylose		16360.9	147247.8	16360.9	147247.8	0.0	0.0	0.0	16360.9	2913.6	0.0	2913.6	150161.4	0.0	0.0	0.0
Cellobiose		130.7	1176.1	130.7	1176.1	0.0	0.0	0.0	130.7	130.7	0.0	130.7	1306.8	0.0	0.0	0.0
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11884.3	891.3	10993.0	10993.0	0.0	0.0	0.0
Water		44312.4	398811.2	44312.4	398811.2	0.0	0.0	905.8	45218.2	45240.4	22.6	45217.8	444029.0	0.0	0.0	0.0
Sulfuric Acid		50.3	452.4	50.3	452.4	0.0	0.0	0.0	50.3	50.3	0.0	50.3	502.7	0.0	0.0	0.0
Furfural		303.6	2732.1	303.6	2732.1	0.0	0.0	0.0	303.6	303.6	0.0	303.6	3035.6	0.0	0.0	0.0
Ammonia		0.0	0.0	0.0	0.0	5.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1	33.1	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	0.0	11336.8	10770.0	566.8	566.8	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	0.0	14.1	14.1	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.7	0.0	43.7	43.7	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	8.0	8.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	146.0	0.0	146.0	146.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.5	0.0	57.5	57.5	0.0	0.0	0.0
CornSteep Liquor		0.0	0.0	0.0	0.0	0.0	1433.0	0.0	1433.0	1433.0	0.0	1433.0	1433.0	0.0	2107.4	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.3	0.0	144.3	144.3	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	18.2	18.2	18.2	0.0	18.2	18.2	0.0	0.0	181.6
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		1387.8	12490.6	1387.8	12490.6	0.0	0.0	0.0	1387.8	1387.8	0.0	1387.8	13878.5	0.0	0.0	0.0

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

Stream Name		S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60
Phase		Mixed	Mixed	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid	Solid	Liquid	Liquid	Vapor	Liquid	Vapor
Temperature	C	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.3	100.5	100.0	100.0	93.8
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.8	4.8	4.8	4.8	1.8
Enthalpy	M*KJ/HR	0.3	0.1	0.1	-1.0	0.0	-0.9	1.1	-2.0	4.2	-6.2	4.2	9.9	0.2	9.7	7.1
Molecular Weight		29.4	29.2	161.0	25.9	90.1	26.1	42.3	24.7	22.2	67.4	22.2	22.2	42.5	21.9	38.7
Vapor Weight Fraction		0.1	0.1	0.0	0.3	0.0	0.3	1.0	0.2	0.0	1.0	0.0	0.0	1.0	0.0	1.0
Liquid Weight Fraction		0.9	0.9	1.0	0.7	1.0	0.7	0.0	0.8	1.0	0.0	1.0	1.0	0.0	1.0	0.0
Total Mass Rate	KG/DAY	835903.8	828322.6	7581.1	828380.1	7581.1	835961.2	107288.3	728672.9	617468.8	111204.2	617468.8	617468.8	15099.6	602369.2	136234.5
Total Weight Comp Rates		KG/DAY														
Cellulose		9078.8	9078.8	0.0	897.0	0.0	897.0	0.0	897.0	0.0	897.0	0.0	0.0	0.0	0.0	0.0
Hemicellulose		7969.1	7969.1	0.0	7969.1	0.0	7969.1	0.0	7969.1	0.0	7969.1	0.0	0.0	0.0	0.0	0.0
Lignin		87684.9	87684.9	0.0	87684.9	0.0	87684.9	0.0	87684.9	0.0	87684.9	0.0	0.0	0.0	0.0	0.0
Glucose		102543.1	99466.8	3076.3	5242.5	0.0	5242.5	0.0	5242.5	5242.5	0.0	5242.5	5242.5	0.0	5242.5	0.0
Xylose		150161.4	145656.5	4504.8	19879.9	0.0	19879.9	0.0	19879.9	19879.9	0.0	19879.9	19879.9	0.0	19879.9	0.0
Cellobiose		1306.8	1306.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol		10993.0	10993.0	0.0	127723.3	0.0	127723.3	6211.5	121511.8	121511.8	0.0	121511.8	121511.8	364.5	121147.3	119689.3
Water		444029.0	444029.0	0.0	443042.1	0.0	443042.1	3164.8	439877.2	439877.2	0.0	439877.2	439877.2	395.9	439481.3	16535.3
Sulfuric Acid		502.7	502.7	0.0	502.7	0.0	502.7	0.0	502.7	502.7	0.0	502.7	502.7	0.0	502.7	0.0
Furfural		3035.6	3035.6	0.0	3035.6	0.0	3035.6	52.6	2983.0	2983.0	0.0	2983.0	2983.0	17.7	2965.3	8.5
Ammonia		0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	186.3	0.0	186.3	183.6	2.7	2.7	0.0	2.7	2.7	2.7	0.0	0.0
Carbon Dioxide		566.8	566.8	0.0	111974.0	0.0	111974.0	97658.5	14315.6	14315.6	0.0	14315.6	14315.6	14315.6	0.0	0.0
Glycerol		14.1	14.1	0.0	101.8	0.0	101.8	0.0	101.8	101.8	0.0	101.8	101.8	0.0	101.8	0.0
Succinic Acid		43.7	43.7	0.0	326.5	0.0	326.5	0.0	326.5	326.5	0.0	326.5	326.5	0.0	326.5	0.0
Lactic Acid		8.0	8.0	0.0	58.3	7581.1	7639.4	0.0	7639.4	7639.4	0.0	7639.4	7639.4	0.0	7639.4	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		146.0	146.0	0.0	1142.2	0.0	1142.2	0.0	1142.2	1142.2	0.0	1142.2	1142.2	0.0	1142.2	0.0
Acetic Acid		57.5	57.5	0.0	420.4	0.0	420.4	3.6	416.7	416.7	0.0	416.7	416.7	0.2	416.5	0.3
CornSteep Liquor		3540.4	3540.4	0.0	3540.4	0.0	3540.4	13.6	3526.8	3526.8	0.0	3526.8	3526.8	3.0	3523.8	1.0
ZM		144.3	144.3	0.0	575.0	0.0	575.0	0.0	575.0	0.0	575.0	0.0	0.0	0.0	0.0	0.0
Cellulase		199.7	199.7	0.0	199.7	0.0	199.7	0.0	199.7	0.0	199.7	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13878.5	13878.5	0.0	13878.5	0.0	13878.5	0.0	13878.5	0.0	13878.5	0.0	0.0	0.0	0.0	0.0

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

Stream Name		S61	S62	S63	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73
Phase		Liquid	Liquid	Liquid	Vapor	Vapor	Vapor	Liquid	Mixed	Mixed	Mixed	Liquid	Liquid	Mixed
Temperature	C	116.7	93.3	110.0	100.0	100.0	100.0	40.0	55.0	56.2	50.7	55.0	84.5	78.3
Pressure	ATM	1.8	1.8	1.8	1.8	1.0	1.0	1.0	1.0	1.0	1.0	4.8	4.8	1.0
Enthalpy	M*KJ/HR	9.3	1.4	0.2	6.2	5.3	0.8	0.5	-6.6	0.2	1.4	5.5	8.3	2.5
Molecular Weight		19.4	42.1	18.7	42.1	46.0	18.0	46.0	29.5	30.1	30.1	22.2	22.2	46.0
Vapor Weight Fraction		0.0	0.0	0.0	1.0	1.0	1.0	0.0	0.3	0.1	0.1	0.0	0.0	0.4
Liquid Weight Fraction		1.0	1.0	1.0	0.0	0.0	0.0	1.0	0.7	0.9	0.9	1.0	1.0	0.6
Total Mass Rate	KG/DAY	466134.7	126743.6	9490.9	126743.6	119150.7	7592.9	119150.7	842954.1	84295.5	758659.3	617468.8	617468.8	119150.7
Total Weight Comp. Rates		KG/DAY												
Cellulose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	103168.6	907.9	8171.0	0.0	0.0	0.0
Hemicellulose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	7969.1	796.9	7172.2	0.0	0.0	0.0
Lignin		0.0	0.0	0.0	0.0	0.0	0.0	0.0	87684.9	8768.5	78916.4	0.0	0.0	0.0
Glucose		5242.5	0.0	0.0	0.0	0.0	0.0	0.0	8723.5	11276.6	101489.5	5242.5	5242.5	0.0
Xylose		19879.9	0.0	0.0	0.0	0.0	0.0	0.0	163608.6	16360.9	147247.8	19879.9	19879.9	0.0
Cellulobiose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	830.0	130.7	1176.1	0.0	0.0	0.0
Ethanol		1457.9	119091.0	598.3	119091.0	119091.0	0.0	119091.0	0.0	0.0	0.0	121511.8	121511.8	119091.0
Water		422946.0	7652.6	8882.8	7652.6	59.7	7592.9	59.7	453552.5	44312.4	398811.2	439877.2	439877.2	59.7
Sulfuric Acid		502.7	0.0	0.0	0.0	0.0	0.0	0.0	502.7	50.3	452.4	502.7	502.7	0.0
Furfural		2956.7	0.0	8.5	0.0	0.0	0.0	0.0	3035.6	303.6	2732.1	2983.0	2983.0	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.7	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14315.6	14315.6	0.0
Glycerol		101.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	101.8	101.8	0.0
Succinic Acid		326.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	326.5	326.5	0.0
Lactic Acid		7639.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7639.4	7639.4	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		1142.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1142.2	1142.2	0.0
Acetic Acid		416.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	416.7	416.7	0.0
ComSteep Liquor		3522.8	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3526.8	3526.8	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		0.0	0.0	0.0	0.0	0.0	0.0	0.0	13878.5	1387.8	12490.6	0.0	0.0	0.0

D.2.3 Alternative 2 Design

Table D3 Stream table of the bioethanol process from cassava rhizome for alternative 2 design

Stream Name		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Phase		Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid
Temperature	C	30.0	160.0	100.0	51.8	25.0	51.6	268.0	188.0	190.0	103.8	103.8	103.8	103.8	51.8
Pressure	ATM	1.0	6.0	1.0	1.0	1.0	1.0	13.0	12.1	12.1	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-25.5	2.2	-23.3	1.1	0.0	1.1	7.8	-14.4	-0.8	6.2	5.5	-12.6	-7.0	5.3
Molecular Weight		103.9	18.0	84.2	18.1	98.1	18.4	18.0	38.3	41.0	18.8	35.4	94.7	47.2	18.1
Vapor Weight Fraction		1.0	1.0	0.9	0.0	0.0	0.0	1.0	0.6	0.4	1.0	0.0	1.0	0.4	0.0
Liquid Weight Fraction		0.0	0.0	0.1	1.0	1.0	1.0	0.0	0.4	0.6	0.0	1.0	0.0	0.6	1.0
Total Mass Rate	KG/DAY	364011.7	18842.2	382853.9	120365.6	2297.1	122668.7	67368.9	572891.5	572891.2	57756.6	309326.6	205808.1	515134.6	585481.9
Total Weight Comp Rates		KG/DAY													
Cellulose		108411.8	0.0	108411.8	0.0	0.0	0.0	0.0	108411.8	100064.1	0.0	0.0	100064.1	100064.1	0.0
Hemicellulose		154585.2	0.0	154585.2	0.0	0.0	0.0	0.0	154585.2	7729.3	0.0	0.0	7729.3	7729.3	0.0
Lignin		84621.2	0.0	84621.2	0.0	0.0	0.0	0.0	84621.2	84621.2	0.0	0.0	84621.2	84621.2	0.0
Glucose		0.0	0.0	0.0	32.8	0.0	32.8	0.0	32.8	8464.9	0.0	8464.9	0.0	8464.9	159.7
Xylose		0.0	0.0	0.0	156.3	0.0	156.3	0.0	156.3	158253.8	0.0	158253.8	0.0	158253.8	760.3
Cellobiose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	801.0	0.0	801.0	0.0	801.0	0.0
Ethanol		0.0	0.0	0.0	166.6	0.0	166.6	0.0	166.6	166.6	130.0	36.5	0.0	36.5	810.3
Water		3000.0	18842.2	21842.2	119689.6	0.0	119695.7	67368.9	208906.7	191158.2	54849.0	136309.2	0.0	136309.2	582194.0
Sulfuric Acid		0.0	0.0	0.0	3.9	2297.1	2301.0	0.0	2301.0	2301.0	0.0	2301.0	0.0	2301.0	19.2
Furfural		0.0	0.0	0.0	189.3	0.0	189.3	0.0	189.3	5810.6	2767.5	3043.1	0.0	3043.1	920.8
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.8	0.0	0.8	0.0	0.8	0.8	0.0	0.8	0.0	0.8	4.1
Succinic Acid		0.0	0.0	0.0	2.7	0.0	2.7	0.0	2.7	2.7	0.0	2.7	0.0	2.7	13.1
Lactic Acid		0.0	0.0	0.0	63.0	0.0	63.0	0.0	63.0	63.0	0.1	62.8	0.0	62.8	306.2
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	9.4	0.0	9.4	0.0	9.4	9.4	0.0	9.4	0.0	9.4	45.9
Acetic Acid		0.0	0.0	0.0	3.4	0.0	3.4	0.0	3.4	3.4	1.2	2.3	0.0	2.3	16.7
CornSteep Liquor		0.0	0.0	0.0	47.6	0.0	47.6	0.0	47.6	47.6	8.8	38.8	0.0	38.8	231.6
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13393.5	0.0	13393.5	0.0	0.0	0.0	0.0	13393.5	13393.5	0.0	0.0	13393.5	13393.5	0.0

