REFERENCES

Bhandhubanyong, P., MTEC., NSTDA. (2010). Development of Ethanol as a transportation fuel in Thailand. Bangkok.

"Biodiesel production process" *Biodiesel Production and Quality* 26 April 2007 <http://www.biodiesel.org/pdf_files/fuelfactsheets/prod_quality.pdf>

"Biofuel Definition." *Clean energy ide.* (2009). 20 May 2010 <http://www.clean-energy-ideas.com/energy_definitions/definition_of_biofuel.html>

Bloyd, C. (2009). An Update on Ethanol Production and Utilization in Thailand. Pacific Northwest National Laboratory, PNNL-19060.

Carvalho, A., Gani, R., and Matos, H. (2009). Design of batch operation: systematic methodology for generation and analysis of sustainable alternatives. Computer and Chemical Engineering, 330, 2075-2090.

Carvalho, A., Gani, R., and Matos, H. (2008). Design of sustainable chemical processes: systematic retrofit analysis generation and evaluation of alternatives. Process Safety and Environment Protection, 86, 328-346.

CHIRAPANDA, S. "Biofuel Crops and Future Outlook." *DEVELOPMENT OF BIOFUELS IN THAILAND.* Thailand Tapioca Development Institute. 15 May 2010 < http://www.biomass-asia-workshop.jp/biomassws/05workshop/>

"Commodity Profile." *Agricultural economic information.* Office of Agricultural Economics (OAE). 18 May 2009 <http://www.oae.go.th/OAE-WEB-SITE/profile/commodityPRo/index.html>

Dias, M.O.S., Ensinas, A.V., Nebra, S.A., Filho, M., Rossell, C.E.V., and Maciel, M.R.W. (2009). Production of bioethanol and other bio-based materials from sugarcane bagasse: Integration to conventional bioethanol production process. chemical engineering research and design, 87(4), 1206-1216.

"Economic Value of Biogas" *Biogas Technology Project.* 15 May 2010 < http://www.thaibiogas.com/user/Detail_GeneralNewList.aspx?id=50>

"Energy statistics" Energy Policy and Planning Office, Ministry of Energy, Thailand (EPPO). 15 July 2010 < http://www.eppo.go.th/info/2petroleum_stat.htm>

"Energy use in Thailand" Ministry of energy. 17 May 2010 <http://www.thaienergydata.in.th/energynew/energyReview/webcontent_show.php?content_id=195 >

"ForestArea." *Forest Statistics*. Royal Forest Department (RFD). 18 May 2009 < http://www.forest.go.th/stat/stat50/TAB1.htm >.

Fu, G.Z., Albert, W.C., and Minns, D.E. (2003). Life cycle assessment of bio-ethanol derived from cellulose. Int J LCA, 8(3), 137–141.

Garcı´a, S.G., Luo, L., Moreira, M.T., Feijoo, G., and Huppes, G. (2009). Life cycle assessment of flax shives derived second generation ethanol fueled automobiles in Spain. Renewable and Sustainable Energy Review, RSER-669, 1–12.

Huber, G. W., Iborra, S., Corma, A. (2006). Synthesis of Transportation Fuels from Biomass: Chemistry, Catalysts, and Engineering. Chemical Reviews, 106: 4044.

ISO 14040-14043. (2006). Environmental management—Life cycle assessment—Principles and framework. Geneva: International Organization for Standardization (ISO).

"Life cycle analysis and assessment" World Resource Foundation. 18 May 2010 < http://www.gdrc.org/uem/lca/life-cycle.html>

"Life Cycle Assessment-An Introduction for Industry." Technical Information. Tangram Technology. 23 May 2009 <http://www.tangram.co.uk/TI-LCA_Introduction.html>.

Luo, L., van der Voet, E., and Huppes, G. (2009). Life cycle assessment and life cycle costing of bioethanol from sugar cane in Brazil. Renewable and Sustainable Energy Review, 13(6–7), 1613–1619.

McConnell, C. "Bio Butanol" *Qittle SMS Message Solution*. 17 March 2008 < http://doyouqittle.com/2008/03/17/ >

McNeff, C.V., Nowlan, D.T., McNeff, L.C., Yan, B., and Fedie, R.L. (2010). Continuous production of 5-hydroxymethylfurfural from simple and complex carbohydrates. Applied Catalysis A: General, 384, 65-69.

"Molasses more economic value" TALENT FLUID TRADE Co., Ltd. 23 May 2010 <http://www.talentfluid.co.th/main/content.php?page=sub&category=9&id=11>

Morales, M.A., Terra, J., Gernaey, K.V., Wooley, J.M., and Gani, R. (2008). Biorefining: Compute aided tools for sustainable design and analysis of bioethanol production. Chemical Engineering Research and Design.

Nag, A. (2008). Biofuels refining and performance. New York: McGraw-Hill.

Nguyen, T.L.T., Gheewala, S.H., and Garivait, S. (2007). Energy balance and GHG-abatement cost of cassava utilization for fuel ethanol in Thailand. Energy Policy, 35(9), 4585-4596.

Nguyen, T.L.T., Gheewala, S.H., and Garivait, S. (2008). Full chain energy analysis of ethanol from cane molasses in Thailand. Applied Energy, 85, 722-734.

Nguyen, T.L.T., and Gheewala, S.H. (2008). Life cycle assessment of fuel ethanol from cane molasses in Thailand. Springer-Verlag.

"Oil price, 1994-2007." *WRT (With Respect To) Technology.* 16 May 2010 <http://wrtassoc.com/archives/date/2007/10>

"OUTLOOK OF RAW MATERIALS FOR ETHANOL INDUSTRY IN THAILAND" Cassava and Starch Technology Research Unit(CSTRU). 26 May 2010 <http://www.cassava.org/News/biofuel2004/Poster_ethanol2.pdf>

"Potentials of Biodiesel Production in Thailand." *Bio-Diesel.* Department of Alternative Energy Development and Efficiency (DEDE). 27 May 2010 < http://www.dede.go.th/dede/index.php?id=595>

"Production and Sales of Gasohol in 2007 and 2008" *Summary of production, importing, sale and export of oil in 2008.* 28 May 2010 < http://www.doeb.go.th/information/info_conclude51.htm >

"Pyrolysis Oil Applications" btg biomass technology group. 15 May 2010 <http://www.btgworld.com/index.php?id=23&rid=8&r=rd>

"Production of gasohol." *Gasohol.* Department of Alternative Energy Development and Efficiency (DEDE). 27 May 2010 < http://www.dede.go.th/dede/index.php?id=586>

Ramey, D., and Yang, S.T. (2004). "Production of Butyric Acid and Butanol from Biomass" U.S. Department of Energy Morgantown, WV. 19 May 2010 < http://www.afdc.energy.gov/afdc/pdfs/843183.pdf>

"Reserves." *ANNUAL REPORT 2007 PETROLEUM AND COAL ACTIVITIES IN THAILAND.* Department of mineral fuels. 27 May 2010 < http://www2.dmf.go.th/download/annual.report/annual2007.pdf >

Ringer, M., Putsche, V., and Scahill, J. (2006). Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis. National Renewable Energy Laboratory, NREL/TP-510-37779.

Roberts, E.J., and Martin, F. (1954). Identification and Determination of Nonnitrogenous Organic Acids of Sugar Cane by Partition Chromatography. Analytical Chemistry. 26, 815 – 818.

Sajjakulnukit, B., Yingyuad, R., Maneekhao, V., Pongnarintasut, V., Bhattacharya, S.C., and Salam, P.A. (2010). Assessment of sustainable energy potential of non-plantation biomass resources in Thailand. National Research Council of Thailand(NRCT), 1–11.

Searcy, E., and Flynn, P.C. (2008). Processing of straw/corn stover: Comparison of life cycle emissions. International Journal of Green Energy, 5(6), 423–437.

SETAC. (1993). Guidelines for Life-Cycle Assessment: A Code of Practice. Brussels: Society for Environmental Toxicology and Chemistry.

Shen, D.K., and Gu, S. (2009). The mechanism for thermal decomposition of cellulose and its main products. Bioresource Technology, 100, 6496-6504.

Sierra, R., Smith, A., Granda, C., and Holtzapple, M.T. (2008). Producing fuels and chemicals from lignocellulosic biomass. Chemical Engineering Progress, 104(8), S10–S18.

Suksaroj, T.T. (2009). Bioethanol production from agro-industrial wastewater. Engineering Conference Prince of Songkla University.

Szulczyk, K. R. (2010). Which is a better transportation fuel – butanol or ethanol? International Journal of Energy and Environment, 1(3), 501-512

Teclu, D., Tivchev, G., Laing, M., and Wallis, M. (2009). Determination of the elemental composition of molasses and its suitability as carbon source for

growth of sulphate-reducing bacteria. Journal of Hazardous Materials. 161, 1157 – 1165.

Terra, J. (2008). Sustainability and life cycle assessment of the bioethanol production process from lignocellulosic feedstock. Master thesis. Technical University of Lisbon.

"Thailand Biomass Resource Assessment." *FINAL REPORT Thailand Biomass-Based Power Generation and Cogeneration within Small Rural Industries.* November 2000. National Energy Policy Office (NEPO). 17 May 2010 <http://www.thaienergy.org/files/2_encon-BV-FinalReport.pdf>

"Thailand Crude Oil Production and Consumption by Year" Indexmundi. 27 May 2010 <http://www.indexmundi.com/energy.aspx?country=th&product=oil&graph=production+consumption>

"Thailand Energy Outlook." *Energy Outlook.* 31 March 2009. Ministry of Energy (MOEN). 15 May 2009 <http:// www.energy.go.th/moen/KnowledgeDetail.aspx?id=351>.

"The Life Cycle Assessment framework" *Life cycle thinking.* 20 May 2010 < http://www.ami.ac.uk/courses/topics/0109_lct/ >

"The Trend of Energy Demand in 2007." *Annual Report 2006.* MINISTRY OF ENERGY. 16 May 2010 <http://www.energy.go.th/moen/upload/File/Statistic/30-10-50/trend%2050.pdf>

"Types of biofuel." *Biofuel.* 26 May 2010 < http://biofuel.org.uk/types-of-biofuel.html >

West, L. "What are the Benefits of Using Ethanol?" *Environmental issues.* About.com 17 May 2010 <http://environment.about.com/od/ethanolfaq/f/ethanol_benefit.htm>

"What is Bioethanol?" *Energy Systems Research Unit.* University of strathclyde Engineering. 15 May 2010 <http://www.esru.strath.ac.uk/EandE/Web_sites/02-03/biofuels/what_bioethanol.htm>

"What is biomass?" *BIOMASS Energy Centre.* 15 July 2010 < http://www.biomassenergycentre.org.uk/portal/page?_pageid=76,15049&_dad=portal&_schema=PORTAL>

"Wheat Ethanol Research and Development." *Canadian Biomass Innovation Network (CBIN).* 15 May 2010 <http://www.cbin-rcib.gc.ca/pro/stumborg-eng.php>

Zhang, Y.-H.P. (2008). Reviving the carbohydrate economy via multi-product lignocellulose biorefineries. Journal of Industrial Microbiology and Biotechnology, 35(5), 367–375.

