Techno-economic analysis of succinic acid production from sugarcane molasses

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งานวิจัยชิ้นนี้เสนอทางเลือกในการจัดการปัญหาสภาวะโลกร้อนด้วยการผลิตกรดซัคซินิกชีวภาพจากกากน้ำตาลและคาร์บอนไดออกไซด์จากกระบวนการผลิตเอทานอลเพื่อทดแทนการผลิตกรดซัคซินิกจากพลังงานฟอสซิล ด้วยการปรับปรุงกระบวนการแยกกรดซัคซินิกด้วยการสกัดแบบเกิดปฏิกิริยา และศึกษาความเป็นไปได้ในการลงทุนในการผลิตทั้งเชิงเทคนิค เศรษฐศาสตร์ พลังงาน และ การปล่อยคาร์บอนไดออกไซด์ ผลการวิจัยพบว่าการผลิตร่วมระหว่างเอทานอลกับกรดซัคซินิก ด้วยอัตรากากน้ำตาล 25:75 ให้ผลที่น่าพึงพอใจ อาทิเช่น ลดการปล่อยคาร์บอนไดออกไซด์จากการผลิตเอทานอลได้ถึง 66% ใช้พลังงานในการผลิตน้อยกว่าการผลิตกรดซัคซินิกจากพลังงานฟอสซิล 77% และ อีกทั้งยังให้กำไรทางเศรษฐศาสตร์เป็นที่น่าพึงพอใจ อาทิเช่น มูลค่าปัจจุบัน 2,180 ล้านสหรัฐ, อัตราผลตอบแทนภายใน 40.81% ภายในระยะเวลาการคืนทุน 5 ปี หลังจากการปรับปรุงเครือข่ายเครื่องแลกเปลี่ยนความร้อนพบว่าสามารถลดการใช้พลังงานได้ถึง 39% และ ลดการปลดคาร์บอนไดออกไซด์ถึง 63% จึงสามารถสรุปได้ว่าการผลิตร่วมระหว่างเอทานอลและกรดซัคซินิกในผลดีทั้งด้านสิ่งแวดล้อม การใช้พลังงาน และ ด้านเศรษฐศาสตร์

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This study proposes an alternative approach to address global warming concerns by introducing bio-based succinic acid production derived from molasses and waste CO_2 in ethanol production as a substitute for conventional petroleum-based methods. The evaluation focuses on the downstream process; reactive extraction, aiming to assess its feasibility in terms of technical, economic, energy, and CO_2 emission performance. The results indicate that the integrated process, Int. ETOH+SA 25:75, exhibits remarkable benefits, including a 66% reduction in CO_2 emissions from ethanol production, a 77% decrease in energy consumption compared to petroleum-based methods, and NPV of 2,180 million USD with a 40.81% IRR and a 5-year payout period. Additionally, the implementation of a heat exchanger network reduces utility requirements by 39% and CO_2 emissions by 63% which can be concluded that that integrating ethanol and succinic acid production offers significant environmental advantages, enhanced energy efficiency, and economic benefits.

Field of Study:	Chemical Engineering	Student's Signature	....
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Apitsada Rongsawad

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CHAPTER 1

Introduction

1.1 Statement of the problems

Succinic acid, a versatile organic acid widely utilized in various industries including food, chemicals, and pharmaceuticals, serves as a precursor for multiple chemical products such as solvents, perfumes, lacquers, plasticizers, dyes, and photographic chemicals [3]. This acid can also be produced through the biochemical conversion of waste carbon dioxide in ethanol production, employing various microorganisms such as *A. succinogenes, E. coli, M. succiniciproducens*, and utilizing different biobased feedstocks like sugars (e.g., glucose, sucrose, xylose) and biomass (e.g., cane molasses, corn fiber, bagasse) [3]. The selection of specific feedstocks and strains significantly impacts succinic acid productivity. For instance, cane molasses can be effectively utilized as a carbon source for succinic acid production by A. succinogenes CMCC1593, achieving notable results of 50.6 g/L succinic acid, 0.84 g/L·h productivity, and 95.6% sugar conversion under anaerobic conditions [4]. Comparing succinic acid selling price with other bio-based chemicals, it is observed that succinic acid carries a higher price point ($2,940 per ton) in contrast to other chemicals like acetic acid ($617/ton), sorbitol ($650/ton), and lactic acid ($1,450/ton) [5].

Succinic acid can be produced from two main routes which are the biochemical route using biomass feedstocks such as corn, sugarcane, and sugar beets etc. together with micro-organism and the petrochemical route using fossil resources derived from the catalytic oxidation of n-butane into maleic anhydride [6]. Nowadays, succinic acid is mainly produced from fossil resources through maleic acid hydrogenation [4]. However, the petrochemical route towards succinic acid, the conversion of n-butane to maleic anhydride is the main conversion step which is highly exothermic and high-pressure steam [6]. Additionally, the petrochemical route has more environmental effects than biochemical route using fossil resources. Moreover, Thailand's crude oil price has been increased constantly which will also affect Petro-based succinic acid price. Recently, the Thai government is trying to drift Thailand toward a new economy model called BCG Economy model which will help evaluate the value of Thailand's agricultural goods economically and culturally using science, technology, and innovations for a sustainable way of living [7]. Thus, the bio-based succinic acid route has been brought into consideration by researchers.

Despite the reasons stated above, bio-succinic acid in commercial scale production suffered from financial crisis. For intances, In May 2018, BioAmber, one of the biggest Bio-Succinic acid producers, filed for bankruptcy because the company kept losing money during the first 2 years and did not escape the fate of failure so called "the valley of death". In the same year, Myriant and Succinity, other big succinic acid producers, declared their bankruptcy. There are several factors for these companies to be financially collapsed such as expensive technologies and not ready for commercialization [8]. Furthermore, substrate cost accounts for around 50% in biological process [4] as well as the results from another research from Morales et al. also found that bio-based succinic acid production from sugar beet or wood had higher operating cost ($2.60-$4.5 per kg) compared to Petro-based succinic acid ($1.92 per kg) [9]. Additionally, Thailand is considered as one of the most important sugar producers which sugarcane is used as the main raw materials in sugar milling industry and has the second lowest price (970-980 Baht/ton) in the world market [10]. For this reason, sugarcane is an interesting feedstock to produce succinic acid in Thailand.

To reduce the cost of bio-succinic acid as stated above, some suggested the potential in the use of waste CO_2 from bioethanol production as a feedstock of BSA production. In 50 million gallon/year ethanol production, 150,000 metric tons of CO_2/year is produced [11]. Without any use of CO_2, it must be emitted into the earth's surface which increases the temperature of the earth or the common name for this is "Climate Change" [12]. Climate Change affects the atmosphere and ocean circulations which impacts animals, plants, and ecosystems [12].

The aim of this work is to study the feasibility of integrating the first-generation ethanol (ETOH) and bio-succinic acid (BSA) productions with sugarcane molasses as a feedstock at various molasses ratios to produce ethanol and succinic acid (Int. ETOH+SA 25:75, 50:50, 75:25).

Techno-economic analysis is performed to see material utilization, energy, economic performance of these scenarios and CO_2 emissions as well as the comparison of between bio-based and Petroleum based succinic acid production.

1.2 Research Objectives

1.2.1. Study the feasibility of integrated ethanol and succinic acid production from sugarcane molasses by performing Techno-economic analysis.

1.2.2. Evaluate the use of agriculture goods as well as provide more sustainable way to produce succinic acid to shift the country toward BCG economy model.

1.2.3. Compare Petroleum based and Biobased succinic acid production using our study parameters.

1.2.4. Perform Heat Exchanger Network Designs for the most outstanding integrated scenarios to achieve energy efficiency.

1.3 Research scopes

1.3.1. The process simulations of biochemical productions namely bioethanol, bio-based succinic acid and three integrated ethanol and succinic acid production scenarios in this study are done on ASPEN PLUS V.11 software.

1.3.2. Study the influence of different molasses ratio to produce ethanol and succinic acid in the integrated scenarios including:

- Integrated ETOH+SA 25:75
- Integrated ETOH+SA 50:50
- Integrated ETOH+SA 75:25

1.3.3. Perform techno-economic analysis, environmental impact assessment and energy analysis on biochemical productions to study the feasibility of the integrated ethanol and succinic acid scenarios in comparison to the base case of the standalone ethanol and succinic acid production.

1.3.4. Process evaluation using heat exchanger network design to enhance the energy efficiency and reduce CO_2 emission within the process.

1.3.5. A comparative study on biobased and petroleum based succinic acid productions.

CHAPTER 2

Theory and Literature review

2.1 Sugar Milling Industry

Sugar is a sweetening substance made from agriculture crops such as sugarcane and sugar beet which contains enough amount of sugar for sugar production commercially [13]. In Thailand sugarcane is the main raw material used in sugar production with the total of 10,862,610 rai sugarcane plantations in 2020-2021 which decrease from the previous year 9.17% due to drought and low sugarcane price [14]. However, in the world market, Thailand is still considered as one of the most important sugar producers since sugarcane price is at the second lowest price (970-980 baht per ton) after Brazil (890-900 baht per ton) as well as the advantage of its location in Asia with high sugar consumption demand (the average sugar imports in Asia increases by the average of 2.0% yearly in which South East Asia increases by the average of 4.1% yearly that is higher than the import amount around the world 0.6% per year) results in the advantage in lower logistic cost than other main sugar producers such as Brazil and Australia [15]. Currently, Thailand has 57 sugar milling plants with 1.10 million ton per day capacity [14] where most of these plants located near plantation areas for (1) the convenient in raw materials storage to suit their production goals (2) reduce transportation cost (3) convenient in contact, encourage and help farmers. Moreover, the convenient in logistic should be considered for plant installation as well such as big city, ports, and commerce center) where Kanchanaburi has the most sugar milling plants (8 mills), follow by Udonthani (4 mills) and Chonburi (4 mills) [14].

2.2 The use of Sugar milling Waste

Kornrakit T. et al. (2012) found that sugar milling industry provides 2 type of products which are the main product, sugar and by products which are bagasse, filter cake, and molasses. Currently, bagasse can be used for steam production for power generating and driving machineries in production plants, power generating for sale and the excess energy storing for the use during the off season or at the end of the production season for dissolving sugar. Furthermore, the benefits of filter cake can be separated into 2 types which are the direct adjustment of soil for farmers and the additives for organic chemical fertilizer for sale. Lastly, 100% of molasses is sold to customers for beneficial use [16] .

2.2.1 Molasses

Molasses is a final liquid from multiple recrystallizations in sugar production. It has a dark brown color and can be separated from various methods such as centrifuge in the final step of sugar production and will not be reused in sugar production. Normally, 100 ton of sugar cane will produce 3.4 ton of molasses (88° Brix)—Thailand can produce 5 tons molasses (88° Brix) from 100 ton of sugar milling [16].

Molasses can be use as fertilizer, animal feed and chemicals such as ethyl alcohol, byproduct and ethyl alcohol derivatives, CO_2, fusel oil, acetic acid, butanol-acetone, lactric acid, citric acid, glycerol, yeast, dextran, MSG etc. [16]

2.2.2 Bagasse

Bagasse is sugarcane stem fiber from juice extraction process which contains water, fiber, and a little number of soluble solids. The amount of these components depends on sugarcane seeding, age, cultivation process and plant efficiency. From the survey of bagasse in many countries the average amount of each component in bagasse are

Components	Percentage
Moisture	46-52%
Fiber	43-52%
Brix or Soluble solids	2-6%

Bagasse fiber is an insoluble component mostly are cellulose, pentovan and lignin [16]. Bagasse can be used as feedstocks for many fiber industries such as paper, fiber boards, fuels such as electrical power using within production plants [16], CH_4, CO_2, N_2 etc. [17] and chemicals such as furfural, α-cellulose, xylitol, bioplastic, alcohol etc.

2.2.3 Filter cake

In sugar production, impurities in sugarcane juice after heating, adding calcium carbonate, SO_2 or CO_2 and defecation will be separated from filtration. These impurities will accumulate to a block called filter cake. Filter cakes have different moisture contents and mostly are anion from defecation. The filtration method in normal sugar production plants uses rotary vacuum fillet which use fine powder filter cake as filter aids which the filter cake from this process will have about 80% of moisture content. The amount and components in filter cake depends on cultivation location, sugarcane seeding, filtration efficiency, defecation process etc. [16]

Filter cake is mainly used as fertilizer in sugarcane cultivation which will be added 6 months before cultivation [17]. Moreover, it can be used as animal feed [17] and cane wax which has various benefits such as pharmaceutics, varnish, corrosion protection etc. [16]

2.3 Ethanol

2.3.1 Ethanol properties

Ethanol is a primary alcohol that is ethane which a hydroxy group substitutes one of its hydrogens [15]. Ethanol is a clear colorless liquid with a characteristic vinous odor and pungent taste. Its boiling point is 78.2 ℃ at 760 mmHg [18] and Flash point of 96 v/v% is at 17.0℃ [15].

Ethanol has many kinds of use such as cosmetics, household products (e.g., solvent use in paints, lacquers and varnish, cleaning products etc.), food additives (e.g., food extract, food flavoring, food curing etc.), Fuel [15].

2.3.2 Industrial pathways for ethanol production

Ethanol Production pathways can be classified into 3 different types: first generation (1G), second generation (2G) and integrated first and second-generation industrial processing. Many studies identified the current and future technical and economic performance of sugarcane first generation processing [13, 19-21] Second-generation has also been studied from the conversion of lignocellulose feedstk such as eucalyptus, elephant grass and cane bagasse or trash [22-27].

2.3.2.1 First generation ethanol distillery (1G)

First generation ethanol distillery is the Ethanol process made by sugar-or starch-rich biomass crops such as sugarcane, energy cane or sweet sorghum which is shredded and milled to extract the sugar-rich juice. Then the sugar-rich juice is treated and concentrated by evaporation before entering the fermentation step [13]. During fermentation (an exothermic process) sucrose is converted to glucose and fructose, then these two sugars will convert into Ethanol, CO_2, and byproducts such as alcohols, organic acid, etc.) [28]. The fermentation broth is fed to centrifuge to separate yeast and recovery. The fermentation gasses are fed into an absorber for ethanol recovery [27]. Both the ethanol recovered from the centrifuge and absorber are fed to a distillation column. The distillation product is fed to a rectification column to hydrate ethanol. For first generation technologies, bagasse and cane-trash are fed to a cogeneration facility to produce process steam and process/surplus electricity.

2.3.2.2 Second generation ethanol distillery (2G)

Second generation ethanol distillery produces ethanol from lignocellulose biomass due to the complex structure of lignocellulose, the biomass needs to be treated to extract sugars for fermentation of ethanol. The first step-in second-generation Ethanol Distillery process is the pretreatment of hemicellulose and very little cellulose to be hydrolyzed, followed by fermentation and ethanol separation [13, 27]. Hydrolysis combined with fermentation is more complex than fermentation of simple sugars [23]. Many researchers have found than pretreatment and hydrolysis of lignocellulose biomass helps improving ethanol yield and reduce ethanol production cost [29]. The most common procedure of pretreatment and hydrolysis are steam pretreatment and enzymatic hydrolysis [29]. The residues from lignocellulos Ethanol processing mostly consisted of lignin and un-reacted cellulose are fed to the cogeneration facility.

2.3.2.3 Integrate first-and-second generation ethanol distillery (1G+2G)

Integrate first-and-second generation ethanol distillery is a potential pathway that used the lignocellulosic residue from first generation process including bagasse and trash fed into the second-generation process. The cogeneration unit, fed with residues of the second-generation process, supplies the steam and electricity for both processes. J.G.G. Jonker et al. used two first generation industrial process, two second-generation processes as their integrated first- and second-generation process. It combines the optimized first-generation process with steam explosion pretreatment or liquid hot water pretreatment for second generation processing [25].

2.3.3 Thailand bioethanol Industry

Ethanol can be produced form starch or sugar rich crops as well as biomass or agricultural waste such as cellulose and hemicellulose by fermentation process to produce 99.5% Ethanol to use as fuel additives and in some industries such as food, beverage, and pharmacy etc. Ethanol is generally produced from agricultural crops such as sugarcane, sweet sorghum, corn and casava [30].

Thailand is the 7th ethanol consumer and producer which mainly produce ethanol for blending with gasoline so called gasohol. The amount of Ethanol produced depends on domestic demand and the government's policy supporting the use of Ethanol. From 2001 on, 10% of Ethanol is blended with gasoline so called gasohol 91 and gasohol 95. In 2008, There were more options of ethanol ratios in gasoline which are 20% ethanol gasohol (E20) and 85% Ethanol gasohol (E85) as a result, Ethanol demand had increased respectively. However, domestic ethanol sell is still being controlled by the government which only allows selling ethanol for fuel use according to fuel trade act while the use of ethanol in industries need to get the approve of the liquor organization [30].

In Thailand, molasses, casava and sugarcane juice are used as feedstocks to produce ethanol. According to the information in 2020, 58% of the total amount of ethanol is produced from molasses, 38% from casava, and 4% from sugarcane juice where the choice of using each feedstock depends on their current prices for example, the amount ethanol produced from molasses will decrease if molasses price increases. Furthermore, Ethanol produced from molasses is more desirable than casava because of the advantage in the amount of feedstock since molasses producers are the main sugar producers. As for casava, the main problem is the disruption in feedstock with other industries and the instability in its cost from government's intervened to help farmers [14].

Currently, there are 26 ethanol production plants with a total 5.97-million-liter capacity per day (April 2021) which increases from 5.92 million liter per day in 2020. This can be separated by their feedstocks which are molasses 2.6 million liter per day, casava 2.09 million liter per day, casava and molasses 1.05 million liter per day, and sugarcane juice 0.23 million liter per day. Mostly, ethanol production plants are in the central and northeast of Thailand which these plants are business chains from sugar and casava production plants [14].

2.3.4 Molasses based ethanol production process

There are 26 ethanol factories with a total capacity of 5.89 million liters per day. Molasses based ethanol accounts for 2.68 million liters per day [1] or 65% of the total ethanol produced in Thailand [14].

According to the financial and production information provided from Thai Agro Energy Pub Co., Ltd. The company uses technology of MAGUIN INTERIS (France) with the production capacity of 365,000 liter per day or 120.75 million liter per year (330 days per year of production). Their ethanol production divided into 2 production lines which are molasses-based Ethanol and casava based Ethanol each production line has the capacity of 150,000 L per day [31]. Molasses is a by-product from sugar processing in which 1 ton of sugar produced in sugar processing can produce 50 kg of molasses or 5% of milled sugarcane. 100% of sugar production capacity requires 75 million tons of sugarcane which produces 3.75 million tons of molasses and, sugar production plants cannot produce sugar at their full capacity. A typical molasses to ethanol conversion rate is 4 kg of molasses per liter of Ethanol however this number can vary based on production practices and sugar content of the molasses [29].

Sugar rich feedstocks used in Ethanol production such as sugarcane, molasses and sugar beet contain mainly sucrose which is a disaccharide sugar consists of 2 monosaccharide sugars which are glucose and fructose. The steps in sucrose fermentation process are hydrolysis reaction of sucrose to fructose and glucose, then glucose and fructose are converted into ethanol and carbon dioxide 4 molecules each [32].

Production and production process comprises 4 main stages as follows:

1. Mash Preparation Process: Molasses is delivered by pipeline from a storage tank for preparation prior to fermentation. The preparation process including diluting the molasses with water to the require concentration. A special acid that reduces surface tension is added to separate out organic salts from molasses [29].
2. Fermentation: Diluted molasses is delivered to the next stage where yeast is added to begin fermentation process. Essential nutrients, acid and air are added in yeast culture chamber. The optimally fermented yeast and other diluted molasses is moved from pre-fermenters to ferment. The company uses 6 continuous fermenters filled with radical flow pumps and cooling systems that stabilizes the temperature in the fermenters. The fermentation process takes 36 hours for the yeast to transform the sugar into alcohol. After fermentation, the fermented liquid is delivered to buffer tank to await distillation. The processes produce alcohol with a purity level of 9-10% by volume [29].
3. Distillation: The fermented alcohol from the buffer tank is transferred to distillation column 1 where the alcohol is separate from the fermentation broth. The distillation performs at a lower atmospheric pressure. The alcohol vapor out of Column 1 flows through a cooling system. The purified alcohol

vapor is condensed into liquid alcohol with approximately 50% purity by volume before being transferred to Column 2 for a higher atmospheric pressure distillation. This will produce 92% purified alcohol by volume. The alcohol vapor from Column 2 is transferred to the dehydration process. The residue from distillation includes fuel oil which can be used in perfume, resins, plastics, lacquer, and ink. Spent wash from distillery is sent to treatment system to generate biogas for electricity generation which will be used in the company [29].

4. Dehydration: This process removes the remaining water after alcohol production which raising it to 99.8% purity by volume. The dehydration unit collecting alcohol vapor is double-barreled. Zeolites installed in the barrels absorb water from the vapor. The dehydrated alcohol is condensed and cooled before delivery to storage tanks to await distribution with 4.5 million liters capacity. Each tank equipped with nitrogen blanketing to maintain the ethanol quality while it waits for delivery to customers [29].

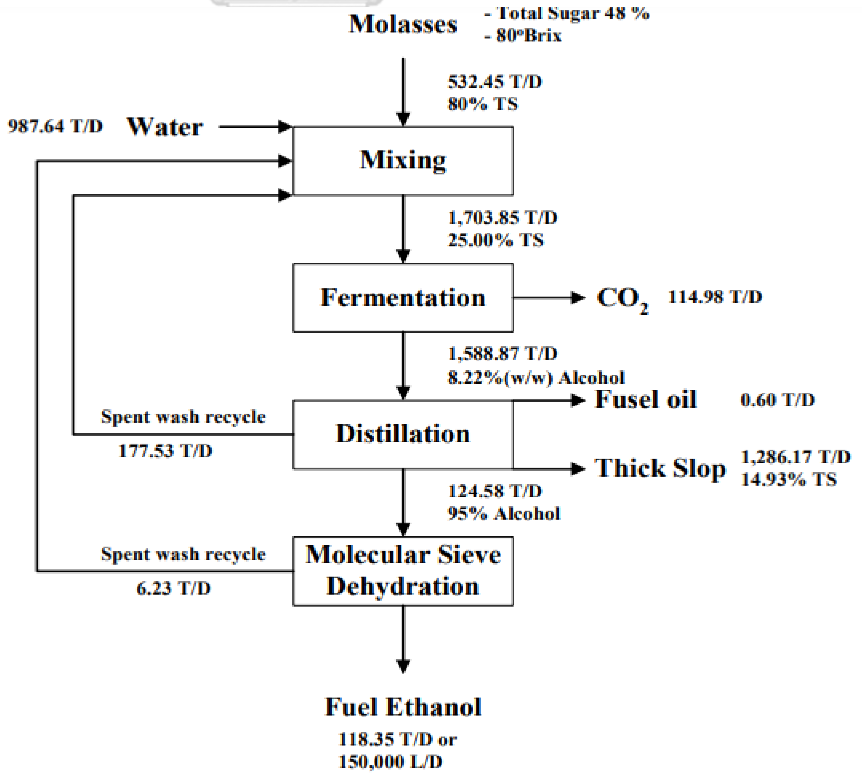

Figure 2.1 Ethanol production from molasses [33]

2.3.5 Ethanol price and Trend

The bioethanol market size was estimated at around 100 billion liters in 2020. The market was negatively impacted by COVID-19 in 2020 due to several countries were forced to go on lockdown and creating a negative impact on the demand for ethanol blended gasoline fuel or gasohol. However, the use of ethanol sanitizers as disinfectants has increased in the current situation, therefore it enhances the market's growth for bioethanol [34]. According to trading economics, ethanol price has decreased by 26.68% in a month and tends to decrease even more. Thailand energy academy in 2015 found that Thailand's ethanol prices produced from both casava, and molasses are higher than those produced by the United States and Brazil due to higher feedstock prices by the government's policy encouraging farmers to grow these crops as a result, Thailand's ethanol production is being over-produced [29, 35].

Bloomberg article in 2021, forecasts that by 2030 Electric Vehicles will be cheaper to make than Internal Combustion Engine cars. The most critical factor for EV cars is the rapidly falling cost of Li-ion batteries and their improving efficiency. Battery costs have fallen almost 80% from 2010-2017. It also forecasts that the world's electric vehicles will displace 7.3 barrels per day transportation fuel by 2040. If the ethanol demand fell by a third as to crude oil demand, this would put 1.86 billion Bu of corn back on the market in the U.S. alone [34].

Soren Jensen, the former chief operating officer to top sugar trader Alvean has said that the demand for Sugarcane Bioethanol in Brazil will likely start to decrease in 2030 as EVs become more popular. This will put the amount of sugarcane splitting to make ethanol in Brazil back in producing more sugar. The shift in Latin America's biggest economy will influence global surpluses and lower prices set to be felt in places like Thailand and India, which have higher cost of production. The demand for ethanol, which in some years equals to 50% of all the sugarcane crushed in Brazil could start decreasing in 2025 and fall to about 40% through 2035 according to the study's worse scenarios [36].

2.3.6 Byproducts from Bioethanol production

In ethanol production, apart from the main product Ethanol. There are many byproducts such as CO_2 produced during fermentation process, Fusel oil from distillation process, and the waste from the production which is wastewater or vinasse which contains yeast. The quality of vinasse depends on the type, the amount of feedstocks and the yield from ethanol production. According to the survey of waste management and byproducts from ethanol production nowadays, it shows that the production plants still does not have a Carbon Dioxide and Fusel oil which contain alcoholic components with higher boiling point than Ethanol storage system. As for vinasse, there is still no use for yeast, but the liquid can be used to produced Biogas to use within the plants. In some cases, vinasse from molasses Ethanol is used to produced fertilizer by adding it with filter cake or bagasse [29].

2.3.7 The use of Byproducts from Bioethanol production

2.3.7.1 Carbon Dioxide (CO_2)

Carbon Dioxide is produced during sugar fermentation to ethanol by yeast which is a half weight of fermentable glucose. From the approximation, ethanol with 150,000 liter per day capacity will produce 100-120 ton per day carbon dioxide. It can be used in all of it forms which are gas, liquid and solid. Carbon dioxide is mostly used in food industry as cooling agent and carbonated drink. Furthermore, it is used in other industries such as chemicals, welding, plastic and rubber, and agriculture. Carbon dioxide can be produced from various processes such as the combustion of carbon contained fuels and byproduct of many processes such as ammonia production, calcium carbonate baking in the furnace, sodium biphosphate production from Sodium bicarbonate and ethanol fermentation [29].