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

Stream Name		S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28
Phase		Mixed	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed	Mixed
Temperature	C	59.0	59.0	50.0	25.0	50.0	25.0	49.9	49.9	25.0	49.8	49.8	49.8	49.8	52.4
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	9.5	-10.2	8.2	0.0	8.2	-0.9	7.4	7.7	0.0	7.7	8.2	-0.1	8.3	-1.9
Molecular Weight		20.4	33.9	20.4	98.1	20.5	74.1	20.6	20.6	98.1	20.7	20.7	136.9	20.4	23.7
Vapor Weight Fraction		0.0	0.4	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.2
Liquid Weight Fraction		1.0	0.6	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0	0.8
Total Mass Rate	KG/DAY	870635.5	464204.7	870635.5	2618.4	873253.9	7874.2	881128.1	881128.1	5957.6	887085.6	887085.6	15225.3	871860.4	1336065.1
Total Weight Comp. Rates		KG/DAY													
Cellulose		500.3	99563.8	500.3	0.0	500.3	0.0	500.3	500.3	0.0	500.3	500.3	500.3	0.0	99563.8
Hemicellulose		38.6	7690.6	38.6	0.0	38.6	0.0	38.6	38.6	0.0	38.6	38.6	38.6	0.0	7690.6
Lignin		423.1	84198.0	423.1	0.0	423.1	0.0	423.1	423.1	0.0	423.1	423.1	0.0	423.1	84621.2
Glucose		6813.4	1811.2	6813.4	0.0	6813.4	0.0	6813.4	6813.4	0.0	6813.4	6813.4	13.6	6799.8	8611.0
Xylose		103359.2	55654.9	103359.2	0.0	103359.2	0.0	103359.2	103359.2	0.0	103359.2	103359.2	206.7	103152.4	158807.4
Cellobiose		632.8	168.2	632.8	0.0	632.8	0.0	632.8	632.8	0.0	632.8	632.8	0.0	632.8	801.0
Ethanol		669.0	177.8	669.0	0.0	669.0	0.0	669.0	669.0	0.0	669.0	669.0	0.0	669.0	846.8
Water		752654.3	200072.7	752654.3	0.0	752654.3	0.0	752654.3	754289.6	0.0	754289.6	756478.2	0.0	756478.2	956550.8
Sulfuric Acid		1833.0	487.2	1833.0	2618.4	4451.4	0.0	4451.4	0.0	5957.6	5957.6	0.0	0.0	0.0	487.2
Furfural		3131.5	832.4	3131.5	0.0	3131.5	0.0	3131.5	3131.5	0.0	3131.5	3131.5	6.3	3125.2	3957.6
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		3.9	1.0	3.9	0.0	3.9	0.0	3.9	3.9	0.0	3.9	3.9	0.0	3.9	4.9
Succinic Acid		12.5	3.3	12.5	0.0	12.5	0.0	12.5	12.5	0.0	12.5	12.5	0.0	12.5	15.8
Lactic Acid		291.5	77.5	291.5	0.0	291.5	0.0	291.5	291.5	0.0	291.5	291.5	0.0	291.5	369.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		43.7	11.6	43.7	0.0	43.7	0.0	43.7	43.7	0.0	43.7	43.7	0.0	43.7	55.3
Acetic Acid		15.0	4.0	15.0	0.0	15.0	0.0	15.0	15.0	0.0	15.0	15.0	0.0	15.0	19.0
ComSteep Liquor		213.7	56.8	213.7	0.0	213.7	0.0	213.7	213.7	0.0	213.7	213.7	0.4	213.2	270.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	7874.2	7874.2	4511.5	0.0	4511.5	10.9	10.9	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	6178.8	0.0	6178.8	14448.4	14448.4	0.0	0.0
Ash		0.0	13393.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13393.5

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

Stream Name		S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40	S41
Phase		Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor	Mixed
Temperature	C	65.0	65.0	65.0	65.0	41.4	41.0	25.0	25.0	25.0	41.0	41.0	41.0	41.0
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	0.5	8.8	0.9	7.9	0.4	3.8	0.0	0.0	0.0	0.4	0.2	0.1	0.1
Molecular Weight		23.7	23.9	23.9	23.9	23.9	23.9	17.0	18.0	18.1	23.7	22.3	43.8	21.3
Vapor Weight Fraction		0.2	0.1	0.1	0.1	0.1	0.1	1.0	0.0	0.0	0.1	0.1	1.0	0.1
Liquid Weight Fraction		0.8	0.9	0.9	0.9	0.9	0.9	0.0	1.0	1.0	0.9	0.9	0.0	0.9
Total Mass Rate	KG/DAY	1336065.1	1336065.7	133606.6	1202459.1	133606.6	1202459.1	19.4	2276.4	891.7	136794.1	136793.9	11385.5	125408.4
Total Weight Comp. Rates		KG/DAY												
Cellulose		99563.8	8761.6	876.2	7885.5	876.2	7885.5	0.0	0.0	0.0	876.2	876.2	0.0	876.2
Hemicellulose		7690.6	7690.6	769.1	6921.6	769.1	6921.6	0.0	0.0	0.0	769.1	769.1	0.0	769.1
Lignin		84621.2	84621.2	8462.1	76159.0	8462.1	76159.0	0.0	0.0	0.0	8462.1	8462.1	0.0	8462.1
Glucose		8611.0	109018.2	10901.8	98116.4	10901.8	98116.4	0.0	0.0	0.0	10901.8	1018.6	0.0	1018.6
Xylose		158807.4	158807.4	15880.7	142926.6	15880.7	142926.6	0.0	0.0	0.0	15880.7	2828.1	0.0	2828.1
Cellobiose		801.0	1261.1	126.1	1135.0	126.1	1135.0	0.0	0.0	0.0	126.1	126.1	0.0	126.1
Ethanol		846.8	846.8	84.7	762.1	84.7	762.1	0.0	0.0	0.0	84.7	11600.1	870.0	10730.1
Water		956550.8	946486.3	94648.6	851837.7	94648.6	851837.7	0.0	0.0	874.2	95522.8	95544.3	47.8	95496.5
Sulfuric Acid		487.2	487.2	48.7	438.5	48.7	438.5	0.0	0.0	0.0	48.7	48.7	0.0	48.7
Furfural		3957.6	3957.6	395.8	3561.9	395.8	3561.9	0.0	0.0	0.0	395.8	395.8	0.0	395.8
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	19.4	0.0	0.0	19.4	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.1	32.1	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10984.9	10435.6	549.2
Glycerol		4.9	4.9	0.5	4.4	0.5	4.4	0.0	0.0	0.0	0.5	14.1	0.0	14.1
Succinic Acid		15.8	15.8	1.6	14.2	1.6	14.2	0.0	0.0	0.0	1.6	44.0	0.0	44.0
Lactic Acid		369.0	369.0	36.9	332.1	36.9	332.1	0.0	0.0	0.0	36.9	44.6	0.0	44.6
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		55.3	55.3	5.5	49.8	5.5	49.8	0.0	0.0	0.0	5.5	147.2	0.0	147.2
Acetic Acid		19.0	19.0	1.9	17.1	1.9	17.1	0.0	0.0	0.0	1.9	57.7	0.0	57.7
CornSteep Liquor		270.0	270.0	27.0	243.0	27.0	243.0	0.0	2276.4	0.0	2303.5	2303.5	0.0	2303.5
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	140.0	0.0	140.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.5	17.5	17.5	0.0	17.5
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13393.5	13393.5	1339.4	12054.2	1339.4	12054.2	0.0	0.0	0.0	1339.4	1339.4	0.0	1339.4

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

Stream Name		S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54
Phase		Mixed	Vapor	Liquid	Solid	Mixed	Mixed	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed	Liquid
Temperature	C	41.0	25.0	25.0	25.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	4.0	0.0	0.0	0.0	4.0	3.9	0.1	2.6	0.0	2.7	0.8	1.8	7.8
Molecular Weight		23.6	17.0	18.0	22.8	23.6	23.5	161.0	22.1	90.1	22.2	42.2	21.5	20.2
Vapor Weight Fraction		0.1	1.0	0.0	1.0	0.1	0.1	0.0	0.1	0.0	0.1	1.0	0.1	0.0
Liquid Weight Fraction		0.9	0.0	1.0	0.0	0.9	0.9	1.0	0.9	1.0	0.9	0.0	0.9	1.0
Total Mass Rate	KG/DAY	1327867.5	57.7	3347.7	175.2	1331448.2	1324101.5	7346.7	1324099.8	7346.6	1331446.4	87216.2	1244230.2	1136908.9
Total Weight Comp. Rates		KG/DAY												
Cellulose		8761.6	0.0	0.0	0.0	8761.6	8761.6	0.0	865.6	0.0	865.6	0.0	865.6	0.0
Hemicellulose		7690.6	0.0	0.0	0.0	7690.6	7690.6	0.0	7690.6	0.0	7690.6	0.0	7690.6	0.0
Lignin		84621.2	0.0	0.0	0.0	84621.2	84621.2	0.0	84621.2	0.0	84621.2	0.0	84621.2	0.0
Glucose		99135.0	0.0	0.0	0.0	99135.0	96160.9	2974.0	5067.4	0.0	5067.4	0.0	5067.4	5067.4
Xylose		145754.7	0.0	0.0	0.0	145754.7	141382.1	4372.6	19296.5	0.0	19296.5	0.0	19296.5	19296.5
Cellobiose		1261.1	0.0	0.0	0.0	1261.1	1261.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol		11492.2	0.0	0.0	0.0	11492.2	11492.2	0.0	124580.5	0.0	124580.5	3067.2	121513.2	121513.2
Water		947334.2	0.0	0.0	0.0	947334.2	947334.2	0.0	946381.6	0.0	946381.6	2682.3	943699.3	943699.3
Sulfuric Acid		487.2	0.0	0.0	0.0	487.2	487.2	0.0	487.2	0.0	487.2	0.0	487.2	487.2
Furfural		3957.6	0.0	0.0	0.0	3957.6	3957.6	0.0	3957.6	0.0	3957.6	39.1	3918.5	3918.5
Ammonia		0.0	57.7	0.0	0.0	57.7	57.7	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	180.8	0.0	180.8	174.9	5.8	5.8
Carbon Dioxide		549.2	0.0	0.0	0.0	549.2	549.2	0.0	108480.4	0.0	108480.4	81240.9	27239.5	27239.5
Glycerol		18.6	0.0	0.0	0.0	18.6	18.6	0.0	103.7	0.0	103.7	0.0	103.7	103.7
Succinic Acid		58.2	0.0	0.0	0.0	58.2	58.2	0.0	332.5	0.0	332.5	0.0	332.5	332.5
Lactic Acid		376.8	0.0	0.0	0.0	376.8	376.8	0.0	425.6	7346.6	7772.2	0.0	7772.2	7772.2
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		197.0	0.0	0.0	0.0	197.0	197.0	0.0	1164.0	0.0	1164.0	0.0	1164.0	1164.0
Acetic Acid		74.8	0.0	0.0	0.0	74.8	74.8	0.0	426.6	0.0	426.6	1.9	424.8	424.8
ComSteep Liquor		2546.5	0.0	3347.7	0.0	5894.2	5894.2	0.0	5894.2	0.0	5894.2	9.9	5884.3	5884.3
ZM		140.0	0.0	0.0	0.0	140.0	140.0	0.0	557.6	0.0	557.6	0.0	557.6	0.0
Cellulase		17.5	0.0	0.0	175.2	192.8	192.8	0.0	192.8	0.0	192.8	0.0	192.8	0.0
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13393.5	0.0	0.0	0.0	13393.5	13393.5	0.0	13393.5	0.0	13393.5	0.0	13393.5	0.0