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

	Compnent name	Component alias	Chemical Formula
1	Ethanol	ETHANOL	C_2H_6O
2	Water	WATER	H_2O
3	Glucose	C6	$C_6H_{12}O_6$
4	Sucrose	C12	$C_{12}H_{22}O_{11}$
5	Acetic Acid	ACETACID	$C_2H_4O_2$
6	Carbondioxide	CO2	CO_2
7	Oxygen	O2	O_2
8	Ammonia	NH3	NH_3
9	Lactic Acid	LACACID	$C_3H_6O_3$
10	Succinic Acid	SUCCNAC	$C_4H_6O_4$
11	Glycerol	GLYCEROL	$C_3H_8O_3$
12	Cellulose	CELLULOS	$C_6H_{10}O_5$
13	Zymomonas mobilis	ZM	CO_2
14	Ash	ASH	$C_6H_{10}O_5$
15	Mesaconic Acid	MESACONIC	$C_5H_6O_4$
16	Fumaric Acid	FUMARIC	$C_4H_4O_4$
17	Aconitic Acid	ACONITIC	$C_6H_6O_6$
18	Glycolic Acid	GLYCOLAC	$C_2H_4O_3$
19	Malic Acid	MALIC	$C_4H_6O_5$
20	Citric Acid	CITRIC	$C_6H_8O_7$
21	Oxalic Acid	OXALIC	$C_2H_2O_4$
22	Carbon Monoxide	CO	CO
23	Hydrogen	H2	H_2
24	Methane	METHANE	CH_4
25	Acetaldehyde	ACETALD	C_2H_4O
26	Hydroxyacetaldehyde	HAA	$C_2H_4O_2$
27	Acetone	ACETONE	C_3H_6O
28	Hydroxyacetone	HA	$C_3H_6O_2$
29	Pyruvaldehyde	PA	$C_3H_4O_2$
30	Furfural	FURFURAL	$C_5H_4O_2$

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

	Compnent name	**Component alias**	**Chemical Formula**
31	2-Furan methanol	FUROH*	$C_5H_6O_2$
32	5-Hydroxymethy-furfural	HMF	$C_6H_6O_3$
33	Levoglucosan	LG**	$C_6H_{10}O_5$
34	Char	CHAR	C
35	Hexane	HEXANE	C_6H_{14}
36	2,2-Diethoxypropionate-ethyl-ester	C9ester	$C_9H_{18}O_4$
37	2,3-Anhydro-D-mannose (2,3-AM)	MANNOSE	$C_6H_8O_4$
38	Methyl Isobutyl Ketone	MIBK	$C_6H_{12}O$
39	Titanium Dioxide	TIO2	TiO_2

*FUROH refer to components which have the same formula such as 2-Hydroxy-2-cyclopenten-1-one and 1, 3-Butadiene-1-carboxylic acid.

** LG refer to components which have the same formula such as Anhydro-D-mannose (AM) and 1, 6-Anhydro-β-glucofuranose (1,6-AGF)

Appendix B Composition of Molasses

Table B1 Composition of molasses (Teclu *et al.*,2009)

%Molasses		
Usual range	Indicative average	Components
17-25	20	Water
30-40	35	Sucrose
4-9	7	Glucose
5-12	9	Fructose
1-5	3	Other reducing substances
2-5	4	Other carbohydrates
7-15	12	Ash
2-6	4.5	Nitrogenous compounds
2-8	5	Non-nitrogenous acid
0.1-1	0.4	Wax, sterols and phospholipids

Table B2 Non-nitrogenous acid of sugar cane (Extracted data from Roberts *et al.*, 1954)

	Liters	Mw	API	SG	density(kg/lit)	kg	mass frac.
Syringic	0.4						
Mesaconic	1.8	130.100	-34.082	1.453	1.453	2.61451	0.038
Fumaric	2.3	116.073	-35.670	1.477	1.477	3.39612	0.050
Succinic	3.5	118.089	-31.599	1.416	1.416	4.95741	0.073
Aconitic	4.6	172.180	-37.922	1.512	1.512	6.95569	0.102
Glycolic	5.9	76.052	-27.972	1.367	1.367	8.064	0.118
Malic	7.8	134.089	-25.732	1.338	1.338	10.4351	0.153
Citric	9.1	192.125	-42.588	1.591	1.591	14.4823	0.213
Oxalic	10	90.036	-49.394	1.723	1.723	17.2338	0.253
						68.1389	1.000

Table B3 Molasses composition for simulation

Component	Mw	%wt	liq	%wt liq	solid	%wt solid
H2O	18.0153	20.10	20.10	23.9521		
C12	342.3	35.18	35.18	41.9162		
C6	180.16	19.10	19.10	22.7545		
Cellulose	162.14	4.02			4.02	25
Ash	105.989	12.06			12.06	75
NH3	17.03	4.52	4.52	5.38922		
Mesaconic	130.100	0.19	0.19	0.22976		
Fumaric	116.073	0.25	0.25	0.29845		
Succinic	118.089	0.37	0.37	0.43566		
Aconitic	172.180	0.51	0.51	0.61126		
Glycolic	76.052	0.59	0.59	0.70866		
Malic	134.089	0.77	0.77	0.91703		
Citric	192.125	1.07	1.07	1.2727		
Oxalic	90.036	1.27	1.27	1.5145		
		100.00	83.92	100	16.08	100

Appendix C Assumption for Simulation and Calculation of Molasses Composition

- Assumption : 1. Ethanol production rate 100 kg/hr
  2. Reducing substances as monosaccharide (glucose)
  3. Nitrogen compound as an Ammonia
  4. Other carbohydrate as cellulose
  5. Negligible wax, sterols and phospholipids
- Density of molasses 1.4134 kg/lit
- Density of ethanol 0.7893 kg/lit
- Molasses 1 ton can produce Ethanol 250 Lit which is Ethanol 193.325 kg
  So, if we produce 100 kg of ethanol Use 506.78 kilograms of molasses.

Note

A sugar is only a reducing sugar if it has an open chain with an aldehyde or a ketone group. Monosaccharides which contain an aldehyde group are known as aldoses, and those with a ketone group are known as ketoses.

Appendix D Chemical Reactions Implemented in PRO/II

Table D1 List of fermentation reactions that take place in the process and were implemented in PRO/II

1	$Cellulose_n + nWater \longrightarrow nGlucose$ $C_6H_{10}O_5 + H_2O \longrightarrow C_6H_{12}O_6$
2	$Cellulose_n + nWater \longrightarrow nSucrose$ $C_6H_{10}O_5 + \frac{1}{2}(H_2O) \longrightarrow \frac{1}{2}C_{12}H_{22}O_{11}$
3	$Sucrose_n + nH_2O \longrightarrow 2nGlucose$ $C_{12}H_{22}O_{11} + H_2O \longrightarrow 2C_6H_{12}O_6$
4	$Glucose \longrightarrow 2Ethanol + 2Carbon\text{-}dioxide$ $C_6H_{12}O_6 \longrightarrow 2C_2H_6O + 2CO_2$
5	$Glucose + 1.2Ammonia \longrightarrow 6Z\,mobilis + 2.4Water + 0.3Oxygen$ $C_6H_{12}O_6 + 1.2NH_3 \longrightarrow 6C_{1.8}H_{0.5}O_{0.2} + 2.4H_2O + 0.3O_2$
6	$Glucose + 2Water \longrightarrow 2Glycerol + Oxygen$ $C_6H_{12}O_6 + 2H_2O \longrightarrow 2C_3H_8O_3 + O_2$
7	$Glucose + 2Carbon\text{-}dioxide \longrightarrow 2Succinic\text{-}acid + Oxygen$ $C_6H_{12}O_6 + 2CO_2 \longrightarrow 2C_4H_6O_4 + O_2$
8	$Glucose \longrightarrow 3Acetic\text{-}acid$ $C_6H_{12}O_6 \longrightarrow 3C_2H_4O_2$
9	$Glucose \longrightarrow 2Lactic\text{-}acid$ $C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3$

Table D2 List of decomposition of cellulose reactions that take place in the process and were implemented in PRO/II (Extracted data from Shen and Gu, 2009)

1	Cellulose → Hydroxyacetone + 3Carbon Monoxide + 2Hydrogen $C_6H_{10}O_5 \rightarrow C_3H_6O_2 + 3CO + 2H_2$
2	2Cellulose → Hydroxyacetaldehyde + 2 Methane + 4Carbon Monoxide $2C_6H_{10}O_5 \rightarrow C_2H_4O_2 + 2CH_4 + 4CO$
3	2Cellulose → Acetone + 9Carbon Monoxide + 7Hydrogen $2C_6H_{10}O_5 \rightarrow C_3H_6O_2 + 3CO + 2H_2$
4	Cellulose → Hydroxymethy-furfural + 2Water $C_6H_{10}O_5 \rightarrow C_6H_6O_3 + 2H_2O$
5	5Cellulose → 6Furfural + 13Water $5C_6H_{10}O_5 \rightarrow 6C_5H_4O_2 + 13H_2O$
6	3Cellulose → Furfural + 13Carbon Monoxide + 13Hydrogen $3C_6H_{10}O_5 \rightarrow C_5H_4O_2 + 13CO + 13H_2$
7	Cellulose → Furan methanol + 2Water + Carbon Monoxide $C_6H_{10}O_5 \rightarrow C_5H_6O_2 + 2H_2O + CO$
8	3Cellulose → Furan methanol + 13Carbon Monoxide + 12Hydrogen $3C_6H_{10}O_5 \rightarrow C_5H_6O_2 + 13CO + 12H_2$
9	2Cellulose → Pyruvaldehyde + 2Carbon Monoxide + 3Carbon-dioxide + 4Methane $C_6H_{10}O_5 \rightarrow C_3H_4O_2 + 2CO + 3CO_2 + 4CH_4$
10	2Cellulose → 2Acetaldehyde + 3Methane + 2Carbon Monoxide + 3Carbon-dioxide $2C_6H_{10}O_5 \rightarrow 2C_2H_4O + 3CH_4 + 2CO + 3CO_2$
11	13Cellulose → 6Hexane + 23Water + 42Carbon Monoxide $13C_6H_{10}O_5 \rightarrow 6C_6H_{14} + 23H_2O + 42CO$
12	Cellulose → Anhydro-D-mannose + 13Water $C_6H_{10}O_5 \rightarrow C_6H_8O_4 + H_2O$
13	7Cellulose → 3Diethoxypropionate-ethyl-ester + 8Water + 15Carbon Monoxide $C_6H_{10}O_5 \rightarrow 3C_9H_{18}O_4 + 8H_2O + 15CO$
14	Cellulose → Levoglucosan $C_6H_{10}O_5 \rightarrow C_6H_{10}O_5$
15	2Cellulose → 7Char $C_6H_{10}O_5 \rightarrow 7C + 5CO_2 + 10H_2$

Table D3 List of synthesis of HMF reaction from cellulose that take place in the process and were implemented in PRO/II (Extracted data from McNeff *et al.*, 2010)