2.3.7.2 Fusel Oil

Fusel oil or sometimes called Fusel alcohol is a name of alcoholic components that has higher boiling point than Ethanol which is one of byproducts from Ethanol distillation. Fusel oil consisted of various types of alcohols mainly are 3-4 or 5 atom carbons components such as Isoamyl alcohol and Active amyl alcohol which is the main noble component. Moreover, there are also butanol and propanol. To use fusel oil, there has to be alcohol separation by distillation, chromatography or chemical method and purification before using it as solvent in industries like plastic and resin, lagger, and ink etc [29].

2.3.7.3 Biogas

Biogas is the gas occurs in nature of organic substances by micro-organism metabolism under anaerobic condition which can be used as a renewable energy. It can be produced from waste and wastewater from agricultural industry. Biogas consists of many gasses mainly is Methane (CH_4) around 50-70%, carbon dioxide (CO_2) 30-50%, and other gasses such as hydrogen (H_2), hydrogen sulfide (H_2S), nitrogen (N_2), and steam. Pure methane provides 35,800 kJ/m^3 heat capacity and biogas consists of 65% methane provides 22,400 kJ/m^3. Since biogas contains mainly methane, it has a good ignition property and can be used as a renewable energy in different ways such as combustion for the use of heat directly which has high heat efficiency that can be used for Steam boiler in plants—normally, production plants use fuel oil as their fuel. 1 m^3 of biogas can substitute 0.55-liter fuel oil which is used for Boiler to produce steam for ethanol distillation.

Usually, biogas production process consists of 2 steps which are firstly, decomposition of large organic molecules such as starch and protein in solution forms and turn into volatile acids by acid producing bacteria and lastly, organic acids conversion to methane and carbon dioxide by methane producing bacteria. Majority of ethanol production plants chose anaerobic fermenters which is anaerobic treatment technology which can be divided in 3 types by micro-organism growth which are Suspended growth, Supported growth and hybrid such as Upflow Anaerobic Sludge Blanket (UASB), Anaerobic Lagoons (AL), and Upflow Sludge Blanket/Fixed Bed Reactor (USB/FBR) [29].

2.3.7.4 Organic Fertilizer

Vinasse contains organic matters and large amount of soluble salts. Potassium (K) is the most element found which is essential for plant, follows by nitrogen (N) and phosphorous (P) respectively. Moreover, it consisted of secondary nutrients and supplementary food which can be made into fertilizer for the direct use or made into concentrated liquid fertilizer or solid fertilizer. However, with the limitation in logistic in which vinasse is used directly. In concentrated liquid fertilizer production, evaporator is used to increase its concentration. Normally, vinasse has 10-15% solid concentration which can be increased to 30% to use in farms by using sprayer used by either humans or machineries. In the case of solid fertilizer production, solids need to be added with vinasse such as filter cake from sugar production or bagasse [29].

2.4 Carbon dioxide emission in ethanol production

In ethanol production, Carbon Dioxide is the main pollution produced. A typical ethanol plant producing 50 million gallons of ethanol per year will produce about 150,000 metric tons of CO_2 per year [11]. Thanapat C. did a life cycle and environment impact assessment of molasse ethanol production in Thailand and has found that in ethanol production with 150,000 L/day capacity the total CO_2 emission from both coal combustion and electricity is 5,039.43 kg CO_2 [37] which indicates that CO_2 is the main contributor to global warming, is the highest pollutant emission amounts to 459.10 kg CO_2. The amount of greenhouse gasses emission in molasses-based bioethanol production is 9.33 times compared to cassava-based bioethanol production. This shows the amount of electricity usage in sugar milling process and amount of coal consumption for combustion processes [37].

2.5 Effects of carbon dioxide on climate change

Carbon dioxide is one of the greenhouse gasses that causes global warming. The link between carbon dioxide and Climate change has caught the attention of the public known as “greenhouse effect”. Normally, solar radiation passes limitlessly through the atmosphere to heat the Earth’s surface, the energy is re-emitted as infrared in return much of which is absorbed by CO_2 and water vapor in the atmosphere which acts as a blanket surrounding the Earth. This causes the surface temperature to increase from -21 ℃ to 14 ℃ [12].

The concentration of carbon dioxide in the atmosphere is increasing yearly as fossil fuels are being burnt, which speeds up the natural greenhouse effect and warm the planet. In 2015, Nations Climate Change Conference with 195 countries agreed on reducing carbon dioxide emission and other greenhouse gasses to limit global temperature increase below 2 ℃.

Climate change can change the circulation of the atmosphere and ocean, the melting of snow and ice, sequestration of carbon dioxide by plants, change the amount and types of clouds, and altered atmospheric water vapor [12].

2.6 Bio-Circular-Green Economic Model (BCG)

Thai government along with the research community has introduced a new economic model called BCG or Bio-Circular-Green Economic model for inclusive and sustainable growth. It capitalizes Thailand’s strengths in biological diversity and cultural richness as well as an employment in technology and innovation to transform the country to a value-based and innovation driven economy. The model also matches the UN Sustainable Development Goals (SDGs) and is also intended to align with the Sufficiency Economy Philosophy (SEP0 which is also the key principle of Thailand’s social and economic development [38].

Based on Thailand’s strengths in solid agricultural activities, rich natural resources, and diversity in terms of both biological resources and physical geography, the BCG model is applied to focus on promoting 4 industries which are agriculture and food, medical and wellness, bioenergy, biomaterial and biochemical as well as the tourism and creative economy. Science, technology, and innovation will be used to enhance the capacity and competitiveness of players in the value chain, both upstream and downstream, in all 4 industries together with innovative policy and supportive legal actions and financial measures [38]. At the moment, these 4 industries have a combined economic value of 3.4 trillion THB, accounting for 21% of the country’s GDP and it is expected that the BCG model can raise the economic value to 4.4 trillion THB (or 24% of the country’s GDP) in the next 5 years. The BCG model can create value addition including

1. Food and Agriculture: The value of this sector is a combination of product diversification, product differentiation, high-value and premium-quality products and services, waste reduction, resource-and land-use efficiency improvement. This strategy can be achieved by R&D and technologies such as customer behavior analytics, optimized and waste production, smart farming technologies, traceability, food, and product safety, as well as the development of high-value and novel food products such as food for special groups of people (e.g., patients and the elderly) and functional ingredients.
2. Medical and Wellness: The strategy includes intensive capacity building in technology and human capital in R&D and production technology for vaccines, biopharmaceuticals, and medical devices, as well as clinical research and product registration of pharmaceuticals and medical devices, all in support of Thailand's healthcare policy of promoting preventive medicine and precision medicine. Platforms to facilitate the utilization of genetic data as well as clinical research among involved parties including researchers, industry and regulatory bodies will also be established.
3. Bioenergy, Biomaterial and Biochemical: This sector has high potential growth due to the government policy setting a renewable energy target of 30% of total final energy consumption by 2036. The energy sector can benefit from advanced technology in energy produced from renewable sources such as refuse derived fuel (RDF) and biogas, as well as the establishment of community-based power plants (CBP) with a distributed energy resources (DERs) system using renewable energy sources, including biomass and biogas, and connected through blockchain-enabled smart microgrids. This vision will require intensive research in energy storage systems. As for the materials and biochemical sector, cutting-edge technologies will develop and employed to convert biomass and agricultural by-products to high-value commodities such as bioplastics, fibers, and pharmaceuticals. This sector shows the potential in the carbon dioxide utilization. There are variety of chemicals that can be produced from CO_2 such as all organic chemicals currently produced from fossil oil and gas including fuels, plastics as well as many chemical products used in our daily lives. CO_2 has been used for many

years as a raw material in various industrial chemical processes, e.g., in urea production and methanol and various other CO_2 based processes are at different stages of technological readiness with the economic factors such as the ability to compete with fossil-based products, CO_2 based process is currently under the development at a large scale [38]. Under current conditions, producing chemicals and fuels from CO_2 as a renewable carbon source is generally still more expensive than fossil fuel oil and gas. The costs mostly rely on the required renewable energy input which will decrease in the future. CO_2 to chemicals has great potential to turn the currently fossil fuel based chemical industry into a renewable and circular industry [38].

4. Tourism and Creative Economy: Thai tourism industry can benefit from the policy to promote secondary cities and communities as new tourist destinations. Technology and innovation will be applied to create and upgrade infrastructure and a digital platform to improve tourists' convenience and experience and advance the industry to high-quality tourism. Science and technology will be employed to define national guidelines for tourism, e.g., carrying capacity, support sustainable tourism standard system and conserve and rehabilitate the environment. Under the creative economy concept, tourism can be linked to other service industries to target niche market such as wellness tourism, culinary tourism, eco-tourism, cultural tourism, and sports tourism [38].

2.7 Crude Oil prices trend and the effects on fossil-based chemicals.

The current Brent crude oil process averaged \$87 per barrel in January, a \$12/barrel increase from December 2021. Crude oil prices have risen steadily since mid-2020 due to the consistent draws on global oil inventories, which averaged 1.8 million barrels per day from the third quarter of 2020 (3Q20) through the end of 2021. According to the international energy outlook, the global oil inventories is estimated to be fell further in January [39]. Furthermore, Oil prices have also risen as result of heightened market concerns about the possibility of oil supply disruptions, related to tensions regarding Ukraine, along with receding market concerns that the Omicron variant of COVID-19 will have widespread effects on oil consumption [39].

In 21st February 2022, the oil prices and trend analyzing team of Thai oil forecasted that the crude oil prices will increase from the current situations of Russia and Ukriane after the natural gas pipe bombing in Luhansk located in east of Ukrine [40]. After that the United States announced that there is a high risk of Russia attacking Ukriane at any time possible and if Russia attacks Ukriane, the United States and its allies will have a boycott policy on Russia. However, the policy will not affect Russia's energy export [40]. Furthermore, the United States and Iran's nuclear negotiation is at the final stage whether they can come to the agreement or not. Either way, if both countries can come to an agreement, this will put Iran back into crude oil export to the global market about 1.3 million barrel/day. Japan has announced that if the boycott on Iran ends, they can import Iran's oil within 2-3 months [40].

Susan G. did an analysis on energy market impacts on fuel and petrochemical prices. She has found that with the increase in U.S. crude oil production price, it doesn't only affect the cost of the feedstocks and fuels refineries and petrochemical manufactures use, but also the cost of the energy used at every step of the supply chain. The crude oil consistently accounts for the largest portion of consumer gasoline prices, while the refining sector margins are small and shrinking. These skinny refiner margins mean there is little ability for refiners to absorb crude oil price increases—and crude oil prices are now at the highest since 2014. As well as natural gas prices—the highest in more than a decade—are similarly driving up the cost of feedstocks for petrochemicals and the cost of fuel for both refiners and petrochemical manufactures [41]. Additionally, the COVID-19 pandemic has disrupted, strained, and twisted supply chains and consumer demand in ways unseen in modern history. The demand for jet fuel tanked almost overnight, for instance, while the demand for chemicals needed to produce PPEs and hand sanitizer surged. Lockdowns and COVID outbreaks destabilized global production, labor and transportation systems in ways that will likely affect supply chains for the predicted future. Combined with the gasoline shortages in the UK resulted in the higher gasoline prices, along with the natural disaster of winter's freeze in Texas causing serious supply disruptions to natural gas and petrochemical production as well as the hurricanes which significantly impacted Gulf Coast oil production. All these events have combined to create the event called “the shortage of everything” [41].

With the uncertain and the constantly increase of crude oil price, which will have a direct effect on the petrochemical manufacturing due to the feedstock price increase. The alternative feedstock resources using renewable resources is another interesting pathway to produce chemicals to avoid the shortage in chemical production and use as well as to serve the demand of customers.

2.8 Succinic Acid

2.8.1 Succinic Acid

Succinic acid is a naturally occurring four-carbon dicarboxylic acid with the molecular formula $C_4H_6O_4$ that is produced by liquefied petroleum gas [42]. However, petroleum gas is expensive and thus succinic acid (SA) is generated by different microbes [43]. It is a common organic acid which can be used in many food, chemical and pharmaceutical industries to generate many chemicals such as solvent, perfumes, lacquers, plasticizers, dyes, and photographic chemicals [3]. Succinic acid can be produced from either fossil resources or bio resources. However, the problem with fossil resources based succinic acid production is a serve condition such as high pressure or high temperature use and toxic to environment, biobased succinic acid is preferred [44]

2.8.2 Petro-based Succinic Acid production

The petrochemical (fossil based) route for succinic acid is derived from the catalytic oxidation of n-butane into maleic anhydride. Maleic anhydride is subsequently catalytically hydrogenated to succinic anhydride followed by hydration to succinic acid. In this reaction cascade, the conversion of n-butane to maleic anhydride is the key to conversion step. The highly exothermal reaction leads to co-generation of high-pressure steam. Furthermore, the conversion yield determines the additional steam generated by the high exothermal combustion of unconverted n-butane [6]. Currently, succinic acid is mainly produced through conversion of maleic anhydride from petroleum via direct oxidation of n-butane. The present market price of succinic acid lies between $2,500 and $3,000 per ton of produced succinic acid [5]. Petro-based succinic acid is more cost-effective and has better efficiency when compares with biobased. However, biobased succinic acid is more environmentally friendly, non-toxic, biodegradable, and has better heat resistance for PBS/PBST compares to other biopolymers [45]. The main environmental impact is allocated to using too maleic anhydride and hydrogen as raw materials in a conventional succinic acid process. The consumed electricity and treated waste through incineration contribute minor to the impact [46]. Furthermore, another parameter to be considered for Petro-based succinic acid is the crude oil price which also has an effect for the product price and restricts demand. Therefore, bio-succinic acid production is expected to rise in popularity of green products among chemical manufactures over the next seven years [47].

2.8.3 Bio succinic Acid production

Similar to other biobased chemicals production, bio succinic acid can be produced by various biomass feedstocks such as lignocellulosic crops and residues, starch corps, and sugar crops via fermentation process [48].

Bio succinic acid production follows 3 steps which are fermentation, separation, and purification [49]. First step in an anaerobic fermentation reaction via micro-organism fermentation, several common strains are *A. succinogenes, E. coli, A. succinoproducens* [50] which serves to produce the succinic acid salt under the optimized conditions such as neutral pH, ambient temperature, the selected micro-organism. The fermentation broth contains glucose, fructose, sucrose, or any other carbohydrate sugar that fits in with the selected technology. The preferred feedstock is glucose. The anaerobic fermentation also requires CO_2 as a feedstock and NH_3 as a neutralizing agent for the carboxylic acids. The fermentation step is eventually complete once diammonium succinate, or the succinic acid salt, is produced. Followed by the partial concentration step, in which diammonium succinate is concentrated prior to the esterification step. At commercial level, the preconcentration process is performed by a multi-effect evaporator system which is more energy efficient than conducting the concentration during esterification under esterification conditions. Moreover, the concentrated diammonium succinate improves the processing such as filtration or centrifugal to remove the remaining precipitate. Lastly, a pressurized reactive distillation is applied and the concentrated diammonium succinate from the previous step is esterified in the presence of ethanol to obtain diethyl succinate. Ethanol is preferred over any alkylnol and the process condition is carried out at a high temperature and pressure using CO_2 as catalyst. Once the diethyl succinate is produced and purified, it can be led to go through one of the 2 types of reactions: 1) Catalytic hydrogenation 2) Catalytic oxydehydrogenation. Both reactions provide different types of final products depending on the desired product. Catalytic hydrogenation produces 1,4-butanediol (BDO), tetrahydrofuran (THF), and/or gamma-butyrolactone (GBL) whereas catalytic oxy-dehydrogenation produces diethyl maleate [49]. In addition to the selection of feedstock, careful examination of the downstream process (DSP) in succinic acid (SA) production is essential. Previous studies have highlighted the significance of the purification process in bio-based SA production, which constitutes a substantial portion (60-80%) of the total production cost [51]. Various DSP techniques have been investigated, each presenting its own advantages and disadvantages [52]. For example, conventional methods such as precipitation, employed by companies like BioAmber and Myriant, have demonstrated high energy consumption during reagent regeneration and can be highly corrosive due to the low pH involved [53, 54]. Direct crystallization, a traditional yet effective process, requires fewer unit operations but yields lower product purity due to impurity crystallization with bio-SA. To achieve high-purity SA, a purification step prior to crystallization is necessary [53]. Electrodialysis has shown high equipment costs, electricity consumption, and environmental impact due to extensive electricity usage, despite its potential for high SA yield [59,63]. In pursuit of a more environmentally friendly and cost-efficient DSP, reactive extraction has emerged as a promising option for SA purification. However, the enhancement of SA yield is crucial as conventional extractive reagents have shown limitations in performance [55]. According to Morales et al. (2016), who compared process models for various DSPs including petroleum-based SA, reactive extraction, electrodialysis, and ion exchange, reactive extraction outperformed other methods both economically, with an operating cost of 2.6 USD/kg, and environmentally, exhibiting a 28% lower environmental impact compared to the conventional route [51]. Studies investigating SA extractability using different extractants have shed light on their effectiveness. For instance, Hong et al. (2000) evaluated the extractability of various tertiary amine extractants, such as Tripropylamine (TPA), Tributylamine (TBA), and Trioctylamine (TOA), in 1-octanol and found that the extractability was proportional to the chain length, with a maximum extractability of 88% [56]. Gaikwad et al. (2017) concluded that the use of Trioctylamine (TOA) in 1-octanol exhibited the most outstanding extraction efficiency of 96% among other long-chain alcohols [57].

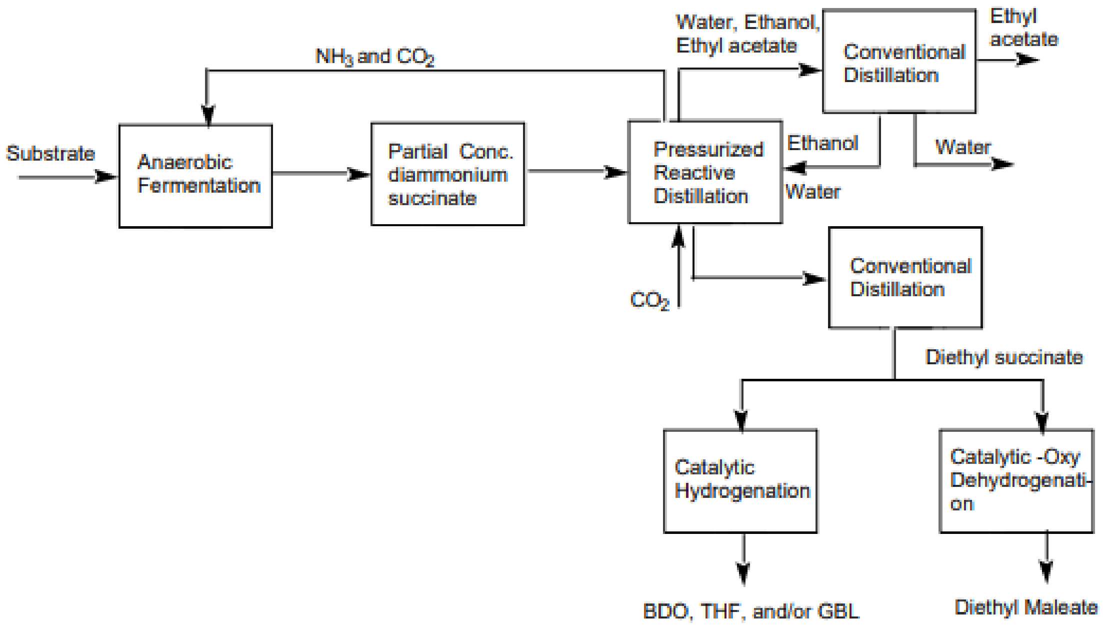

Figure 2.2 BioAmber's Succinic acid produciton [42].

2.8.4 Parameters affect succinic acid production

In bio succinic acid production several parameters must be considered in order to reach the desirable yield and industrial needs. These parameters include

2.8.4.1 Carbon Sources

Bio succinic acid can be produced from various types of carbon sources using *A. succinogenes*. Many things must be brought to consideration such as the reduction of production cost. Substrates cost generally accounts for around 50% in Biotechnological process. The adoption of low-cost substrates for succinic acid production is a critical parameter to make the bioprocess more economical [58]. Carbon sources were originated from agro-industrial wastes as they are inexpensive and renewable resources which is available abundantly such as empty fruit bunch (EFB), corn fiber, sugarcane bagasse, cane molasses, corn stover, and many other crops [59]. A study has shown that after sulfuric acid treatment, cane molasses could also be used as carbon source for succinic acid production by *A. Succinogenes* CMCC1593 with 50.6 g/L succinic acid concentration, 0.84 g/L·h productivity and the sugar conversion ratio could reach up to 95.6% under anaerobic condition. During fed-batch fermentation with external CO_2 gassing and pH controlled, 55.5 g/L of succinic acid and 1.15 g/L·h was achieved [58].

2.8.4.2 pH regulator

The intracellular enzymatic activities, dissolution level of CO_2 and dissociation equilibrium of HCO_3^- and CO_3^{2-} are dependent on pH. During the fermentation process, succinic acid is gradually accumulated lead to a corresponding decrease in pH therefore, large amount of neutralization agents is needed to adjust pH values. Many neutralization reagents including $MgCO_3$, $CaCO_3$, $NaCO_3$, NaOH and $NH_3{\cdot}H_2O$ must be investigated for succinic acid production by using *A. Succinogenes*. Results showed that the supplementation of NaOH or KOH would lead to a decrease in succinic acid due to the severe cell flocculation. The inhibition of bacterial growth was also observed when $NH_3{\cdot}H_2O$ or $Ca(OH)_2$ was used as the neutralizing agent. However, the combination of 5 M NaOH and 40 g/L of $MgCO_3$ could prevent cell flocculation and results in 27.9% higher succinic acid concentration than using NaOH alone [60]. Apart form the fascinating advantage of $MgCO_3$, it is not economically feasible for large-scale application. Some study use a mixture of $Mg(OH)_2$ and NaOH with a ratio of 1:1 to replace the used of $MgCO_3$ alone which give the similar succinic acid production results [61]. However, more effective and economic pH regulator for competitive bio-succinic production is still ongoing [61].

2.8.4.3 Gaseous CO_2

Dissolved CO_2 concentration in the fermentation broth could regulate the carbon metabolic flux and PCK activity. When gaseous CO_2 is supplied, the concentration of dissolved CO_2 relied on the components of fermentation broth, temperature, agitation, flow rate of CO_2 and CO_2 partial pressure. At 1 atm gaseous CO_2 shows poor solubility therefore, CO_3^{2-} and HCO_3^- are preferred. $MgCO_3$ was preferable carbonate, because it would not lead to the rapid change in the culture pH. When replaced the gaseous CO_2, a higher amount of $MgCO_3$ could promote succinic acid synthesis to be more effective. The maximum succinic acid production of 61.92 $g{\cdot}L^{-1}$ with a yield of 0.58 $g{\cdot}g^{-1}$ and productivity of 0.84 $g{\cdot}L^{-1}h^{-1}$ was obtained with 159.22 mM dissolved CO_2 concentration through supplementation of 40 $g{\cdot}L^{-1}$ $MgCO_3$ and 100% CO_2 [62]. Generally, high CO_2 concentration could increase the ratio of succinic acid to byproducts, leading to the improved succinic acid yield [62]. However, Hendrik A. et al. studied the effect of different carbonate supplies on succinic acid production which are 100% gaseous CO_2, 100% $MgCO_3$, a combination of CO_2 and $MgCO_3$ and vary the concentration of $MgCO_3$ the results showed no significant differences between different carbonate supplies on succinic acid yield. The yield and production mainly depend on type of sugar used in which glucose gave the highest succinic acid yield at the concentration below 30 g/L [62]

2.8.4.4 Redox potential

Redox potential also known as oxido-reduction potential (ORP), is a physicochemical parameter for the oxidization or reduction of the medium. The ORP is function of pH, dissolved oxygen, equilibrium constant and redox potential of compounds dissolved in the medium [58]. Redox potential plays a key role in productivity and yield. When redox potential increases, the productivity and yield also increase [58].

2.8.5 Bio succinic acid production and situations

There are several companies who produce bio-based succinic acid in a commercial scale such as Myriant, BioAmber, Succinity, Reverdia, BioAmber Mitsui, PTT MCC Biochem etc [8]. In which the last two located in Thailand. PTTMCC produces bio-based succinic acid from sugar rich feedstocks as an intermediate to produce polybutylene succinate which is important for bioplastic production [63]. From 2012-2015, four companies including Revedia, Myriant, Succinity,and BioAmber launched commercial plants to produce Bio-based succinic acid. However, the current situation of bio-based succinic acid around the world is that all main producers suffer from a financial crisis. Bio-Amber and Reverdia useda yeast process of Succinic acid production, while Succinity and Myriant developed bacteria-based fermentation within a downstream process of precipitation involved model [8]. The process used by Myriant in its 14,000 ton/year capacity plant utilizes a platform involving modified *E. coli* strains in fermentation [42]. It has a multiple renewable feedstock capability which includes sugars derives from sorghum grains and other commercial sugars. However, Canadian Succinic acid producer BioAmber declared bankruptcy in 2018, Myrian and Succinity are not running while Reverdia dissolved in 2019 [8] with the combination of factors that lead these companies to collapse such as some technologies proved to be too expensive and not ready for commercialization [27]. Furthermore, there are numerous risks associated with implementation and commercialization of the biorefinery concept. Morales et al. [9] found that biobased succinic acid produced from sugar beet or wood had higher operating costs ($2.60-$4.5 per kg) compared to petro-based succinic acid ($1.92 per kg).

Xue L. et al. [8] studied about a detained ex ante and ex post TEA (Techno-Economic analysis) of an established business operation on BioAmber case study in Canada. The study shows that BioAmer did not escape the fate of failure typified by the valley of death; the reason is its inability to secure further financing or achieve its restricting objective. Although, they raised $200 million to launch their Samia facility, the facility kept losing money during the first 2 years. The company's operation cost is around $2.23 per kg which was 10 times higher than BioAmber's prediction. Moreover, the company could not operate the plant at full or even half capacity and they overestimate the product selling price which drop significantly over the years. The results of this paper proved that there is the need for ex ante TEA in the preliminary design stages to identify the risks and potential of “valley of death” pitfalls for start-up companies venturing on a large-scale commercialization.

2.9 Potential of integrated 1G+Succinic acid production

With the reasons stated above such as the decrease in ethanol production in the future and high succinic acid production cost, there are several studies about the combination of ethanol production and succinic acid production to study the feasibility of integration of both processes together whether about the production cost, the effect of CO_2 gas from Ethanol production on succinic acid production, or the effect of different feedstocks used.