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

Stream Name		S55	S56	S57	S58	S59	S60	S61	S62	S63	S64	S65	S66
Phase		Solid	Liquid	Liquid	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Vapor	Vapor	Vapor
Temperature	C	41.0	41.2	100.5	100.0	100.0	94.0	116.8	93.3	110.6	100.0	100.0	100.0
Pressure	ATM	1.0	4.8	4.8	4.8	4.8	1.8	1.8	1.8	1.8	1.8	1.0	1.0
Enthalpy	M*KJ/HR	-6.0	7.9	18.9	0.4	18.5	7.3	19.6	1.4	0.2	6.2	5.3	0.9
Molecular Weight		67.4	20.2	20.2	42.2	19.9	38.3	18.7	42.1	18.7	42.1	46.0	18.0
Vapor Weight Fraction		1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0
Liquid Weight Fraction		0.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0
Total Mass Rate	KG/DAY	107321.3	1136908.9	1136908.9	28487.8	1108421.2	137671.7	970749.4	126754.1	10917.6	126754.1	119151.9	7602.3
Total Weight Comp Rates		KG/DAY											
Cellulose		865.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hemicellulose		7690.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lignin		84621.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glucose		0.0	5067.4	5067.4	0.0	5067.4	0.0	5067.4	0.0	0.0	0.0	0.0	0.0
Xylose		0.0	19296.5	19296.5	0.0	19296.5	0.0	19296.5	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	0.0	0.0	0.0	0.0	0.0
Ethanol		0.0	121513.2	121513.2	364.5	121148.7	119690.6	1458.1	119092.1	598.5	119092.1	119092.1	0.0
Water		0.0	943699.3	943699.3	849.3	942850.0	17953.7	924896.3	7662.0	10291.6	7662.0	59.8	7602.3
Sulfuric Acid		0.0	487.2	487.2	0.0	487.2	0.0	487.2	0.0	0.0	0.0	0.0	0.0
Furfural		0.0	3918.5	3918.5	23.3	3895.2	26.0	3869.2	0.0	26.0	0.0	0.0	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	5.8	5.8	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	27239.5	27239.5	27239.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	103.7	103.7	0.0	103.7	0.0	103.7	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	332.5	332.5	0.0	332.5	0.0	332.5	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	7772.2	7772.2	0.0	7772.2	0.0	7772.2	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	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	1164.0	1164.0	0.0	1164.0	0.0	1164.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	424.8	424.8	0.2	424.6	0.3	424.3	0.0	0.3	0.0	0.0	0.0
ComSteep Liquor		0.0	5884.3	5884.3	5.1	5879.2	1.2	5878.1	0.0	1.2	0.0	0.0	0.0
ZM		557.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		192.8	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13393.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Stream Name		S67	S68	S69	S70	S71	S72	S73	S74	S77	TO-S14	TO-S4	FROM-S68
Phase		Liquid	Mixed	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Mixed
Temperature	C	40.0	116.7	51.2	51.8	51.8	51.8	51.8	25.0	44.1	51.8	51.8	116.7
Pressure	ATM	1.0	1.8	1.8	21.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8
Enthalpy	M*KJ/HR	0.5	19.8	8.9	9.0	6.7	2.2	0.3	1.0	6.3	5.3	1.1	19.8
Molecular Weight		46.0	18.7	18.7	18.7	18.1	20.7	18.1	18.0	18.1	18.1	18.1	18.7
Vapor Weight Fraction		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Liquid Weight Fraction		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total Mass Rate	KG/DAY	119151.9	981667.0	981700.1	981700.1	742997.3	238702.7	37149.9	234194.3	819676.2	585481.9	120365.6	981667.0
Total Weight Comp. Rates		KG/DAY											
Cellulose		0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0
Lignin		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glucose		0.0	5067.4	5067.4	5067.4	202.7	4864.7	10.1	0.0	159.7	159.7	32.8	5067.4
Xylose		0.0	19296.5	19296.4	19296.4	964.8	18331.6	48.2	0.0	760.3	760.3	156.3	19296.5
Cellobiose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol		119092.1	2056.6	2056.5	2056.5	1028.3	1028.3	51.4	0.0	810.3	810.3	166.6	2056.6
Water		59.8	935187.9	935221.3	935221.3	738824.9	196396.5	36941.2	234194.3	816388.3	582194.0	119689.6	935187.9
Sulfuric Acid		0.0	487.2	487.2	487.2	24.4	462.9	1.2	0.0	19.2	19.2	3.9	487.2
Furfural		0.0	3895.2	3895.1	3895.1	1168.5	2726.6	58.4	0.0	920.8	920.8	189.3	3895.2
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	103.7	103.7	103.7	5.2	98.5	0.3	0.0	4.1	4.1	0.8	103.7
Succinic Acid		0.0	332.5	332.5	332.5	16.6	315.8	0.8	0.0	13.1	13.1	2.7	332.5
Lactic Acid		0.0	7772.2	7772.2	7772.2	388.6	7383.5	19.4	0.0	306.2	306.2	63.0	7772.2
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	1164.0	1163.9	1163.9	58.2	1105.8	2.9	0.0	45.9	45.9	9.4	1164.0
Acetic Acid		0.0	424.6	424.6	424.6	21.2	403.4	1.1	0.0	16.7	16.7	3.4	424.6
CornSteep Liquor		0.0	5879.2	5879.2	5879.2	294.0	5585.3	14.7	0.0	231.6	231.6	47.6	5879.2
ZM		0.0	0.0	0.0	0.0	0.0	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	0.0	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	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0

D.2.4 Alternative 3 Design

Table D4 Stream table of the bioethanol process from cassava rhizome for alternative 3 design