1	Cellulose $\xrightarrow[TiO_2]{MIBK:\ H_2O}$ Hydroxymethy-furfural + 2Water $C_6H_{10}O_5 \xrightarrow[TiO_2]{MIBK:\ H_2O} C_6H_6O_3 + 2H_2O$

Appendix E Bioethanol Conversion Process Flowsheet Implemented in PRO/II

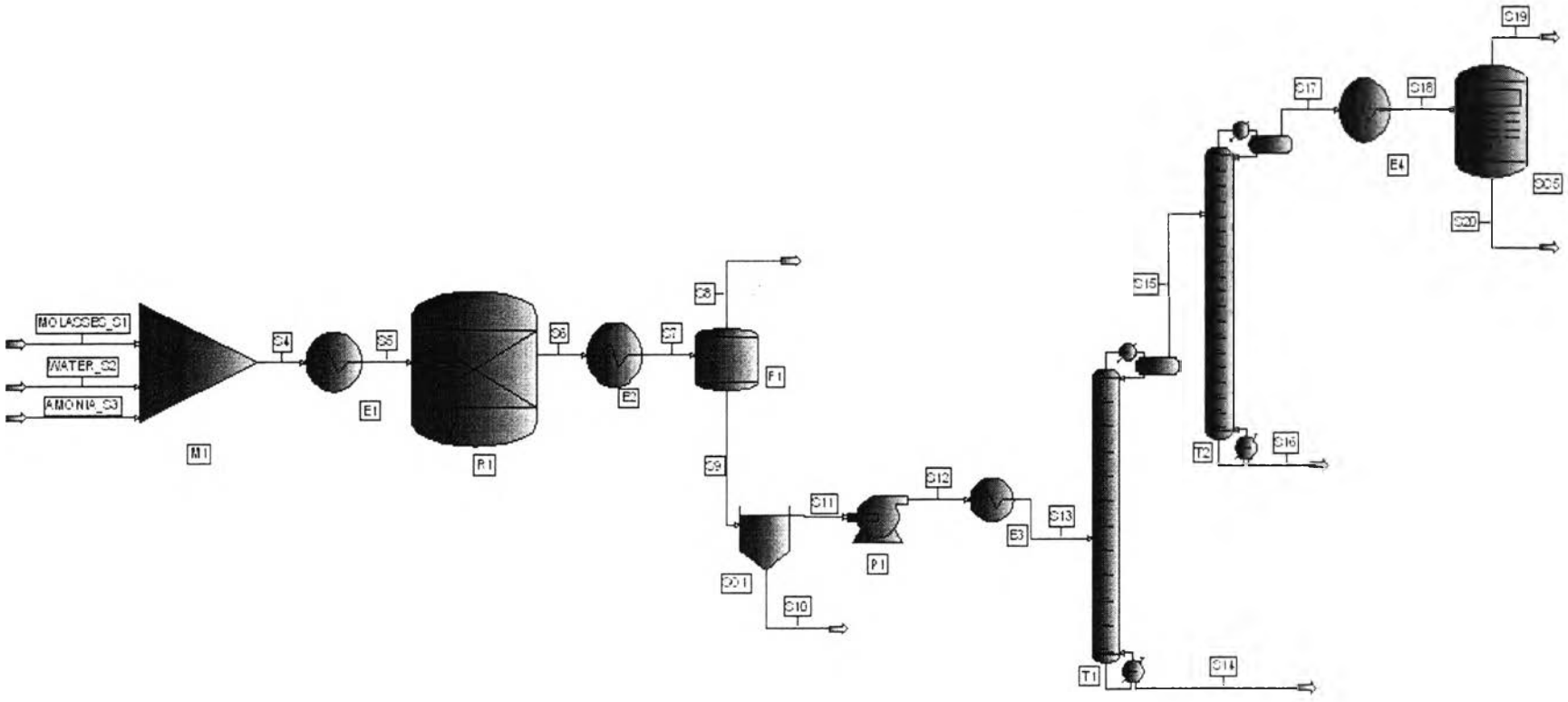

Figure E1 The main operations of the bio-ethanol process from molases for Base Case Design.

Table E1 Stream summary of the bio-ethanol process from molases for Base Case Design

Stream Name	MOLASSES_S1	WATER_S2	AMONIA S3	S4	S5	S6	S7
Components (kg/h)							
ETHANOL	0.00	0.00	0.00	0.00	0.00	142.37	142.37
WATER	101.86	1400.00	0.00	1501.87	1501.87	1490.81	1490.81
C6	96.77	0.00	0.00	96.77	96.77	22.51	22.51
C12	178.26	0.00	0.00	178.26	178.26	0.00	0.00
ACETACID	0.00	0.00	0.00	0.00	0.00	0.51	0.51
CO2	0.00	0.00	0.00	0.00	0.00	135.91	135.91
O2	0.00	0.00	0.00	0.00	0.00	0.08	0.08
NH3	22.92	0.00	0.01	22.93	22.93	22.86	22.86
LACACID	0.00	0.00	0.00	0.00	0.00	0.30	0.30
SUCCNAC	1.87	0.00	0.00	1.87	1.87	2.12	2.12
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.05	0.05
CELLULOS	20.37	0.00	0.00	20.37	20.37	4.03	4.03
ZM	0.00	0.00	0.00	0.00	0.00	0.54	0.54
ASH	61.12	0.00	0.00	61.12	61.12	61.12	61.12
MESACONIC	0.98	0.00	0.00	0.98	0.98	0.98	0.98
FUMARIC	1.28	0.00	0.00	1.28	1.28	1.28	1.28
ACONITIC	2.59	0.00	0.00	2.59	2.59	2.59	2.59
GLYCOLAC	3.02	0.00	0.00	3.02	3.02	3.02	3.02
MALIC	3.91	0.00	0.00	3.91	3.91	3.91	3.91
CITRIC	5.40	0.00	0.00	5.40	5.40	5.40	5.40
OXALIC	6.42	0.00	0.00	6.42	6.42	6.42	6.42
TotalMass Flow(kg/h)	506.78	1400.00	0.01	1906.79	1906.79	1906.79	1906.79
Temperature (C)	25.00	25.00	25.00	25.00	30.00	30.00	10.00
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EnthalpyFlow (GJ/h)	0.05	0.15	0.00	0.19	0.23	0.23	0.08

Table E1 Stream summary of the bio-ethanol process from molases for Base Case Design (Cont.)

Stream Name	S8	S9	S10	S11	S12	S13	S14
Components (kg/h)							
ETHANOL	0.18	142.19	0.00	142.19	142.19	142.19	0.00
WATER	0.22	1490.59	0.00	1490.59	1490.59	1490.59	894.35
C6	0.00	22.51	0.00	22.51	22.51	22.51	22.51
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.00	0.51	0.00	0.51	0.51	0.51	0.07
CO2	47.20	88.71	0.00	88.71	88.71	88.71	0.00
O2	0.07	0.01	0.00	0.01	0.01	0.01	0.00
NH3	0.22	22.64	0.00	22.64	22.64	22.64	0.00
LACACID	0.00	0.30	0.00	0.30	0.30	0.30	0.30
SUCCNAC	0.00	2.12	0.00	2.12	2.12	2.12	2.12
GLYCEROL	0.00	0.05	0.00	0.05	0.05	0.05	0.05
CELLULOS	0.00	4.03	4.03	0.00	0.00	0.00	0.00
ZM	0.00	0.54	0.54	0.00	0.00	0.00	0.00
ASH	0.00	61.12	61.12	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.98	0.00	0.98	0.98	0.98	0.98
FUMARIC	0.00	1.28	0.00	1.28	1.28	1.28	1.28
ACONITIC	0.00	2.59	0.00	2.59	2.59	2.59	2.59
GLYCOLAC	0.00	3.02	0.00	3.02	3.02	3.02	3.02
MALIC	0.00	3.91	0.00	3.91	3.91	3.91	3.91
CITRIC	0.00	5.40	0.00	5.40	5.40	5.40	5.40
OXALIC	0.00	6.42	0.00	6.42	6.42	6.42	6.42
Total Mass Flow(kg/h)	47.89	1858.90	65.68	1793.23	1793.23	1793.23	942.99
Temperature (C)	10.00	10.00	10.00	10.00	13.49	116.00	117.07
Pressure (atm)	1.00	1.00	1.00	1.00	2.00	2.00	1.77
Enthalpy Flow (GJ/h)	0.01	0.07	0.00	0.08	0.10	2.23	0.45

Table E1 Stream summary of the bio-ethanol process from molases for Base Case Design (Cont.)

Stream Name	S15	S16	S17	S18	S19	S20
Components (kg/h)						
ETHANOL	142.19	0.00	142.19	142.19	142.19	0.00
WATER	596.24	578.37	17.88	17.88	0.00	17.88
C6	0.00	0.00	0.00	0.00	0.00	0.00
C12	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.44	0.41	0.03	0.03	0.00	0.03
CO2	88.71	0.00	88.71	88.71	0.00	88.71
O2	0.01	0.00	0.01	0.01	0.00	0.01
NH3	22.64	0.00	22.64	22.64	0.00	22.64
LACACID	0.00	0.00	0.00	0.00	0.00	0.00
SUCCNAC	0.00	0.00	0.00	0.00	0.00	0.00
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.00
CELLULOS	0.00	0.00	0.00	0.00	0.00	0.00
ZM	0.00	0.00	0.00	0.00	0.00	0.00
ASH	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.00	0.00	0.00	0.00	0.00
FUMARIC	0.00	0.00	0.00	0.00	0.00	0.00
ACONITIC	0.00	0.00	0.00	0.00	0.00	0.00
GLYCOLAC	0.00	0.00	0.00	0.00	0.00	0.00
MALIC	0.00	0.00	0.00	0.00	0.00	0.00
CITRIC	0.00	0.00	0.00	0.00	0.00	0.00
OXALIC	0.00	0.00	0.00	0.00	0.00	0.00
Total Mass Flow(kg/h)	850.23	578.78	271.46	271.46	142.19	129.27
Temperature (C)	111.77	116.85	79.02	141.00	141.00	141.00
Pressure (atm)	1.77	1.77	1.77	1.77	1.77	1.77
Enthalpy Flow (GJ/h)	1.82	0.28	0.24	0.26	0.16	0.10