Bruno C. K. et al. did a Techno-economic analysis of bio-based succinic acid from a sugarcane biorefinery on ASEPN PLUS v.8.6 [64]. They integrated a first-generation ethanol distillery with succinic acid produced from second-generation feedstocks to obtain fermentable sugars and compared 2 scenarios between base case of a first generation (1G) optimized autonomous distillery and the integrated first generation and succinic acid production (1G+SA). In the 1G ethanol distillery, the main process steps involved are sugarcane cleaning, sugar extraction, juice treatment, fermentation, distillation, dehydration, and energy production in combined heat and power (CHP) unit [64]. In this work, 4 million tons of sugarcane (TC) producing anhydrous ethanol (99.6 w/w%) and generating surplus electricity and the optimization features include electrified drivers, high pressure boilers (65 bar), thermal integration and dehydration using molecular sieve with 200 days operation days [64]. The succinic acid production use bagasse as a feedstock. The production process involved pretreatment step, multistep washing, evaporation to concentrate pentose concentration and limit the acetic acid concentration, detoxification, sterilization, fermentation, centrifuge, acidification, adsorption, and crystallization + drying with 330 operating days [64]. The economic parameters to be considered are Fixed investment (CAPEX), The operational expense (OPEX), The revenues from commercialization of the production (e.g., ethanol, electricity, and succinic acid) or the internal rate of return (IRR) and the net present value (NPV)

[64]. They had found that Succinic acid production integrated to sugarcane biorefinery based on pentose fermentation from hemicellulose feedstock will be competitive in the future. The production cost obtained was 2.3 USD per kg which is an interesting value for bio-based succinic acid commercialization. Sugarcane cost and CAPEX were the main cost components. From risk analysis, the internal rate of return (IRR) of 1G and 1G+SA are 16.7% and 14.3% respectively with the confidence level of 98.5% and 84.6% respectively. The fluctuation of ethanol price is an important parament that affects IRR for both biorefineries since ethanol price is 80% and 66% of the total revenue of 1G and 1G+SA respectively. Different prices in succinic acid also affects IRR of 1G+SA as well as the unexpected CAPEX, sugarcane prices and electricity price which is less reliable than the 1G [64]. However, the 1G production is a mature process known for many years however this research showed the potential in the integrated 1G+SA production and there are still rooms of improvement of bio-succinic acid production [64].

Quanguo Z. et al. studied about the integrated ethanol fermentation and succinic acid production as an efficient platform. The purpose of this study is to devise an efficient biological system to capture and utilize the large amount of CO_2 release during ethanol production. They compare 2 carbon fixing pathways which are the microalgal *A. succinogenes* cultivation which use CO_2 as a carbon source and the use of CO_2 to produce succinate [80,68,80]. The ethanol fermentation using *Z. moblis* strain and glucose as a feedstock gave 50.1 g/L with CO_2 concentration of 95.4 v/v%. It indicates that highly concentrated CO_2 was released from the system [60]. The carbon capture performance by *A. succinogenes* in a 200 mL reactor integrated with ethanol fermentation system with CO_2 directly sparged into the medium and glucose as a feedstock, the succinic acid production was 25.8 g/L after 27 hours. The succinate productivity was 23.5 g/L-d maximum at 24 hours. The succinic acid yield obtained was 0.81 mol succinate per mol glucose approximately [22]. The result also showed that *A. succinogenes* is 188 times higher than those associated with *C. vulgaris* cultivation process. Furthermore, the nearly pure fermentation CO_2 has only finite inhibition to growth of *A. succinogenes* so it can be directly used without dilution [80,68,80].

Nhuan P. N. et al. studied integration of succinic acid and ethanol production with potential application in a corn or barley biorefinery using glucose to produce succinic acid by E. Coli strain AFP184 in a batch fermenter [65]. They studied the effect of different pH control and the presence of CO_2 supplied sparging from the Ethanol fermenter directly into the liquid media in the succinic fermenter without any pretreatment. They have found that the yield of succinic acid with CO_2 supplement from Ethanol fermenter is when using Na_2CO_3 as a pH regulator is equal to NH_4OH [65]. The benefit of sparging CO_2 from ethanol fermentation including the increase of glucose consumption rate when using the noncarbonate bases, producing succinic acid over other byproducts when NaOH and KOH were used, the molar ratio of succinate:acetate was doubled in the presence of KOH and 30% increase for other cases etc. on the succinic acid yield showed the feasibility of integration of succinic acid fermentation with ethanol fermentation in biorefinery industries [65].

2.10 Life Cycle Assessment (LCA)

Life cycle assessment (LCA) is a systematic phase approach which consists of 4 components which are

1. Goal definition and scoping: describe the process or activity involved in the process and set up the boundary for the environmental effects assessment review.
2. Inventory analysis: identify and quantify the materials used in the process (e.g., energy, water, and materials usage) as well as the environmental release. (e.g., air emission, solid waste disposal, wastewater discharge etc.)
3. Impact assessment: estimate the potential on humans and ecology of energy, water, material usage and the environmental releases which has been identified in the inventory analysis.
4. Interpretation: select the preferred product, process, or service from the results of the inventory analysis and impact assessment under the uncertainty and the assumptions used to generate the results [37].

2.10.1 Life cycle assessment of 1G ethanol distillery from molasses

Thanapat C. studied about the life cycle assessment of bioethanol production from feedstocks in Thailand. He compares 3 feedstocks used to produce bioethanol with 1000L capacity and 99.7 vol% purity which are molasses, casava and rice straw with the studied parameters including materials use (e.g., fertilizer, herbicide, chemical input, fuel used, primary raw material, and final product), energy performance (e.g., energy consumption in cultivation, pretreatment, and bioethanol production.), Environmental assessment based on LCA including 6 parameters such as global warming, human toxicity, freshwater toxicity, terrestrial toxicity, acidification and eutrophication [37]. For the environmental impact assessment and comparison, this part is focused on the environmental impact using BRE ecopoint which can be determined by the multiplying of toxic leakage with the characterize factors in each category. The study has found that pollutant emissions are mainly come from 2 main sources which are coal combustion and electricity. Furthermore, the total amount of toxic gasses emissions from the molasses-based ethanol production is the summation of the amount that emit from coal combustion and electricity which can be calculated to the total of 5,039.43 kg of CO_2. Other than that, there are other emitted gasses as well such as CH_4, CO, CO_2, N_2O, NO_2 and SO_2. Apart from CO_2 that has been mentioned above, the results also suggest that NO_2 and SO_2 which are the main source of acidification, have been released around 10.33 and 33.68 kg respectively. CH_4 is also emitted from the process around 20.93 kg and the other pollutants are released in traceable amount [37]. Additionally, the global warming potential result shown that molasses-based gave the global warming potential of 5491.36 kg/1000 L of bioethanol produced which is the highest compares to cassava-based and rice straw-based. However, it gave the lowest terrestrial toxicity and eutrophication amounts. Furthermore, the amount of greenhouse gasses emission in molasses-based bioethanol production is 9.33 times compared to cassava-based bioethanol production. It reflects the amount of electricity usage in sugar milling process and amount of coal consumption for combustion processes.

The results for energy comparison to determine the amount of energy consumption in 3 different bioethanol production processes have shown that in casava based bioethanol production the energy consumption is the lowest. (3,081.62 MJ of combustion energy and 554.42 kW-h of electricity) On the other hand, the amount of energy usage in molasses-based bioethanol production is the highest (45,418.49 MJ of combustion energy and 1,928 kW-h of electricity). The result also shows that the cassava-based bioethanol production requires only 6.78% and 10.91% of total biomass combustion energy compares to molasses-based bioethanol production and rice straw-based bioethanol production respectively. The main reason being the simplicity of the process [37].

LCA normalization is performed to determine the most appropriate method for bioethanol production. The calculations are acquired by manipulation of each reference intervention with applicable characterization factor for all impact categories mentioned before. The result shows that the ecopoint score of cassava-based bioethanol production is the lowest. It scored 105.53. Ecopoint for molasses-based bioethanol production is 988.34. The main impact category that affected the ecopoint of molasses-based bioethanol productions are human toxicity, and acidification and the ecopoint of rice straw-based bioethanol is the highest therefore, it is the worst process in term of environmental impact. The main impact category that affected the ecopoint of rice straw-based bioethanol productions are global warming, human toxicity, freshwater toxicity, terrestrial toxicity, and eutrophication. The results insists that the cassava-based bioethanol production contributed only 10.6% and 10.2% compared to molasses-based bioethanol production and rice straw-based bioethanol production respectively [37].

Annand R G. et al. (2009) studied about the economic and a new pathway of environmental impacts of sugarcane ethanol using molasses as a feedstock from the sugar manufacturing in Brazil, Indonesia, and India. They did a LCA model for greenhouse gas, regulated emissions and energy use in transportation called GREET on the integrated sugarcane factories that have sugar manufacturing co-located with an ethanol distillery that can use molasses as a feedstock for ethanol in addition to raw cane juice directly from the mill. From

GREET analysis they had found that the ethanol manufactured with only molasses as a feedstock with all other processes and inputs identical to those of the average Brazilian mill has a lifecycle greenhouse gas rating of 15.1 g CO_2 eq/MJ, which is significantly lower than the current California-GREET assigned rating of 26.6 CO_2 eq/MJ. This result of CA-GREET for Brazil ignores raw sugar production and thus does not report raw sugar process emission. It is assumed that the emissions from raw sugar process is due to the non-CO_2 emission from bagasse combustion, which, does not make up most sugar production emissions. Additives like lime and flocculant that are consumed in the sugar production process make up the rest of the emissions, which is a very small part of the total emissions for sugar production. Furthermore, based on current sugar and molasses process, the LCA GHG emissions of 100% molasses ethanol is 15.1 g CO_2 eq/MJ. From the well-to-tank GHG emissions for 100% cane juice ethanol as well as when the sugar to molasses price ratio drops below a given breakeven value, it is worse, from a lifecycle GHG standpoint, to produce molasses ethanol than cane juice ethanol. This analysis result in a general purpose-add on for GREET and other LCA tools that more completely describes lifecycle greenhouse gas emissions from sugarcane ethanol. This pathway much more accurately describes sugarcane mills in major cane producing countries. Moreover, if this model is used to set fuel lifecycle ratings for the LCFS (low carbon fuel standard), it is likely to results in substantial monetary saving for California [66].

Ephrata D. et al. (2019) studied the life cycle assessment of ethanol production from molasses in Ethiopia. They use two dominant sugar factories (Metechara and Fincha) as their base case of a 1000 L-ethanol capacity. The main objective of their study is to assess the environmental effects of ethanol production from sugarcane molasses during the period 2016 to 2017 using ReCiPe life cycle impact assessment method considering both midpoint and endpoint indicators. The impact categories that were considered for in this study included: global warming, photochemical oxidation formation, terrestrial acidification, marine eutrophication, terrestrial ecotoxicity, land use, resources depletion and ozone layer depletion. The result shows that the main contributor to climate change for the process of 1506 kg CO_2 eq is the cultivation stage (54.5%), photochemical oxidant formation (80%) and land use (99%)

impact categories due to fertilizer production, cane burning and decomposition and application of fertilizers. On the other hand, ethanol production had a greatest contribution for resource depletion (63%), terrestrial acidification (92%), terrestrial ecotoxicity (99%), marine eutrophication (92%) and ozone depletion (84.4%) due to consumption of light fuel for ethanol plant. Furthermore, waste came from vinasses discharges into ethanol production. The writers also suggested that in order to prevent/reduce the burdens (I) prevent cane trash open burning in the field by changing the mechanism of harvesting from burning to the use of machines such as harvesters, (II) change from the use of chemical fertilizers to organic fertilizers like compost (e.g., filter cake with vinasses) or animal manure rather than discharging these in the landfill and water bodies; this can lead to the decrease in global warming impact in cultivation stage from 821 to 714.5 kg CO_2 eq and the total percentage contribution in ethanol stage for terrestrial acidification and marine eutrophication will decrease by 5% and 49% respectively (ii) using different kind of fertilizers can reduce the global warming potential, photochemical oxidation formation and resource depletion impacts respectively by 11%, 2% and 1% (iv) up 45% of burning cane during harvesting can be considered an important waste of energy, this could reduce the dependence of fuel in ethanol plant station and thus contribute in small way to reduce environmental impacts. For high energy use activities, it may be preferrable using renewable resources [66].

2.10.2 Life cycle assessment of succinic acid production

Benjamin C. et al. (2014) studied about the energy and greenhouse gas assessment of succinic acid production derived from carbohydrates. They did a life cycle assessment of different bio-based succinic acid production processes, based on dextrose from corn and investigated their non-renewable energy use (NREU) and greenhouse gas (GHG) emissions from cradle to factory gate in Europe with three different fermentation and downstream processes in comparison which are (I) low pH yeast fermentation with downstream processing (DSP) by direct crystallization, (II) anaerobic fermentation to succinate salt at neutral pH (pH7) and subsequent DSP by electrodialysis, and (III) a similar process producing ammonium sulfate as co-product in DSP. As well as comparing these processes to the Petro-chemical maleic anhydride, succinic acid and adipic acid production [67].

The result from the study shows that the low pH yeast fermentation process with DSP of direct crystallization has a significantly lower impact on NREU (51% and 38%) and climate change (92% and 67%) compared to the electrodialysis (ED) and ammonium sulfate (AS) process, respectively. However, in the GHG emissions analysis between this process and the ED process becomes less prominent if one considers a cleaner electricity mix than the current European production mix. Moreover, the NREU and GHG emissions of the DC process compared to three petrochemical counterparts are a factor of 1.9-3.8 and 2.0-10.0 lower, respectively. As for a sensitivity analysis, this study has highlighted that the allocation approach—partitioning the input or output flows of a process or a product system between the product system under study and one or more other product system, in the CWM (corn wet milling) processes strongly influences the modeling results. When giving priority to avoid allocation, the system expansion approach for CWM involves large uncertainties of up to about 20% of climate change. The uncertainties came from the assumptions made for land use before soybean cultivation, which depends on the country of origin of soybean substitution products which makes the CWM process does not make it a suitable approach in this study. The solution for the CWM process is the subdivision approach combined with mass allocation for the CWM process, following the ISO allocation procedure. Furthermore, this study also highlights that the benefits of the DC process are increased, compared to the AS process, if a different allocation approach is used. Moreover, this study also highlights that the plant location strongly influences the results. This can be explained by different electricity production mix, available feedstock, and fuel for the on-site CHP [67].

For example, in Brazil it shows that the plant has a large improvement potential, due to a feedstock switch of dextrose from corn to sucrose from sugarcane while in China significantly increases the environmental burden of the succinic acid life cycle, due to a fuel switch from natural gas to coal for the on-site CHP. The main environmental hot spots contributors are utilities, direct field emissions and corn drying in the dextrose production process. In conclusion the study suggested that the low pH yeast fermentation with direct crystallization is the most promising process to bio-based succinic acid from an environmental perspective [67].

Lastly, when compares the bio-based succinic acid to all three petrochemical productions on the impact assessment analysis, The NREU and climate change of the DC process is lower than all three petrochemical production processes. Butane-based maleic acid production has a nearly 90% higher NREU and approximately a factor or two higher GHG emissions compared to the DC process. The error bar in the graphs indicates a large rage of GHG emissions i.e., 1.2-1.96 kg CO_2 eq per kg maleic anhydride, depending on the electricity mix. The maleic anhydride based succinic acid production shows slightly higher GHG emissions and even lower NREU results than petrochemical maleic anhydride. The reason being in a petrochemical based succinic acid production it only requires 0.85 kg of maleic anhydride to produce succinic acid. Furthermore, it also shows that the NREU and GHG emissions for adipic acid are by the factor of 3.8 and 10.0 higher compared to the DC process. NREU and GHG savings are 74% and 90%, respectively per kg of feedstocks when petrochemical adipic acid is replaced by bio-based succinic acid, produced by the DC process, to produce polyurethanes [67].

Marieke S. et al. (2016) studied about the life cycle assessment of biobased and fossil based succinic acid production. They compared between a biobased succinic acid production from corn wet milling as a feedstock by a low pH fermentation route and the petrochemical or fossil based succinic acid produced from the oxidation of n-butane into maleic anhydride. The goal of their study is to compare the environmental impacts of producing succinic acid from fossil and biobased resources. The system boundaries are cradle-to-factory gate (from extraction of raw materials up to and including the production of succinic acid). The life cycle stages after the factory gate are not included in the study [6].

The result shows that the CFP (carbon footprint) of biobased succinic acid is 0.85 kg CO_2 eq/kg, including the footprint reducing effect of CO_2 uptake by the corn-based succinic acid of 1.49 CO_2 eq/kg, and less than half as high as the CFP of fossil based succinic acid (1.8 kg CO_2 eq/kg). In European corn-based succinic acid production, the 2 largest contributions to the CFP are the production of dextrose and energy production and use, which results in about 90% of the CFP.

The carbon uptake effect is clearly visible. Furthermore, for fossil based succinic acid synthesized from maleic anhydride, which is produced by butane oxidation. The large amount of CO_2 is emitted during this process, contributing to 80% of the CFP and the energy consumption is uptake to about 18% [67]. From the WBCSD Life cycle metrics for chemical products guideline, dextrose production is the hotspot contributing to the high scores in most categories (i.e., global warming, air acidification, human toxicity, land use etc.). Moreover, the ReCiPe results show that the biobased succinic acid has lower impacts on the endpoint impact categories, human health, and resources. The higher impact on ecosystem quality levels out these advantages. This study further reviewed about the potential of using another feedstock for bio-succinic acid production which is sugar cane, they have found that for fossil based succinic acid, climate change is closely related to the air emissions reductions, the fossil depletion impact is even below zero, due to credits for excess energy consumption from the integrated incineration of sugarcane bagasse. Agricultural land occupation is much lower than for corn because the annual yield of sugarcane in Brazil is much higher than the annual yield of corn in Europe. The potential of sugarcane as a C-source of biobased succinic acid has a lower footprint in all three endpoint impact categories (Human health, Ecosystems, and resources) and thus also on the total weight single score (reduction from 245 to 36 mPt). It shows that by using a different feedstock, environmental impacts can be reduced in several aspects and fossil based succinic acid can be outperformed by far [6].

2.10.3 Heat exchanger network (HEN) design

Gabr. E. (2018) studied the importance of HEN design and found the advantage in maximizing heat recovery and reducing the need for external heating and cooling utilities in industrial chemical processes by Pinch technique. The pinch technique, also known as Pinch Analysis (PA), is a systematic methodology used for energy saving in industrial processes and total sites. It is based on thermodynamic principles and aims to maximize energy recovery and minimize the required external heating and cooling loads. The technique involves the following steps [68]:

1. Pinch Point Identification: The first step is to identify the pinch points in the process, which are the temperature intervals where the heating and cooling requirements are the highest.

2. Composite Curve Construction: A composite curve is constructed by plotting the hot and cold process streams' temperature profiles. This curve represents the minimum temperature difference between the hot and cold streams.
3. Problem Table Analysis: A problem table is created to analyze the temperature intervals and identify the potential for heat recovery. It helps in determining the minimum hot and cold utilities required for the process.
4. Heat Exchanger Network (HEN) Design: Based on the analysis from the composite curve and problem table, the HEN is designed to maximize heat recovery and minimize the use of external utilities. This involves the selection and placement of heat exchangers to optimize the heat transfer between process streams.

The pinch technique is a powerful tool for energy integration and has been widely used in various industries to improve energy efficiency and reduce operating costs. From the study, it was found that by implementing the HEN design, significant savings in utilities consumption can be achieved. In the case study mentioned in the paper, the HEN design resulted in a 66% reduction in utilities usage. The revamping of existing processes to incorporate the HEN design can lead to substantial cost savings. In the case study, the net annual saving reached $1,400,000. The importance of considering factors such as minimization of units and cost, process control, and operability when choosing the suitable HEN design. This ensures that the design is not only energy-efficient but also practical and feasible for implementation.

Yong et al. (2015) uses Pinch Analysis to investigate the heat recovery targets and indicators for retrofitting the existing heat exchanger networks (HENs). From this study, it was found that the temperature of waste heat stream is too low to be utilized and reduce the energy consumption. Thus, the HEN is modified to generate hot water from waste heat stream. The utility reduction is from the heat exchange between hot and cold streams [69].

Alongkorn A. (2015) improves the HEN designs for BTX process using Pinch Analysis due to the use of turbine wasting the heat into the atmosphere within the process by Aspen Energy Analyzer V.8.6. software for maximizing heat recovery where ΔT_{min} = 3 °C. It was found that among

10 designs generated the design 4 gave the lowest the lower total annual cost among others with 9.77 million baht [70].

Chapter 3

Methodology

This section provides the details regarding the methods used to obtain the study parameters from biochemical production processes in this study which are bioethanol, succinic acid, and integrated ethanol and succinic acid productions with various molasses ratios to produce ethanol and succinic. Aspen Plus V.11 ® is used in the process designs to study the feasibility of integrated ethanol and succinic acid productions.

3.1 Process simulation

In this study, the process simulations are performed using ASPEN PLUS V.11. The chemicals produced from the process simulations are ethanol and succinic acid. Chemical productions can be subdivided into 2 categories depending on the choices of feedstocks used in the productions namely bio-based and petroleum based chemical productions. The overall framework of process designs in this study is shown in Figure. 3.1. It should be noted that only biochemical productions are simulated but the details regarding the petroleum-based succinic acid production are obtained from literature reviews. The process simulation starts with ethanol production. For accuracy, the amount of ethanol produced is compared with the actual amount of ethanol produced from the actual ethanol production company for validation of the process. Additionally, the non-random two liquid (NRTL) model is employed for the thermodynamic packaging in biochemical productions and CISOLID is enabled as there is a presence of solids in the process.

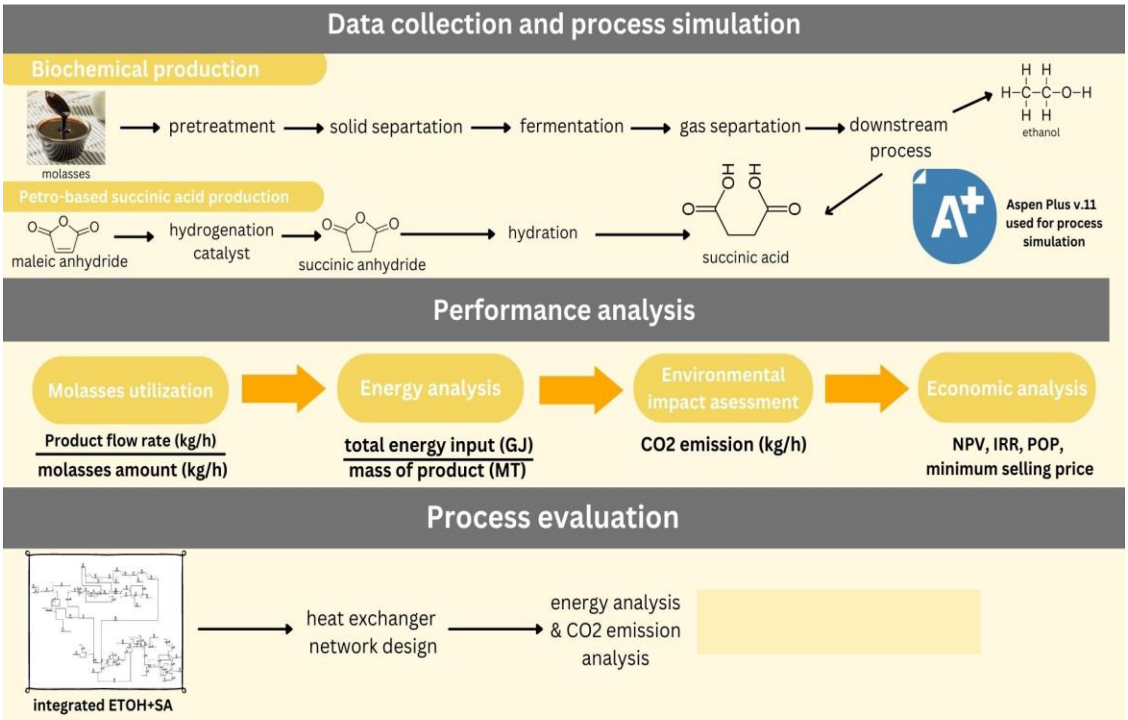

Figure 3.1 Overall process framework regarding chemical production in this study.

3.2 Feedstocks of interest

In this study, molasses is used as a feedstock for all biochemical productions since molasses-based ethanol held the majority of the ethanol production in Thailand and it can be utilized in both biochemicals e.g., ethanol and succinic acid and maleic anhydride is used in the petroleum-based succinic acid production. The amount of molasses used can be obtained from the annual report THAI AGRO ENERGY PCL [31] and it is fixed to 494.25 tonne/day for all biochemical productions in this study. Additionally, other essential chemicals used in the production are from the work of Thanapat C. (2015) [37]. Table 3.1 shows components in molasses and their amounts. However, the summation of components in molasses is more than 1 which is usual for biochemical processing and the excess amount does not have any effect on the chemical conversion because the surplus only accounts for 0.039 thus in Aspen plus V.11, the material balance is normalized to 1 for every fraction of components in molasses.