Stream Name		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Phase		Mixed	Vapor	Mixed	Liquid	Liquid	Liquid	Vapor	Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Liquid
Temperature	C	30.0	160.0	100.0	25.0	25.0	25.0	268.0	188.0	190.0	103.9	103.9	103.9	103.9	25.0
Pressure	ATM	1.0	6.0	1.0	1.0	1.0	1.0	13.0	12.1	12.1	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-26.4	2.1	-24.3	0.5	0.0	0.5	8.9	-14.9	-0.8	6.5	5.7	-13.0	-7.3	1.4
Molecular Weight		103.9	18.0	85.4	18.0	98.1	18.3	18.0	38.2	40.9	18.7	35.4	94.7	47.2	18.0
Vapor Weight Fraction		1.0	1.0	0.9	0.0	0.0	0.0	1.0	0.6	0.4	1.0	0.0	1.0	0.4	0.0
Liquid Weight Fraction		0.0	0.0	0.1	1.0	1.0	1.0	0.0	0.4	0.6	0.0	1.0	0.0	0.6	1.0
Total Mass Rate	KG/DAY	377147.5	17985.9	395133.5	119303.9	2391.4	121695.2	76514.3	593343.0	593342.6	59691.0	320416.8	213234.9	533651.7	309517.3
Total Weight Comp. Rates		KG/DAY													
Cellulose		112324.0	0.0	112324.0	0.0	0.0	0.0	0.0	112324.0	103675.0	0.0	0.0	103675.0	103675.0	0.0
Hemicellulose		160163.6	0.0	160163.6	0.0	0.0	0.0	0.0	160163.6	8008.2	0.0	0.0	8008.2	8008.2	0.0
Lignin		87674.8	0.0	87674.8	0.0	0.0	0.0	0.0	87674.8	87674.8	0.0	0.0	87674.8	87674.8	0.0
Glucose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8736.3	0.0	8736.3	0.0	8736.3	0.0
Xylose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	163802.7	0.0	163802.7	0.0	163802.7	0.0
Cellobiose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	829.9	0.0	829.9	0.0	829.9	0.0
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water		3108.3	17985.9	21094.2	119303.9	0.0	119303.9	76514.3	216912.3	198523.3	56907.6	141615.7	0.0	141615.7	309517.3
Sulfuric Acid		0.0	0.0	0.0	0.0	2391.4	2391.4	0.0	2391.4	2391.4	0.0	2391.4	0.0	2391.4	0.0
Furfural		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5824.2	2783.4	3040.8	0.0	3040.8	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CornSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13876.9	0.0	13876.9	0.0	0.0	0.0	0.0	13876.9	13876.9	0.0	0.0	13876.9	13876.9	0.0
N2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Stream Name		S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27
Phase		Mixed	Mixed	Mixed	Liquid	Mixed	Solid	Mixed	Mixed	Liquid	Mixed	Mixed	Mixed	Mixed
Temperature	C	62.7	62.7	50.0	25.0	49.9	25.0	49.9	49.9	25.0	49.8	49.8	49.8	49.8
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	5.7	-11.6	4.8	0.0	4.8	-0.5	4.3	4.7	0.0	4.7	4.8	0.0	4.9
Molecular Weight		23.1	46.5	23.1	98.1	23.2	74.1	23.4	23.3	98.1	23.3	23.3	137.8	23.0
Vapor Weight Fraction		0.0	0.6	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
Liquid Weight Fraction		1.0	0.4	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	0.0	1.0
Total Mass Rate	KG/DAY	475712.3	367456.6	475712.3	2696.9	478409.2	4305.2	482714.4	482714.4	1110.5	483825.0	483825.0	8699.1	475125.9
Total Weight Comp. Rates		KG/DAY												
Cellulose		518.4	103156.7	518.4	0.0	518.4	0.0	518.4	518.4	0.0	518.4	518.4	518.4	0.0
Hemicellulose		40.0	7968.1	40.0	0.0	40.0	0.0	40.0	40.0	0.0	40.0	40.0	40.0	0.0
Lignin		438.4	87236.4	438.4	0.0	438.4	0.0	438.4	438.4	0.0	438.4	438.4	0.0	438.4
Glucose		6901.7	1834.6	6901.7	0.0	6901.7	0.0	6901.7	6901.7	0.0	6901.7	6901.7	13.8	6887.9
Xylose		106471.7	57330.9	106471.7	0.0	106471.7	0.0	106471.7	106471.7	0.0	106471.7	106471.7	212.9	106258.8
Cellulobiose		655.7	174.3	655.7	0.0	655.7	0.0	655.7	655.7	0.0	655.7	655.7	0.0	655.7
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water		356395.1	94737.9	356395.1	0.0	356395.1	0.0	356395.1	358079.8	0.0	358079.8	358487.8	0.0	358487.8
Sulfuric Acid		1889.2	502.2	1889.2	2696.9	4586.1	0.0	4586.1	0.0	1110.5	1110.5	0.0	0.0	0.0
Furfural		2402.2	638.6	2402.2	0.0	2402.2	0.0	2402.2	2402.2	0.0	2402.2	2402.2	4.8	2397.4
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CornSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lime		0.0	0.0	0.0	0.0	0.0	4305.2	4305.2	840.7	0.0	840.7	1.8	1.8	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	6365.8	0.0	6365.8	7907.3	7907.3	0.0
Ash		0.0	13876.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Stream Name		S28	S29	S30	S31	S32	S33	S34	S35	S36	S37	S38	S39	S40
Phase		Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Vapor	Liquid	Mixed	Mixed	Mixed	Vapor
Temperature	C	54.1	65.0	65.0	65.0	65.0	41.6	40.8	25.0	25.0	25.0	41.0	41.0	42.6
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-6.7	-5.6	3.0	0.3	2.7	0.1	0.5	0.0	0.0	0.0	0.1	-0.1	0.1
Molecular Weight		29.5	29.5	30.1	30.1	30.1	30.1	30.1	17.0	18.0	18.1	29.6	26.2	44.0
Vapor Weight Fraction		0.3	0.3	0.1	0.1	0.1	0.1	0.1	1.0	0.0	0.0	0.1	0.3	1.0
Liquid Weight Fraction		0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.0	1.0	1.0	0.9	0.7	0.0
Total Mass Rate	KG/DAY	842582.5	842582.5	842583.2	84258.3	758324.9	84258.3	758324.9	5.0	1432.4	923.9	86619.6	86634.4	11715.7
Total Weight Comp. Rates		KG/DAY												
Cellulose		103156.7	103156.7	9077.8	907.8	8170.0	907.8	8170.0	0.0	0.0	0.0	907.8	907.8	0.0
Hemicellulose		7968.1	7968.1	7968.1	796.8	7171.3	796.8	7171.3	0.0	0.0	0.0	796.8	796.8	0.0
Lignin		87674.8	87674.8	87674.8	8767.5	78907.3	8767.5	78907.3	0.0	0.0	0.0	8767.5	8767.5	0.0
Glucose		8722.5	8722.5	112753.1	11275.3	101477.8	11275.3	101477.8	0.0	0.0	0.0	11275.3	1053.4	0.0
Xylose		163589.7	163589.7	163589.7	16359.0	147230.7	16359.0	147230.7	0.0	0.0	0.0	16359.0	2913.3	0.0
Cellobiose		829.9	829.9	1306.6	130.7	1176.0	130.7	1176.0	0.0	0.0	0.0	130.7	130.7	0.0
Ethanol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11883.0	891.2
Water		453225.7	453225.7	442798.0	44279.8	398518.2	44279.8	398518.2	0.0	0.0	905.7	45185.5	45207.7	22.6
Sulfuric Acid		502.2	502.2	502.2	50.2	452.0	50.2	452.0	0.0	0.0	0.0	50.2	50.2	0.0
Furfural		3036.0	3036.0	3036.0	303.6	2732.4	303.6	2732.4	0.0	0.0	0.0	303.6	303.6	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	5.0	0.0	0.0
Oxygen		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.1	33.1
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11335.5	10768.7
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	43.7	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	146.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.5	0.0
ComSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1432.4	0.0	1432.4	1432.4	0.0
ZM		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.3	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	18.2	18.2	0.0
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		13876.9	13876.9	13876.9	1387.7	12489.2	1387.7	12489.2	0.0	0.0	0.0	1387.7	1387.7	0.0
N2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Stream Name		S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53
Phase		Mixed	Mixed	Vapor	Liquid	Solid	Mixed	Mixed	Liquid	Mixed	Liquid	Mixed	Vapor	Mixed
Temperature	C	42.6	41.0	25.0	25.0	25.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0
Pressure	ATM	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Enthalpy	M*KJ/HR	-0.2	0.3	0.0	0.0	0.0	0.3	0.1	0.1	-1.0	0.0	-1.0	1.1	-2.1
Molecular Weight		24.6	29.5	17.0	18.0	22.8	29.4	29.2	161.0	25.9	90.1	26.1	42.3	24.7
Vapor Weight Fraction		0.2	0.1	1.0	0.0	1.0	0.1	0.1	0.0	0.3	0.0	0.3	1.0	0.2
Liquid Weight Fraction		0.8	0.9	0.0	1.0	0.0	0.9	0.9	1.0	0.7	1.0	0.7	0.0	0.8
Total Mass Rate	KG/DAY	74918.7	833243.6	14.9	2106.5	181.6	835546.5	827966.3	7580.3	828009.1	7580.2	835589.3	107237.9	728351.4
Total Weight Comp. Rates		KG/DAY												
Cellulose		907.8	9077.8	0.0	0.0	0.0	9077.8	9077.8	0.0	896.9	0.0	896.9	0.0	896.9
Hemicellulose		796.8	7968.1	0.0	0.0	0.0	7968.1	7968.1	0.0	7968.1	0.0	7968.1	0.0	7968.1
Lignin		8767.5	87674.8	0.0	0.0	0.0	87674.8	87674.8	0.0	87674.8	0.0	87674.8	0.0	87674.8
Glucose		1053.4	102531.2	0.0	0.0	0.0	102531.2	99455.3	3075.9	5241.9	0.0	5241.9	0.0	5241.9
Xylose		2913.3	150144.0	0.0	0.0	0.0	150144.0	145639.7	4504.3	19877.6	0.0	19877.6	0.0	19877.6
Cellulose		130.7	1306.6	0.0	0.0	0.0	1306.6	1306.6	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol		10991.7	10991.7	0.0	0.0	0.0	10991.7	10991.7	0.0	127708.6	0.0	127708.6	6194.8	121513.7
Water		45185.1	443703.3	0.0	0.0	0.0	443703.3	443703.3	0.0	442716.5	0.0	442716.5	3154.9	439561.5
Sulfuric Acid		50.2	502.2	0.0	0.0	0.0	502.2	502.2	0.0	502.2	0.0	502.2	0.0	502.2
Furfural		303.6	3036.0	0.0	0.0	0.0	3036.0	3036.0	0.0	3036.0	0.0	3036.0	52.4	2983.6
Ammonia		0.0	0.0	14.9	0.0	0.0	14.9	14.9	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	0.0	186.3	0.0	186.3	183.6	2.7
Carbon Dioxide		566.8	566.8	0.0	0.0	0.0	566.8	566.8	0.0	111961.1	0.0	111961.1	97634.9	14326.2
Glycerol		14.1	14.1	0.0	0.0	0.0	14.1	14.1	0.0	101.8	0.0	101.8	0.0	101.8
Succinic Acid		43.7	43.7	0.0	0.0	0.0	43.7	43.7	0.0	326.4	0.0	326.4	0.0	326.4
Lactic Acid		7.9	7.9	0.0	0.0	0.0	7.9	7.9	0.0	58.3	7580.2	7638.5	0.0	7638.5
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		146.0	146.0	0.0	0.0	0.0	146.0	146.0	0.0	1142.1	0.0	1142.1	0.0	1142.1
Acetic Acid		57.5	57.5	0.0	0.0	0.0	57.5	57.5	0.0	420.3	0.0	420.3	3.6	416.7
ComSteep Liquor		1432.4	1432.4	0.0	2106.5	0.0	3538.8	3538.8	0.0	3538.8	0.0	3538.8	13.6	3525.3
ZM		144.3	144.3	0.0	0.0	0.0	144.3	144.3	0.0	574.9	0.0	574.9	0.0	574.9
Cellulase		18.2	18.2	0.0	0.0	181.6	199.7	199.7	0.0	199.7	0.0	199.7	0.0	199.7
Lime		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		1387.7	13876.9	0.0	0.0	0.0	13876.9	13876.9	0.0	13876.9	0.0	13876.9	0.0	13876.9
N2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Stream Name		S54	S55	S56	S57	S58	S59	S60	S61	S62	S63	S64	S65	S66
Phase		Liquid	Solid	Liquid	Liquid	Vapor	Liquid	Vapor	Liquid	Liquid	Liquid	Vapor	Vapor	Vapor
Temperature	C	41.0	41.0	41.2	100.5	100.0	100.0	93.8	116.7	93.3	110.0	100.0	100.0	100.0
Pressure	ATM	1.0	1.0	4.8	4.8	4.8	4.8	1.8	1.8	1.8	1.8	1.8	1.0	1.0
Enthalpy	M*KJ/HR	4.2	-6.2	4.2	9.9	0.2	9.7	7.1	9.3	1.4	0.2	6.2	5.3	0.9
Molecular Weight		22.2	67.4	22.2	22.2	42.5	21.9	38.7	19.4	42.1	18.7	42.1	46.0	18.0
Vapor Weight Fraction		0.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	1.0
Liquid Weight Fraction		1.0	0.0	1.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0
Total Mass Rate	KG/DAY	617160.1	111191.3	617160.1	617160.1	15110.0	602050.2	136250.7	465799.5	126757.6	9493.1	126757.6	119152.3	7605.3
Total Weight Comp. Rates		KG/DAY												
Cellulose		0.0	896.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hemicellulose		0.0	7968.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lignin		0.0	87674.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glucose		5241.9	0.0	5241.9	5241.9	0.0	5241.9	0.0	5241.9	0.0	0.0	0.0	0.0	0.0
Xylose		19877.6	0.0	19877.6	19877.6	0.0	19877.6	0.0	19877.6	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	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol		121513.7	0.0	121513.7	121513.7	364.5	121149.2	119691.0	1458.2	119092.5	598.5	119092.5	119092.5	0.0
Water		439561.5	0.0	439561.5	439561.5	395.6	439165.9	16549.9	422616.0	7665.1	8884.8	7665.1	59.8	7605.3
Sulfuric Acid		502.2	0.0	502.2	502.2	0.0	502.2	0.0	502.2	0.0	0.0	0.0	0.0	0.0
Furfural		2983.6	0.0	2983.6	2983.6	17.7	2965.8	8.5	2957.3	0.0	8.5	0.0	0.0	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		2.7	0.0	2.7	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carbon Dioxide		14326.2	0.0	14326.2	14326.2	14326.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycerol		101.8	0.0	101.8	101.8	0.0	101.8	0.0	101.8	0.0	0.0	0.0	0.0	0.0
Succinic Acid		326.4	0.0	326.4	326.4	0.0	326.4	0.0	326.4	0.0	0.0	0.0	0.0	0.0
Lactic Acid		7638.5	0.0	7638.5	7638.5	0.0	7638.5	0.0	7638.5	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	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		1142.1	0.0	1142.1	1142.1	0.0	1142.1	0.0	1142.1	0.0	0.0	0.0	0.0	0.0
Acetic Acid		416.7	0.0	416.7	416.7	0.2	416.5	0.3	416.2	0.0	0.3	0.0	0.0	0.0
CornSteep Liquor		3525.3	0.0	3525.3	3525.3	3.0	3522.3	1.0	3521.3	0.0	1.0	0.0	0.0	0.0
ZM		0.0	574.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellulase		0.0	199.7	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		0.0	13876.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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

Stream Name		S67	S68	S69	S70	S71	S72	S73	S74	S75	S76	S77	S78	S79
Phase		Liquid	Vapor	Liquid	Vapor	Liquid	Mixed	Mixed	Vapor	Mixed	Vapor	Vapor	Vapor	Vapor
Temperature	C	40.0	30.0	30.0	46.7	34.8	46.1	650.0	599.7	56.9	268.0	268.0	268.0	160.0
Pressure	ATM	1.0	1.0	1.0	1.1	100.0	1.0	1.0	100.0	1.0	13.0	13.0	13.0	5.2
Enthalpy	M*KJ/HR	0.5	1.7	2.8	3.2	3.3	-3.0	68.4	59.7	12.0	62.7	14.8	47.9	47.5
Molecular Weight		46.0	28.9	18.0	28.9	18.0	30.5	29.0	18.0	29.0	18.0	18.0	18.0	18.0
Vapor Weight Fraction		0.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Liquid Weight Fraction		1.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Mass Rate	KG/DAY	119152.3	1041091.2	540458.4	1041091.2	540458.4	1152282.5	1152280.7	540458.4	1152280.7	540458.4	127672.5	412785.9	412785.9
Total Weight Comp. Rates		KG/DAY												
Cellulose		0.0	0.0	0.0	0.0	0.0	896.9	179.4	0.0	179.4	0.0	0.0	0.0	0.0
Hemicellulose		0.0	0.0	0.0	0.0	0.0	7968.1	1593.6	0.0	1593.6	0.0	0.0	0.0	0.0
Lignin		0.0	0.0	0.0	0.0	0.0	87674.8	17535.0	0.0	17535.0	0.0	0.0	0.0	0.0
Glucose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xvlose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cellobiose		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ethanol		119092.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water		59.8	0.0	540458.4	0.0	540458.4	0.0	75568.9	540458.4	75568.9	540458.4	127672.5	412785.9	412785.9
Sulfuric Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Furfural		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ammonia		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oxygen		0.0	242487.9	0.0	242487.9	0.0	242487.9	48402.3	0.0	48402.3	0.0	0.0	0.0	0.0
Carbon Dioxide		0.0	0.0	0.0	0.0	0.0	0.0	195746.7	0.0	195746.7	0.0	0.0	0.0	0.0
Glycerol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Succinic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lactic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HMF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Xylitol		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acetic Acid		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ComSteep Liquor		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZM		0.0	0.0	0.0	0.0	0.0	574.9	574.9	0.0	574.9	0.0	0.0	0.0	0.0
Cellulase		0.0	0.0	0.0	0.0	0.0	199.7	199.7	0.0	199.7	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	0.0	0.0	0.0	0.0	0.0
CASO4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ash		0.0	0.0	0.0	0.0	0.0	13876.9	13876.9	0.0	13876.9	0.0	0.0	0.0	0.0
N2		0.0	798603.4	0.0	798603.4	0.0	798603.4	798603.4	0.0	798603.4	0.0	0.0	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 (2011-2013).