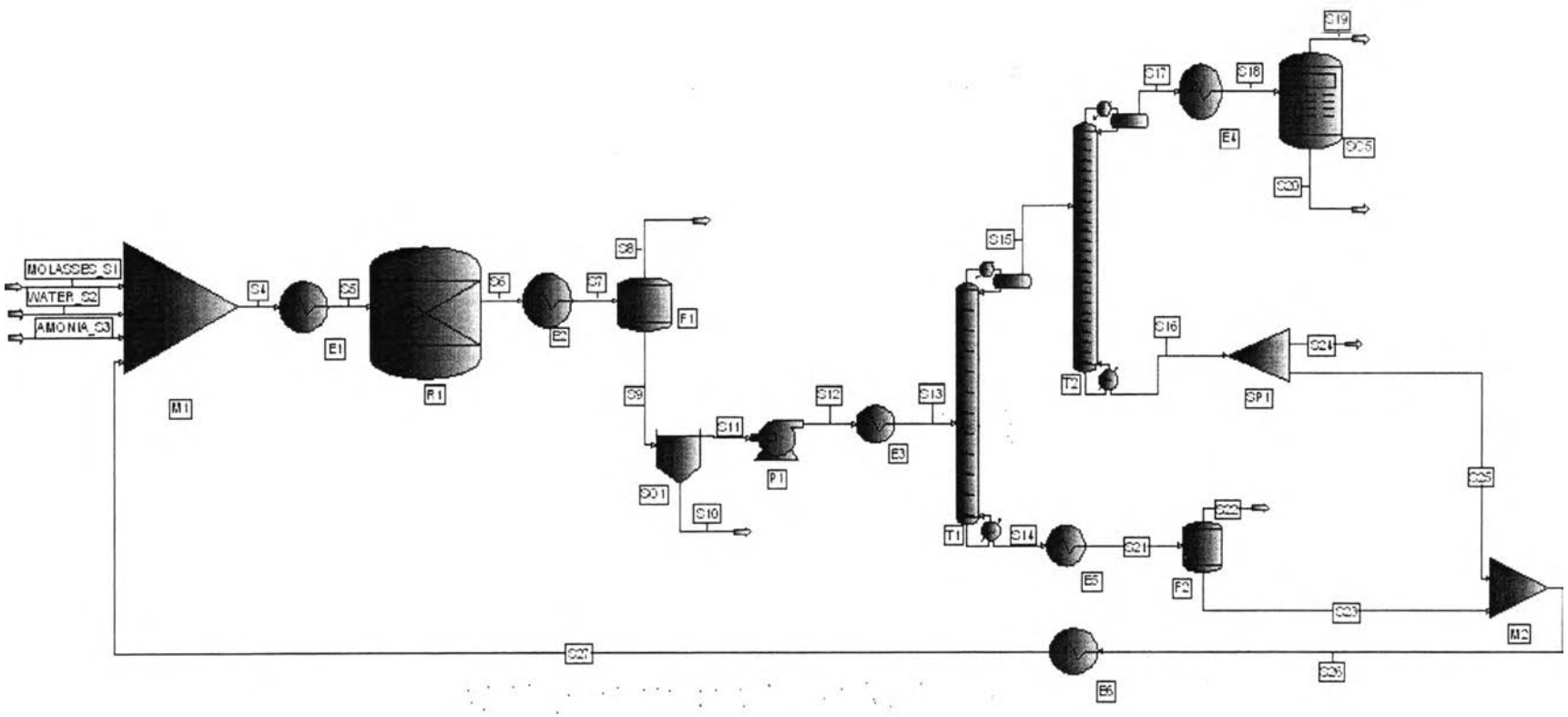

Figure E2 The main operations of the bio-ethanol process from molases for Alternative 1 (Recycle Glucose and Water).

Table E2 Stream summary of the bio-ethanol process from molases for Alternative 1 (Recycle Glucose and Water)

Stream Name	MOLASSES_S1	WATER_S2	AMONIA S3	S4	S5	S6	S7
Components (kg/h)							
ETHANOL	0.00	0.00	0.00	0.00	0.00	153.75	153.75
WATER	101.86	828.70	0.00	1474.08	1474.08	1463.04	1463.04
C6	96.77	0.00	0.00	120.95	120.95	24.31	24.31
C12	178.26	0.00	0.00	178.26	178.26	0.00	0.00
ACETACID	0.00	0.00	0.00	2.40	2.40	2.96	2.96
CO2	0.00	0.00	0.00	0.00	0.00	146.77	146.77
O2	0.00	0.00	0.00	0.00	0.00	0.08	0.08
NH3	22.92	0.00	0.01	22.93	22.93	22.85	22.85
LACACID	0.00	0.00	0.00	0.00	0.00	0.32	0.32
SUCCNAC	1.87	0.00	0.00	1.88	1.88	2.15	2.15
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.05	0.05
CELLULOS	20.37	0.00	0.00	20.37	20.37	4.03	4.03
ZM	0.00	0.00	0.00	0.00	0.00	0.58	0.58
ASH	61.12	0.00	0.00	61.12	61.12	61.12	61.12
MESACONIC	0.98	0.00	0.00	0.98	0.98	0.98	0.98
FUMARIC	1.28	0.00	0.00	1.28	1.28	1.28	1.28
ACONITIC	2.59	0.00	0.00	2.69	2.69	2.69	2.69
GLYCOLAC	3.02	0.00	0.00	3.02	3.02	3.02	3.02
MALIC	3.91	0.00	0.00	3.94	3.94	3.94	3.94
CITRIC	5.40	0.00	0.00	5.65	5.65	5.65	5.65
OXALIC	6.42	0.00	0.00	6.44	6.44	6.44	6.44
Total Mass Flow(kg/h)	506.78	828.70	0.01	1906.00	1906.00	1906.00	1906.00
Temperature (C)	25.00	25.00	25.00	25.00	30.00	30.00	10.00
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enthalpy Flow (GJ/h)	0.05	0.09	0.00	0.20	0.23	0.23	0.09

Table E2 Stream summary of the bio-ethanol process from molases for Alternative 1 (Recycle Glucose and Water) (Cont.)

Stream Name	S8	S9	S10	S11	S12	S13	S14
Components (kg/h)							
ETHANOL	0.24	153.51	0.00	153.51	153.51	153.51	0.00
WATER	0.28	1462.76	0.00	1462.76	1462.76	1462.76	877.66
C6	0.00	24.31	0.00	24.31	24.31	24.31	24.31
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.00	2.95	0.00	2.95	2.95	2.95	0.41
CO2	58.82	87.96	0.00	87.96	87.96	87.96	0.00
O2	0.08	0.01	0.00	0.01	0.01	0.01	0.00
NH3	0.27	22.58	0.00	22.58	22.58	22.58	0.00
LACACID	0.00	0.32	0.00	0.32	0.32	0.32	0.32
SUCCNAC	0.00	2.15	0.00	2.15	2.15	2.15	2.15
GLYCEROL	0.00	0.05	0.00	0.05	0.05	0.05	0.05
CELLULOS	0.00	4.03	4.03	0.00	0.00	0.00	0.00
ZM	0.00	0.58	0.58	0.00	0.00	0.00	0.00
ASH	0.00	61.12	61.12	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.98	0.00	0.98	0.98	0.98	0.98
FUMARIC	0.00	1.28	0.00	1.28	1.28	1.28	1.28
ACONITIC	0.00	2.69	0.00	2.69	2.69	2.69	2.69
GLYCOLAC	0.00	3.02	0.00	3.02	3.02	3.02	3.02
MALIC	0.00	3.94	0.00	3.94	3.94	3.94	3.94
CITRIC	0.00	5.65	0.00	5.65	5.65	5.65	5.65
OXALIC	0.00	6.44	0.00	6.44	6.44	6.44	6.44
Total Mass Flow(kg/h)	59.68	1846.32	65.72	1780.60	1780.60	1780.60	928.90
Temperature (C)	10.00	10.00	10.00	10.00	13.51	116.00	117.08
Pressure (atm)	1.00	1.00	1.00	1.00	2.00	2.00	1.77
Enthalpy Flow (GJ/h)	0.01	0.07	0.00	0.08	0.10	2.28	0.45

Table E2 Stream summary of the bio-ethanol process from molases for Alternative 1 (Recycle Glucose and Water) (Cont.)

Stream Name	S15	S16	S17	S18	S19	S20	S21
Components (kg/h)							
ETHANOL	153.51	0.00	153.51	153.51	153.51	0.00	0.00
WATER	585.10	567.55	17.55	17.55	0.00	17.55	877.66
C6	0.00	0.00	0.00	0.00	0.00	0.00	24.31
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	2.54	2.51	0.03	0.03	0.00	0.03	0.41
CO2	87.96	0.00	87.96	87.96	0.00	87.96	0.00
O2	0.01	0.00	0.01	0.01	0.00	0.01	0.00
NH3	22.58	0.00	22.58	22.58	0.00	22.58	0.00
LACACID	0.00	0.00	0.00	0.00	0.00	0.00	0.32
SUCCNAC	0.00	0.00	0.00	0.00	0.00	0.00	2.15
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.00	0.05
CELLULOS	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ASH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.00	0.00	0.00	0.00	0.00	0.98
FUMARIC	0.00	0.00	0.00	0.00	0.00	0.00	1.28
ACONITIC	0.00	0.00	0.00	0.00	0.00	0.00	2.69
GLYCOLAC	0.00	0.00	0.00	0.00	0.00	0.00	3.02
MALIC	0.00	0.00	0.00	0.00	0.00	0.00	3.94
CITRIC	0.00	0.00	0.00	0.00	0.00	0.00	5.65
OXALIC	0.00	0.00	0.00	0.00	0.00	0.00	6.44
Total Mass Flow(kg/h)	851.70	570.07	281.63	281.63	153.51	128.12	928.90
Temperature (C)	111.53	116.84	79.43	141.00	141.00	141.00	320.00
Pressure (atm)	1.77	1.77	1.77	1.77	1.77	1.77	1.77
Enthalpy Flow (GJ/h)	1.80	0.28	0.25	0.27	0.17	0.10	2.39

Table E2 Stream summary of the bio-ethanol process from molases for Alternative 1 (Recycle Glucose and Water) (Cont.)

Stream Name	S22	S23	S24	S25	S26	S27
Components (kg/h)						
ETHANOL	0.00	0.00	0.00	0.00	0.00	0.00
WATER	877.62	0.04	25.11	542.44	542.48	542.48
C6	0.12	24.18	0.00	0.00	24.18	24.18
C12	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.41	0.00	0.11	2.40	2.40	2.40
CO2	0.00	0.00	0.00	0.00	0.00	0.00
O2	0.00	0.00	0.00	0.00	0.00	0.00
NH3	0.00	0.00	0.00	0.00	0.00	0.00
LACACID	0.32	0.00	0.00	0.00	0.00	0.00
SUCCNAC	2.14	0.01	0.00	0.00	0.01	0.01
GLYCEROL	0.05	0.00	0.00	0.00	0.00	0.00
CELLULOS	0.00	0.00	0.00	0.00	0.00	0.00
ZM	0.00	0.00	0.00	0.00	0.00	0.00
ASH	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.98	0.01	0.00	0.00	0.01	0.01
FUMARIC	1.28	0.00	0.00	0.00	0.00	0.00
ACONITIC	2.59	0.10	0.00	0.00	0.10	0.10
GLYCOLAC	3.02	0.00	0.00	0.00	0.00	0.00
MALIC	3.91	0.03	0.00	0.00	0.03	0.03
CITRIC	5.40	0.25	0.00	0.00	0.25	0.25
OXALIC	6.42	0.02	0.00	0.00	0.02	0.02
Total Mass Flow(kg/h)	904.27	24.63	25.22	544.85	569.48	569.48
Temperature (C)	320.00	320.00	116.84	116.84	116.98	25.00
Pressure (atm)	1.77	1.77	1.77	1.77	1.77	1.77
Enthalpy Flow (GJ/h)	2.37	0.02	0.01	0.27	0.28	0.07