Table 3.1 Molasses component

Component	Mass fraction
Sucrose	0.35
Fructose	0.043
Glucose	0.046
Ash	0.12
water	0.48

Table 3.2 Ash component

Component	Mass fraction
CaO	0.25
K_2O	0.25
MgO	0.25
Na_2O	0.25

Table 3.3 Hydrolysis reactions and conditions [71], [31]

Condition	Value	Unit
Temperature, Pressure	40	℃
Pressure	1	atm
96 w/v% H_2SO_4	164.75	Tonne/day
Water	1,077.47	Tonne/day
Molasses	494.252	Tonne/day

Reactions	Conversion	Fractional conversion of the component
Sucrose + H_2O → Glucose + Frucose	1	Sucrose
H_2SO_4 + MgO → $MgSO_4$ + H_2O	1	MgO
H_2SO_4 + CaO → $CaSO_4$ + H_2O	1	CaO
H_2SO_4 + Na_2O → Na_2SO_4 + H_2O	1	Na_2O
H_2SO_4 + K_2O → K_2SO_4 + H_2O	1	K_2O

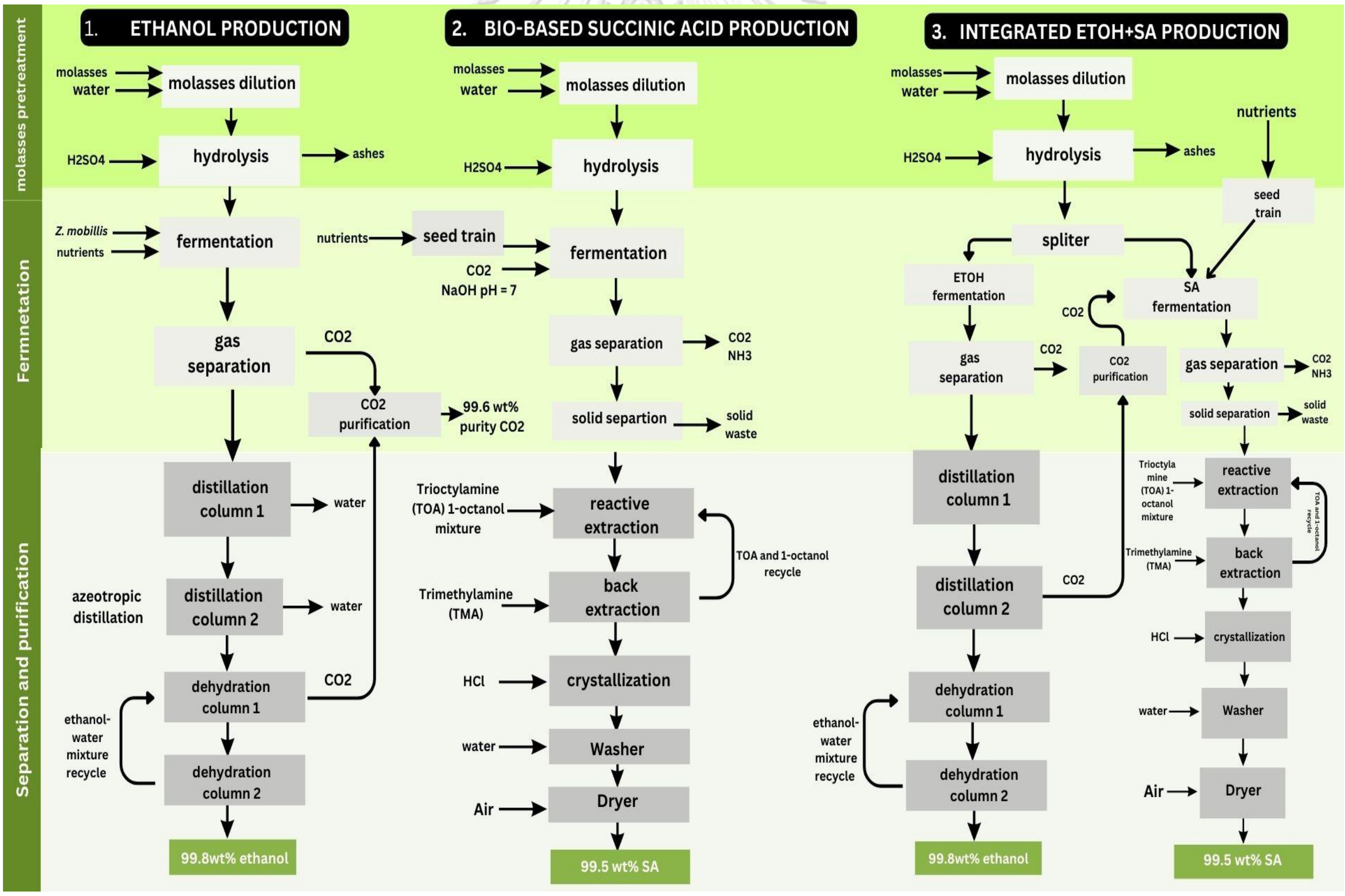

Figure 3.2 process flow charts of each biochemical production including ethanol, bio-based succinic acid, and the integrated ethanol and succinic acid productions.

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3.3 System process

The overall process for biochemical productions is provided in Figure 3.2. This study only focuses on the chemical production processes in which the cultivation and transportation are excluded. In biochemical productions, the process starts with molasses pretreatment, pretreated molasses fermentation, and the product purification processes e.g., distillation and dehydration for bioethanol production and reactive extraction and crystallization for bio-based succinic acid production. The details regarding each production process are provided in the following section.

3.4.1 Ethanol production (ETOH)

In this study, ethanol production is divided into 4 stages including molasses pretreatment, fermentation, CO_2 purification and ethanol purification process. From Figure 3.2, the first stage is molasses pretreatment with sulfuric acid (H_2SO_4) due to 2 main reasons which are first contamination removal in this case is ash to increase ethanol conversion efficiency. Table 3.2 provides details regarding components in ash and for simplicity the component in ash is assumed to have the equal amount of mass fraction. Secondly, sucrose hydrolysis since sucrose is a disaccharide made up of two monosaccharides which are glucose and fructose [72] and it was found that during the alcoholic fermentation process monosaccharide shows faster rate of reaction (0.83) than disaccharides (0.50) thus to increase the ethanol conversion efficiency, sucrose needs to be hydrolysis to glucose and fructose [72]. In hydrolysis process, molasses is mixed with water with a ratio 1:2.18 [37] in the mixer to dilute molasses concentration after that the dilute molasses is sent to a reactor (R-100) for hydrolysis process with H_2SO_4 with 3:1 molasses to acid ratio [33]. The condition regarding the hydrolysis process is shown in Table 3.3. In this study, it is assumed that the hydrolysis conversion for sucrose is 1 for process simplicity since sucrose cannot be converted to ethanol directly. Then the ashes obtained from this process get separated in the decanter (S-100) before sending the monosaccharide sugars into fermenter (R-101) along with the nutrients for cell growth e.g., 0.67 g/L diammonium phosphate (DAP) and 0.5 wt/wt% corn steep liquor (CSL).

The second stage is fermentation under anaerobic condition meaning no oxygen required pathway where sugar gets converted to ethanol and byproducts since the strain of choice *Z. mobillis* can increase ethanol production and have a rapid glucose consumption under this condition [73]. It should be noted that the sugar fraction converted to cell mass, *Z. mobillis* is rather small which is the reason for seed train and ethanol fermentation to be performed in the same fermenter [74]. To reduce the process complexity due to biochemical production processes, stoichiometric coefficients are applied, and the reactions involved in ethanol production are shown in Table 3.4 [88,89] is assumed that glucose and fructose have the same conversion since the structure of both monosaccharide sugars are dextrose. Furthermore, the residence time of ethanol fermentation is 36 hours with 6 fermenters employed [31]. After the fermentation process, Stream 3 or cold fermentation broth is sent to exchange the heat with the bottom product from distillation tower 1 (S-100) mainly contain water (Stream 21) at E-100 heat exchanger to obtain a cold-water stream (Stream 22) and hot fermentation broth (Stream 4).

The third process is gas separation involving CO_2 purification by a conventional high pressure CO_2 application called multistage CO_2 compression technique [75]. In this process, the main impurity of CO_2 is water. This CO_2 purification is employed in the ethanol production process to be able to compare it with the integrated ethanol and succinic acid productions where CO_2 is needed in succinic acid fermentation. Stream 4 is then sent to a heater (E-101) before separating the fermentation broth (Stream 6) and CO_2 (Stream 7) in the flash drum (D-100) before entering a series of three compressors, two heat exchangers and two flash drums and obtain 99.6 wt/wt% CO_2 at 69 °C and 1000 psi which is the typical pressure used in high pressure CO_2 storage process, it is assumed that CO_2 gets compressed to this high pressure since it will get storage inside CO_2 tanks before transporting to other process [76], in this case, the integrated scenarios where CO_2 from ethanol production is essential for succinic acid production.

The last stage involved ethanol purification process consists of two main steps which are distillation and dehydration processes. First step, Stream 6 passes through S-100 where four product streams are obtained and only Streams 19 and 20 are sent to the second distillation column (S-101). Four product streams from S-100 including:

1. Top product (Stream 18): The left-over CO_2 in vapor product stream entering C-100 along with Stream 7.
2. Top product (Stream 19): The condensate stream contains about 25 wt/wt% ethanol entering S-101.
3. Side product (Stream 20): contains about 97.2 wt/wt% entering S-101 to further purify some amount of ethanol.
4. The bottom product (Stream 21) contains about 81.4 wt/wt% water which has been mentioned in the second stage of ethanol production.

It should be noted that the byproducts e.g., methanol, 1-propanol and 2-propanol occur during ethanol fermentation are vent out of the process as waste in Stream 21 since only trace amount of byproducts are formed in comparison to the main product ethanol and water. Furthermore, S-101 is where the azeotropic distillation occurs to obtain the ethanol product with the least water as possible before further purification in the dehydration unit. The product purity obtained is vapor phase ethanol with 72.4 wt/wt% purity at the top stream (Stream 23) and the bottom stream (Stream 24) contains 99.99 wt/wt% water. The distillation condition is adjusted to its maximum distillation capacity for this process according to [77]. Moreover, Stream 23 is sent to the first dehydration (S-102) then the second dehydration column (S-103) packed with molecular sieve. It should be noted that SEP model is used for two adsorption columns in this work however, the equipment sizing, and economic calculation is performed based on the industrial adsorption columns aspect ratio for the accuracy of the economic analysis which is be discussed in the economic performance section further. Lastly, the ethanol vapor is then sent to a cooler (E-105) to obtain a liquid ethanol at 25 °C. The overall process and equipment involved in ethanol production process is shown in Appendix A.

Table 3.4 Chemical reactions in ethanol production

Reaction	% conversion
Glucose → 2 Ethanol + 2 CO_2	0.95
3 Glucose → 2 H_2O + 4 1-propanol + 6 CO_2	0.0005
3 Glucose → 2 H_2O + 4 2-propanol + 6 CO_2	0.0035
Glucose + 2 H2O → 2 CO_2 + 4 methanol	0.0005
Fructose → 2 ethanol + 2 CO_2	0.95
Fructose + 2 H_2O → 2 CO_2 + 4 methanol	0.0005
3 Fructose → 2 H_2O + 4 1-propanol + 6 CO_2	0.0035
3 Fructose → 2 H2O + 4 2-propanol + 6 CO2	0.0005

3.4.2 Bio-based succinic acid (BSA) production

Figure 3.2 provides detailed information regarding the bio-based succinic acid production. Like ethanol production, the process is divided into four sections. The same amount of molasses as ethanol production is applied in bio succinic acid production. The first stage is molasses pretreatment which is the same as in ethanol production occurs in hydrolysis reactor (R-100). The second stage begins with seed training in this case *A. succinogenes* which takes place in a reactor (R-101) with nutrient mediums e.g., corn steep liquor and NH_3 for 24 hours at 41°C to obtain Stream 3 [78, 79]. After that the pretreated molasses (Stream 2) along with Stream 3 pass through a cooler (E-100) and it is identified as Stream 4 before entering succinic acid fermenter (R-102). Then the commercial CO_2 and sodium hydroxide (NaOH) for pH control (pH = 6.5) to avoid corrosion [78] in the fermenter is sent into to R-102 at 37 °C for 48 hours to obtain Stream 5. The reactions involved in the process used in R-101 and R-102 are shown on Table 3.5 [79] For simplicity, the assumption made for the process reaction is that the conversions of glucose and fructose is the same since both sugars are dextrose. Moreover, CELL represents *A. succinogenes* with a chemical formula $CH_{1.8}O_{0.5}N_{0.2}$. After the fermentation process, Stream 5 is sent to the gas separation unit (S-101) to remove excess NH_3 and CO_2 and obtain Stream 6 which gets to solid separation unit (S-102) for cell separation (Stream 7) before beginning the downstream process.

The third stage for bio succinic acid is the purification process in this case reactive extraction is employed. In succinic acid fermentation, mixed carboxylic acid byproducts including acetic and formic acid are formed which increase the cost of purification process of SA since some of these byproducts can formed azeotropic mixture with water due to their close boiling points with water (Formic acid = 100.8 °C, acetic acid = 118 °C and water = 100 °C) [80] thus the conventional distillation cannot be utilized. Reactive extraction is favored over the conventional purification processes including vacuum distillation since it requires temperature raised for a long period of time and is less effective at high concentration of organic acids, precipitation with $Ca(OH)_2$ and $Ca(CO_3)$ to form acid salts due to the large amount of $CaSO_4$ formation [80]. It should be noted that Aspen Plus does not have a direct reactive extraction model thus a SEP model is applied. Reactive extraction consists of two main stages which are the reactive extraction and back extraction. Firstly, Stream 7 passes through a heater (E-102) to reach 50 °C [50] together with the extraction reagents tri-octylamine (TOA) and diluent 1-octanol proven to give 86% extractability [56] in which both chemicals get heated in a heat (E-102) before entering the extraction column (S-103) with equal amount of mol succinic acid to mol of extraction reagent and diluent [9] Under the reactive extraction process, the TOA-SA complex is formed soluble in an organic phase (Stream 10) which water gets separated [81] as a raffinate through Stream 11. After that Stream 11 gets passed through a heater (E-103) to increase the temperature of 100 °C which is the optimum condition for back extraction [52] to become Stream 12 along with the made up 1-octanol that gets loss from S-103 and trimethylamine (TMA) to recover succinic acid back into the water phase and recover the organic phase back into S-103. TMA is added at TMA to succinic ratio of 2 mol

TMA:1 mol succinic acid for economic purposes and high efficiency [52] after the back-extraction process Stream 13 is obtained.

The last stage of bio-succinic acid in this study is crystallization where Stream 13 goes through a cooler (E-104) to obtain the temperature of 4 °C before entering a crystallizer (C-100) and the pH gets maintained at 2 using hydrochloric acid (HCl) for succinic acid selectivity over other carboxylic acid under this condition [78]r the crystallization, succinic acid crystals (Stream 17) is wash in a washer (W-100) with water to crystal ratio 2:1 to prior purify succinic acid crystals (Stream 20) then the impurities e.g., acetic acid and formic acid get separated in the separator (S-105) to obtain Stream 22. Lastly, the crystals are dried with hot air (Stream 25) in a dryer (D-100) along with Stream 22 to obtain 99.5 wt/wt% dry succinic acid crystal (Stream 17). The overall process as well as the equipment of bio-based succinic acid production is shown in Appendix B.

Table 3.5 Chemical reactions in bio-based succinic acid production

Reaction	% conversion	Fractional conversion of component
Cell growth reactions		
Glucose + 1.1429 NH_3 → 5.7143 CELL + 2.5714 H_2O + 0.2857 CO_2	0.085	Glucose
Fructose + 1.1429 NH_3 → 5.7143 CELL + 2.5714 H_2O + 0.2857 CO_2	0.043	Fructose
Sugar reactions		
Glucose + 0.8571 CO_2 → 1.7142 SA + 0.8571 H_2O	0.646	Glucose
3 Glucose + 2 CO_2 → 4 SA + 2 Acetic + 2 H_2O	0.162	Glucose
3 Fructose + 2 CO_2 → 4 SA + 2 Acetic + 2 H_2O	0.162	Fructose
Fructose + 0.8571 CO_2 → 1.7142 SA + 0.8571 H_2O	0.646	Fructose
2 Glucose + 3 CO_2 → 3 SA + 3 formic	0.003	Glucose
2 Fructose + 3 CO_2 → 3 SA + 3 formic	0.003	Fructose

Glucose + 0.8571 $CO_2 \rightarrow$ 1.7142 SA + 0.8571 H_2O	0.646	Glucose
3 Glucose + 2 $CO_2 \rightarrow$ 4 SA + 2 Acetic + 2 H_2O	0.162	Glucose

3.4.3 Integrated ethanol and succinic acid production (Int. ETOH+SA)

This process is the combination of ethanol and succinic acid production illustrated in Figure 2 where it starts with molasses pretreatment as well as in both chemical productions. However, the difference begins after the pretreatment process occurs in a hydrolysis reactor (R-100) where pretreated molasses (Stream 1) with the same molasses amount used in both ethanol and succinic acid productions which gets split into two to produce ethanol (Stream 2) and succinic acid (Stream 3) with three different study ratios to produce ethanol and succinic acid of 25:75, 50:50 and 75:25. Stream 2 is sent to the ethanol fermenter (R-101) while Stream 3 is sent to the succinic acid fermenter (R-103) along with the purified CO_2 (Stream 33) from ethanol process to produce succinic acid and the downstream processes for both chemical productions are the same as section 3.3.1 and 3.3.2. The overall process is shown in Appendix C.

3.4.4 Petroleum-based succinic acid (PSA) production

In this study, the Petroleum-based succinic acid production is based on Pinazo et al. (2015) [44] which mainly has two steps starting from hydrogenation of maleic anhydride (MAN) to succinic acid (SAN) at the temperature range between 120-180 °C and hydrogen pressure between 0.5 and 4.0 MPa which Ni or Pd based catalyst is employed follows by the hydration of SAN to succinic acid using hot water. After that succinic acid gets separated by crystallization, filtration and drying.

3.4 Performance indexes

To see the feasibility of integrating ethanol and succinic acid production, techno-economic is performed to obtain four performance indexes in this study e.g., molasses utilization, energy analysis, CO_2 emission and economic analysis. Moreover, for the process evaluation, the most outstanding integrated ethanol and succinic production process is chosen to enhance the process in term of utility requirement in this case is HEN designs.

3.4.1 Molasses utilization

In this study molasses is used in every biochemical production including ethanol, succinic acid and integrated ethanol and succinic acid productions, molasses utilization is used as a parameter to see the amount of chemical produced per the amount of molasses in feed stream which can be expressed using Eq. (1). If the result shows higher molasses utilization, that means the process requires less amount of molasses to convert into the desired product rather than byproducts. It should be noted that Petroleum-based succinic acid is excluded in this section due to different feedstock of choice which is incomparable.

$$Molasses\ utilization = \frac{Amount\ of\ product\ (\frac{kg}{h})}{Amount\ of\ molasses\ feedstock\ (\frac{kg}{h})} \qquad (1)$$

3.4.2 Energy Analysis

In this study, specific energy consumption (SEC) is used for energy analysis as expressed in Eq. (2) in the unit of gigajoules per metric ton (GJ/MT) which represents the total energy consumption e.g., heating, cooling, and electricity per metric ton of products e.g., ethanol and succinic which provides separately to investigate more energy intensive process in comparison to the Petroleum based succinic acid from the work of Pinazo, (2015) [44]. The process with a low SEC value represents an energy efficient process.

$$SEC = \frac{total\ energy\ utilization\ (\frac{GJ}{day})}{Total\ product\ produced\ (MT/day)} \qquad (2)$$

3.4.3 Environmental impact assessment (CO_2 emission)

The system boundary for this study is set to a gate-to-gate according to Pinazo, (2015) in which the cultivation and transportation are excluded. CO_2 emission (kg/h) is employed for the environmental impact assessment in this study [44]. For every biochemical production the CO_2 emissions can be subdivided into 2 categories 1. CO_2 produced from chemical reactions which can be calculated using the chemical equations in Table 3.4 and 3.5 using Eq. (3). and 2. CO_2 produced from utilities used can be calculated from utility requirements and CO_2 emission factor expressed in Eq. (4). The result can be portrayed as net CO_2 emission. Moreover, to provide a comparable CO_2 emission value to the Petroleum based succinic acid production the value is converted to CO_2 equivalent value (kg CO_2/kg).

$$CO_2 \text{ emission from reaction } (kg/h) = \frac{mass\ flow\ rate\ in\ of\ sugar\ \left(\frac{kg}{h}\right)}{Mw\ sugar\ \left(\frac{kg}{kmol}\right)} \times \frac{stoicheometry\ of\ CO_2}{stoicheometry\ of\ sugar} \times Mw\ of\ CO_2\left(\frac{kg}{kmool}\right) \tag{3}$$

$$CO_2 \text{ emission from utility used } (kg/h) = 2.34 \times 10^{-7}\left(\frac{\mathrm{kg}}{\mathrm{cal}}\right) \times specific\ utility\ requirement\ \left(\frac{cal}{\mathrm{sec}}\right) \times \frac{3600}{1}\ \left(\frac{\mathrm{sec}}{\mathrm{h}}\right) \times \frac{1}{CO_2\ energy\ source\ efficiency\ factor}$$

From Eq. (4) it should be noted that 2.34 x 10^{-7} (kg/cal) is CO_2 emission factor and its energy source efficiency factor e.g., electricity = 0.58, LP-Steam = 0.85 and electricity = 1 which can be obtained from Aspen Plus using US-EPA-Rule-E9-5711 data source and the specific utility requirement in the process including low pressure (LP) steam, refrigerant (R-1) and electricity.

3.4.4 Economic analysis

In this study, Aspen Process Economic Analyzer (APEA) is used to calculate three economic parameters based on the key economic parameters as shown in Table 3.6 as well as the equipment sizing done on some of the unit operations for accuracy of the economic analysis in comparison to industrial scale processes of ethanol and succinic acid production, the details regarding calculated equipment sizing of interested unit operations for both chemical productions are shown in Table 3.7. Additionally, most equipment in this study used SS304 as the equipment material type. However, some unit operations involving acid pretreatment and SA fermentation, SS316 is applied due to its acid resistance property [74]. The economic parameters including the minimum selling price of the product (USD/kg) to obtain the payout period of 5 years, the net present value (NPV) as expressed in Eq (5), and the internal rate of return (%IRR) as expressed in Eq. (6) and payout period can be expressed in Eq. (7).

Table 3.6 key parameters for economic analysis in this study

Key parameter	Value
Project lifetime	15 years
Tax rate[a]	20%
Desire rate of return[b]	10%
Payout period[c]	5

[a] Tax rate is based on Thailand corporate income rate [82]

[b] Desired rate of return is based on the real industrial scale ethanol and succinic acid production [8, 83]

[c] Payout period is set to 5 years since it is an optimum criterion for investment [84]

$$NPV = \sum_{n=0}^{N} \frac{CF_n}{(1+ROR)^n} \tag{5}$$

$$0 = \sum_{n=0}^{N} \frac{CF_n}{(1+IRR)^n} \tag{6}$$

$$POP = A + \frac{B}{c} \tag{7}$$

Where “n” = number of operating years, “CF” = cash flow, “A” = the last period with a negative cumulative cash flow, “B” = the absolute value of the cumulative cash flow at the end of period A and “C” = cash flow during the subsequent period.

Table 3.7 details regarding the interested unit operations for equipment sizing [31], [85].

Process	Unit operations
Ethanol production & Succinic acid	Hydrolysis: residence time = 4 h., no. of identical unit = 1
Ethanol production	Fermenter: residence time= 36 h., no. of identical units = 6
Ethanol production	Dehydration column: residence time = 30 min, no. of identical unit = 2, packing material = zeolite 3A.
Succinic acid production	Fermenter: residence time = 48 h.
Succinic acid production	Seed cultivation: residence time = 24 h.

3.4.5 Heat exchanger network (HEN) design

In this section the most outstanding integrated scenario is selected to evaluate the utility requirement of the process using two methods, first being hand calculation and the second being the designs generated (10 designs) from Aspen Energy Analyzer (AEA). The purpose of the HEN design is the reduce the reliability on external utilities when the principles of Pinch analysis/Pinch technology is employed by matching hot process streams which require cooling utility and cold process streams which require the heating utility. Pinch analysis is preferred since it is simple, time efficient and adaptable for complex processes. In this study, the minimum temperature difference between hot and cold process streams is 10 °C which is an optimum temperature for chemical [86]. The rule for pinch matching to satisfy the heat duties of the process can be followed these requirements [68].

1. Above pinch $C_{pH} < C_{pC}$
2. Below pinch $C_{pC} < C_{pH}$
3. CANNOT match streams above pinch with streams below pinch.
4. Tick off rule; match from the pinch out.

HEN designs are portrayed as grid diagrams for both hand calculation and AEA approaches. The results from HEN designs are compared with the non-HEN design in terms of utility requirements and CO_2 emission performance which can be calculated using Eq. (4) to see the improvement before and after HEN designs.

Chapter 4

Results and discussion

In this study, the techno-economic analysis of each biochemical is performed using Aspen Plus V.11 and the study parameters are discussed in Chapter 3, followed by the process evaluation using HEN design for the most outstanding integrated process. Lastly, the comparative study is done between Petroleum and bio-based succinic acid production using the data obtained from Pinazo et al. (2015) [44].

4.1. Process Validation

In this study, the molasses amount is calculated from the total capacity of molasses-based ethanol production capacity from THAI AGRO ENERGY PCL. (2020) [31] which was reported to produce 40,775,801 L/year of 99.8 wt/wt% ethanol with the 330 days in 1 operating year. According to Thanapat C. (2015), to produce 1 L of ethanol 4 kg of molasses is required. The calculations can be as follows [37].

1. The amount of ethanol produced per day can be calculated using equation (4.1)

$$ethanol\ capacity\ \left(\frac{L}{day}\right) = \frac{40{,}775{,}801\ L}{330\ day} \tag{4.1}$$

$$= 123{,}563.003\ L/day$$

2. The amount of molasses required per day can be calculated using equation (4.2)

$$molasses\ required\ \left(\frac{kg}{day}\right) = \frac{123{,}563.033\,\frac{L}{day} \times 4\ kg}{1\ kg} \tag{4.2}$$

$$= 494{,}252.17\ kg/day$$

3. Process validation

Table 4.1 shows the differences between the Aspen Plus simulation of ethanol and the amount of ethanol produced from THAI AGRO ENERGY PCL. [31]. Which is used as a reference process. The difference may be due to the components in molasses used in this study and the reference process since the lack of information regarding the number of components or percentage of sugar in molasses.

Table 4. 1 The differences between ethanol production from Aspen Plus simulation vs the reference process

Cases	Ethanol amount (L/day)	%Differences
Bioethanol simulation in this study	127,545.71	3.22
Thai Agro energy CO. Ltd. (2020) [base case]	123,563.033	-

The percentage of differences can be calculated using equation (4.3)

$$\%Differences = \left(\frac{127{,}545.71 - 123{,}563.033}{123{,}563.033}\right) \times 100 \qquad (4.3)$$

$$= 3.22\%$$

4.2. Performance analysis

4.2.1. Molasses utilization

In this study the efficiency of feedstock utilization is used as a key parameter to investigate the performance of the process when the same amount of molasses is employed for each biochemical production scenario. From Figure 4.1 The result shows that bio-succinic acid (BSA) gives the highest molasses utilization (0.292) in comparison to other biochemical production scenarios in which the same amount of molasses 494.252 MT/day can produce 144.556 MT/day succinic acid. This indicates that the process requires less amount of feedstock in order to convert to the desired product succinic acid and the sugar conversion favors succinic acid than ethanol production. Moreover, for the integrated ethanol and succinic acid (Int. ETOH+SA) production, the products obtained from this process are ethanol and succinic acid. The result shows that Int. ETOH+SA 25:75 shows the most desirable molasses utilization (0.282) which is almost as high as the standalone bio-succinic acid production.

Additionally, if the ratio of molasses to produce ethanol increases the molasses utilization decreases which agrees well with the result of ETOH production resulting in Int. ETOH+SA 75:25 to be the most undesirable biochemical production.