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
Cassava Rhizome ^[1]	250	Baht/ton	0.017	\$/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]	20.22	Baht/L	0.874	\$/kg

References: [1] Sutree, 2009

[4] www.icis.com

[2] Provincial Waterworks Authority (PWA)

[5] www.alibaba.com

[3] www.clickchemical.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

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 EPP0

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)
Cassava Rhizome	124,469,822.697	2,074,497.045	0.042
Corn Steep Liqior	1,167,977.087	934,381.569	0.019
Cellulase	364,833.773	1,824,168.865	0.037
Sulfuric Acid	2,046,059.806	1,227,635.883	0.025
Lime	1,420,965.055	568,386.077	0.011
Ammonia	26,238.768	14,824.894	0.000
Water	141,533,095.572	110,820.493	0.002
LP steam	6,217,914.252	149,229.825	0.003
HP steam	24,974,754.357	624,368.753	0.013
Total		7,528,313.403	0.152

Table E2.2 Products annual price

Product	Quantity (kg/day)	Quantity (kg/year)	Annual Price
Ethanol	119,152.177	39,320,218.443	44,825,049.025
Total		39,320,218.443	44,825,049.025

E3 Annual Utility Cost for Base Case Design

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

Equipment	Quantity (MJ/hr)	Price (\$/GJ)	Annual Price	Cost per Ethanol (\$/L)
E-1	859.00	0.350	2,408.00	0.00005
E-2	1,113.00	0.350	3,120.00	0.00006
E-3	235.00	0.350	659.00	0.00001
E-6	4,806.00	0.350	13,474.00	0.00027
E-7	4,840.00	0.350	13,570.00	0.00027
cT-1	18,089.20	0.350	50,716.00	0.00102
cT-2	19,971.20	0.350	55,993.00	0.00113
Total			139,940.00	0.00283

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

Equipment	Quantity (MJ/hr)	Price (\$/GJ)	Annual Price	Cost per Ethanol (\$/L)
E-4	2180.00	7.780	134,326.00	0.0027
E-5	5679.00	7.780	349,926.00	0.0071
rT-1	24889.60	7.780	1,533,637.00	0.0310
rT-2	14371.40	7.780	885,531.00	0.0179
Total			2,903,420.00	0.0587

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

Equipment	Quantity (MJ/hr)	Price (\$/GJ)	Annual Price	Cost per Ethanol (\$/L)
R-1	1,570.00	9.830	122,230.00	0.0025
Total			122,230.00	0.0025

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

Equipment	Quantity (MJ/hr)	Price (\$/GJ)	Annual Price	Cost per Ethanol (\$/L)
Feed Handling Unit	300.00	16.800	143,700.47	0.00290
Cooling Tower	313.00	16.800	149,927.00	0.00303
Total			3,627.47	0.005932

Therefore, total annual utility cost for the base case design was **\$3,459,217.47**

and cost per ethanol production for the base case design was **0.07 \$/L**

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

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

Equipment		Size	Unit	Material	Purchase Cost(\$)
P-1	Pump	0.0074	m ³ /s	Stainless Steel	9,325.00
M-1	Mixer	2.8700	m ³	Carbon Steel	19,510.00
M-2	Mixer	0.8400	m ³	Stainless Steel	14,640.00
M-3	Mixer	4.6600	m ³	Stainless Steel	37,451.00
M-4	Mixer	1.9200	m ³	Stainless Steel	23,033.00
M-5	Mixer	2.6100	m ³	Stainless Steel	27,256.00
M-6	Mixer	2.6300	m ³	Stainless Steel	27,370.00
M-7	Mixer	2.6400	m ³	Stainless Steel	27,427.00
M-8	Mixer	4.4300	m ³	Stainless Steel	36,426.00
M-9	Mixer	0.4000	m ³	Stainless Steel	9,748.00
M-10	Mixer	3.9200	m ³	Stainless Steel	34,064.00
M-11	Mixer	3.9300	m ³	Stainless Steel	34,111.00
M-12	Mixer	7.2900	m ³	Stainless Steel	47,863.00
E-1	Heat Exchanger	7.9600	m ²	SS shell & SS tube	20,402.00
E-2	Heat Exchanger	10.4200	m ²	SS shell & SS tube	20,965.00
E-3	Heat Exchanger	2.5200	m ²	SS shell & SS tube	20,402.00
E-4	Heat Exchanger	23.9000	m ²	SS shell & SS tube	27,667.00
E-5	Heat Exchanger	12.9600	m ²	SS shell & SS tube	22,238.00
E-6	Heat Exchanger	14.9400	m ²	CS shell & tube	7,743.00
E-7	Heat Exchanger	22.4200	m ²	CS shell & tube	8,979.00
R-1	Heat Exchanger	158.1800	m ²	SS shell & SS tube	99,772.00
V-F1	Vessel	3.8000	m	316 Stainless Steel	49,870.00
V-F2	Vessel	5.3000	m	316 Stainless Steel	122,076.00
R-2	Vessel	5.0000	m	316 Stainless Steel	117,215.00
R-3	Vessel	10.0000	m	316 Stainless Steel	305,484.00
R-4/1	Vessel	1.2000	m	316 Stainless Steel	19,994.00
R-4/2	Vessel	2.8000	m	316 Stainless Steel	39,036.00
R-4/3	Vessel	5.0000	m	316 Stainless Steel	117,215.00
R-4/4	Vessel	8.0000	m	316 Stainless Steel	327,722.00
R-4/5	Vessel	15.0000	m	316 Stainless Steel	503,231.00
R-5	Vessel	36.0000	m	316 Stainless Steel	634,067.00
R-6-7	Vessel	37.0000	m	316 Stainless Steel	1,038,618.00

Table E4.1 Equipment sizing and purchase cost for the base case design (continue)

Equipment		Size	Unit	Material	Purchase Cost (\$)
S-H2SO4	Storage	33.9100	m ³	Stainless Steel	50,485.00
S-NH3	Storage	1.1200	m ³	Stainless Steel	50,485.00
S-CLS	Storage	35.5700	m ³	Carbon Steel	33,656.00
S-EtOH	Storage	2159.7400	m ³	Carbon Steel	424,501.00
T-1	Tower Unit	24.9000	m	316 Stainless Steel	712,964.00
tT-1	valvetray	32.0000	trays	Stainless Steel	40,930.00
rT-1	Heat Exchanger	62.6300	m ²	SS shell & SS tube	46,180.00
cT-1	Heat Exchanger	60.4000	m ²	316 Stainless Steel	22,353.00
V-T1	Vessel	4.4800	m	316 Stainless Steel	48,235.00
T-2	Tower Unit	33.6700	m	316 Stainless Steel	950,707.00
tT-2	valvetray	60.0000	trays	Stainless Steel	76,744.00
rT-2	Heat Exchanger	28.0100	m ²	SS shell & SS tube	29,684.00
cT-2	Heat Exchanger	70.1800	m ²	316 Stainless Steel	25,103.00
V-T2	Vessel	2.8900	m	316 Stainless Steel	27,993.00
CT-1	Cooling Tower	797.1300	m ³ /s		1,574,510.00
U-1	Feed Handling Unit				856,000.00
SC-1	Solid/Liquid Filter				320,000.00
SC-2	Gypsum Filter				30,120.00
SC-3	Seed Hold Tank				33,000.00
SC-6	Molecular Sieve				475,000.00
U-Facility	Facility Equipment				5,261,556.00
Total					14,941,126.00

Therefore, Total Purchase Equipment Cost for base case design was **\$14,941,126.00**

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)	27.4	16,398,938.60
Purchased Equipment Installation (6-14 % of fixed-capital investment)	12.9	7,707,501.14
Instrumentation and Controls (installed) (2-12 % of fixed-capital investment)	9.9	5,903,617.90
Piping (Installed) (4-17 % of fixed-capital investment)	18.6	11,151,278.25
Electrical Systems (Installed) (2-10 % of fixed-capital investment)	3.0	1,803,883.25
Buildings (Including Services) (2-18 % of fixed-capital investment)	4.9	2,951,808.95
Yard Improvement (2-5 % of fixed-capital investment)	2.7	1,639,893.86
Service Facilities (Installed) (8-30 % of fixed-capital investment)	19.2	11,479,257.02
Land Cost (1-2 % of fixed-capital investment)	1.5	573,006.26
Total Direct Cost		59,609,185.22
II. Indirect costs (15-35 % of Fixed-capital investment)		
Engineering and Supervision (4-20 % of fixed-capital investment)	9.2	5,411,649.74
Construction Expenses (4-17 % of fixed-capital investment)	11.4	6,723,564.83
Legal Expenses (0.5-3 % of fixed-capital investment)	1.1	655,957.54
Contractor's Fees (2-6 % of fixed-capital investment)	6.1	3,607,766.49
Contingency (5-15 % of fixed-capital investment)	12.2	7,215,532.98
Total Indirect Cost		23,614,471.58
III. Fixed-capital Investment (FCI) = Direct cost + Indirect cost		82,650,650.54
IV. Working capital Investments (WC) (5-20 % of Total capital investment)	5	327,978.77
V. Total Capital Investment (TCI) = Fixed-capital investment + Working capital		82,978,629.32

Thus, Total Capital Investment for the base case design was \$82,978,629.32

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	-	-	7,600,517.00
Utilities	-	-	3,483,167.00
Maintenance and Repairs	1.00%	Fixed Capital Investment	4,959,039.04
Operating Supplies	0.75%	Fixed Capital Investment	743,855.85
Royalties	1.00%	Total Product Cost	255,311.32
Total Variable Cost			17,041,889.69
II. Fixed Charges			
Property Taxes	1.00%	Fixed Capital Investment	1,653,013.02
Insurance	0.75%	Fixed Capital Investment	826,506.51
Total Fixed Charges			2,479,519.53
III. Manufacturing Cost			
Plant Overhead	60.00%	Labor + Supervision + Maintenance	2,975,423.40
Total Manufacturing Cost			19,521,409.22
IV. General Expense			
Administration	40.00%	Labor + Supervision + Maintenance	991,807.80
Distribution & selling	4.00%	Total Product Cost	1,021,245.28
Research & Development	4.00%	Total Product Cost	1,021,245.28
General Expense			3,034,298.36
V. Total Product Cost with Out Depreciation			25,531,130.98

Thus, Total Operating Cost for the base case design was \$25,531,130.98

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

F.1 Alternative 1

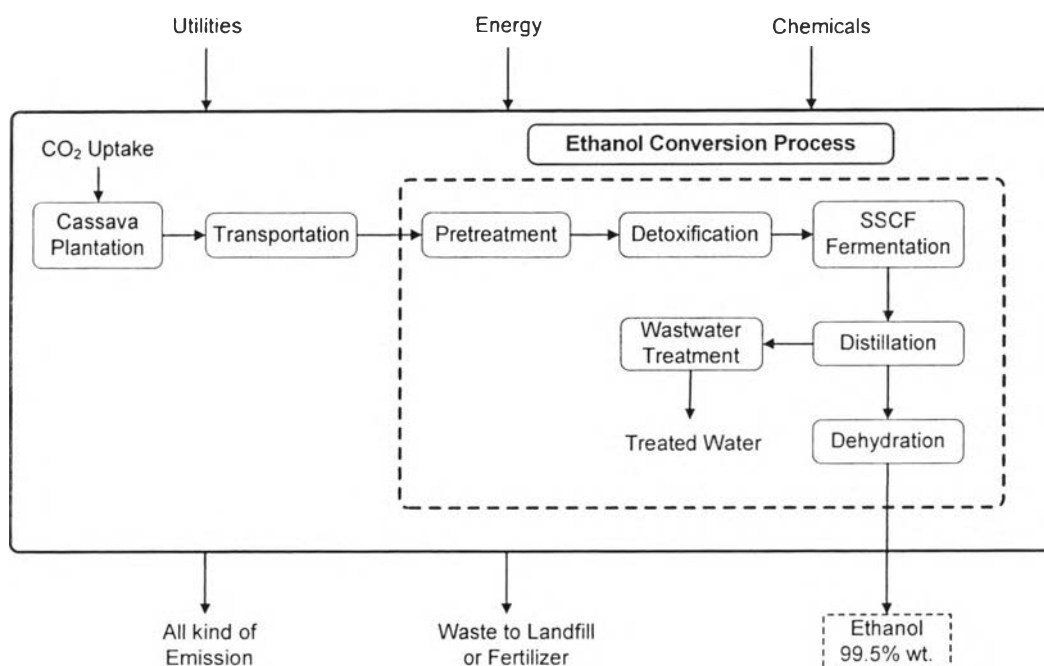


Figure F1.1 System boundary of alternative 1 design.