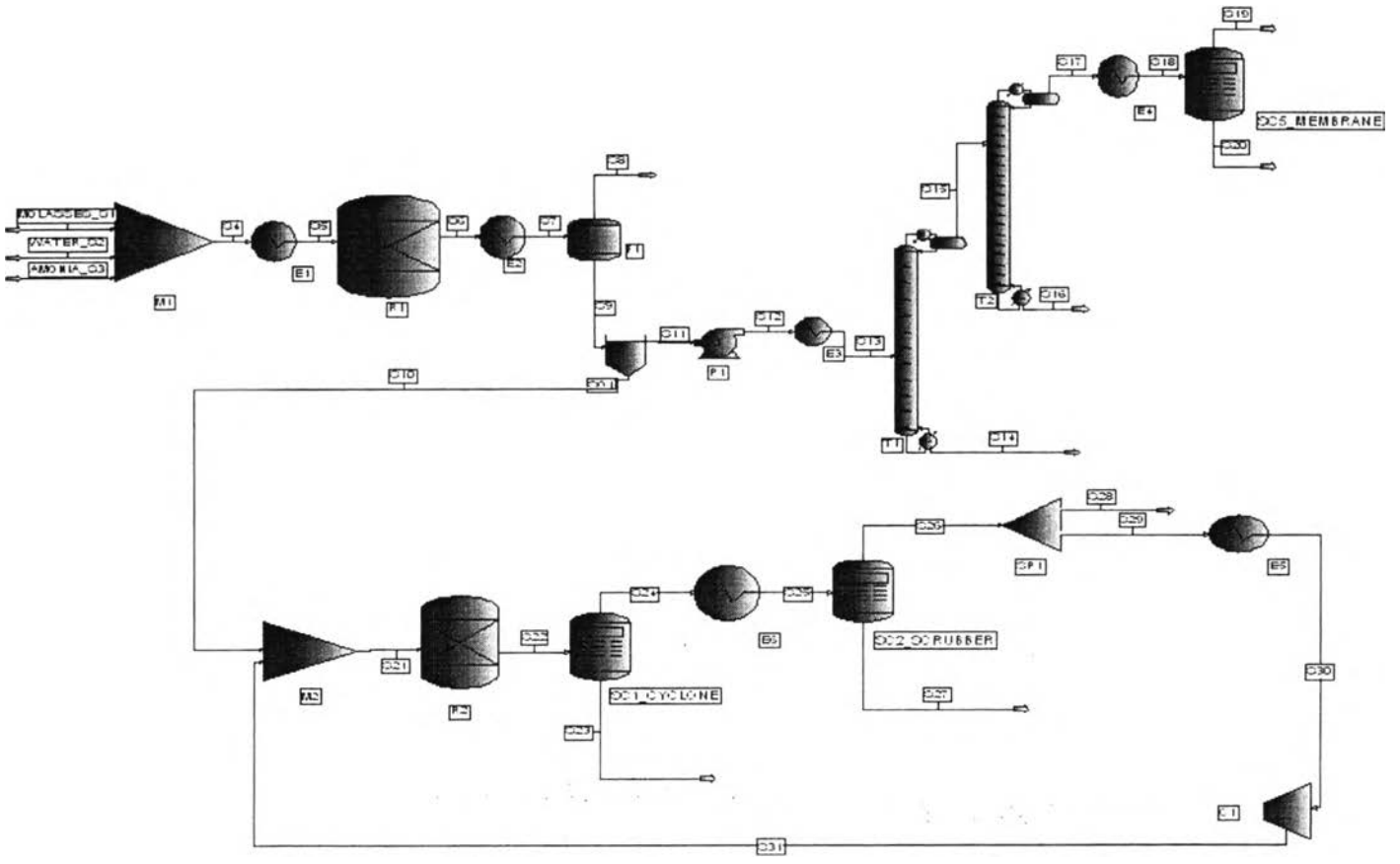

Figure E3 The main operations of the bio-ethanol process from molasses for Alternative 3 (Pyrolysis of Unconverted Cellulose to Produce Biooil).

Table E3 Stream summary of the bio-ethanol process from molases for Alternative 3 (Pyrolysis of Unconverted Cellulose to Produce Biooil)

Stream Name	MOLASSES S1	WATER S2	AMONIA S3	S4	S5	S6	S7
Components (kg/h)							
ETHANOL	0.00	0.00	0.00	0.00	0.00	142.37	142.37
WATER	101.87	1400.00	0.00	1501.87	1501.87	1490.82	1490.82
C6	96.77	0.00	0.00	96.77	96.77	22.51	22.51
C12	178.27	0.00	0.00	178.27	178.27	0.00	0.00
ACETACID	0.00	0.00	0.00	0.00	0.00	0.51	0.51
CO2	0.00	0.00	0.00	0.00	0.00	135.91	135.91
O2	0.00	0.00	0.00	0.00	0.00	0.08	0.08
NH3	22.92	0.00	0.01	22.93	22.93	22.86	22.86
LACACID	0.00	0.00	0.00	0.00	0.00	0.30	0.30
SUCCNAC	1.85	0.00	0.00	1.85	1.85	2.10	2.10
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.05	0.05
CELLULOS	20.37	0.00	0.00	20.37	20.37	4.03	4.03
ZM	0.00	0.00	0.00	0.00	0.00	0.54	0.54
ASH	61.12	0.00	0.00	61.12	61.12	61.12	61.12
CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
METHANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETALD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETONE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FURFURAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FUROH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HMF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HEXANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C9ester	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MANNOSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.98	0.00	0.00	0.98	0.98	0.98	0.98
FUMARIC	1.27	0.00	0.00	1.27	1.27	1.27	1.27
ACONITIC	2.60	0.00	0.00	2.60	2.60	2.60	2.60
GLYCOLAC	3.01	0.00	0.00	3.01	3.01	3.01	3.01
MALIC	3.90	0.00	0.00	3.90	3.90	3.90	3.90
CITRIC	5.41	0.00	0.00	5.41	5.41	5.41	5.41
OXALIC	6.44	0.00	0.00	6.44	6.44	6.44	6.44
Total Mass Flow(kg/h)	**506.78**	**1400.00**	**0.01**	**1906.79**	**1906.79**	**1906.79**	**1906.79**
Temperature (C)	25.00	25.00	25.00	25.00	30.00	30.00	10.00
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enthalpy Flow (GJ/h)	0.05	0.15	0.00	0.19	0.23	0.23	0.08

Table E3 Stream summary of the bio-ethanol process from molases for Alternative 3 (Pyrolysis of Unconverted Cellulose to Produce Biooil) (Cont.)

Stream Name	S8	S9	S10	S11	S12	S13	S14
Components (kg/h)							
ETHANOL	0.18	142.19	0.00	142.19	142.19	142.19	0.00
WATER	0.22	1490.59	0.00	1490.59	1490.59	1490.59	894.36
C6	0.00	22.51	0.00	22.51	22.51	22.51	22.51
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.00	0.51	0.00	0.51	0.51	0.51	0.07
CO2	47.20	88.71	0.00	88.71	88.71	88.71	0.00
O2	0.07	0.01	0.00	0.01	0.01	0.01	0.00
NH3	0.22	22.64	0.00	22.64	22.64	22.64	0.00
LACACID	0.00	0.30	0.00	0.30	0.30	0.30	0.30
SUCCNAC	0.00	2.10	0.00	2.10	2.10	2.10	2.10
GLYCEROL	0.00	0.05	0.00	0.05	0.05	0.05	0.05
CELLULOS	0.00	4.03	4.03	0.00	0.00	0.00	0.00
ZM	0.00	0.54	0.54	0.00	0.00	0.00	0.00
ASH	0.00	61.12	61.12	0.00	0.00	0.00	0.00
CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
METHANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETALD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HAA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETONE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FURFURAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FUROH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HMF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HEXANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C9ester	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MANNOSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.98	0.00	0.98	0.98	0.98	0.98
FUMARIC	0.00	1.27	0.00	1.27	1.27	1.27	1.27
ACONITIC	0.00	2.60	0.00	2.60	2.60	2.60	2.60
GLYCOLAC	0.00	3.01	0.00	3.01	3.01	3.01	3.01
MALIC	0.00	3.90	0.00	3.90	3.90	3.90	3.90
CITRIC	0.00	5.41	0.00	5.41	5.41	5.41	5.41
OXALIC	0.00	6.44	0.00	6.44	6.44	6.44	6.44
Total Mass Flow(kg/h)	**47.89**	**1858.90**	**65.68**	**1793.22**	**1793.22**	**1793.22**	**942.99**
Temperature (C)	10.00	10.00	10.00	10.00	13.49	116.00	117.07
Pressure (atm)	1.00	1.00	1.00	1.00	2.00	2.00	1.77
Enthalpy Flow (GJ/h)	0.01	0.07	0.00	0.08	0.10	2.23	0.45

Table E3 Stream summary of the bio-ethanol process from molases for Alternative 3 (Pyrolysis of Unconverted Cellulose to Produce Biooil) (Cont.)

Stream Name	S15	S16	S17	S18	S19	S20	S21
Components (kg/h)							
ETHANOL	142.19	0.00	142.19	142.19	142.19	0.00	0.00
WATER	596.24	578.35	17.89	17.89	0.00	17.89	0.00
C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.44	0.44	0.00	0.00	0.00	0.00	0.00
CO2	88.71	0.00	88.71	88.71	0.00	88.71	14.22
O2	0.01	0.00	0.01	0.01	0.00	0.01	0.00
NH3	22.64	0.00	22.64	22.64	0.00	22.64	0.00
LACACID	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUCCNAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CELLULOS	0.00	0.00	0.00	0.00	0.00	0.00	4.03
ZM	0.00	0.00	0.00	0.00	0.00	0.00	0.54
ASH	0.00	0.00	0.00	0.00	0.00	0.00	61.12
CO	0.00	0.00	0.00	0.00	0.00	0.00	12.44
H2	0.00	0.00	0.00	0.00	0.00	0.00	1.83
METHANE	0.00	0.00	0.00	0.00	0.00	0.00	0.59
ACETALD	0 00	0.00	0.00	0.00	0.00	0.00	0.00
HAA	0 00	0.00	0.00	0.00	0.00	0.00	0.00
ACETONE	0 00	0.00	0.00	0.00	0.00	0.00	0.00
HA	0 00	0.00	0.00	0.00	0.00	0.00	0.00
PA	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FURFURAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FUROH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HMF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LG	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHAR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HEXANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C9ester	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MANNOSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FUMARIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACONITIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCOLAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CITRIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OXALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mass Flow(kg/h)	**850.23**	**578.79**	**271.44**	**271.44**	**142.19**	**129.25**	**94.76**
Temperature (C)	111.77	116.85	79.01	141.00	141.00	141.00	504.77
Pressure (atm)	1.77	1.77	1.77	1.77	1.77	1.77	1.00
Enthalpy Flow (GJ/h)	1.82	0.28	0.24	0.26	0.16	0.10	0.08

Table E3 Stream summary of the bio-ethanol process from molases for Alternative 3 (Pyrolysis of Unconverted Cellulose to Produce Biooil) (Cont.)