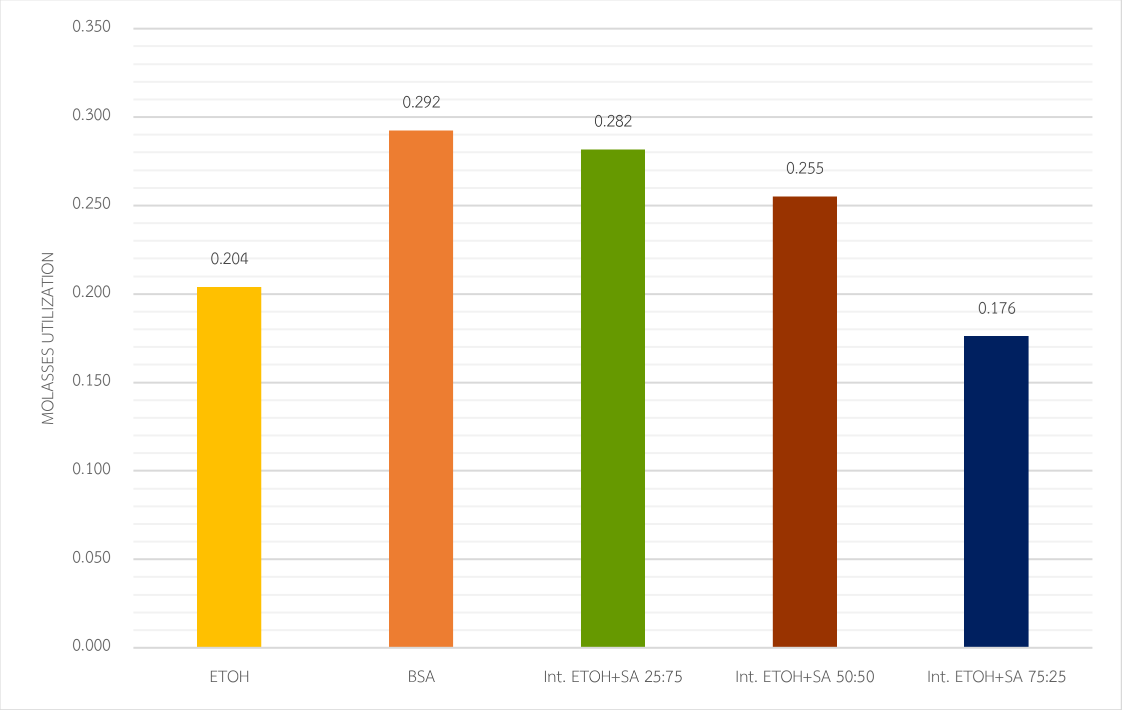

Figure 4. 1 Molasses utilization of ethanol, succinic acid and the integrated ethanol and succinic acid productions.

4.2.2. Energy analysis

The overall energy consumption comprises heating, cooling, and electricity components, as depicted in Figure 4.2 SEC values can be divided into two sections based on the product: ETOH and SA. To begin with, let's consider the SECs for scenarios involving ETOH production. The results indicate that Int. ETOH+SA 75:25 scenario yields the highest SEC value (341.75 GJ/MT ETOH), while Int. ETOH+SA 25:75 scenario exhibits the lowest SEC among other integrated scenarios. However, it is worth noting that the standalone ETOH production consumes more energy (2.34×10^4 GJ/day compares to 1.85×10^4 GJ/day for Int. ETOH+SA 75:25). Despite this, Int. ETOH+SA 75:25 scenario's SEC is higher due to its lower ETOH production (54.05 MT/day) compared to standalone ETOH production (100.96 MT/day). This suggests that Int. ETOH+SA 75:25 scenario has an unfavorable energy performance since it requires a significant amount of energy to produce a smaller quantity of the product. Furthermore, Figure 4.3 illustrates the utility breakdown for each scenario. In ETOH production, cooling and heating utilities are equally required (50% each), whereas 60% of the total utility requirement in BSA production comes from cooling utility.

In the case of Int. ETOH+SA 75:25, the first distillation column (S-101) in the ETOH distillation process accounts for approximately 96% of the total heating requirement, as shown in Figure 4.2 This indicates that ETOH production consumes more energy than SA production. Meaning if the molasses ratios to produce ethanol increase, the SEC increases since ETOH production consumes more energy than SA production. Similarly, the SEC/MT SA results can be explained in a manner similar to the SEC/MT ETOH. Among the scenarios, Int. ETOH+SA 25:75 exhibits the lowest SEC/MT SA (12.62 GJ/MT SA) due to its higher SA production. Notably, the heat exchanger E-110, located after the back extraction unit (S-104), contributes to 33% of the total utility requirement and results in the highest energy consumption for its SA production. From these findings, it can be concluded that SA production demonstrates greater energy efficiency compared to ETOH production. This can be attributed to the DSP process, specifically reactive extraction, which is recognized as a less energy-consuming method for SA production [49].

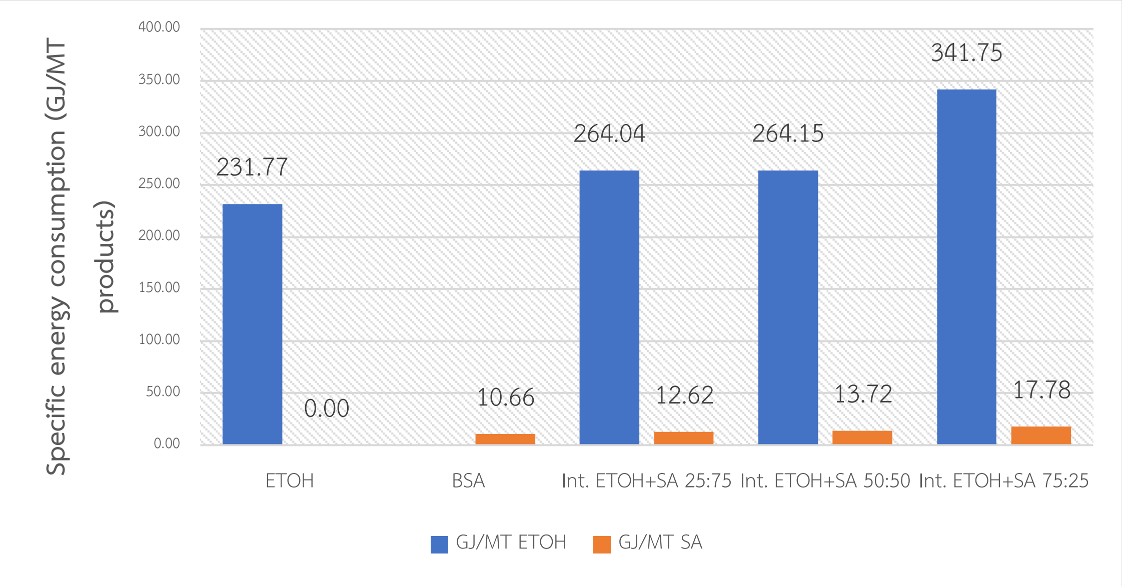

Figure 4. 2 specific energy consumption of ethanol, succinic acid and integrated ethanol and succinic acid productions.

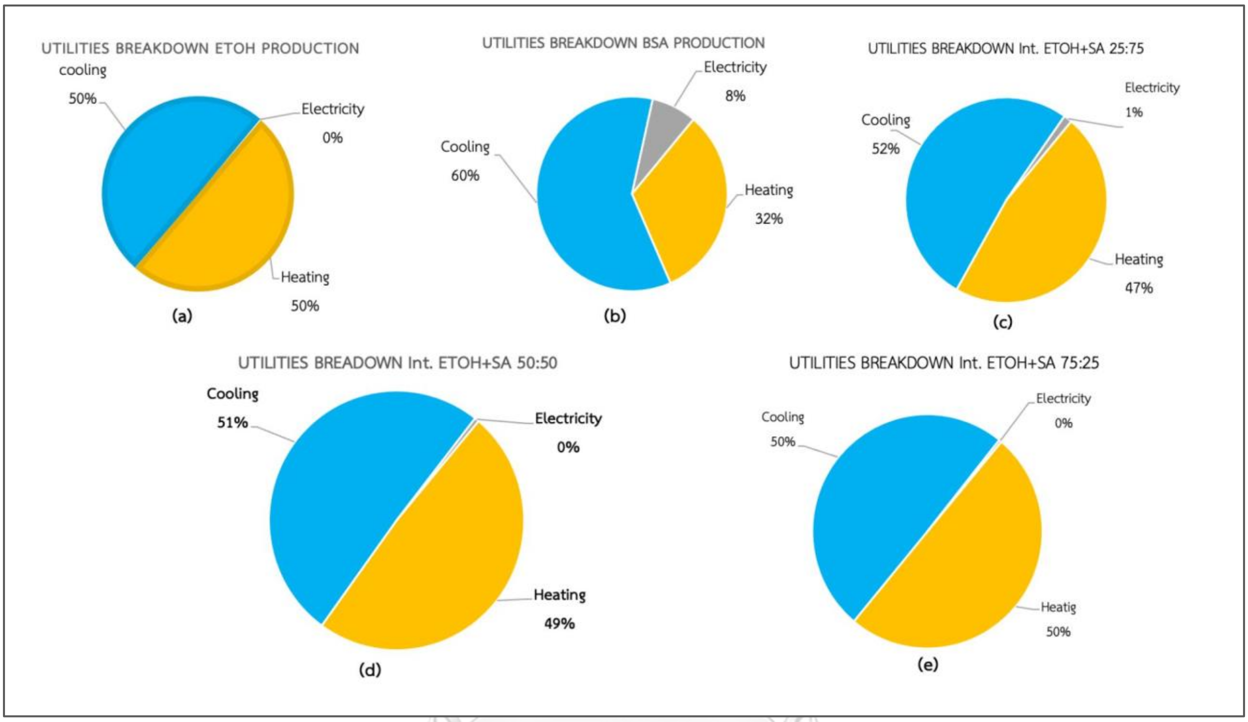

Figure 4. 3 Utilities breakdown for biochemical productions (a) ethanol production (b) bio-based succinic acid production (c) integrated ethanol and succinic acid 25:75 (d) integrated ethanol and succinic acid 50:50 (e) integrated ethanol and succinic acid 75:25.

4.2.3. Environmental impact assessment

In this section, net CO_2 emission is used to compare the environmental impact in each biochemical processes which can be calculated using the summation of CO_2 emission from chemical reactions and CO_2 emission from utilities. The reactions can be subdivided into two categories which are.

1. CO_2 generated from ethanol production; the reactions are shown in Table 3.4.
2. CO_2 uptake from succinic acid production; the reactions are shown in Table 3.5

From Figure 4.4 it can be observed that BSA exhibits the lowest net CO_2 emission (1,852.32 kg/h). This can be attributed to the chemical reactions involved in SA production, where CO_2 is consumed as seen in the reactions in Table 3.5, leading to a negative value of CO_2 emission (-1,548.61 kg/h) associated with SA production. However, it is important to note that the CO_2 emission cannot reach a negative value due to the emissions from the utilities used (3,400.93 kg/h), mainly from the cooling utility in BSA production, which R-1 accounting for 45% of the total CO_2 emission from utility usage.

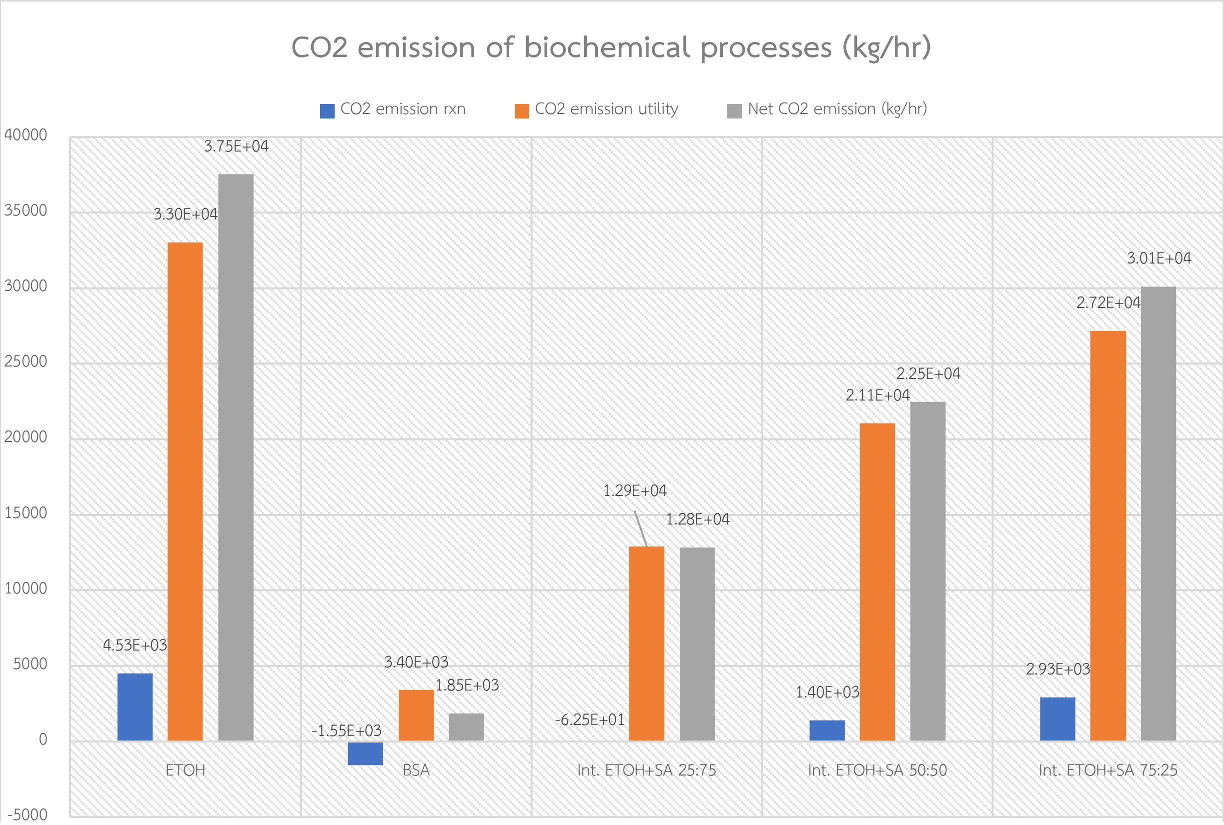

Figure 4. 4 CO_2 emissions of ethanol, succinic acid and integrated ethanol and succinic acid productions.

However, it can help reduce the CO_2 emission from the utilities by 46%. Additionally, among the integrated scenarios, Int. ETOH+SA 25:75 scenario stands out with a negative net CO_2 emission value (-62.45 kg/h). This can be explained by the increase in molasses ratios for ETOH production, which leads to higher CO_2 emissions. Nevertheless, these integrated scenarios contribute to reducing CO_2 emissions from ETOH production. Specifically, the integrated ETOH 25:75, 50:50, and 75:25 scenarios can help achieve CO_2 emission reductions of 66%, 42%, and 20%, respectively as seen in Table 4.1.

Regarding the CO_2 emission advantages of the integrated ETOH+SA 25:75 system, it is important to introduce additional commercial CO_2 into the SA fermenter to ensure the completion of the fermentation process. This is necessary because the ethanol production side has lower productivity, resulting in a limited amount of CO_2 generated. Consequently, it is crucial to investigate the economic performance of this system.

Table 4. 2 CO_2 emission reduction of integrated ethanol and succinic acid from ethanol production

Scenario	**Net CO_2 emission (kg/h)**	**% reduction**
ETOH	3.75E+04	-
Int. ETOH+SA 25:75	1.28E+04	66%
Int. ETOH+SA 50:50	2.25E+04	40%
Int. ETOH+SA 75:25	3.10E+04	20%

4.2.4. Economic analysis

Table 4.3 shows the economic performances summary for each biochemical production with the investment parameters shown in Table 3.6. The results are obtained from Aspen Process Economic Analyzer (APEA). The price of ETOH is a critical factor for conducting an economic analysis, as it directly impacts the outcomes of Int. ETOH+SA production. However, it is important to note that the ETOH price is constrained and cannot exceed 2.07 USD/L, which represents the highest ETOH price in Spain, the chosen production location [34]. This limitation is primarily due to the competitive nature of the global market, where major producers such as Brazil and the USA are capable of manufacturing substantial volumes of ETOH at lower selling prices [34]. For this specific case, the ETOH selling price is set at 1.32 USD/L, representing the average selling price of ETOH in the market [34].

However, the economic analysis reveals a negative Net Present Value (NPV) for ETOH production at the given price, amounting to -206 million USD. In which the operating cost of ETOH production per liter of ethanol is 1.71 USD/L which is higher than the average selling price of ETOH. The largest investment cost is attributed to the total project capital cost, which is 130 million USD, with the ETOH fermenter (R-101) being the most expensive equipment, accounting for 62% of the total equipment cost for the process. Moreover, raw material costs contribute to 72% of the total operating cost, with DI water cost accounting for 45% of the total raw material cost and molasses cost representing 42%. Utilities cost contributes to 11% of the total operating cost where the utility used in distillation tower 1 (S-100) reboiler accounts for 90% of total utility used where LP-steam is employed and 10% is from its condenser where cooling water is employed. Consequently, the economic performance of ETOH production in this study is unfavorable, potentially due to the inappropriate choice of molasses source. Other studies have demonstrated more economically beneficial approaches by producing ETOH within the sugar milling process or through sugarcane cultivation [103,104].

Furthermore, to achieve a Payback Period (POP) of 5 years, the minimum selling price of products in each project involved in SA production needs to be regulated. Among the scenarios, the integrated ETOH+SA 25:75 scenario stands out with the highest NPV (2,180 million USD), Internal Rate of Return (IRR) of 40.81%, and POP of 5 years. However, it is important to note that this scenario has the highest total capital cost due to the combination of equipment costs from both ETOH and SA productions. Additionally, to ensure a POP of 5 years, the selling price of SA must exceed 15 USD/kg.

Moreover, the global trend for ETOH prices has recently experienced an increase over the past three months, coinciding with a decrease in crude oil prices [87]. However, it should be considered that the uncertain situations in Russia and Ukraine may still influence the global crude oil price [41], thereby affecting the ETOH price. Conventionally, BSA prices have ranged between 0.99-3.12 USD/kg [107,108], depending on factors such as product quality, choice of feedstocks, and technologies used in SA production. A case study based on BioAmber company conducted by Li and Edmund, (2021) [8] revealed misinterpretation of low pricing (0.12-0.20 USD/kg) due to cost competitiveness with petroleum-based production, leading to bankruptcy in 2018. Therefore, the prices of SA ranging between 15-37 USD/kg in Table 4.3 of this study are considered reasonable. The higher operating costs observed in this study may be attributed to the significant utilization of fermenters in the SA fermentation process, resulting from the high feedstock quantities employed in BSA production. Our study employed 26 tanks for standalone BSA production, each with a capacity of 1,000 m^3, whereas previous studies reported a maximum utilization of approximately 11 tanks [88]. As a result, R-102 represents the most expensive equipment, accounting for 95-60% of the total equipment expenses for each chemical production involving SA production. Additionally, the price of CO_2, despite its commercial addition in integrated ETOH+SA 25:75, constitutes only 0.23% of the total raw material costs. However, Trimethylamine (TMA) used in the back extraction process accounts for 36.32% of the total raw material costs due to its high volatility, requiring a large amount to ensure high extractability and has higher cost than other raw materials (2.89 USD/kg). To propose a more economically efficient process and alleviate financial strain, our study suggests reducing the plant size to less than 47,000 tonne/year. This reduction is expected to lead to decreased equipment and operating costs.

Table 4.3 Economic parameters of biochemical productions.

Economic information	**Unit**	**ETOH**	**BSA**	**Integrated**	***Integrated***	**Integrated**
				ETOH+SA	*ETOH+SA*	ETOH+SA
				25:75	*50*:50	75:25
Total Capital Cost	$	1.31E+08	7.96E+08	7.75E+08	*4.79E+08*	3.38E+08
Total Operating Cost	$/y	7.19E+07	2.89E+08	2.43E+08	*2.24E+08*	3.54E+08
Total Equipment Cost	$	6.31E+07	4.07E+08	3.49E+08	*2.69E+08*	1.86E+08
Total Operating Labor Cost	$/y	1.24E+06	9.20E+05	1.72E+06	*1.72E+06*	1.72E+06
Total Maintenance Cost	$/y	5.84E+06	4.80E+07	3.59E+07	*2.76E+07*	1.90E+07
Total Utilities Cost	$/y	1.22E+06	2.77E+07	2.59E+07	*3.81E+07*	1.86E+07
Total Products Sales	$/y	5.59E+07	6.57E+08	5.87E+08	*4.58E+08*	5.28E+08
Total Raw materials Cost	$/y	7.93E+07	1.66E+08	1.42E+08	*1.25E+08*	2.77E+08
Main material cost						
Molasses	$/y	3.49E+07	3.49E+07	3.49E+07	*3.49E+07*	3.49E+07
Water	$/y	3.56E+07	4.12E+07	4.12E+07	*4.12E+07*	4.12E+07
H2SO4	$/y	9.73E+06	9.73E+06	9.73E+06	*9.73E+06*	9.73E+07
TMA	$/y	-	5.97E+07	4.52E+07	*3.02E+07*	1.66E+07
Economic indicator						
Minimum selling price (ETOH)	$/L	1.32	-	1.32	*1.32*	1.32
Minimum selling price (SA)	$/kg	-	13	15	*16*	37
NPV	$	-2.06E+08	1.97E+09	2.18E+09	*1.32E+09*	1.08E+09
IRR	%	-	36.62	40.81	*38.39*	37.86

4.2.5. Process evaluation: Heat exchanger network (HEN) design

Since Int. ETOH+SA 25:75 gives the most standout all over performances including molasses utilization, SEC, CO_2 emission and the economic performance over the other integrated scenario thus it is selected for performing HEN design. It is important to mention that temperature-sensitive process streams, such as the ETOH distillation towers (S-101 and S-102), are excluded from the analysis to maintain product purity. Figure 4.5 illustrates the composite curve which is the relationship between hot and cold process streams, highlighting the minimum cooling utility of 1.68E+07 kJ/h, minimum heating utility of 1.33E+07 kJ/h, and a heat recovery of 1.33E+06 kJ/h.

The results indicate that complete heat exchange between hot and cold process streams is not achieved, since the use of external heating and cooling utilities is still required for some of the streams. Table 4.3 displays the results before and after HEN design and grid diagrams representing HEN of each process are shown in Figure 4.6 Two HEN design approaches are compared, demonstrating that the hand calculation design reduces the total utility requirement by 12.34% with 23 heat exchangers, while the AEA-generated designs (Design 5 and Design 10) reduce utility requirements by 39.7% and 39.6% with 25 and 24 heat exchangers, respectively. This increase in process-to-process heat exchangers allows for effective heat exchange between hot and cold process streams, resulting in reduced external utility consumption.

Furthermore, HEN design provides the additional benefit of CO_2 emission reduction. The utilities contributing to CO_2 emissions in this analysis are low-pressure steam (LP-steam) and refrigerant 1 (R-1). Table 4.4 shows that the hand calculation design achieves a 28.10% reduction in CO_2 emissions, while Design 5 and Design 10 achieve a significant reduction of 63.3%. It is essential to consider that the addition of heat exchangers may lead to increased capital and installation costs, despite the advantages of reduced external utility requirements and utility costs. The economic analysis before and after HEN design should be considered in the future work. Lastly, one thing to be considered is a good controllability of HEN design since heat integration occurs between 2 processes could result in complexity in process control system. For example, the more heat integrated, the less utilities available to absorb control disturbances and the more difficult in controllability it becomes which can lead to the increase of cost over the predicted cost [89] or if there is an upset in one process, it could result in the upset of the whole process. Several controllability methods of HEN are proposed e.g., optimal operation and control of HEN, interaction measures and controllability index based on interaction measures for input-output pairing [89]. In a proper heat-integrated system, not all streams have a utility exchanger thus bypasses are required in the control structure. Therefore, the selection of controllability systems depends on network configuration and control structure selection [89].

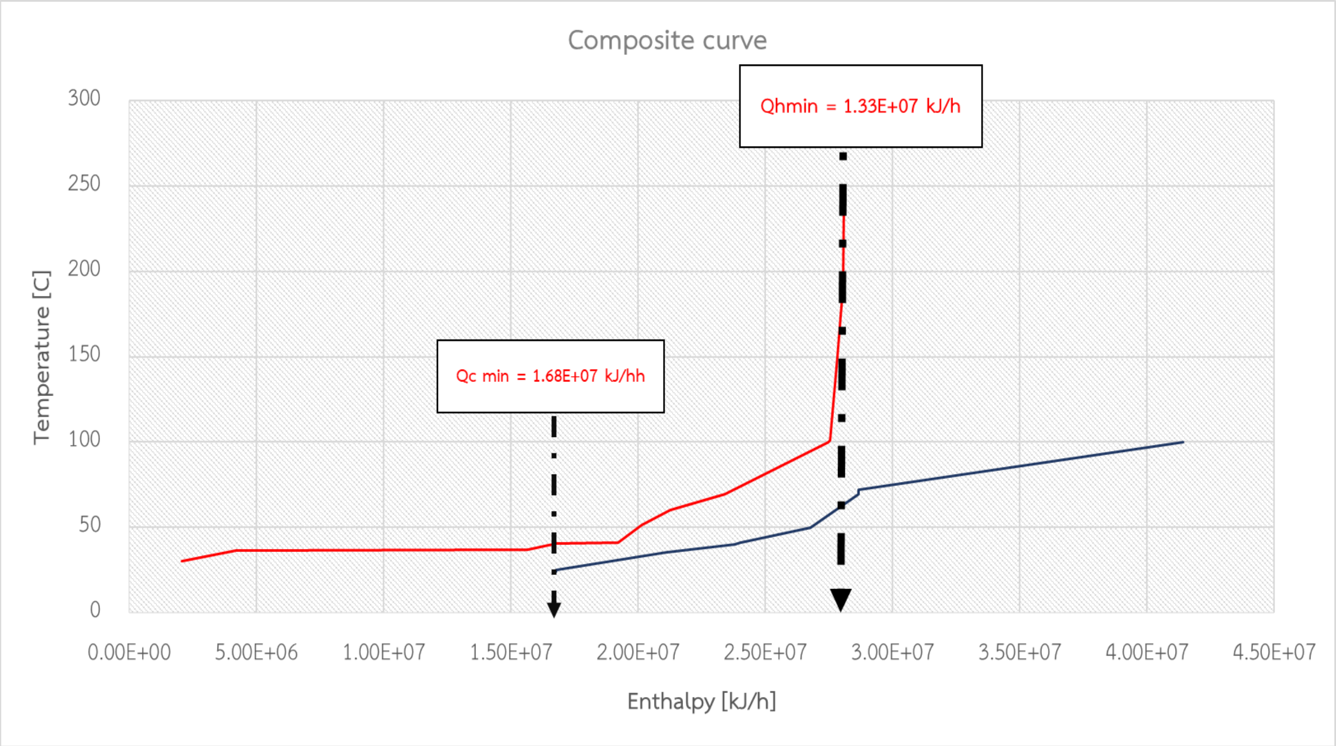

Figure 4. 5 Composite curve of Int. ETOH+SA 25:75

Table 4.4 Utility requirement before and after HEN designs.