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

Impact category	Unit	Total
abiotic depletion	kg Sb eq	1.01E-02
global warming (GWP100)	kg CO2 eq	2.17E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.33E-07
human toxicity	kg 1,4-DB eq	3.17E+00
fresh water aquatic ecotox.	kg 1,4-DB eq	1.16E+01
marine aquatic ecotoxicity	kg 1,4-DB eq	1.04E+04
terrestrial ecotoxicity	kg 1,4-DB eq	6.07E-03
photochemical oxidation	kg C2H4	3.26E-02
acidification	kg SO2 eq	7.18E-03
eutrophication	kg PO4 eq	2.77E-03

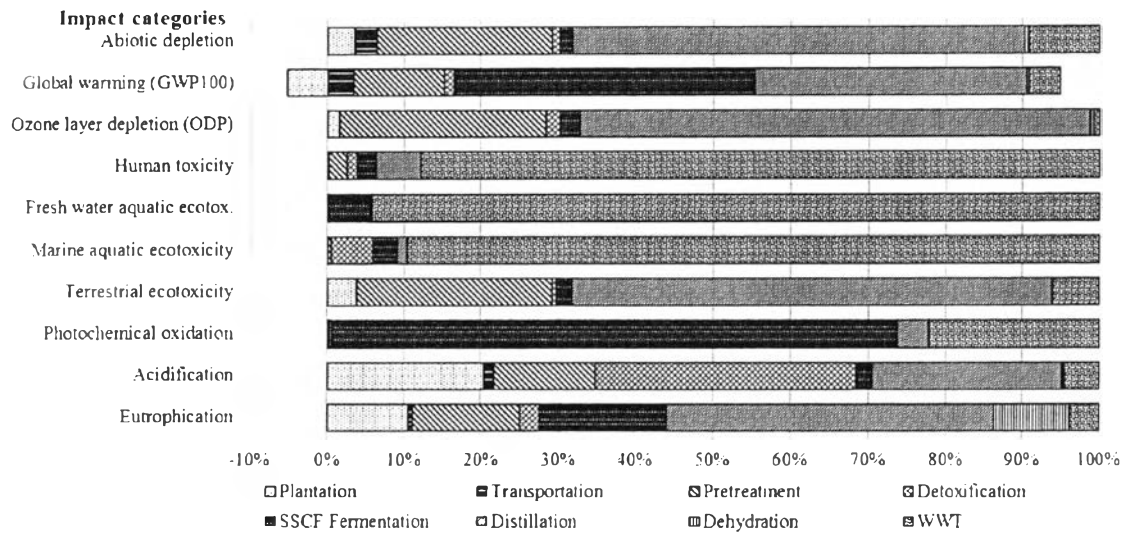


Figure F1.2 Distribution of environmental impacts classified stage by stage of alternative 1 design.

F.2 Alternative 2

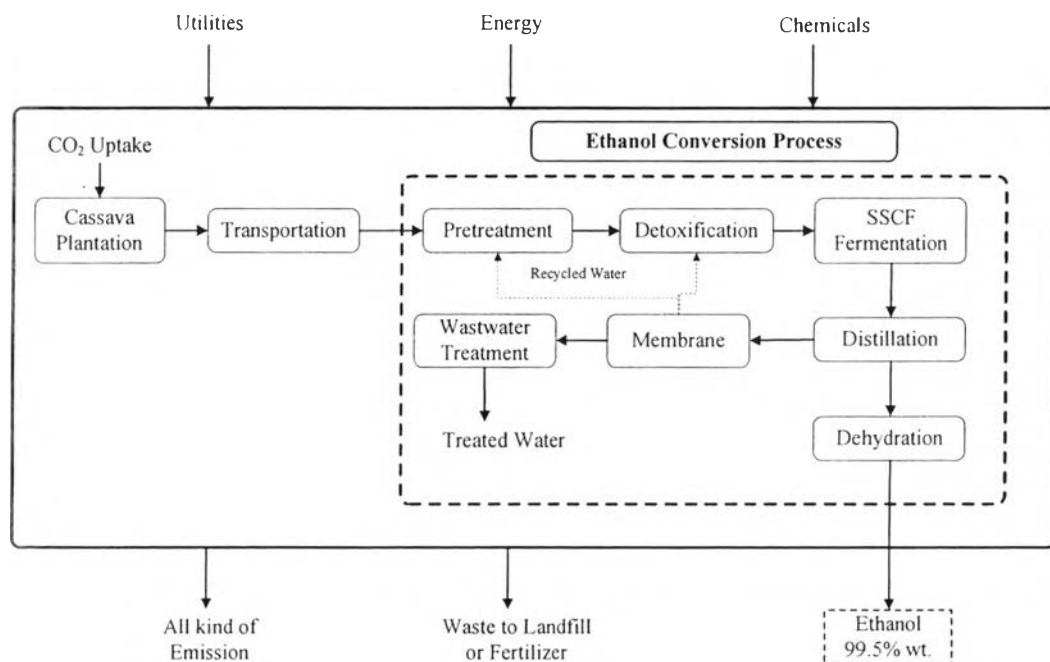


Figure F2.1 System boundary of alternative 2 design.

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

Impact category	Unit	Total
abiotic depletion	kg Sb eq	9.78E-03
global warming (GWP100)	kg CO ₂ eq	2.04E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.34E-07
human toxicity	kg 1,4-DB eq	3.19E+00
fresh water aquatic ecotox.	kg 1,4-DB eq	1.13E+01
marine aquatic ecotoxicity	kg 1,4-DB eq	1.07E+04
terrestrial ecotoxicity	kg 1,4-DB eq	6.21E-03
photochemical oxidation	kg C ₂ H ₄	1.84E-02
acidification	kg SO ₂ eq	8.95E-03
eutrophication	kg PO ₄ eq	4.85E-03

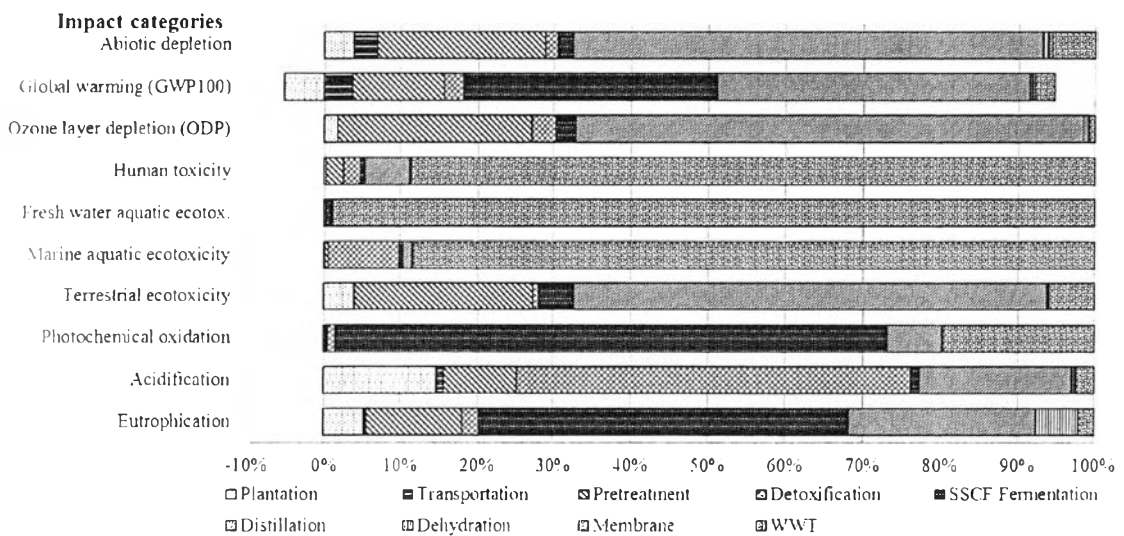


Figure F2.2 Distribution of environmental impacts classified stage by stage of alternative 2 design.

F.3 Alternative 3

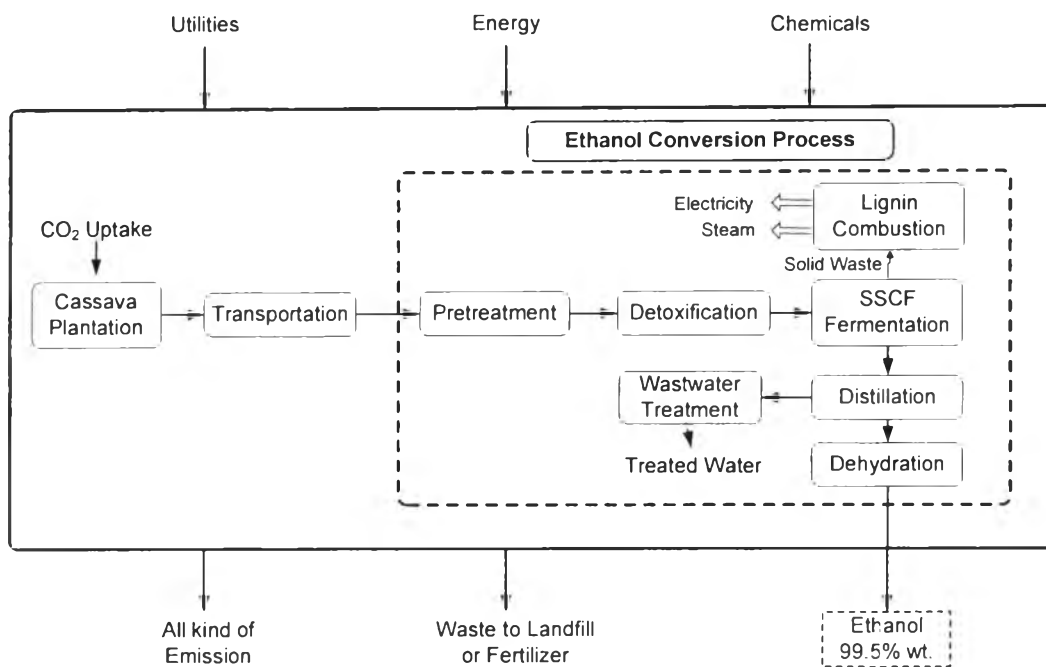


Figure F3.1 System boundary of alternative 3 design.