Stream Name	S22	S23	S24	S25	S26	S27	S28
Components (kg/h)							
ETHANOL	0.00	0.00	0.00	0.00	0.00	0.000	0.00
WATER	0.04	0.00	0.04	0.04	0.00	0.043	0.00
C6	0.00	0.00	0.00	0.00	0.00	0.000	0.00
C12	0.00	0.00	0.00	0.00	0.00	0.000	0.00
ACETACID	0.00	0.00	0.00	0.00	0.00	0.000	0.00
CO2	14.70	0.00	14.70	14.70	14.70	0.000	0.48
O2	0.00	0.00	0.00	0.00	0.00	0.000	0.00
NH3	0.00	0.00	0.00	0.00	0.00	0.000	0.00
LACACID	0.00	0.00	0.00	0.00	0.00	0.000	0.00
SUCCNAC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.000	0.00
CELLULOS	0.00	0.00	0.00	0.00	0.00	0.000	0.00
ZM	0.54	0.54	0.00	0.00	0.00	0.000	0.00
ASH	61.12	61.12	0.00	0.00	0.00	0.000	0.00
CO	12.86	0.00	12.86	12.86	12.86	0.000	0.42
H2	1.90	0.00	1.90	1.90	1.90	0.000	0.06
METHANE	0.61	0.00	0.61	0.61	0.61	0.000	0.02
ACETALD	0.00	0.00	0.00	0.00	0.00	0.002	0.00
HAA	0.09	0.00	0.09	0.09	0.00	0.089	0.00
ACETONE	0.04	0.00	0.04	0.04	0.00	0.039	0.00
HA	0.05	0.00	0.05	0.05	0.00	0.052	0.00
PA	0.00	0.00	0.00	0.00	0.00	0.004	0.00
FURFURAL	0.02	0.00	0.02	0.02	0.00	0.023	0.00
FUROH	0.03	0.00	0.03	0.03	0.00	0.029	0.00
HMF	0.07	0.00	0.07	0.07	0.00	0.066	0.00
LG	3.32	0.00	3.32	3.32	0.00	3.317	0.00
CHAR	0.18	0.18	0.00	0.00	0.00	0.000	0.00
HEXANE	0.00	0.00	0.00	0.00	0.00	0.004	0.00
C9ester	0.03	0.00	0.03	0.03	0.00	0.034	0.00
MANNOSE	0.02	0.00	0.02	0.02	0.00	0.020	0.00
MESACONIC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
FUMARIC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
ACONITIC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
GLYCOLAC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
MALIC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
CITRIC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
OXALIC	0.00	0.00	0.00	0.00	0.00	0.000	0.00
Total Mass Flow(kg/h)	**95.63**	**61.84**	**33.80**	**33.80**	**30.08**	**3.722**	**0.99**
Temperature (C)	500.00	500.00	500.00	22.00	47.39	47.391	47.39
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.000	1.00
Enthalpy Flow (GJ/h)	0.29	0.26	0.04	0.00	0.00	-0.006	0.00

Table E3 Stream summary of the bio-ethanol process from molases for Alternative 3 (Pyrolysis of Unconverted Cellulose to Produce Biooil) (Cont.)

Stream Name	S29	S30	S31
Components (kg/h)			
ETHANOL	0.00	0.00	0.00
WATER	0.00	0.00	0.00
C6	0.00	0.00	0.00
C12	0.00	0.00	0.00
ACETACID	0.00	0.00	0.00
CO2	14.22	14.22	14.22
O2	0.00	0.00	0.00
NH3	0.00	0.00	0.00
LACACID	0.00	0.00	0.00
SUCCNAC	0.00	0.00	0.00
GLYCEROL	0.00	0.00	0.00
CELLULOS	0.00	0.00	0.00
ZM	0.00	0.00	0.00
ASH	0.00	0.00	0.00
CO	12.44	12.44	12.44
H2	1.83	1.83	1.83
METHANE	0.59	0.59	0.59
ACETALD	0.00	0.00	0.00
HAA	0.00	0.00	0.00
ACETONE	0.00	0.00	0.00
HA	0.00	0.00	0.00
PA	0.00	0.00	0.00
FURFURAL	0.00	0.00	0.00
FUROH	0.00	0.00	0.00
HMF	0.00	0.00	0.00
LG	0.00	0.00	0.00
CHAR	0.00	0.00	0.00
HEXANE	0.00	0.00	0.00
C9ester	0.00	0.00	0.00
MANNOSE	0.00	0.00	0.00
MESACONIC	0.00	0.00	0.00
FUMARIC	0.00	0.00	0.00
ACONITIC	0.00	0.00	0.00
GLYCOLAC	0.00	0.00	0.00
MALIC	0.00	0.00	0.00
CITRIC	0.00	0.00	0.00
OXALIC	0.00	0.00	0.00
Total Mass Flow(kg/h)	29.08	29.08	29.08
Temperature (C)	47.39	850.00	1160.89
Pressure (atm)	1.00	1.00	3.06
Enthalpy Flow (GJ/h)	0.00	0.06	0.09

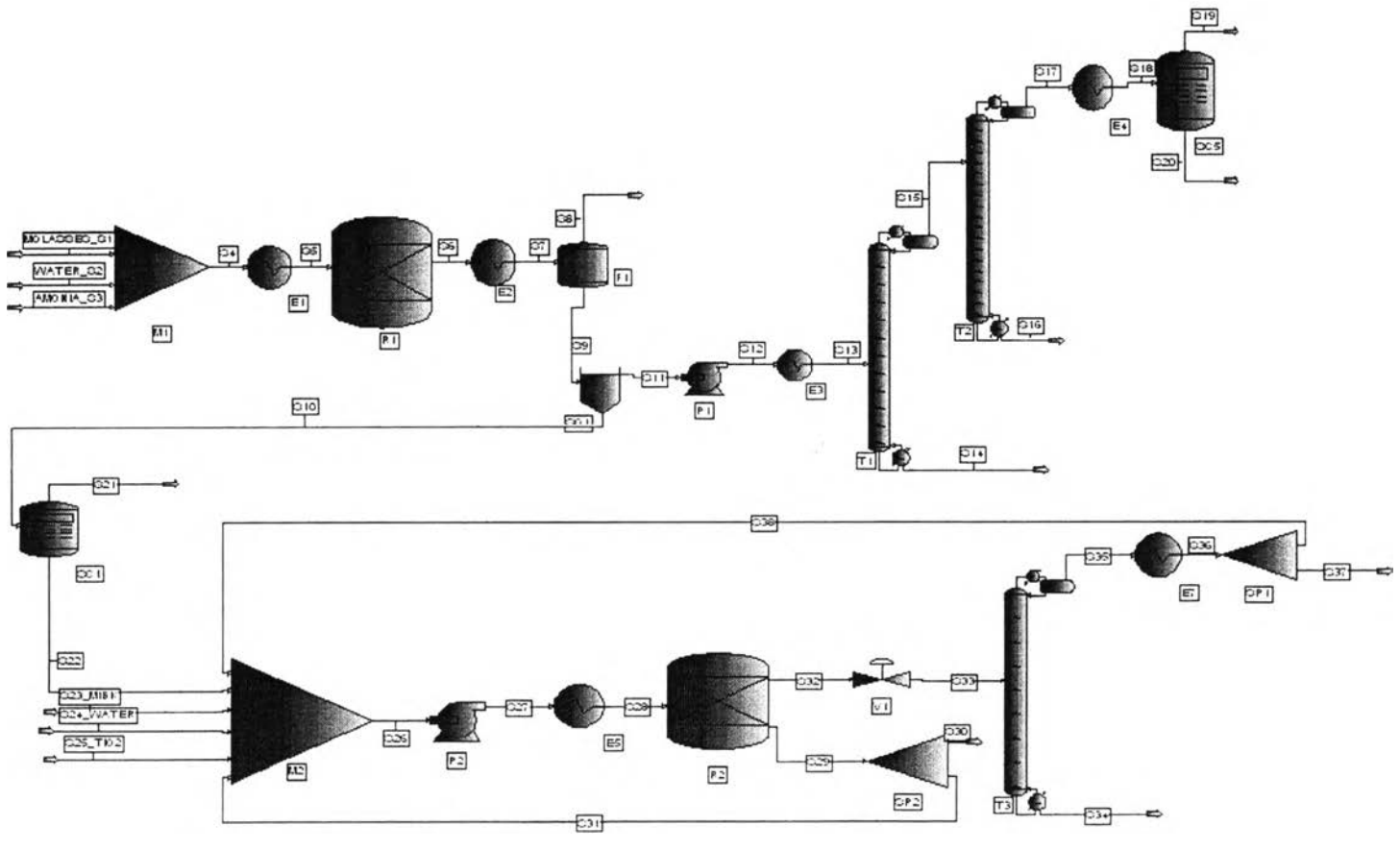

Figure E4 The main operations of the bio-ethanol process from molases for alternative 4 (Production of Hydroxymethyl Furfural from Unconverted Cellulose).

Table E4 Stream summary of the bio-ethanol process from molasses for Alternative 4 (Production of Hydroxymethyl Furfural from Unconverted Cellulose)

Stream Name	MOLASSES_S1	WATER_S2	AMONIA S3	S4	S5	S6	S7
Components (kg/h)							
ETHANOL	0.00	0.00	0.00	0.00	0.00	142.16	142.16
WATER	101.78	1398.81	0.00	1500.59	1500.59	1489.55	1489.55
C6	96.69	0.00	0.00	96.69	96.69	22.49	22.49
C12	178.11	0.00	0.00	178.11	178.11	0.00	0.00
ACETACID	0.00	0.00	0.00	0.00	0.00	0.51	0.51
CO2	0.00	0.00	0.00	0.00	0.00	135.88	135.88
O2	0.00	0.00	0.00	0.00	0.00	0.08	0.08
NH3	22.88	0.00	0.01	22.89	22.89	22.82	22.82
LACACID	0.00	0.00	0.00	0.00	0.00	0.30	0.30
SUCCNAC	1.85	0.00	0.00	1.85	1.85	2.10	2.10
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.05	0.05
CELLULOS	20.35	0.00	0.00	20.35	20.35	4.02	4.02
ZM	0.00	0.00	0.00	0.00	0.00	0.54	0.54
ASH	61.12	0.00	0.00	61.12	61.12	61.12	61.12
MIBK	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TIO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HMF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.98	0.00	0.00	0.98	0.98	0.98	0.98
FUMARIC	1.27	0.00	0.00	1.27	1.27	1.27	1.27
ACONITIC	2.60	0.00	0.00	2.60	2.60	2.60	2.60
GLYCOLAC	3.01	0.00	0.00	3.01	3.01	3.01	3.01
MALIC	3.90	0.00	0.00	3.90	3.90	3.90	3.90
CITRIC	5.41	0.00	0.00	5.41	5.41	5.41	5.41
OXALIC	6.44	0.00	0.00	6.44	6.44	6.44	6.44
Total Mass Flow(kg/h)	**506.39**	**1398.81**	**0.01**	**1905.21**	**1905.21**	**1905.21**	**1905.21**
Temperature (C)	25.00	25.00	25.00	25.00	30.00	30.00	10.00
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enthalpy Flow (GJ/h)	0.05	0.15	0.00	0.19	0.23	0.23	0.08

Table E4 Stream summary of the bio-ethanol process from molasses for Alternative 4 (Production of Hydroxymethyl Furfural from Unconverted Cellulose) (Cont.)