Design	No. of heat exchangers	Total Utilities [kJ/h]	%Utility reduction	%CO2 emission reduction
Base case	21	6.73E+07	-	-
Hand-Cal	23	5.90E+07	12.34%	28.10%
Design 5	25	4.07E+07	39.7%	63.33%
Design 10	24	4.07E+07	39.6%	63.33%

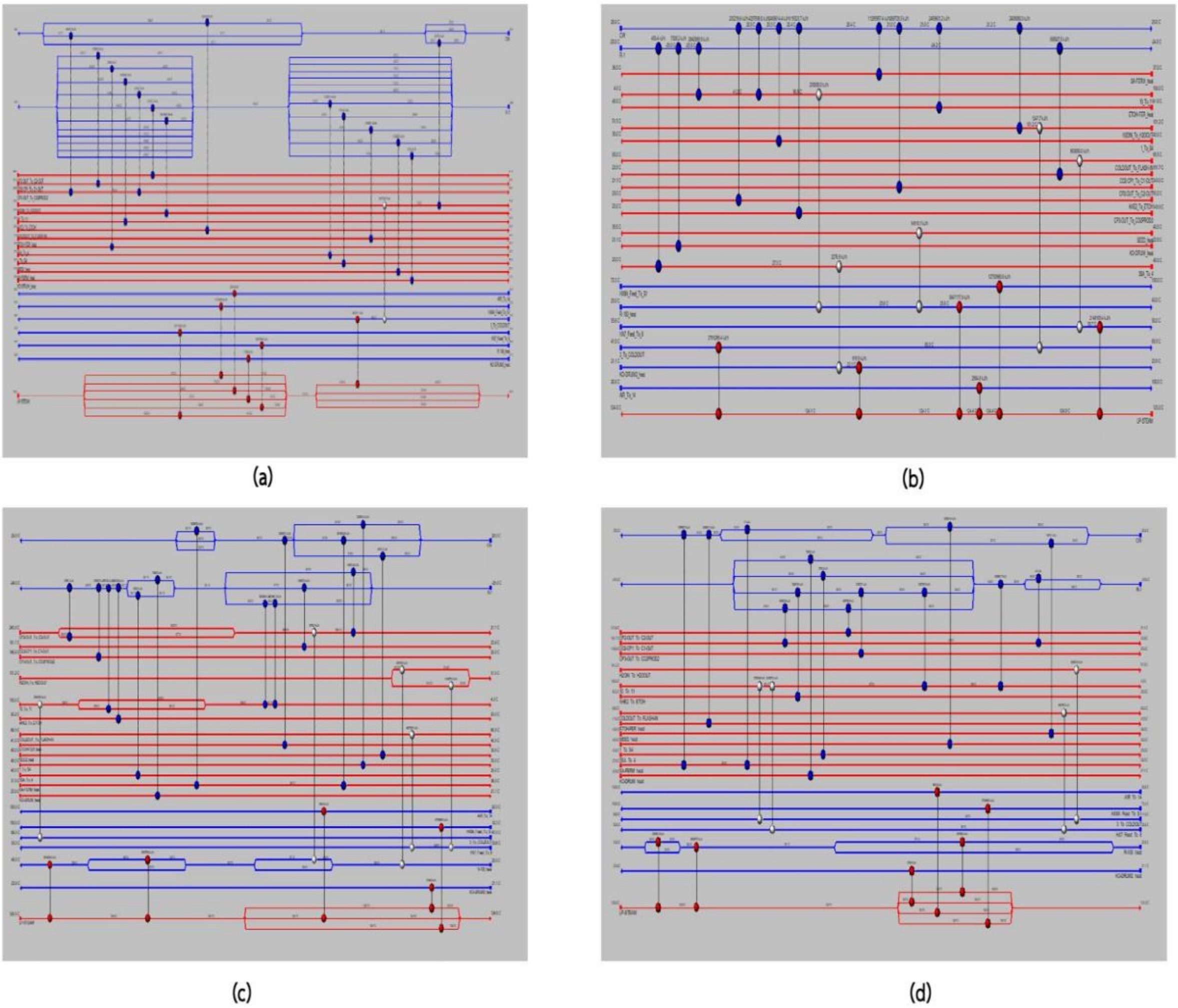
(a)
(b)
(c)
(d)

Figure 4. 6 Grid diagram of heat exchanger network designs including (a) base-case (b) hand calculation (c) Design 5 (d) Design 10.

4.3. Comparison between Petroleum-based, and bio-based succinic acid production

In this section, a comparative analysis is conducted between bio-based succinic acid (BSA) and petroleum-based succinic acid (PSA) productions, utilizing three performance indexes: specific energy consumption (SEC), CO_2 emissions, and total costs per MTSA. The SEC and economic data are sourced from Pinazo et al. (2015), while CO_2 emissions data is obtained from Smidt et al. (2015) [90].

From the findings presented in Table 4.5, it is evident that petroleum-based SA exhibits higher energy consumption (55.1 GJ/MTSA) compared to bio-based SA (10.66 GJ/MTSA) and any integrated scarios as well, primarily attributed to the energy-intensive maleic anhydride hydrogenation step. Additionally, for the purpose of comparability, CO_2 emissions in this study are converted to CO_2 equivalent (kg CO_2e/kg) to align with the CO_2 emissions of petroleum-based SA as reported by Smidt et al. (2015) [90]. The results indicate that BSA demonstrates lower CO_2 equivalent value (0.29 kgCO_2e/kg) compared to PSA, with 80% of PSA CO_2 emissions arising from n-butane conversion to maleic anhydride and 13% from steam co-generation.

Furthermore, total costs, comprising capital costs and operating costs, are utilized as economic performance indicators. It is important to note that the values obtained from Smidt's study are from 2015 and in Euros [90]. Thus, adjustment for present value is necessary using a cumulative inflation rate of 0.23% [91], and conversion to USD using the exchange rate of 1 Euro = 1.09 USD **[92]**. The results indicate that every biochemical in this study show higher total costs than the Petroleum based one. This finding aligns with the pricing of PSA, which can be sold as low as 1.40 USD/kg [44].

Table 4.5 Key parameters comparison between Petroleum-based and bio-based succinic acid productions.

Scenario	SEC (GJ/MT SA)	CO_2 equivalent ($kgCO_2e/kg$)	Total cost (USD/MTSA)
Petroleum based SA	55.1	1.89	3,425.87
Bio-based SA	10.66	0.29	7,165.03
Int. ETOH+SA 25:75	12.62	2.21	8,254.74
Int. ETOH+SA 50:50	13.72	2.44	10,814.28
Int. ETOH+SA 75:25	17.78	3.54	34,534.25

Chapter 5

Conclusion and Recommendation for Future Works

5.1 Conclusion

This study examined the process integration of Ethanol (ETOH) and Bio-succinic acid (BSA) as a sustainable alternative to Petroleum-based succinic acid (PSA). The findings revealed that the Int. ETOH+SA 25:75 ratio demonstrated remarkable performance across various metrics. Notably, it achieved high molasses utilization (0.282 kg SA/kg molasses) and significantly lower energy consumption (264.04 GJ/MTETOH and 12.62 GJ/MTSA) compared to PSA (55.10 GJ/MTSA) due to the energy-efficient reactive extraction downstream process. Moreover, it exhibited a substantial reduction of 66% in CO_2 emissions from ETOH production. However, the study identified that the operating cost per kg SA (6.79 USD/kg) was 34 times higher than conventional BSA production (0.2 USD/kg), resulting in a higher selling price of 16 USD/kg to achieve a 5-year payout period due to significant capital investment costs. To improve economic feasibility, reducing SA production capacity and exploring cost-effective alternatives for extractant in back-extraction process, specifically regarding the major raw material cost of TMA, are recommended. Additionally, the evaluation of heat exchanger network (HEN) design demonstrated the potential to reduce utility requirements by approximately 39% and achieve a significant 60% reduction in CO_2 emissions. These findings highlight the potential of bio-based SA, and with advancements in extraction techniques, it could become a competitive substitute for petroleum-based SA.

5.2 Recommendation for Future Works

Firstly, For the BSA production, the author recommends scaling down the bio-succinic acid production process not to exceed the capacity of succinic production of 47,000 tonne/year which is the capacity used in this study to minimize the operating cost and reduce the selling price of succinic acid per kg to be able to compete with the Petroleum based succinic acid. Moreover, TMA represents the most expensive raw material cost thus if there is any cheaper extractive reagent with the same or higher efficiency, the operating cost of BSA would be lower. In ETOH production, the source of molasses is important because the price cannot be lower than 0.2 USD/kg in Thailand. However, if co-producing ETOH and sugar milling the price of molasses might be lower and more revenues can be achieved.

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Appendix

Appendix A

The process flow diagram and flow Stream summary table for ethanol production.

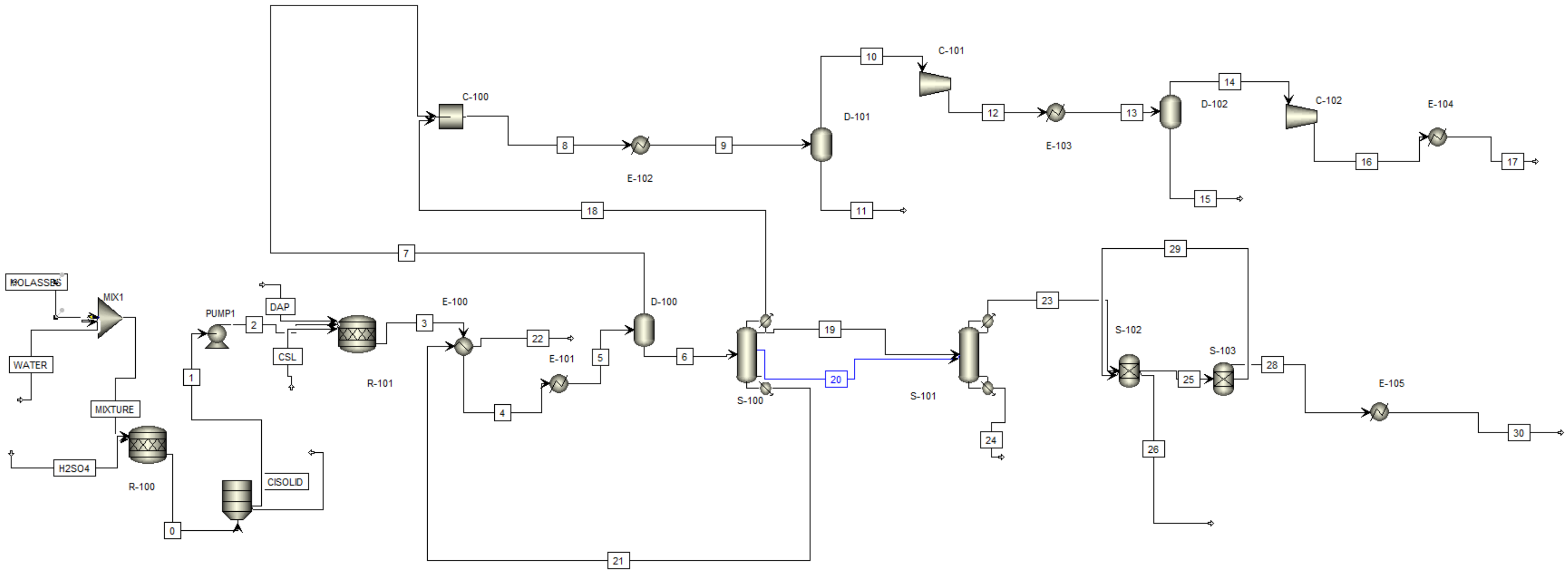

Figure A 1 process flow diagram of ethanol production

Table A 1 Stream summary of molasses-based ethanol.

Stream Name	Units	0	1	2	3	4	5
Temperature	C	40.00	40.00	40.17	41.00	69.37	60.00
Pressure	bar	1.01	1.01	5.15	1.01	1.01	1.03
Molar Vapor Fraction		0.00	0.00	0.00	0.03	0.05	0.04
Mole Flows	kmol/hr	3232.87	3232.75	3232.75	3397.96	3397.96	3397.96
Mass Flows	kg/hr	72358.74	72345.13	72345.13	72863.81	72863.81	72863.81
GLUCOSE	kg/hr	4814.10	4.81E+03	4.81E+03	1.04E+02	1.04E+02	1.04E+02
FRUCTOSE	kg/hr	4890.39	4.89E+03	4.89E+03	1.05E+02	1.05E+02	1.05E+02
SUFLURIC	kg/hr	6581.17	6.58E+03	6.58E+03	6.58E+03	6.58E+03	6.58E+03
CO2	kg/hr	0.00	0.00E+00	0.00E+00	4.53E+03	4.53E+03	4.53E+03
ZYMO	kg/hr	0.00	0.00E+00	0.00E+00	1.59E+02	1.59E+02	1.59E+02
DAP	kg/hr	0.00	0.00E+00	0.00E+00	9.12E+01	9.12E+01	9.12E+01
ETHANOL	kg/hr	0.00	0.00E+00	0.00E+00	4.71E+03	4.71E+03	4.71E+03
GLYCEROL	kg/hr	0.00	0.00E+00	0.00E+00	3.97E+01	3.97E+01	3.97E+01
O2	kg/hr	0.00	0.00E+00	0.00E+00	6.89E+00	6.89E+00	6.89E+00
H2O	kg/hr	56060.18	5.61E+04	5.61E+04	5.61E+04	5.61E+04	5.61E+04
2-PROP	kg/hr	0.00	0.00E+00	0.00E+00	1.51E+01	1.51E+01	1.51E+01
1-PROP	kg/hr	0.00	0.00E+00	0.00E+00	2.16E+00	2.16E+00	2.16E+00
METHANOL	kg/hr	0.00	0.00E+00	0.00E+00	3.45E+00	3.45E+00	3.45E+00
CSL	kg/hr	0.00	0.00E+00	0.00E+00	4.16E+02	4.16E+02	4.16E+02
MGSO4	kg/hr	2.71	2.71E-05	2.71E-05	2.71E-05	2.71E-05	2.71E-05
NA2SO4	kg/hr	3.20	3.20E-05	3.20E-05	3.20E-05	3.20E-05	3.20E-05
K2SO4	kg/hr	3.92	3.92E-05	3.92E-05	3.92E-05	3.92E-05	3.92E-05
CASO4	kg/hr	3.06	3.06E-05	3.06E-05	3.06E-05	3.06E-05	3.06E-05

Stream Name	Units	6	7	8	9	10	11
Temperature	C	60.00	60.00	191.46	23.89	21.11	21.11
Pressure	bar	1.03	1.03	3.45	4.83	4.83	4.83
Molar Vapor Fraction		0.00	1.00	1.00	0.73	1.00	0.00
Mole Flows	kmol/hr	3263.84	134.12	142.44	142.44	103.58	38.86
Mass Flows	kg/hr	67589.63	5274.18	5544.01	5544.01	4545.31	998.70
GLUCOSE	kg/hr	1.04E+02	1.86E-10	1.86E-10	1.86E-10	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	1.05E+02	1.89E-10	1.89E-10	1.89E-10	0.00E+00	0.00E+00
SUFLURIC	kg/hr	6.58E+03	7.80E-04	7.80E-04	7.80E-04	1.53E-11	7.80E-04
CO2	kg/hr	4.19E+01	4.48E+03	4.52E+03	4.52E+03	4.50E+03	2.11E+01
ZYMO	kg/hr	1.59E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	9.12E+01	5.00E-79	1.10E-68	1.10E-68	0.00E+00	0.00E+00
ETHANOL	kg/hr	4.38E+03	3.37E+02	4.95E+02	4.95E+02	2.76E+01	4.67E+02
GLYCEROL	kg/hr	3.97E+01	8.94E-06	8.94E-06	8.94E-06	1.03E-12	8.94E-06
O2	kg/hr	3.63E-03	6.89E+00	6.89E+00	6.89E+00	6.89E+00	1.66E-03
H2O	kg/hr	5.57E+04	4.44E+02	5.16E+02	5.16E+02	8.28E+00	5.08E+02
2-PROP	kg/hr	1.35E+01	1.59E+00	2.29E+00	2.29E+00	1.16E-01	2.17E+00
1-PROP	kg/hr	1.97E+00	1.87E-01	2.68E-01	2.68E-01	6.51E-03	2.61E-01
METHANOL	kg/hr	3.26E+00	1.96E-01	2.94E-01	2.94E-01	2.03E-02	2.74E-01
CSL	kg/hr	4.16E+02	7.50E-10	7.50E-10	7.50E-10	9.11E-24	7.50E-10
MGSO4	kg/hr	2.71E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	3.20E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	3.92E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	3.06E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	12	13	14	15	16	17
Temperature	C	243.00	150.00	23.89	23.89	149.88	25.00
Pressure	bar	34.47	20.68	20.68	20.68	68.95	68.95
Molar Vapor Fraction		1.00	1.00	1.00	0.00	1.00	1.00
Mole Flows	kmol/hr	103.58	103.58	102.74	0.85	102.74	102.74
Mass Flows	kg/hr	4545.31	4545.31	4516.51	28.81	4516.51	4516.51
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SUFLURIC	kg/hr	1.53E-11	1.53E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	4.50E+03	4.50E+03	4.50E+03	3.42E+00	4.50E+03	4.50E+03
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	2.76E+01	2.76E+01	8.73E+00	1.89E+01	8.73E+00	8.73E+00
GLYCEROL	kg/hr	1.03E-12	1.03E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	6.89E+00	6.89E+00	6.89E+00	3.50E-04	6.89E+00	6.89E+00
H2O	kg/hr	8.28E+00	8.28E+00	1.87E+00	6.41E+00	1.87E+00	1.87E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	1.16E-01	1.16E-01	3.10E-02	8.54E-02	3.10E-02	3.10E-02
1-PROP	kg/hr	6.51E-03	6.51E-03	8.51E-04	5.66E-03	8.51E-04	8.51E-04
METHANOL	kg/hr	2.03E-02	2.03E-02	8.79E-03	1.15E-02	8.79E-03	8.79E-03
CSL	kg/hr	9.11E-24	9.11E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	18	19	20	21	22	23
Temperature	C	83.26	83.26	100.76	101.47	51.47	83.93
Pressure	bar	1.03	1.03	1.03	1.03	1.03	1.01
Molar Vapor Fraction		1.00	0.00	0.00	0.00	0.00	1.00
Mole Flows	kmol/hr	8.32	823.52	2.27	2429.74	2429.74	180.00
Mass Flows	kg/hr	269.83	17418.80	41.79	49859.21	49859.21	5825.61
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	2.05E-42	1.48E-31	1.60E-02	1.03E+02	1.03E+02	0.00E+00
FRUCTOSE	kg/hr	2.05E-42	1.48E-31	1.63E-02	1.05E+02	1.05E+02	6.26E-43
SUFLURIC	kg/hr	1.55E-38	8.08E-32	1.02E+00	6.58E+03	6.58E+03	0.00E+00
CO2	kg/hr	3.99E+01	2.02E+00	1.47E-23	1.17E-20	1.17E-20	2.02E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.59E+02	1.59E+02	0.00E+00
DAP	kg/hr	1.10E-68	1.09E-31	1.41E-02	9.12E+01	9.12E+01	0.00E+00
ETHANOL	kg/hr	1.57E+02	4.22E+03	3.49E-19	3.93E-18	3.93E-18	4.22E+03
GLYCEROL	kg/hr	2.67E-31	9.42E-25	6.15E-03	3.97E+01	3.97E+01	0.00E+00
O2	kg/hr	3.61E-03	1.49E-05	1.27E-24	4.01E-24	4.01E-24	1.49E-05
H2O	kg/hr	7.17E+01	1.32E+04	4.07E+01	4.24E+04	4.24E+04	1.59E+03
2-PROP	kg/hr	6.96E-01	1.28E+01	6.96E-28	1.11E-23	1.11E-23	1.28E+01
1-PROP	kg/hr	8.04E-02	1.89E+00	1.85E-24	1.95E-18	1.95E-18	1.89E+00
METHANOL	kg/hr	9.85E-02	3.16E+00	7.49E-19	1.59E-17	1.59E-17	3.16E+00
CSL	kg/hr	2.20E-30	1.59E-19	6.47E-02	4.16E+02	4.16E+02	2.78E-27
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.71E-05	2.71E-05	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.20E-05	3.20E-05	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.92E-05	3.92E-05	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.06E-05	3.06E-05	0.00E+00

Stream Name	Units	24	25	26	28	29	30
Temperature	C	100.05	84.13	84.13	109.18	109.18	25.00
Pressure	bar	1.01	1.01	1.01	3.04	3.04	1.01
Molar Vapor Fraction		0.00	1.00	0.00	0.00	1.00	0.00
Mole Flows	kmol/hr	645.79	92.52	88.57	91.43	1.10	91.43
Mass Flows	kg/hr	11634.98	4257.55	1613.76	4211.86	45.69	4211.86
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	1.60E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	1.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SUFLURIC	kg/hr	1.02E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	2.02E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	1.41E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.47E-02	4.25E+03	8.53E+00	4.21E+03	4.25E+01	4.21E+03
GLYCEROL	kg/hr	6.15E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	1.23E-21	0.00E+00	1.49E-05	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	1.16E+04	3.18E+00	1.59E+03	3.18E-02	3.15E+00	3.18E-02
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	1.63E-08	0.00E+00	1.28E+01	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	5.11E-08	0.00E+00	1.89E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	8.68E-04	0.00E+00	3.16E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	6.47E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SUCCACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	CISOLID	CSL	DAP	H2SO4	MIXTURE	MOLASSES	WATER
Temperature	C	40.00	25.00	25.00	25.00	25.00	25.00	25.00
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mole Flows	kmol/hr	0.12	2.36	0.71	82.43	3150.44	658.41	2492.03
Mass Flows	kg/hr	13.61	425.00	93.75	6864.58	65494.10	20599.52	44894.58
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.21E+03	7.21E+03	0.00E+00
GLUCOSE	kg/hr	4.81E-02	0.00E+00	0.00E+00	0.00E+00	1.02E+03	1.02E+03	0.00E+00
FRUCTOSE	kg/hr	4.89E-02	0.00E+00	0.00E+00	0.00E+00	1.10E+03	1.10E+03	0.00E+00
SUFLURIC	kg/hr	6.58E-02	0.00E+00	0.00E+00	6.59E+03	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	9.38E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	5.61E-01	0.00E+00	0.00E+00	2.75E+02	5.62E+04	1.13E+04	4.49E+04
CSL	kg/hr	0.00E+00	4.25E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SUCCACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.07E-01	9.07E-01	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E+00	1.26E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.12E+00	2.12E+00	0.00E+00
NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E+00	1.39E+00	0.00E+00
MGSO4	kg/hr	2.71E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	3.20E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	3.92E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	3.06E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Appendix B

Process flow diagram and Stream summary table for bio-succinic acid production

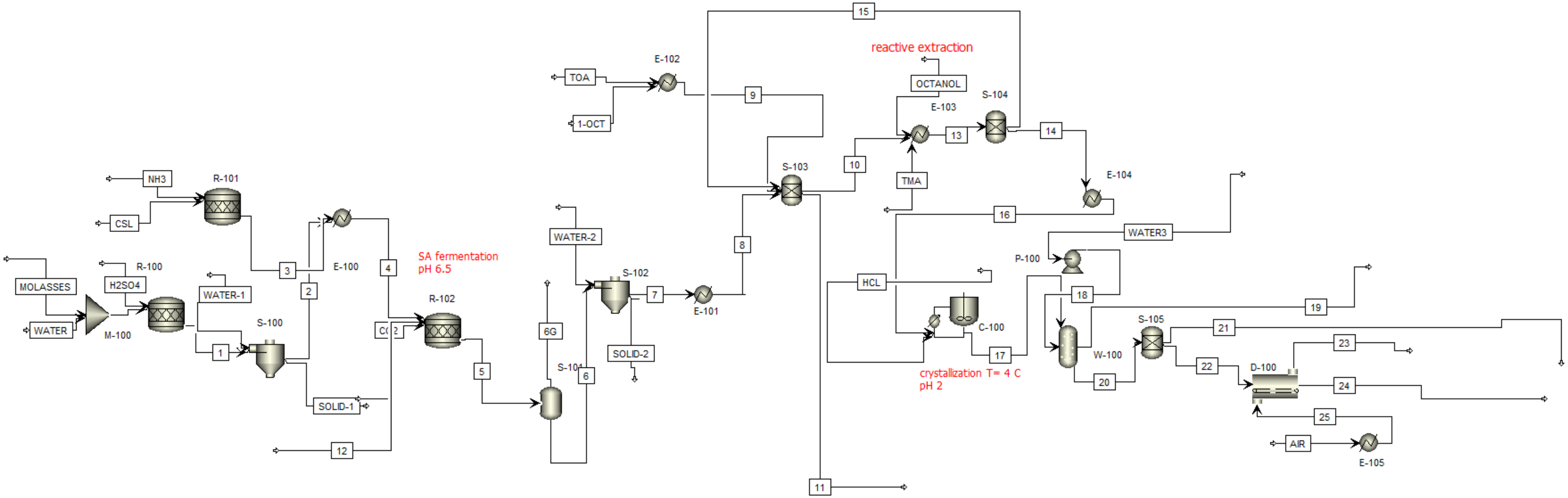

Figure B. 1 Process flow diagram of biobased succinic acid

Table B. 1 Stream summary for bio succinic acid production.