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

Impact category	Unit	Total
abiotic depletion	kg Sb eq	9.45E-03
global warming (GWP100)	kg CO ₂ eq	2.92E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.39E-07
human toxicity	kg 1,4-DB eq	3.69E-01
fresh water aquatic ecotox.	kg 1,4-DB eq	3.62E-01
marine aquatic ecotoxicity	kg 1,4-DB eq	9.23E+02
terrestrial ecotoxicity	kg 1,4-DB eq	6.01E-03
photochemical oxidation	kg C ₂ H ₄	3.25E-02
acidification	kg SO ₂ eq	6.85E-03
eutrophication	kg PO ₄ eq	2.53E-03

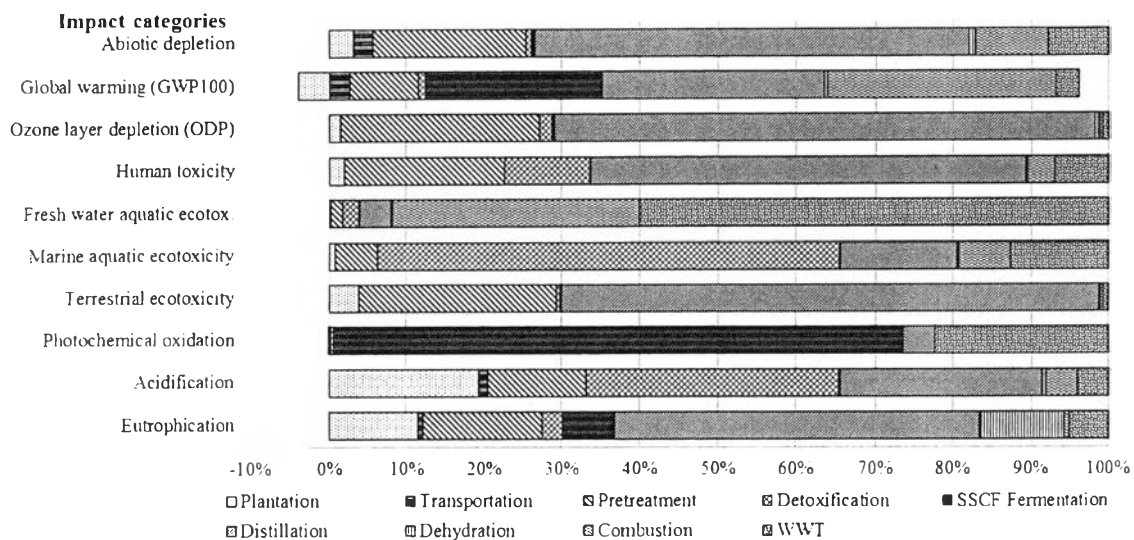


Figure F3.2 Distribution of environmental impacts classified stage by stage of alternative 3 design.

F.4 Alternative 4

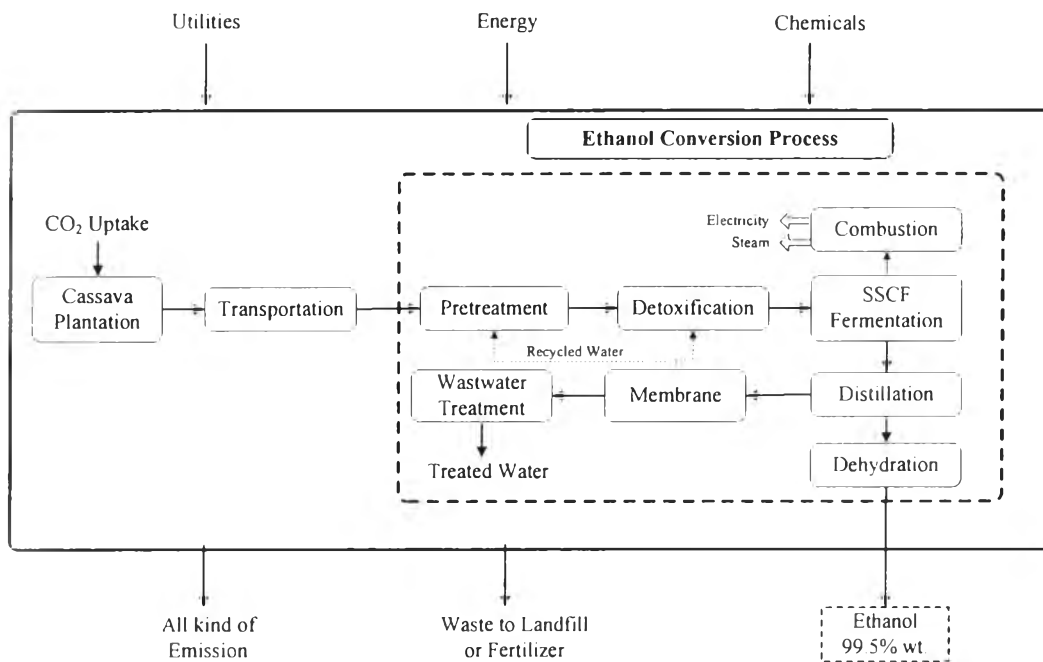


Figure F4.1 System boundary of alternative 4 design.

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

Impact category	Unit	Total
abiotic depletion	kg Sb eq	9.16E-03
global warming (GWP100)	kg CO2 eq	2.82E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.37E-07
human toxicity	kg 1,4-DB eq	3.81E+00
fresh water aquatic ecotox.	kg 1,4-DB eq	1.14E+01
marine aquatic ecotoxicity	kg 1,4-DB eq	1.95E+04
terrestrial ecotoxicity	kg 1,4-DB eq	6.21E-03
photochemical oxidation	kg C2H4	2.00E-02
acidification	kg SO2 eq	5.05E-02
eutrophication	kg PO4 eq	3.31E-03

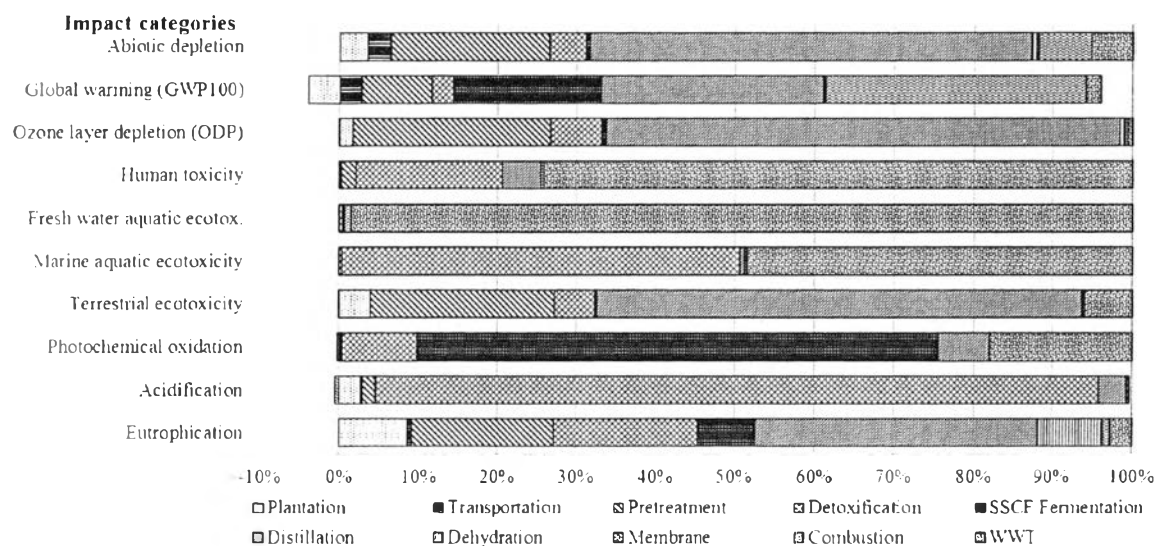


Figure F4.2 Distribution of environmental impacts classified stage by stage of alternative 4 design.

F.5 Alternative 5

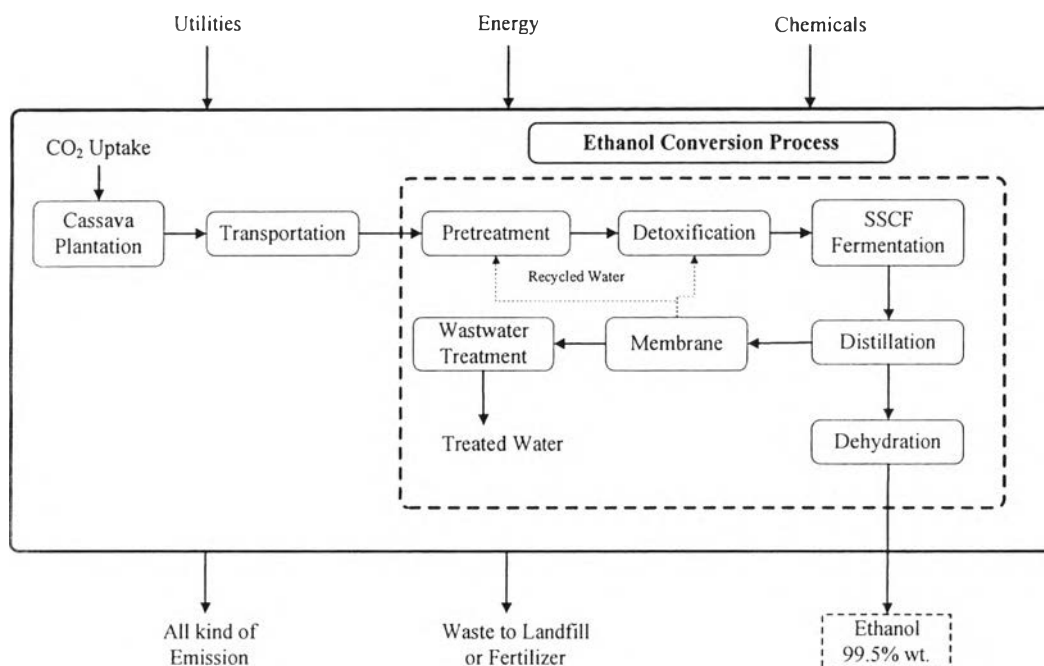


Figure F5.1 System boundary of alternative 5 design.

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

Impact category	Unit	Total
abiotic depletion	kg Sb eq	9.53E-03
global warming (GWP100)	kg CO ₂ eq	2.05E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.32E-07
human toxicity	kg 1,4-DB eq	3.61E+00
fresh water aquatic ecotox.	kg 1,4-DB eq	1.09E+01
marine aquatic ecotoxicity	kg 1,4-DB eq	1.89E+04
terrestrial ecotoxicity	kg 1,4-DB eq	6.07E-03
photochemical oxidation	kg C ₂ H ₄	2.44E-02
acidification	kg SO ₂ eq	5.07E-02
eutrophication	kg PO ₄ eq	3.11E-03

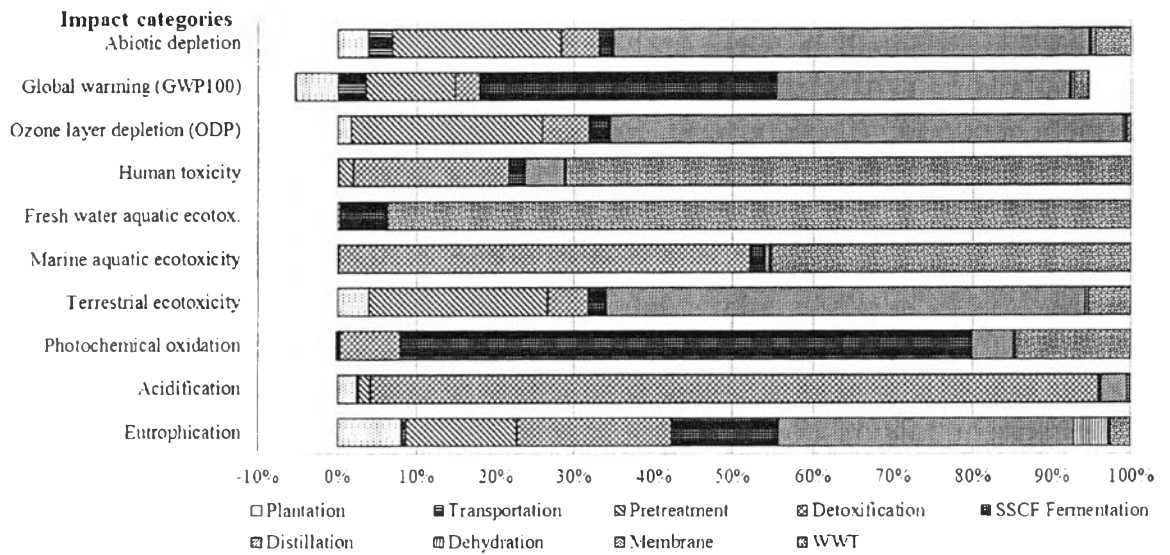


Figure F5.2 Distribution of environmental impacts classified stage by stage of alternative 5 design.