Stream Name	S8	S9	S10	S11	S12	S13	S14
Components (kg/h)							
ETHANOL	0.18	141.98	0.00	141.98	141.98	141.98	0.00
WATER	0.22	1489.33	0.00	1489.33	1489.33	1489.33	893.60
C6	0.00	22.49	0.00	22.49	22.49	22.49	22.49
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.00	0.51	0.00	0.51	0.51	0.51	0.07
CO2	47.19	88.69	0.00	88.69	88.69	88.69	0.00
O2	0.07	0.01	0.00	0.01	0.01	0.01	0.00
NH3	0.22	22.60	0.00	22.60	22.60	22.60	0.00
LACACID	0.00	0.30	0.00	0.30	0.30	0.30	0.30
SUCCNAC	0.00	2.10	0.00	2.10	2.10	2.10	2.10
GLYCEROL	0.00	0.05	0.00	0.05	0.05	0.05	0.05
CELLULOS	0.00	4.02	4.02	0.00	0.00	0.00	0.00
ZM	0.00	0.54	0.54	0.00	0.00	0.00	0.00
ASH	0.00	61.12	61.12	0.00	0.00	0.00	0.00
MIBK	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TIO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HMF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.98	0.00	0.98	0.98	0.98	0.98
FUMARIC	0.00	1.27	0.00	1.27	1.27	1.27	1.27
ACONITIC	0.00	2.60	0.00	2.60	2.60	2.60	2.60
GLYCOLAC	0.00	3.01	0.00	3.01	3.01	3.01	3.01
MALIC	0.00	3.90	0.00	3.90	3.90	3.90	3.90
CITRIC	0.00	5.41	0.00	5.41	5.41	5.41	5.41
OXALIC	0.00	6.44	0.00	6.44	6.44	6.44	6.44
Total Mass Flow(kg/h)	**47.88**	**1857.34**	**65.67**	**1791.66**	**1791.66**	**1791.66**	**942.21**
Temperature (C)	10.00	10.00	10.00	10.00	13.49	116.00	117.07
Pressure (atm)	1.00	1.00	1.00	1.00	2.00	2.00	1.77
Enthalpy Flow (GJ/h)	0.01	0.07	0.00	0.08	0.10	2.23	0.45

Table E4 Stream summary of the bio-ethanol process from molasses for Alternative 4 (Production of Hydroxymethyl Furfural from Unconverted Cellulose) (Cont.)

Stream Name	S15	S16	S17	S18	S19	S20	S21
Components (kg/h)							
ETHANOL	141.98	0.00	141.98	141.98	141.98	0.00	0.00
WATER	595.73	577.85	17.88	17.88	0.00	17.88	0.00
C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.44	0.44	0.00	0.00	0.00	0.00	0.00
CO2	88.69	0.00	88.69	88.69	0.00	88.69	0.00
O2	0.01	0.00	0.01	0.01	0.00	0.01	0.00
NH3	22.60	0.00	22.60	22.60	0.00	22.60	0.00
LACACID	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUCCNAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CELLULOS	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZM	0.00	0.00	0.00	0.00	0.00	0.00	0.54
ASH	0.00	0.00	0.00	0.00	0.00	0.00	61.12
MIBK	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TIO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HMF	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MESACONIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FUMARIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACONITIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCOLAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CITRIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OXALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mass Flow(kg/h)	**849.45**	**578.29**	**271.16**	**271.16**	**141.98**	**129.18**	**61.65**
Temperature (C)	111.77	116.85	79.01	141.00	141.00	141.00	10.00
Pressure (atm)	1.77	1.77	1.77	1.77	1.77	1.77	1.00
Enthalpy Flow (GJ/h)	1.82	0.28	0.24	0.26	0.16	0.10	0.00

Table E4 Stream summary of the bio-ethanol process from molasses for Alternative 4 (Production of Hydroxymethyl Furfural from Unconverted Cellulose) (Cont.)

Stream Name	S22	S23_MIBK	S24_WATER	S25_TIO2	S26	S27	S28
Components (kg/h)							
ETHANOL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WATER	0.00	0.00	2.70	0.00	47.64	47.64	47.64
C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LACACID	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUCCNAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CELLULOS	4.02	0.00	0.00	0.00	5.01	5.01	5.01
ZM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ASH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MIBK	0.00	13.02	0.00	0.00	165.27	165.27	165.27
TIO2	0.00	0.00	0.00	0.80	51.92	51.92	51.92
HMF	0.00	0.00	0.00	0.00	0.05	0.05	0.05
MESACONIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FUMARIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACONITIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCOLAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CITRIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OXALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mass Flow(kg/h)	4.02	13.02	2.70	0.80	269.89	269.89	269.89
Temperature (C)	10.00	25.00	25.00	25.00	42.02	45.66	270.00
Pressure (atm)	1.00	1.00	1.00	1.00	1.00	68.05	68.05
Enthalpy Flow (GJ/h)	-0.01	0.00	0.00	-0.01	-0.50	-0.50	-0.27

Table E4 Stream summary of the bio-ethanol process from molasses for Alternative 4 (Production of Hydroxymethyl Furfural from Unconverted Cellulose) (Cont.)

Stream Name	S29	S30	S31	S32	S33	S34	S35
Components (kg/h)							
ETHANOL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WATER	0.00	0.00	0.00	48.53	48.53	0.00	48.53
C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACETACID	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NH3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LACACID	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUCCNAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCEROL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CELLULOS	1.00	0.02	0.99	0.00	0.00	0.00	0.00
ZM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ASH	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MIBK	0.00	0.00	0.00	165.27	165.27	0.02	165.25
TIO2	51.92	0.80	51.12	0.00	0.00	0.00	0.00
HMF	0.00	0.00	0.00	3.17	3.17	3.11	0.06
MESACONIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FUMARIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACONITIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GLYCOLAC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CITRIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OXALIC	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Mass Flow(kg/h)	**52.92**	**0.81**	**52.11**	**216.97**	**216.97**	**3.13**	**213.84**
Temperature (C)	270.00	270.00	270.00	270.00	143.70	160.87	90.59
Pressure (atm)	68.05	68.05	68.05	68.05	1.00	1.00	1.00
Enthalpy Flow (GJ/h)	-0.51	-0.01	-0.50	0.24	0.24	0.00	0.22

Table E4 Stream summary of the bio-ethanol process from molasses for Alternative 4 (Production of Hydroxymethyl Furfural from Unconverted Cellulose) (Cont.)

Stream Name	S36	S37	S38
Components (kg/h)			
ETHANOL	0.00	0.00	0.00
WATER	48.53	3.82	44.71
C6	0.00	0.00	0.00
C12	0.00	0.00	0.00
ACETACID	0.00	0.00	0.00
CO2	0.00	0.00	0.00
O2	0.00	0.00	0.00
NH3	0.00	0.00	0.00
LACACID	0.00	0.00	0.00
SUCCNAC	0.00	0.00	0.00
GLYCEROL	0.00	0.00	0.00
CELLULOS	0.00	0.00	0.00
ZM	0.00	0.00	0.00
ASH	0.00	0.00	0.00
MIBK	165.25	13.00	152.24
TIO2	0.00	0.00	0.00
HMF	0.06	0.00	0.06
MESACONIC	0.00	0.00	0.00
FUMARIC	0.00	0.00	0.00
ACONITIC	0.00	0.00	0.00
GLYCOLAC	0.00	0.00	0.00
MALIC	0.00	0.00	0.00
CITRIC	0.00	0.00	0.00
OXALIC	0.00	0.00	0.00
Total Mass Flow(kg/h)	**213.84**	**16.83**	**197.01**
Temperature (C)	25.00	25.00	25.00
Pressure (atm)	1.00	1.00	1.00
Enthalpy Flow (GJ/h)	0.01	0.00	0.01

Appendix F Life Cycle Inventory Analysis of New Design Alternatives

F.1 Alternative-1

Table F1.1 List of inventory of alternative 1 in sugarcane plantation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Fuel:				***Product***		
Diesel	1.39E-02	kg		Sugarcane	13.883	kg
Chemical:						
Fertilizer (N)	2.06E-02	kg				
Fertilizer (P)	9.59E-03	kg				
Fertilizer (K)	8.55E-03	kg				
Paraquat (Bipyridylium)	1.49E-04	kg				
Glyphosate	2.38E-05	kg				
Atrazine	5.21E-04	kg				
Ametryne	3.72E-04	kg				
2,4-D	1.49E-04	kg				

Table F1.2 List of inventory of alternative 1 in sugarcane milling stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Raw material:				***Product***		
Sugarcane plant	13.883	kg		Molasses	3.301	kg
Energy:				***Avoid Product***		
Production of Electricity & Steam Bagasse mainly & other	3.865	kg		Electricity	0.406	kWh
-Electricity from bagasse	0.241	kWh				
-Steam from bagasse	6.242	kg				
Chemical:						
Lime	2.93E-02	kg				
Sodium chloride	1.09E-02	kg				
Hydrochloric acid	6.25E-06	kg				
SiO2	3.21E-05	kg				
Biocide	5.09E-05	kg				
Aluminium sulfate	5.18E-05	kg				
Caustic soda flake	1.61E-05	kg				
Flocculants (Iron sulphate)	5.35E-04	kg				
Miscellaneous	7.94E-05	kg				

Table F1.3 List of inventory of alternative 1 in fermentation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Molasses	3.301	Kg		Output-1 From fermentation stage	11.592	Kg
Water	5.398	Kg				
Ammonia	0.000	Kg		***Final waste flow***		
				Residues	0.428	Kg
Utilities				***Emission to Air***		
Steam(1 bar)	9.84E-02	Kg		Ethanol	1.56E-03	Kg
				Water	1.81E-03	Kg
				Acetic acid	7.18E-06	Kg
				Carbondioxide	3.84E-01	Kg
				Oxygen	4.90E-04	Kg
				Ammonia	1.77E-03	Kg

Table F1.4 List of inventory of alternative 1 in recovery stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Output-1 From fermentation stage	11.592	kg		Ethanol 99.5 wt%	1.000	kg
Energy						
Steam	17.309	kg		***Liquid waste***		
Electricity	0.045	kW		Waste water	6.884	kg

Table F1.5 List of inventory of alternative 1 in biogas and cogeneration stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Waste water	6.884	Kg		Steam	1.414	kg
				Electricity	0.375	kWh
				Emission to air		
				Nitrogen oxides	6.75E-05	kg
				Carbon monoxide, biogenic	2.16E-04	kg
				Methane, biogenic	1.04E-04	kg
				NMVOC	9.00E-06	kg
				Dinitrogen monoxide	1.13E-05	kg
				Sulfur dioxide	9.45E-05	kg
				Platinum	3.15E-11	kg
				Heat, waste	3.99E+00	MJ
				Used mineral oil, to waste inceneration	3.72E-05	kg