Stream Name	Units	1	1-OCT	2	3	4	5
Temperature	C	25.00	25.00	25.00	40.00	37.00	37.00
Pressure	bar	1.01	1.00	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	0.00	0.00	0.89	0.00	0.00
Mass Flows	kmol/hr	7.24E+04	2.83E+03	7.44E+04	1.43E+01	7.44E+04	7.65E+04
GLUCOSE	kg/hr	4.81E+03	0.00E+00	4.72E+03	5.76E+00	4.72E+03	8.93E+02
FRUCTOSE	kg/hr	4.89E+03	0.00E+00	4.79E+03	0.00E+00	4.79E+03	9.06E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.74E-02	3.74E-02	1.51E+02
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.94E+00	7.94E+00	7.94E+00
H2O	kg/hr	5.42E+04	3.68E+02	5.66E+04	1.38E-01	5.66E+04	5.73E+04
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.28E+03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.43E+02
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+01
CELL	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.18E-01	4.18E-01	4.18E-01
H2SO4	kg/hr	6.59E+03	0.00E+00	6.46E+03	0.00E+00	6.46E+03	6.46E+03
MGO	kg/hr	4.63E+02	0.00E+00	4.54E+02	0.00E+00	4.54E+02	4.54E+02
CAO	kg/hr	4.63E+02	0.00E+00	4.54E+02	0.00E+00	4.54E+02	4.54E+02
K2O	kg/hr	4.63E+02	0.00E+00	4.54E+02	0.00E+00	4.54E+02	4.54E+02
NA2O	kg/hr	4.63E+02	0.00E+00	4.54E+02	0.00E+00	4.54E+02	4.54E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	2.47E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.90E+02

Stream Name	Units	6	7	8	9	10	11
Temperature	C	37.00	37.00	36.37	50.00	40.00	50.78
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	1.00	0.00	0.00	0.00	0.00
Mass Flows	kmol/hr	7.64E+04	9.14E+01	7.84E+04	7.84E+04	3.64E+03	2.93E+04
GLUCOSE	kg/hr	8.93E+02	4.46E-13	8.75E+02	8.75E+02	0.00E+00	8.75E+02
FRUCTOSE	kg/hr	9.06E+02	4.53E-13	8.88E+02	8.88E+02	0.00E+00	8.88E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	6.23E+01	8.91E+01	6.11E+01	6.11E+01	0.00E+00	6.11E+01
NH3	kg/hr	7.94E+00	6.90E-03	7.78E+00	7.78E+00	0.00E+00	7.78E+00
H2O	kg/hr	5.73E+04	2.29E+00	5.96E+04	5.96E+04	1.07E+03	7.89E+03
SA	kg/hr	8.28E+03	2.94E-07	8.12E+03	8.12E+03	0.00E+00	7.06E+03
ACETIC	kg/hr	3.43E+02	8.64E-03	3.36E+02	3.36E+02	0.00E+00	3.36E+02
FORMIC	kg/hr	1.09E+01	6.90E-04	1.07E+01	1.07E+01	0.00E+00	1.07E+01
CELL	kg/hr	4.18E-01	0.00E+00	8.37E-03	8.37E-03	0.00E+00	8.37E-03
H2SO4	kg/hr	6.46E+03	1.26E-06	6.33E+03	6.33E+03	0.00E+00	6.33E+03
MGO	kg/hr	4.54E+02	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
CAO	kg/hr	4.54E+02	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
K2O	kg/hr	4.54E+02	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
NA2O	kg/hr	4.54E+02	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.47E+03	3.78E+03
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E+02	1.79E+02
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	3.90E+02	4.40E-18	3.83E+02	3.83E+02	0.00E+00	7.65E+01
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	12	13	14	15	16	17
Temperature	C	50.78	20.00	100.00	100.00	100.00	4.00
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	0.00	0.02	0.03	0.00	0.00
Mass Flows	kmol/hr	5.52E+04	3.90E+02	3.36E+04	3.12E+04	2.42E+03	3.12E+04
GLUCOSE	kg/hr	0.00E+00	0.00E+00	8.75E+02	8.75E+02	0.00E+00	8.75E+02
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	8.88E+02	8.88E+02	0.00E+00	8.88E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	6.11E+01	6.11E+01	0.00E+00	6.11E+01
NH3	kg/hr	0.00E+00	0.00E+00	7.78E+00	7.78E+00	0.00E+00	7.78E+00
H2O	kg/hr	5.28E+04	0.00E+00	1.12E+04	1.12E+04	0.00E+00	1.12E+04
SA	kg/hr	1.06E+03	0.00E+00	7.06E+03	7.06E+03	0.00E+00	7.06E+03
ACETIC	kg/hr	0.00E+00	0.00E+00	3.36E+02	3.36E+02	0.00E+00	3.36E+02
FORMIC	kg/hr	0.00E+00	0.00E+00	1.07E+01	1.07E+01	0.00E+00	1.07E+01
CELL	kg/hr	0.00E+00	0.00E+00	8.37E-03	8.37E-03	0.00E+00	8.37E-03
H2SO4	kg/hr	0.00E+00	0.00E+00	6.33E+03	6.33E+03	0.00E+00	6.33E+03
MGO	kg/hr	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
CAO	kg/hr	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
K2O	kg/hr	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
NA2O	kg/hr	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00	4.45E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	1.01E+03	0.00E+00	4.15E+03	1.82E+03	2.32E+03	1.82E+03
TOA	kg/hr	2.67E+01	0.00E+00	1.79E+02	7.85E+01	1.00E+02	7.85E+01
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	3.06E+02	3.90E+02	7.65E+01	7.65E+01	0.00E+00	7.65E+01
TMA	kg/hr	0.00E+00	0.00E+00	6.52E+02	6.52E+02	0.00E+00	6.52E+02

Stream Name	Units	18	19	20	21	22	23
Temperature	C	4.00	25.26	3.90	3.90	3.90	3.90
Pressure	bar	1.01	4.14	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00
Mass Flows	kmol/hr	3.12E+04	1.80E+01	6.93E+03	2.43E+04	1.72E+04	7.13E+03
GLUCOSE	kg/hr	8.75E+02	0.00E+00	2.62E+02	6.13E+02	6.13E+02	0.00E+00
FRUCTOSE	kg/hr	8.88E+02	0.00E+00	2.66E+02	6.22E+02	6.22E+02	0.00E+00
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	6.11E+01	0.00E+00	1.83E+01	4.28E+01	4.28E+01	0.00E+00
NH3	kg/hr	7.78E+00	0.00E+00	2.33E+00	5.45E+00	5.45E+00	0.00E+00
H2O	kg/hr	1.12E+04	1.80E+01	3.37E+03	7.87E+03	7.08E+03	7.87E+02
SA	kg/hr	7.46E+02	0.00E+00	2.24E+02	5.23E+02	5.23E+02	0.00E+00
ACETIC	kg/hr	3.36E+02	0.00E+00	1.01E+02	2.35E+02	2.12E+02	2.35E+01
FORMIC	kg/hr	1.07E+01	0.00E+00	3.21E+00	7.51E+00	6.76E+00	7.51E-01
CELL	kg/hr	8.37E-03	0.00E+00	0.00E+00	8.37E-03	8.37E-03	0.00E+00
H2SO4	kg/hr	6.33E+03	0.00E+00	1.90E+03	4.43E+03	4.43E+03	0.00E+00
MGO	kg/hr	4.45E+02	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00
CAO	kg/hr	4.45E+02	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00
K2O	kg/hr	4.45E+02	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00
NA2O	kg/hr	4.45E+02	0.00E+00	0.00E+00	4.45E+02	4.45E+02	0.00E+00
1-OCT	kg/hr	1.82E+03	0.00E+00	5.47E+02	1.28E+03	1.28E+03	0.00E+00
TOA	kg/hr	7.85E+01	0.00E+00	2.35E+01	5.50E+01	5.50E+01	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	6.32E+03	0.00E+00	0.00E+00	6.32E+03	0.00E+00	6.32E+03
NAOH	kg/hr	7.65E+01	0.00E+00	2.29E+01	5.36E+01	5.36E+01	0.00E+00
HCL	kg/hr	1.79E+00	0.00E+00	5.37E-01	1.26E+00	1.26E+00	0.00E+00
TMA	kg/hr	6.52E+02	0.00E+00	1.95E+02	4.57E+02	4.57E+02	0.00E+00

Stream Name	Units	24	25	26	AIR	CO2	CSL
Temperature	C	130.00	130.00	100.00	20.00	25.00	25.00
Pressure	bar	1.01	1.01	1.01	1.01	2.00	1.01
Molar Vapor Fraction		1.00	0.00	1.00	1.00	1.00	0.00
Mass Flows	kmol/hr	8.47E+02	6.32E+03	3.58E+01	3.58E+01	1.70E+03	6.30E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.30E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E+03	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	7.87E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ACETIC	kg/hr	2.35E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	7.51E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CELL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	8.96E+00	0.00E+00	8.96E+00	8.96E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	6.32E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	H2SO4	HCL	MIXTURE	MOLASSES	NH3	OCTANOL	SOLID-1
Temperature	C	25.00	4.00	25.00	25.00	25.00	50.00	25.00
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	1.00	0.00	0.00	1.00	0.00	0.00
Mass Flows	kmol/hr	6.86E+03	1.79E+00	6.55E+04	2.06E+04	8.00E+00	1.73E+03	1.52E+03
GLUCOSE	kg/hr	0.00E+00	0.00E+00	1.02E+03	1.02E+03	0.00E+00	0.00E+00	9.63E+01
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	1.10E+03	1.10E+03	0.00E+00	0.00E+00	9.78E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	7.21E+03	7.21E+03	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	2.75E+02	0.00E+00	5.43E+04	9.42E+03	0.00E+00	1.37E+03	1.16E+03
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CELL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	6.59E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.32E+02
MGO	kg/hr	0.00E+00	0.00E+00	4.63E+02	4.63E+02	0.00E+00	0.00E+00	9.27E+00
CAO	kg/hr	0.00E+00	0.00E+00	4.63E+02	4.63E+02	0.00E+00	0.00E+00	9.27E+00
K2O	kg/hr	0.00E+00	0.00E+00	4.63E+02	4.63E+02	0.00E+00	0.00E+00	9.27E+00
NA2O	kg/hr	0.00E+00	0.00E+00	4.63E+02	4.63E+02	0.00E+00	0.00E+00	9.27E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.64E+02	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	1.79E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	SOLID-2	TMA	TOA	WATER	WATER3	WATER-1	WATER-2
Temperature	C	36.37	25.00	25.00	25.00	25.00	25.00	25.00
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mass Flows	kmol/hr	1.60E+03	2.61E+03	8.09E+02	4.49E+04	1.80E+01	3.58E+03	3.58E+03
GLUCOSE	kg/hr	1.79E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	1.81E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	1.25E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	1.59E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	1.22E+03	1.96E+03	7.04E+02	4.49E+04	1.80E+01	3.58E+03	3.58E+03
SA	kg/hr	1.66E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ACETIC	kg/hr	6.85E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	2.19E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CELL	kg/hr	4.10E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	1.29E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	9.08E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	9.08E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	9.08E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2O	kg/hr	9.08E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	1.05E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	7.81E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	6.52E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Appendix C

Process flow diagram and stream summary of Int. ETOH+SA 25:75

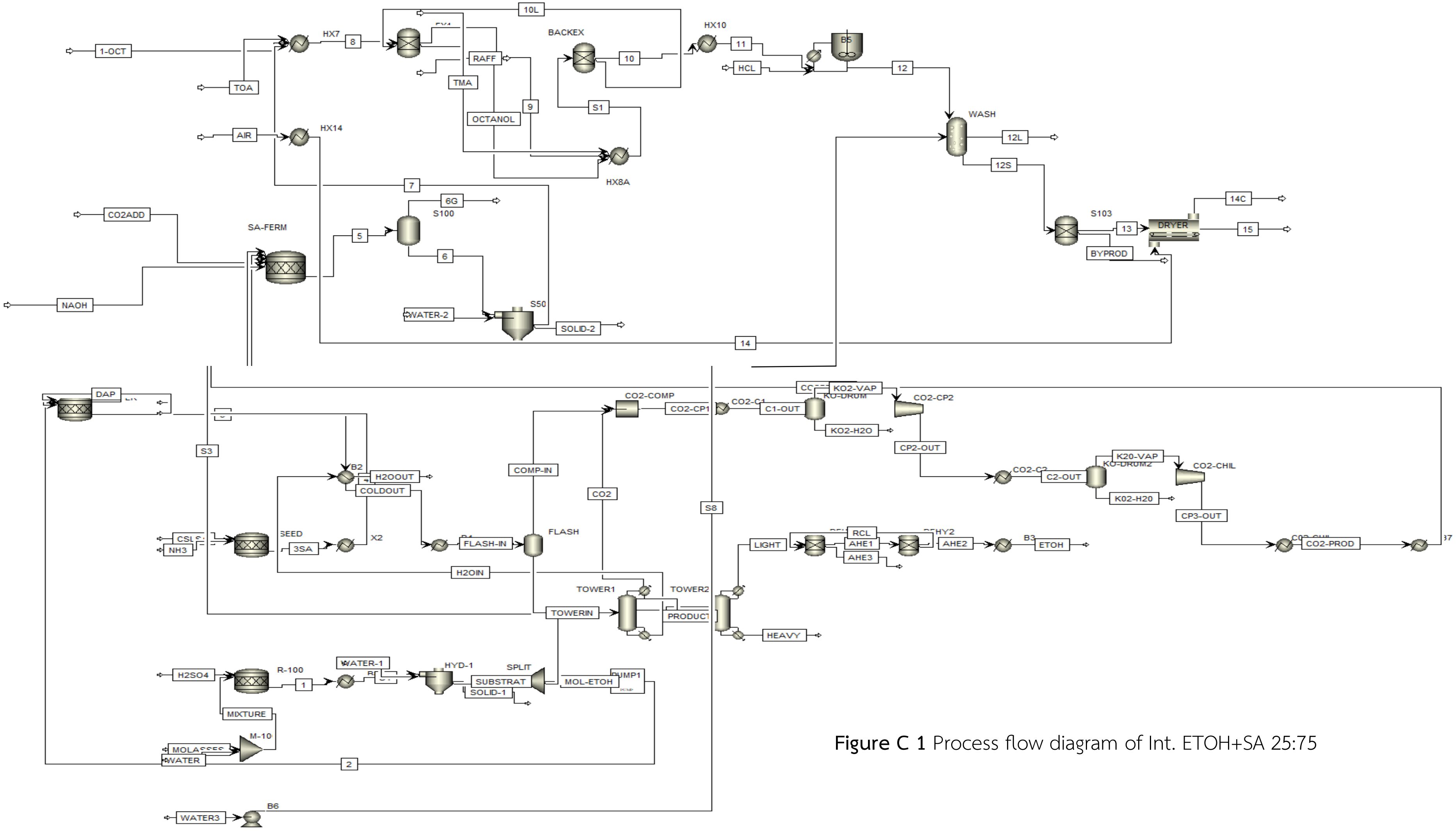

Figure C 1 Process flow diagram of Int. ETOH+SA 25:75

Table C.1 Stream summary for Int. ETOH+SA 25:75 production.

Stream Name	Units	1	1-ต.ค.	2	3	3SA	4
Temperature	C	40.00	25.00	29.94	41.00	40.00	25.00
Pressure	bar	1.01	1.00	5.15	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	2.76E-02	3.60E-01	3.28E-01
Mole Flows	kmol/hr	3.27E+03	2.60E+01	8.38E+02	8.76E+02	1.10E+00	1.10E+00
Mass Flows	kg/hr	7.52E+04	1.87E+03	1.77E+04	1.82E+04	8.10E+01	8.10E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	4.25E+03	0.00E+00	1.04E+03	2.24E+01	6.68E+01	6.68E+01
FRUCTOSE	kg/hr	4.31E+03	0.00E+00	1.06E+03	2.27E+01	0.00E+00	0.00E+00
H2SO4	kg/hr	2.11E+03	0.00E+00	5.17E+02	5.17E+02	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	9.77E+02	4.33E-01	4.33E-01
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.44E+01	4.85E+00	4.85E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.63E+01	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.02E+03	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	8.57E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.49E+00	0.00E+00	0.00E+00
H2O	kg/hr	5.62E+04	2.43E+02	1.46E+04	1.47E+04	1.60E+00	1.60E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.26E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.66E-01	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.45E-01	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.23E+02	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	4.63E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00
CAO	kg/hr	4.63E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00

K2O	kg/hr	4.63E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00
NA2O	kg/hr	4.63E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00
MGSO4	kg/hr	1.37E+03	0.00E+00	6.87E+00	6.87E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	1.62E+03	0.00E+00	8.11E+00	8.11E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	1.99E+03	0.00E+00	9.95E+00	9.95E+00	0.00E+00	0.00E+00
CASO4	kg/hr	1.55E+03	0.00E+00	7.77E+00	7.77E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E+00	7.33E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	1.63E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	5	6	6G	7	8	9
Temperature	C	37.00	37.00	37.00	36.15	50.00	72.91
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		8.77E-04	0.00E+00	1.00E+00	0.00E+00	0.00E+00	2.25E-02
Mole Flows	kmol/hr	2.56E+03	2.56E+03	2.25E+00	2.70E+03	2.76E+03	2.43E+03
Mass Flows	kg/hr	5.45E+04	5.44E+04	9.48E+01	5.67E+04	5.92E+04	1.86E+05
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	6.02E+02	6.02E+02	4.15E-13	5.90E+02	5.90E+02	2.42E+04
FRUCTOSE	kg/hr	5.98E+02	5.98E+02	4.12E-13	5.86E+02	5.86E+02	2.11E+04
H2SO4	kg/hr	1.55E+03	1.55E+03	4.18E-07	1.52E+03	1.52E+03	6.24E+04
CO2	kg/hr	1.38E+02	4.72E+01	9.09E+01	4.63E+01	4.63E+01	1.90E+03
ZYMO	kg/hr	4.85E+00	4.85E+00	0.00E+00	9.69E-02	9.69E-02	3.97E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.87E+00	1.87E+00	1.07E-03	1.83E+00	1.83E+00	7.50E+01
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	1.49E+00	3.22E-02	1.46E+00	3.16E-02	3.16E-02	1.29E+00
H2O	kg/hr	4.43E+04	4.43E+04	2.46E+00	4.70E+04	4.77E+04	6.23E+03
ACETIC	kg/hr	2.29E+02	2.29E+02	7.54E-03	2.24E+02	2.24E+02	9.19E+03
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	6.95E-03	6.94E-03	5.50E-06	6.80E-03	6.80E-03	2.79E-01
1-PROP	kg/hr	1.98E-04	1.98E-04	1.41E-07	1.94E-04	1.94E-04	6.99E-03
METHANOL	kg/hr	1.79E-03	1.79E-03	8.30E-07	1.75E-03	1.75E-03	7.19E-02
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	5.53E+03	5.53E+03	2.71E-07	5.42E+03	5.42E+03	4.84E+03
MGO	kg/hr	3.41E+02	3.41E+02	0.00E+00	3.34E+02	3.34E+02	1.20E+04
CAO	kg/hr	3.41E+02	3.41E+02	0.00E+00	3.34E+02	3.34E+02	1.20E+04
K2O	kg/hr	3.41E+02	3.41E+02	0.00E+00	3.34E+02	3.34E+02	1.37E+04

NA2O	kg/hr	3.41E+02	3.41E+02	0.00E+00	3.34E+02	3.34E+02	1.37E+04
MGSO4	kg/hr	2.06E+01	2.06E+01	0.00E+00	4.12E-01	4.12E-01	1.69E+01
NA2SO4	kg/hr	2.43E+01	2.43E+01	0.00E+00	4.86E-01	4.86E-01	1.99E+01
K2SO4	kg/hr	2.98E+01	2.98E+01	0.00E+00	5.97E-01	5.97E-01	2.45E+01
CASO4	kg/hr	2.33E+01	2.33E+01	0.00E+00	4.66E-01	4.66E-01	1.91E+01
NH3	kg/hr	7.33E+00	7.32E+00	8.85E-03	7.17E+00	7.17E+00	2.94E+02
FORMIC	kg/hr	7.30E+00	7.30E+00	6.38E-04	7.16E+00	7.16E+00	3.29E+02
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.63E+03	2.41E+03
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.95E+01	1.18E+02
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	3.23E+01	3.23E+01	4.17E-81	3.16E+01	3.16E+01	1.45E+03
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E+01

Stream Name	Units	10	10L	11	12	12L	12S
Temperature	C	100.00	100.00	4.00	4.00	4.04	4.04
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		1.84E-01	2.93E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	4.97E+02	2.00E+03	4.97E+02	4.97E+02	5.19E+01	4.46E+02
Mass Flows	kg/hr	1.43E+04	1.70E+05	1.43E+04	1.43E+04	1.12E+03	1.32E+04
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	2.36E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	2.05E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	6.08E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	1.85E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	3.88E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	7.32E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	1.26E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	7.93E+03	2.44E+02	7.93E+03	7.93E+03	8.96E+02	7.06E+03
ACETIC	kg/hr	0.00E+00	8.97E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	2.72E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	6.80E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	7.01E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	4.69E+03	1.41E+02	4.69E+03	2.97E+02	3.34E+01	2.63E+02
MGO	kg/hr	0.00E+00	1.17E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	1.17E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	1.34E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	1.34E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	1.65E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	1.95E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	2.39E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	1.86E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	2.87E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	3.22E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	1.11E+03	1.42E+03	1.11E+03	1.11E+03	1.25E+02	9.88E+02
TOA	kg/hr	5.19E+01	6.60E+01	5.19E+01	5.19E+01	5.84E+00	4.60E+01
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.40E+03	0.00E+00	4.40E+03
NAOH	kg/hr	0.00E+00	1.42E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.79E+00	2.02E-01	1.59E+00
TMA	kg/hr	4.93E+02	1.48E+01	4.93E+02	4.93E+02	5.55E+01	4.37E+02

Stream Name	Units	13	14	14C	15	AHE1	AHE2
Temperature	C	4.04	100.00	100.00	100.00	95.49	95.49
Pressure	bar	1.01	1.01	1.01	1.01	1.52	1.52
Molar Vapor Fraction		0.00E+00	1.00E+00	1.00E+00	0.00E+00	1.00E+00	1.00E+00
Mole Flows	kmol/hr	7.64E+01	1.24E+00	4.04E+01	3.72E+01	1.99E+01	1.98E+01
Mass Flows	kg/hr	5.10E+03	3.58E+01	7.41E+02	4.40E+03	9.16E+02	9.14E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.15E+02	9.14E+02
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	8.96E+00	8.96E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	7.06E+02	0.00E+00	7.06E+02	0.00E+00	7.96E-01	1.59E-03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	2.69E+01	2.69E+01	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	4.40E+03	0.00E+00	0.00E+00	4.40E+03	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	AHE3	AIR	BYPROD	C1-OUT	C2-OUT	CO2
Temperature	C	95.49	20.00	4.04	23.89	21.11	84.22
Pressure	bar	1.52	1.01	1.01	4.83	20.68	1.03
Molar Vapor Fraction		8.80E-04	1.00E+00	0.00E+00	7.25E-01	9.91E-01	1.00E+00
Mole Flows	kmol/hr	2.22E+01	1.24E+00	3.70E+02	3.09E+01	2.24E+01	2.13E+00
Mass Flows	kg/hr	4.03E+02	3.58E+01	8.09E+03	1.20E+03	9.81E+02	6.76E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.39E-11	0.00E+00	6.19E-40
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.44E-11	0.00E+00	1.39E-36
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	5.17E-05	1.00E-12	4.42E-36
CO2	kg/hr	4.53E-01	0.00E+00	0.00E+00	9.77E+02	9.72E+02	1.00E+01
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.81E-66	0.00E+00	2.81E-66
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.83E+00	0.00E+00	0.00E+00	1.03E+02	5.82E+00	3.81E+01
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.60E-06	1.77E-13	4.63E-33
O2	kg/hr	3.22E-06	8.96E+00	0.00E+00	1.49E+00	1.49E+00	8.95E-04
H2O	kg/hr	3.97E+02	0.00E+00	6.35E+03	1.16E+02	1.80E+00	1.92E+01
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	2.77E+00	0.00E+00	0.00E+00	4.90E-01	2.56E-02	1.75E-01
1-PROP	kg/hr	4.08E-01	0.00E+00	0.00E+00	5.81E-02	1.48E-03	2.03E-02
METHANOL	kg/hr	6.86E-01	0.00E+00	0.00E+00	5.95E-02	4.09E-03	2.31E-02
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	6.41E-10	0.00E+00	5.20E-29
SA	kg/hr	0.00E+00	0.00E+00	2.63E+02	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	9.88E+02	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	4.60E+01	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	2.69E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	1.59E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	4.37E+02	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	CO2-CP1	CO2-PROD	CO2ADD	CO2PROD2	COLDOUT	COMP-IN
Temperature	C	192.50	48.54	25.00	25.00	70.30	60.00
Pressure	bar	3.45	68.95	2.00	2.00	1.01	1.03
Molar Vapor Fraction		1.00E+00	1.00E+00	1.00E+00	1.00E+00	4.06E-02	1.00E+00
Mole Flows	kmol/hr	3.09E+01	2.22E+01	4.54E+00	2.22E+01	8.76E+02	2.88E+01
Mass Flows	kg/hr	1.20E+03	9.75E+02	2.00E+02	9.75E+02	1.82E+04	1.13E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	3.39E-11	0.00E+00	0.00E+00	0.00E+00	2.24E+01	3.39E-11
FRUCTOSE	kg/hr	3.44E-11	0.00E+00	0.00E+00	0.00E+00	2.27E+01	3.44E-11
H2SO4	kg/hr	5.17E-05	0.00E+00	0.00E+00	0.00E+00	5.17E+02	5.17E-05
CO2	kg/hr	9.77E+02	9.72E+02	2.00E+02	9.72E+02	9.77E+02	9.67E+02
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.44E+01	0.00E+00
DAP	kg/hr	2.81E-66	0.00E+00	0.00E+00	0.00E+00	4.63E+01	2.14E-79
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.03E+02	1.87E+00	0.00E+00	1.87E+00	1.02E+03	6.46E+01
GLYCEROL	kg/hr	1.60E-06	0.00E+00	0.00E+00	0.00E+00	8.57E+00	1.60E-06
O2	kg/hr	1.49E+00	1.49E+00	0.00E+00	1.49E+00	1.49E+00	1.49E+00
H2O	kg/hr	1.16E+02	4.07E-01	0.00E+00	4.07E-01	1.47E+04	9.70E+01
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	4.90E-01	6.95E-03	0.00E+00	6.95E-03	3.26E+00	3.15E-01
1-PROP	kg/hr	5.81E-02	1.98E-04	0.00E+00	1.98E-04	4.66E-01	3.79E-02
METHANOL	kg/hr	5.95E-02	1.79E-03	0.00E+00	1.79E-03	7.45E-01	3.64E-02
CSL	kg/hr	6.41E-10	0.00E+00	0.00E+00	0.00E+00	4.23E+02	6.41E-10
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E+02	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E+02	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E+02	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.14E+02	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.87E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.11E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.95E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.77E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	CP2-OUT	CP3-OUT	CSL	CSLSA	DAP	ETOH
Temperature	C	243.04	149.88	25.00	25.00	25.00	25.00
Pressure	bar	34.47	68.95	1.01	1.01	1.01	1.01
Molar Vapor Fraction		1.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	2.24E+01	2.22E+01	2.36E+00	4.05E-01	3.55E-01	1.98E+01
Mass Flows	kg/hr	9.81E+02	9.75E+02	4.25E+02	7.30E+01	4.69E+01	9.14E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.30E+01	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	1.00E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	9.72E+02	9.72E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.69E+01	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	5.82E+00	1.87E+00	0.00E+00	0.00E+00	0.00E+00	9.14E+02
GLYCEROL	kg/hr	1.77E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	1.49E+00	1.49E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	1.80E+00	4.07E-01	0.00E+00	0.00E+00	0.00E+00	1.59E-03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	2.56E-02	6.95E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	1.48E-03	1.98E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	4.09E-03	1.79E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	4.25E+02	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	FLASH-IN	H2ODEC	H2OIN	H2OOUT	H2SO4	HCL
Temperature	C	60.00	100.69	100.62	51.01	25.00	4.00
Pressure	bar	1.03	1.03	1.03	1.03	1.01	1.01
Molar Vapor Fraction		3.29E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00
Mole Flows	kmol/hr	8.76E+02	2.27E+00	6.32E+02	6.32E+02	8.24E+01	4.92E-02
Mass Flows	kg/hr	1.82E+04	4.14E+01	1.26E+04	1.26E+04	6.86E+03	1.79E+00
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	2.24E+01	1.35E-02	2.24E+01	2.24E+01	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	2.27E+01	1.37E-02	2.27E+01	2.27E+01	0.00E+00	0.00E+00
H2SO4	kg/hr	5.17E+02	3.13E-01	5.17E+02	5.17E+02	6.59E+03	0.00E+00
CO2	kg/hr	9.77E+02	1.96E-30	6.17E-29	6.17E-29	0.00E+00	0.00E+00
ZYMO	kg/hr	3.44E+01	0.00E+00	3.44E+01	3.44E+01	0.00E+00	0.00E+00
DAP	kg/hr	4.63E+01	2.80E-02	4.63E+01	4.63E+01	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.02E+03	2.74E-19	8.56E-19	8.56E-19	0.00E+00	0.00E+00
GLYCEROL	kg/hr	8.57E+00	5.19E-03	8.56E+00	8.56E+00	0.00E+00	0.00E+00
O2	kg/hr	1.49E+00	2.12E-25	1.99E-29	1.99E-29	0.00E+00	0.00E+00
H2O	kg/hr	1.47E+04	4.08E+01	1.11E+04	1.11E+04	2.75E+02	0.00E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	3.26E+00	5.91E-31	3.74E-29	3.74E-29	0.00E+00	0.00E+00
1-PROP	kg/hr	4.66E-01	1.04E-27	9.99E-20	9.99E-20	0.00E+00	0.00E+00
METHANOL	kg/hr	7.45E-01	6.43E-19	3.52E-18	3.52E-18	0.00E+00	0.00E+00
CSL	kg/hr	4.23E+02	2.56E-01	4.23E+02	4.23E+02	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	1.14E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00
CAO	kg/hr	1.14E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00
K2O	kg/hr	1.14E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00