F.6 Alternative 6

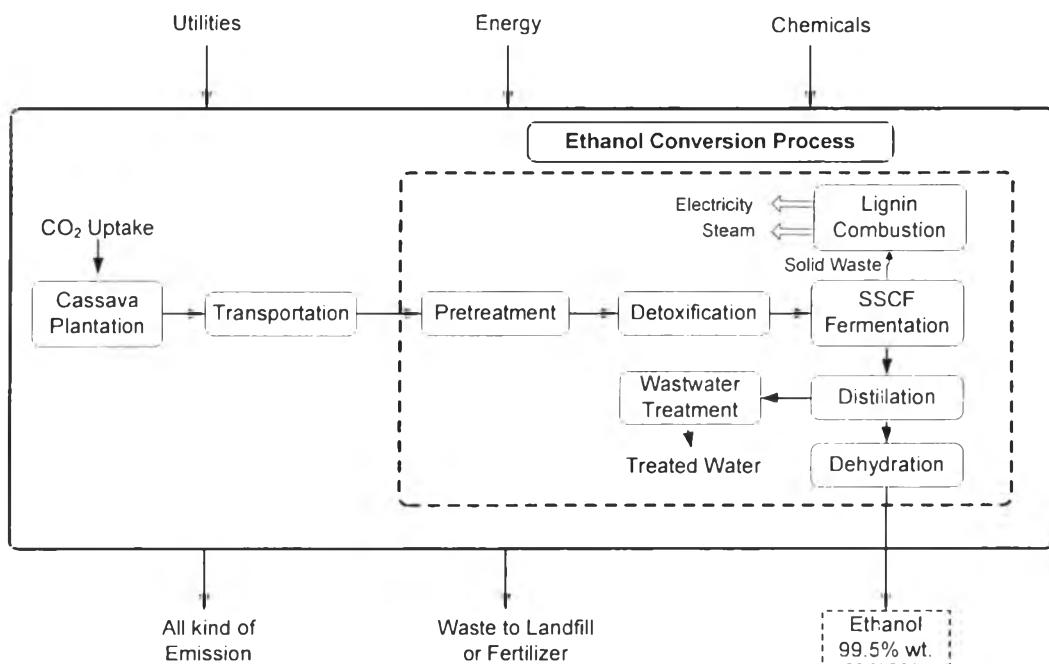


Figure F6.1 System boundary of alternative 6 design.

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

Impact category	Unit	Total
abiotic depletion	kg Sb eq	8.88E-03
global warming (GWP100)	kg CO2 eq	2.84E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.30E-07
human toxicity	kg 1,4-DB eq	3.09E+00
fresh water aquatic ecotox.	kg 1,4-DB eq	1.10E+01
marine aquatic ecotoxicity	kg 1,4-DB eq	1.00E+04
terrestrial ecotoxicity	kg 1,4-DB eq	6.00E-03
photochemical oxidation	kg C2H4	3.25E-02
acidification	kg SO2 eq	6.71E-03
eutrophication	kg PO4--- eq	2.81E-03

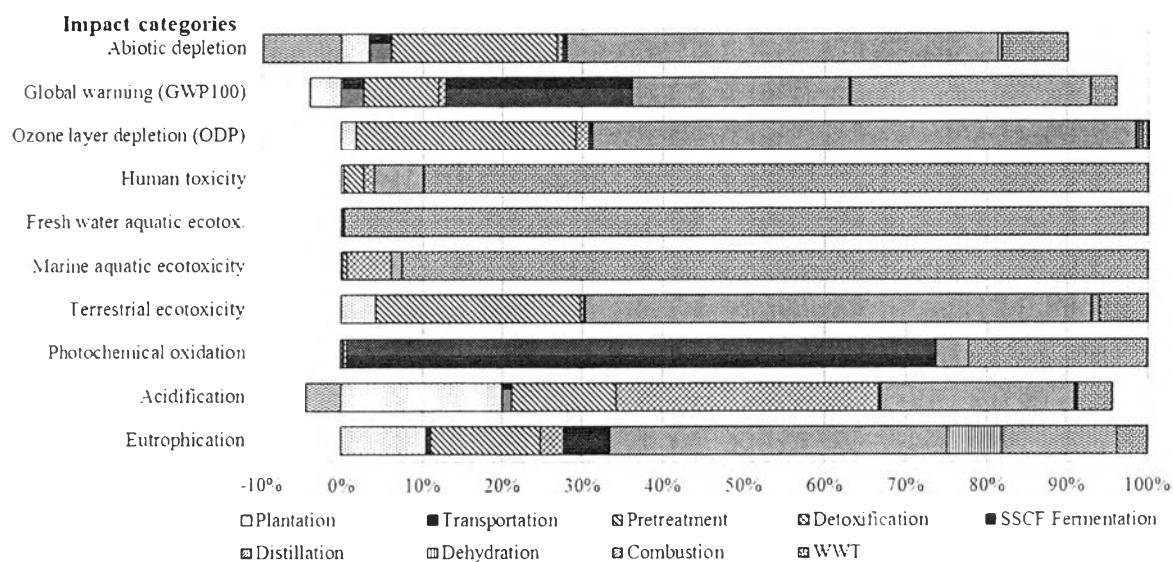


Figure F6.2 Distribution of environmental impacts classified stage by stage of alternative 6 design.

F.7 Alternative 7

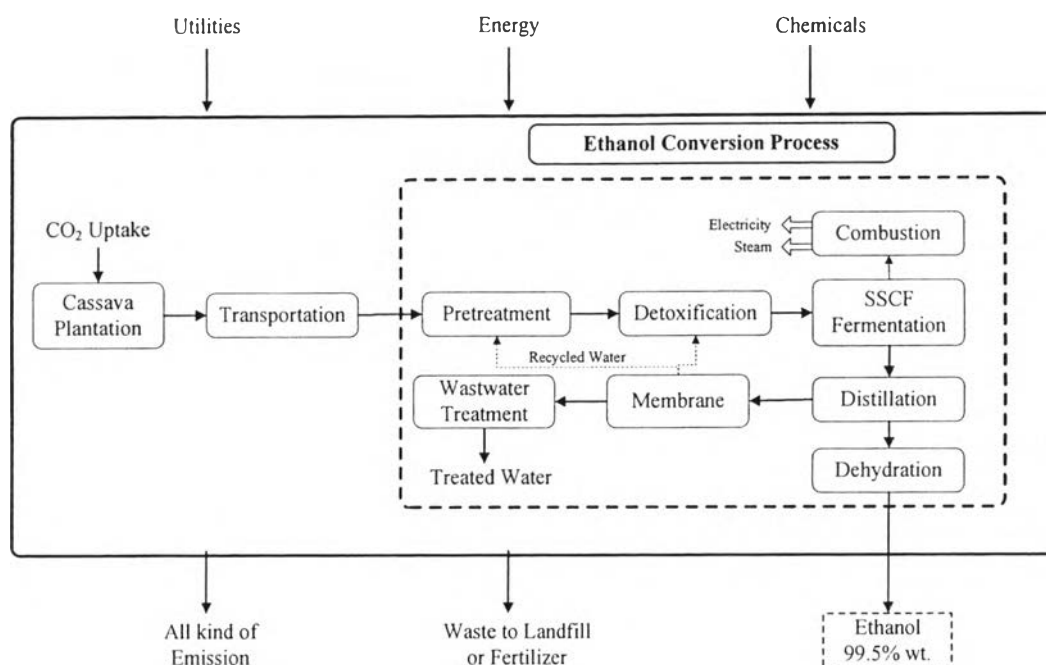


Figure F7.1 System boundary of alternative 7 design.

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

Impact category	Unit	Total
abiotic depletion	kg Sb eq	9.18E-03
global warming (GWP100)	kg CO ₂ eq	2.78E+00
ozone layer depletion (ODP)	kg CFC-11 eq	1.37E-07
human toxicity	kg 1,4-DB eq	3.57E+00
fresh water aquatic ecotox.	kg 1,4-DB eq	1.03E+01
marine aquatic ecotoxicity	kg 1,4-DB eq	1.87E+04
terrestrial ecotoxicity	kg 1,4-DB eq	6.23E-03
photochemical oxidation	kg C ₂ H ₄	2.00E-02
acidification	kg SO ₂ eq	5.06E-02
eutrophication	kg PO ₄ --- eq	3.51E-03

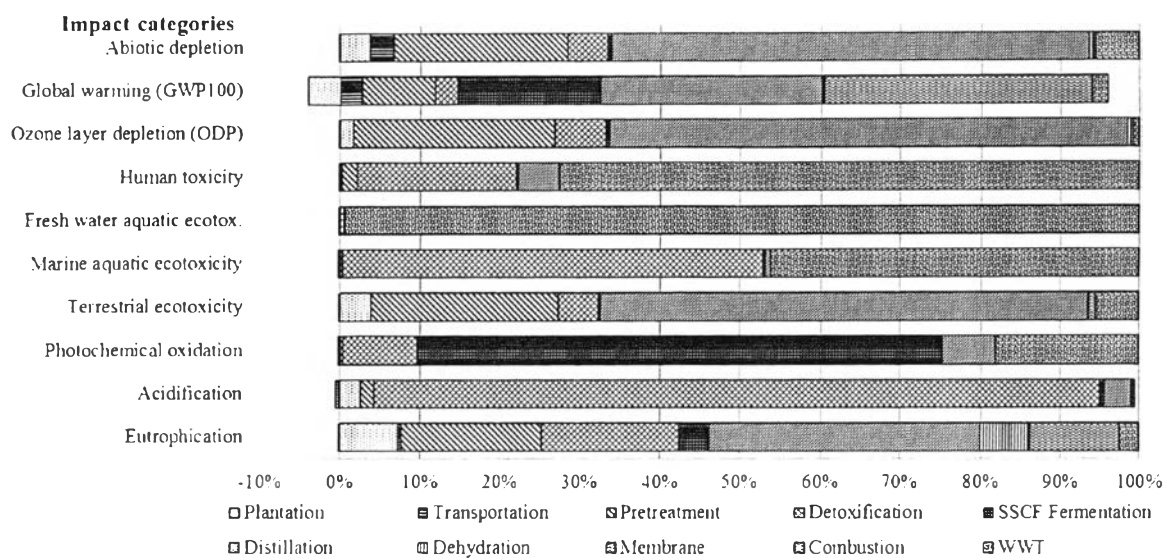


Figure F7.2 Distribution of environmental impacts classified stage by stage of alternative 7 design.

CURRICULUM VITAE

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Presentations:

1. Mangnimit, S., Malakul, P. and Rafiqul, G. (2013, June 25) Sustainable Process Design of Biofuels : Bioethanol Production from Cassava rhizome. Paper presented at 6th International Conference on Process Systems Engineering (PSE ASIA 2013), Kuala Lumpur, Malaysia.
2. Mangnimit, S., Malakul, P. and Rafiqul, G. (2013, August 18) Sustainable Process Design of Lignocellulose Based Biofuel. Paper presented at the 9th World Congress of Chemical Engineering (WCCE9) incorporating the 15th Asian Pacific Confederation of Chemical Engineering Congress (APCCChE 2013), Seoul, Korea.

Extra-Curricular Activities:

1. Completing Internship from the Petroleum Products and Alternative Fuels Research Department, PTT. Research and Technology Institute (PTT RTI), PTT Public Company Limited, Wang Noi, Ayutthaya, Thailand, 2009
2. Completing Process simulation using PRO/II, economic evaluate using ECON and sustainability analysis using SustainPro from the Computer Aided Process Engineering System Center (CAPEC), Department of Chemical and Biochemical Engineering, Technical University of Denmark, Lyngby, Denmark, 2012
3. Completing the 1st ASEAN Synchrotron Science Camp at Synchrotron Light Research Institute (SLRI), Nakhon Ratchasima, Thailand, 2012
4. Vice President of science student union of Chiangmai University, Chiangmai, Thailand, 2010