F.2 Alternative-2

Table F2.1 List of inventory of alternative 2 in sugarcane plantation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Fuel:				***Product***		
Diesel	1.50E-02	kg		Sugarcane	14.988	kg
Chemical:						
Fertilizer (N)	2.22E-02	kg				
Fertilizer (P)	1.04E-02	kg				
Fertilizer (K)	9.23E-03	kg				
Paraquat (Bipyridylium)	1.61E-04	kg				
Glyphosate	2.57E-05	kg				
Atrazine	5.62E-04	kg				
Ametryne	4.01E-04	kg				
2,4-D	1.61E-04	kg				

Table F2.2 List of inventory of alternative 2 in sugarcane milling stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Raw material:				***Product***		
Sugarcane plant	14.988	kg		Molasses	3.564	kg
Energy:				***Avoid Product***		
Production of Electricity & Steam Bagasse mainly & other	4.172	kg		Electricity	0.438	kWh
-Electricity from bagasse	0.260	kWh				
-Steam from bagasse	6.739	kg				
Chemical:						
Lime	3.16E-02	kg				
Sodium chloride	1.18E-02	kg				
Hydrochloric acid	6.74E-06	kg				
SiO2	3.47E-05	kg				
Biocide	5.49E-05	kg				
Aluminium sulfate	5.59E-05	kg				
Caustic soda flake	1.73E-05	kg				
Flocculants (Iron sulphate)	5.78E-04	kg				
Miscellaneous	8.57E-05	kg				

Table F2.3 List of inventory of alternative 2 in sugarcane fermentation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Molasses	3.564	kg		Output-1 From fermentation stage	12.612	kg
Water	9.846	kg				
Ammonia	7.75E-05	kg				
				Emission to Air		
Utilities				Ethanol	1.25E-03	kg
Steam	0.106	kg		Water	3.85E-01	kg
				Acetic acid	1.08E-06	kg
				Carbondioxide	1.46E+00	kg
				Oxygen	4.78E-04	kg
				Ammonia	1.53E-03	kg
				Nitrogen	4.29E-04	kg

Table F2.4 List of inventory of alternative 2 in sugarcane recovery stage

Input Inventory				*Output Inventory*		
Type	**Amount**	**Unit**		***Type***	***Amount***	***Unit***
Material				***Product***		
Output-1	12.612	kg		Ethanol 99.5 wt%	1.000	kg
Energy						
Steam	8.710	kg		***Liquid waste***		
Electricity	0.048	kWh		Waste water	11.612	kg

Table F2.5 List of inventory of alternative 2 in sugarcane biogas and cogeneration stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Waste water	11.612	Kg		Cogen Steam	2.325	kg
				Cogen Electricity	0.625	KWh
				Emission to air		
				Nitrogen oxides	1.13E-04	kg
				Carbon monoxide, biogenic	3.60E-04	kg
				Methane, biogenic	1.73E-04	kg
				NMVOC	1.50E-05	kg
				Dinitrogen monoxide	1.88E-05	kg
				Sulfur dioxide	1.58E-04	kg
				Platinum	5.26E-11	kg
				Heat, waste	6.66E+00	MJ
				Used mineral oil, to waste inceneration	6.20E-05	kg

F.3 Alternative-3

Table F3.1 List of inventory of alternative 3 in sugarcane plantation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Fuel:				***Product***		
Diesel	1.44E-02	kg		Sugarcane	14.418	kg
Chemical:						
Fertilizer (N)	2.14E-02	kg				
Fertilizer (P)	9.96E-03	kg				
Fertilizer (K)	8.88E-03	kg				
Paraquat (Bipyridylium)	1.54E-04	kg				
Glyphosate	2.47E-05	kg				
Atrazine	5.41E-04	kg				
Ametryne	3.86E-04	kg				
2,4-D	1.54E-04	kg				

Table F3.2 List of inventory of alternative 3 in sugarcane milling stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Raw material:				***Product***		
Sugarcane plant	14.418	kg		Molasses	3.429	kg
Energy:				***Avoid Product***		
Production of Electricity & Steam Bagasse mainly & other	4.014	kg		Electricity	0.422	kWh
-Electricity from bagasse	0.251	kWh				
-Steam from bagasse	6.483	kg				
Chemical:						
Lime	3.04E-02	kg				
Sodium chloride	1.13E-02	kg				
Hydrochloric acid	6.49E-06	kg				
SiO2	3.34E-05	kg				
Biocide	5.28E-05	kg				
Aluminium sulfate	5.38E-05	kg				
Caustic soda flake	1.67E-05	kg				
Flocculants (Iron sulphate)	5.56E-04	kg				
Miscellaneous	8.25E-05	kg				

Table F3.3 List of inventory of alternative 3 in sugarcane fermentation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Molasses	3.429	kg		Output-1 From fermentation stage	12.133	kg
Water	9.472	kg		Solid stream	0.444	kg
Ammonia	7.46E-05	kg				
				Emission to Air		
Utilities				Ethanol	1.20E-03	kg
Steam	0.102	kg		Water	1.51E-03	kg
				Acetic acid	1.04E-06	kg
				Carbondioxide	3.19E-01	kg
				Oxygen	4.60E-04	kg
				Ammonia	1.47E-03	kg

Table F3.4 List of inventory of alternative 3 in sugarcane recovery stage

Input Inventory				*Output Inventory*		
Type	**Amount**	**Unit**		***Type***	***Amount***	***Unit***
Material				***Product***		
Output-1 From fermentation stage	12.133	Kg		Ethanol 99.5 wt%	1.000	Kg
Energy				***Liquid waste***		
Steam	10.296	Kg		Waste water	11.612	Kg
Electricity	0.048	kW				

Table F3.5 List of inventory of alternative 3 in sugarcane biogas and cogeneration stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Waste water	11.612	kg		Steam	2.325	kg
				Electricity	0.625	KWh
				Emission to air		
				Nitrogen oxides	1.13E-04	kg
				Carbon monoxide, biogenic	3.60E-04	kg
				Methane, biogenic	1.73E-04	kg
				NMVOC	1.50E-05	kg
				Dinitrogen monoxide	1.88E-05	kg
				Sulfur dioxide	1.58E-04	kg
				Platinum	5.26E-11	kg
				Heat, waste	6.66E+00	MJ
				Used mineral oil, to waste inceneration	6.20E-05	kg

Table F3.6 List of inventory of alternative 3 in pyrolysis stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Solid stream	0.444	kg		Bio-oil	0.026	kg
Energy				***Emission to air***		
Electricity	0.114	kWh		Carbondioxide	1.09E+00	kg
				Water	3.72E-01	kg
				Nitrogen	4.29E-04	kg

F.4 Alternative-4

Table F4.1 List of inventory of alternative 4 in sugarcane plantation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Fuel:				***Product***		
Diesel	1.39E-02	kg		Sugarcane	13.889	kg
Chemical:						
Fertilizer (N)	2.06E-02	kg				
Fertilizer (P)	9.60E-03	kg				
Fertilizer (K)	8.56E-03	kg				
Paraquat (Bipyridylium)	1.49E-04	kg				
Glyphosate	2.38E-05	kg				
Atrazine	5.21E-04	kg				
Ametryne	3.72E-04	kg				
2,4-D	1.49E-04	kg				

Table F4.2 List of inventory of alternative 4 in sugarcane milling stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Raw material:				***Product***		
Sugarcane plant	13.889	kg		Molasses	3.303	kg
Energy:				***Avoid Product***		
Production of Electricity & Steam Bagasse mainly & other	3.866	kg		Electricity	0.406	kWh
-Electricity from bagasse	0.241	kWh				
-Steam from bagasse	6.245	kg				
Chemical:						
Lime	2.93E-02	kg				
Sodium chloride	1.09E-02	kg				
Hydrochloric acid	6.25E-06	kg				
SiO2	3.21E-05	kg				
Biocide	5.09E-05	kg				
Aluminium sulfate	5.18E-05	kg				
Caustic soda flake	1.61E-05	kg				
Flocculants (Iron sulphate)	5.36E-04	kg				
Miscellaneous	7.95E-05	kg				

Table F4.3 List of inventory of alternative 4 in sugarcane fermentation stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Molasses	3.303	kg		Output-1 From fermentation stage	11.687	kg
Water	9.124	kg		Solid stream	0.428	kg
Ammonia	7.18E-05	kg				
				Emission to Air		
Utilities				Ethanol	1.16E-03	kg
Steam(1 bar)	0.098	kg		Water	1.46E-03	kg
				Acetic acid	1.00E-06	kg
				Carbondioxide	3.08E-01	kg
				Oxygen	4.43E-04	kg
				Ammonia	1.42E-03	kg

Table F4.4 List of inventory of alternative 4 in sugarcane recovery stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Output-1 From fermentation stage	11.687	Kg		Ethanol 99.5 wt%	1.000	Kg
Energy						
Steam	10.296	Kg		***Liquid waste***		
Electricity	0.048	kW		Waste water	11.612	Kg

Table F4.5 List of inventory of alternative 4 in sugarcane biogas and cogeneration stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Waste water	11.612	Kg		Steam	2.325	Kg
				Electricity	0.625	KWh
				Emission to air		
				Nitrogen oxides	1.13E-04	kg
				Carbon monoxide, biogenic	3.60E-04	kg
				Methane, biogenic	1.73E-04	kg
				NMVOC	1.50E-05	kg
				Dinitrogen monoxide	1.88E-05	kg
				Sulfur dioxide	1.58E-04	kg
				Platinum	5.26E-11	kg
				Heat, waste	6.66E+00	MJ
				Used mineral oil, to waste inceneration	6.20E-05	kg

Table F4.6 List of inventory of alternative 4 in HMF production stage

Input Inventory				Output Inventory		
Type	**Amount**	**Unit**		**Type**	**Amount**	**Unit**
Material				***Product***		
Solid Stream	0.462	kg		HMF	0.022	kg
MIBK	0.092	kg				
Water	0.019	kg		***Final waste flow***		
				Residues	0.434	kg
Utilities						
Steam	1.240	kg		***Waste and emissions to treatment***		
Electricity	0.004	kWh		Disposal, solvents mixture	0.118	kg

CURRICULUM VITAE

Name: Ms. Naruporn Narot

Date of Birth: January 26, 1987

Nationality: Thai

University Education:

2005-2009 Bachelor Degree of Science, Department of Chemical Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand

Working Experience:

March-May 2008	Position:	Student Internship in Department of Technical Economic and Planning (TNEP)
	Company name:	Thaioil Public Company Limited, Sri-racha, Chonburi, Thailand.
May-Sep 2010	Position:	Process simulation using PRO/II and sustainability analysis using SustainPro
	Company name:	Computer Aided Process Engineering System Center (CAPEC), Department of Chemical and Biochemical Engineering, Technical University of Denmark, Lyngby, Denmark.

Proceedings:

1. Narot, N., Malakul, P., and Gani, R. (2011, April 26) Sustainable Process Design for Biomass-based Biofuel: Bioethanol Production from Molasses. Proceeding of The 2nd Research Symposium on Petroleum, Petrochemicals, and Advanced Materials and The 17th PPC Symposium on Petroleum, Petrochemicals, and Polymers, Bangkok, Thailand.