NA2O	kg/hr	1.14E+02	0.00E+00	1.14E+02	1.14E+02	0.00E+00	0.00E+00
MGSO4	kg/hr	6.87E+00	0.00E+00	6.87E+00	6.87E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	8.11E+00	0.00E+00	8.11E+00	8.11E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	9.95E+00	0.00E+00	9.95E+00	9.95E+00	0.00E+00	0.00E+00
CASO4	kg/hr	7.77E+00	0.00E+00	7.77E+00	7.77E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.79E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	HEAVY	K02-H20	K20-VAP	KO2-H2O	KO2-VAP	LIGHT
Temperature	C	81.68	23.89	23.89	21.11	21.11	68.45
Pressure	bar	0.51	20.68	20.68	4.83	4.83	0.51
Molar Vapor Fraction		0.00E+00	0.00E+00	1.00E+00	0.00E+00	1.00E+00	1.00E+00
Mole Flows	kmol/hr	1.71E+02	1.80E-01	2.22E+01	8.57E+00	2.24E+01	4.20E+01
Mass Flows	kg/hr	3.08E+03	6.08E+00	9.75E+02	2.16E+02	9.81E+02	1.32E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	1.35E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.95E-108
FRUCTOSE	kg/hr	1.37E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.01E-108
H2SO4	kg/hr	3.13E-01	0.00E+00	0.00E+00	5.17E-05	1.00E-12	3.69E-55
CO2	kg/hr	1.55E-197	7.16E-01	9.72E+02	4.40E+00	9.72E+02	4.53E-01
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	2.80E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.32E-40	3.95E+00	1.87E+00	9.69E+01	5.82E+00	9.15E+02
GLYCEROL	kg/hr	5.19E-03	0.00E+00	0.00E+00	1.60E-06	1.77E-13	3.38E-55
O2	kg/hr	6.42E-267	7.29E-05	1.49E+00	3.40E-04	1.49E+00	3.22E-06
H2O	kg/hr	3.08E+03	1.40E+00	4.07E-01	1.14E+02	1.80E+00	3.97E+02
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	3.55E-59	1.87E-02	6.95E-03	4.65E-01	2.56E-02	2.77E+00
1-PROP	kg/hr	9.40E-55	1.28E-03	1.98E-04	5.66E-02	1.48E-03	4.08E-01
METHANOL	kg/hr	3.89E-34	2.30E-03	1.79E-03	5.54E-02	4.09E-03	6.86E-01
CSL	kg/hr	2.56E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.48E-107
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	MIXTURE	MOL-ETOH	MOLASSES	NAOH	NH3	OCTANOL
Temperature	C	25.00	29.72	25.00	20.00	25.00	50.00
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E+00	0.00E+00
Mole Flows	kmol/hr	3.18E+03	8.38E+02	6.91E+02	8.07E-01	4.70E-01	2.70E+01
Mass Flows	kg/hr	6.84E+04	1.77E+04	2.35E+04	3.23E+01	8.00E+00	5.94E+02
SUCROSE	kg/hr	6.38E+03	0.00E+00	6.38E+03	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	8.86E+02	1.04E+03	8.86E+02	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	9.47E+02	1.06E+03	9.47E+02	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	5.17E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	5.54E+04	1.46E+04	1.05E+04	0.00E+00	0.00E+00	4.69E+02
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	9.23E+02	1.14E+02	9.23E+02	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	1.10E+03	1.14E+02	1.10E+03	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	1.54E+03	1.14E+02	1.54E+03	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	1.17E+03	1.14E+02	1.17E+03	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	6.87E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	8.11E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	9.95E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	7.77E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E+02
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.23E+01	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	PRODUCT	RAFF	RCL	S1	S3	S4
Temperature	C	84.22	72.91	95.49	100.00	29.72	30.00
Pressure	bar	1.03	1.01	1.52	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	9.61E-01	3.36E-02	0.00E+00	0.00E+00
Mole Flows	kmol/hr	2.11E+02	2.33E+03	8.37E-02	2.55E+03	2.51E+03	3.27E+03
Mass Flows	kg/hr	4.35E+03	4.31E+04	2.62E+00	1.89E+05	5.32E+04	7.52E+04
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	3.79E-29	0.00E+00	0.00E+00	2.42E+04	3.12E+03	4.25E+03
FRUCTOSE	kg/hr	8.50E-26	0.00E+00	0.00E+00	2.11E+04	3.17E+03	4.31E+03
H2SO4	kg/hr	2.07E-29	0.00E+00	0.00E+00	6.24E+04	1.55E+03	2.11E+03
CO2	kg/hr	4.53E-01	0.00E+00	0.00E+00	1.90E+03	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.97E+00	0.00E+00	0.00E+00
DAP	kg/hr	2.78E-29	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	9.15E+02	0.00E+00	1.83E+00	7.50E+01	0.00E+00	0.00E+00
GLYCEROL	kg/hr	1.52E-26	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	3.22E-06	0.00E+00	0.00E+00	1.29E+00	0.00E+00	0.00E+00
H2O	kg/hr	3.43E+03	4.17E+04	7.93E-01	8.18E+03	4.39E+04	5.62E+04
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	9.19E+03	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	2.77E+00	0.00E+00	0.00E+00	2.79E-01	0.00E+00	0.00E+00
1-PROP	kg/hr	4.08E-01	0.00E+00	0.00E+00	6.99E-03	0.00E+00	0.00E+00
METHANOL	kg/hr	6.86E-01	0.00E+00	0.00E+00	7.19E-02	0.00E+00	0.00E+00
CSL	kg/hr	3.19E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	7.23E+02	0.00E+00	4.84E+03	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.20E+04	3.41E+02	4.63E+02
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.20E+04	3.41E+02	4.63E+02
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.37E+04	3.41E+02	4.63E+02

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.37E+04	3.41E+02	4.63E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.69E+01	2.06E+01	1.37E+03
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.99E+01	2.43E+01	1.62E+03
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.45E+01	2.98E+01	1.99E+03
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.91E+01	2.33E+01	1.55E+03
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.94E+02	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.29E+02	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	6.39E+02	0.00E+00	2.53E+03	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	1.76E+01	0.00E+00	1.18E+02	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.45E+03	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	5.08E+02	0.00E+00	0.00E+00

Stream Name	Units	S8	SOLID-1	SOLID-2	SUBSTRAT	TMA	TOA
Temperature	C	25.26	29.72	36.15	29.72	25.00	25.00
Pressure	bar	4.14	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	1.00E+00	1.13E+02	5.61E+01	3.35E+03	9.05E+01	2.60E+01
Mass Flows	kg/hr	1.80E+01	7.85E+03	1.26E+03	7.10E+04	1.97E+03	5.34E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	8.49E+01	1.20E+01	4.16E+03	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	8.61E+01	1.20E+01	4.22E+03	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	4.22E+01	3.10E+01	2.07E+03	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	9.45E-01	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	4.75E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	3.73E-02	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	6.44E-04	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	1.80E+01	1.20E+03	9.59E+02	5.86E+04	1.48E+03	4.65E+02
ACETIC	kg/hr	0.00E+00	0.00E+00	4.57E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	1.39E-04	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	3.96E-06	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	3.58E-05	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	1.11E+02	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	9.27E+00	6.81E+00	4.54E+02	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	9.27E+00	6.81E+00	4.54E+02	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	9.27E+00	6.81E+00	4.54E+02	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	9.27E+00	6.81E+00	4.54E+02	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	1.35E+03	2.02E+01	2.75E+01	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	1.59E+03	2.38E+01	3.24E+01	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	1.95E+03	2.92E+01	3.98E+01	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	1.52E+03	2.28E+01	3.11E+01	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	1.46E-01	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	1.46E-01	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.95E+01
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	6.45E-01	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.93E+02	0.00E+00

Stream Name	Units	TOWERIN	WATER	WATER3	WATER-1	WATER-2
Temperature	C	60.00	25.00	25.00	25.00	25.00
Pressure	bar	1.03	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	8.47E+02	2.49E+03	1.00E+00	1.99E+02	1.99E+02
Mass Flows	kg/hr	1.71E+04	4.49E+04	1.80E+01	3.58E+03	3.58E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	2.24E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	2.27E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	5.17E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	1.05E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	3.44E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	4.63E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	9.53E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	8.57E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	8.98E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	1.46E+04	4.49E+04	1.80E+01	3.58E+03	3.58E+03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	2.95E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	4.28E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	7.09E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	4.23E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	1.14E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	1.14E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	1.14E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	1.14E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	6.87E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	8.11E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	9.95E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	7.77E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-oct	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Appendix D

Process flow diagram and summary table of Int. ETOH+SA 50:50

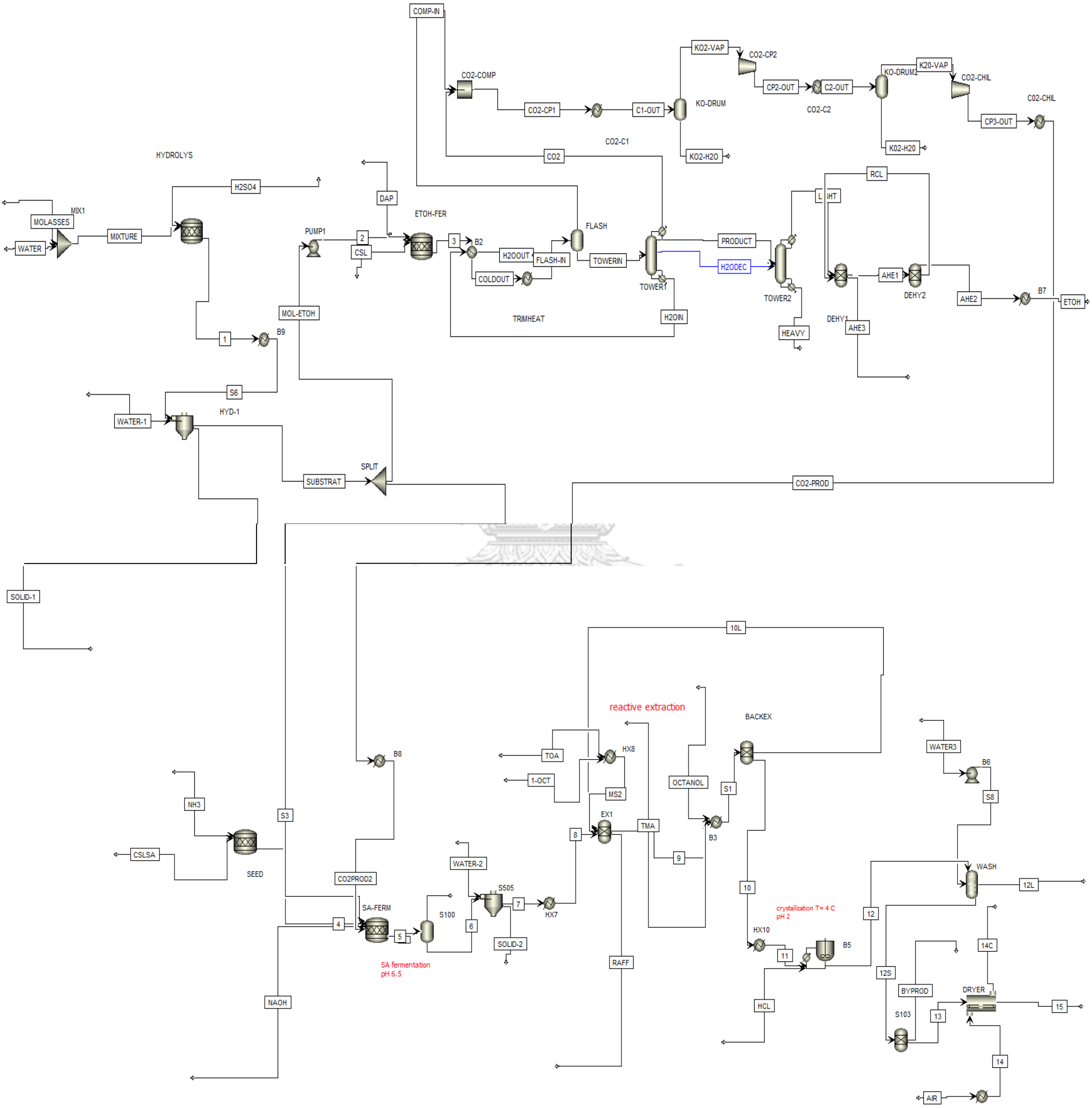

Figure D. 1 Process flow diagram of Int.ETOH+SA 50:50

Table D-1 Stream summary for Int. ETOH+SA 50:50 production

Stream Name	Units	1	1-oct	2	3	4	5
Temperature	C	40.00	25.00	29.91	41.00	30.00	40.00
Pressure	bar	1.01	1.00	5.15	1.01	1.01	1.01
Molar Vapor Fraction		0.00	0.00	0.00	0.03	0.34	0.02
Mole Flows	kmol/hr	3.16E+03	2.02E+01	1.65E+03	1.73E+03	1.10E+00	1.72E+03
Mass Flows	kg/hr	7.24E+04	1.45E+03	3.72E+04	3.77E+04	8.10E+01	3.95E+04
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	4.81E+03	0.00E+00	2.36E+03	5.07E+01	6.68E+01	4.58E+02
FRUCTOSE	kg/hr	4.89E+03	0.00E+00	2.40E+03	5.15E+01	0.00E+00	4.53E+02
H2SO4	kg/hr	6.59E+03	0.00E+00	3.23E+03	3.23E+03	0.00E+00	3.23E+03
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.22E+03	4.33E-01	1.42E+03
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.80E+01	4.85E+00	4.85E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.56E+01	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.31E+03	0.00E+00	4.27E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.94E+01	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.38E+00	0.00E+00	3.38E+00
H2O	kg/hr	5.42E+04	1.89E+02	2.83E+04	2.83E+04	1.60E+00	2.86E+04
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.74E+02
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.40E+00	0.00E+00	1.52E-02
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.06E+00	0.00E+00	4.19E-04
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.69E+00	0.00E+00	4.30E-03
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.21E+02	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.20E+03
MGO	kg/hr	4.63E+02	0.00E+00	2.27E+02	2.27E+02	0.00E+00	2.27E+02
CAO	kg/hr	4.63E+02	0.00E+00	2.27E+02	2.27E+02	0.00E+00	2.27E+02

K2O	kg/hr	4.63E+02	0.00E+00	2.27E+02	2.27E+02	0.00E+00	2.27E+02
NA2O	kg/hr	4.63E+02	0.00E+00	2.27E+02	2.27E+02	0.00E+00	2.27E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E+00	7.33E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.54E+00
1-OCT	kg/hr	0.00E+00	1.26E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E+01
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	6	6G	7	8	9	10
Temperature	C	40.00	40.00	38.46	50.00	50.00	100.00
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	1.00	0.00	0.00	0.00	0.17
Mole Flows	kmol/hr	1.68E+03	3.41E+01	1.84E+03	1.84E+03	5.09E+02	3.50E+02
Mass Flows	kg/hr	3.81E+04	1.44E+03	4.08E+04	4.08E+04	3.09E+04	1.05E+04
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	4.58E+02	1.29E-11	4.49E+02	4.49E+02	1.80E+03	0.00E+00
FRUCTOSE	kg/hr	4.53E+02	1.28E-11	4.44E+02	4.44E+02	1.78E+03	0.00E+00
H2SO4	kg/hr	3.23E+03	2.78E-05	3.16E+03	3.16E+03	1.27E+04	0.00E+00
CO2	kg/hr	2.94E+01	1.39E+03	2.88E+01	2.88E+01	1.15E+02	0.00E+00
ZYMO	kg/hr	4.85E+00	0.00E+00	9.69E-02	9.69E-02	3.88E-01	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	4.21E+00	6.36E-02	4.13E+00	4.13E+00	1.65E+01	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	3.13E-03	3.37E+00	3.06E-03	3.06E-03	1.23E-02	0.00E+00
H2O	kg/hr	2.86E+04	4.30E+01	3.15E+04	3.15E+04	4.17E+03	5.51E+03
ACETIC	kg/hr	1.73E+02	1.54E-01	1.70E+02	1.70E+02	6.80E+02	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	1.49E-02	3.10E-04	1.46E-02	1.46E-02	5.84E-02	0.00E+00
1-PROP	kg/hr	4.11E-04	7.36E-06	4.03E-04	4.03E-04	1.61E-03	0.00E+00
METHANOL	kg/hr	4.24E-03	5.26E-05	4.16E-03	4.16E-03	1.66E-02	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	4.20E+03	6.72E-06	4.11E+03	4.11E+03	3.58E+03	3.58E+03
MGO	kg/hr	2.27E+02	0.00E+00	2.23E+02	2.23E+02	8.90E+02	0.00E+00
CAO	kg/hr	2.27E+02	0.00E+00	2.23E+02	2.23E+02	8.90E+02	0.00E+00
K2O	kg/hr	2.27E+02	0.00E+00	2.23E+02	2.23E+02	8.90E+02	0.00E+00

NA2O	kg/hr	2.27E+02	0.00E+00	2.23E+02	2.23E+02	8.90E+02	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	7.08E+00	2.46E-01	6.94E+00	6.94E+00	2.78E+01	0.00E+00
FORMIC	kg/hr	5.53E+00	1.28E-02	5.42E+00	5.42E+00	2.17E+01	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.23E+03	1.02E+03
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.15E+01	4.02E+01
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	3.23E+01	9.65E-80	3.16E+01	3.16E+01	1.26E+02	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.30E+02

Stream Name	Units	10L	11	12	12L	12S	13
Temperature	C	100.00	4.00	4.00	4.05	4.05	4.05
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.01	0.00	0.00	0.00	0.00	0.00
Mole Flows	kmol/hr	1.83E+02	3.50E+02	3.50E+02	1.84E+01	3.32E+02	5.74E+01
Mass Flows	kg/hr	1.69E+04	1.05E+04	1.05E+04	4.06E+02	1.01E+04	3.89E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	1.35E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	1.33E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	9.49E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	8.63E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	2.91E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.24E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	9.19E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	0.00E+00	5.51E+03	5.51E+03	3.15E+02	5.21E+03	5.21E+02
ACETIC	kg/hr	5.10E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	4.38E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	1.21E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	1.25E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	3.58E+03	2.14E+02	1.22E+01	2.01E+02	0.00E+00
MGO	kg/hr	6.68E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	6.68E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	6.68E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	6.68E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	2.08E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	1.63E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	1.30E+03	1.02E+03	1.02E+03	5.82E+01	9.64E+02	0.00E+00
TOA	kg/hr	5.12E+01	4.02E+01	4.02E+01	2.29E+00	3.80E+01	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	3.36E+03	0.00E+00	3.36E+03	3.36E+03
NAOH	kg/hr	9.48E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	1.79E+00	1.02E-01	1.69E+00	0.00E+00
TMA	kg/hr	0.00E+00	3.30E+02	3.30E+02	1.88E+01	3.12E+02	0.00E+00

Stream Name	Units	14	14C	15	AHE1	AHE2	AHE3
Temperature	C	100.00	100.00	100.00	93.32	93.32	93.32
Pressure	bar	1.00	1.01	1.01	1.52	1.52	1.52
Molar Vapor Fraction		1.00	1.00	0.00	1.00	1.00	0.00
Mole Flows	kmol/hr	1.24E+00	3.02E+01	2.85E+01	4.52E+01	4.51E+01	3.99E+01
Mass Flows	kg/hr	3.58E+01	5.57E+02	3.36E+03	2.08E+03	2.08E+03	7.28E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.03E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.08E+03	2.08E+03	4.17E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	8.96E+00	8.96E+00	0.00E+00	0.00E+00	0.00E+00	7.46E-06
H2O	kg/hr	0.00E+00	5.21E+02	0.00E+00	1.43E+00	2.86E-03	7.14E+02
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.34E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.33E-01
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.55E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	2.69E+01	2.69E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	3.36E+03	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	AIR	BYPROD	C1-OUT	C2-OUT	CO2	CO2-CP1
Temperature	C	25.00	4.05	23.89	23.89	83.30	190.63
Pressure	bar	1.01	1.01	4.83	20.68	1.03	3.45
Molar Vapor Fraction		1.00	0.00	0.74	0.99	1.00	1.00
Mole Flows	kmol/hr	1.24E+00	2.75E+02	6.89E+01	5.08E+01	4.20E+00	6.89E+01
Mass Flows	kg/hr	3.58E+01	6.21E+03	2.69E+03	2.23E+03	1.36E+02	2.69E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	7.37E-11	0.00E+00	1.04E-39	7.37E-11
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	7.49E-11	0.00E+00	1.06E-38	7.49E-11
H2SO4	kg/hr	0.00E+00	0.00E+00	3.33E-04	6.89E-12	7.89E-36	3.33E-04
CO2	kg/hr	0.00E+00	0.00E+00	2.22E+03	2.21E+03	2.07E+01	2.22E+03
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	5.54E-66	0.00E+00	5.54E-66	5.54E-66
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	2.30E+02	1.35E+01	7.85E+01	2.30E+02
GLYCEROL	kg/hr	0.00E+00	0.00E+00	3.87E-06	4.68E-13	1.47E-33	3.87E-06
O2	kg/hr	8.96E+00	0.00E+00	3.38E+00	3.38E+00	1.85E-03	3.38E+00
H2O	kg/hr	0.00E+00	4.69E+03	2.41E+02	4.06E+00	3.63E+01	2.41E+02
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	1.07E+00	5.71E-02	3.51E-01	1.07E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	1.25E-01	3.20E-03	4.04E-02	1.25E-01
METHANOL	kg/hr	0.00E+00	0.00E+00	1.37E-01	9.91E-03	4.89E-02	1.37E-01
CSL	kg/hr	0.00E+00	0.00E+00	6.11E-10	0.00E+00	2.34E-30	6.11E-10
SA	kg/hr	0.00E+00	2.01E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	9.64E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	3.80E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	2.69E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	1.69E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	3.12E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	CO2-PROD	CO2PROD2	COLDOUT	COMP-IN	CP2-OUT	CP3-OUT
Temperature	C	48.58	25.00	69.50	59.00	243.00	149.88
Pressure	bar	68.95	2.00	1.01	1.03	34.47	68.95
Molar Vapor Fraction		1.00	1.00	0.05	1.00	1.00	1.00
Mole Flows	kmol/hr	5.04E+01	5.04E+01	1.73E+03	6.47E+01	5.08E+01	5.04E+01
Mass Flows	kg/hr	2.21E+03	2.21E+03	3.77E+04	2.56E+03	2.23E+03	2.21E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	5.07E+01	7.37E-11	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	5.15E+01	7.49E-11	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	3.23E+03	3.33E-04	6.89E-12	0.00E+00
CO2	kg/hr	2.21E+03	2.21E+03	2.22E+03	2.20E+03	2.21E+03	2.21E+03
ZYMO	kg/hr	0.00E+00	0.00E+00	7.80E+01	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	4.56E+01	2.39E-79	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	4.27E+00	4.27E+00	2.31E+03	1.52E+02	1.35E+01	4.27E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	1.94E+01	3.87E-06	4.68E-13	0.00E+00
O2	kg/hr	3.38E+00	3.38E+00	3.38E+00	3.38E+00	3.38E+00	3.38E+00
H2O	kg/hr	9.15E-01	9.15E-01	2.83E+04	2.05E+02	4.06E+00	9.15E-01
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	1.52E-02	1.52E-02	7.40E+00	7.15E-01	5.71E-02	1.52E-02
1-PROP	kg/hr	4.19E-04	4.19E-04	1.06E+00	8.42E-02	3.20E-03	4.19E-04
METHANOL	kg/hr	4.30E-03	4.30E-03	1.69E+00	8.81E-02	9.91E-03	4.30E-03
CSL	kg/hr	0.00E+00	0.00E+00	4.21E+02	6.11E-10	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	2.27E+02	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	2.27E+02	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	2.27E+02	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	2.27E+02	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	CSL	CSLSA	DAP	ETOH	FLASH-IN	H2ODEC
Temperature	C	20.00	20.00	20.00	25.00	59.00	100.77
Pressure	bar	1.01	1.01	1.01	1.01	1.03	1.03
Molar Vapor Fraction		0.00	0.00	0.00	0.00	0.04	0.00
Mole Flows	kmol/hr	2.36E+00	4.05E-01	3.55E-01	4.51E+01	1.73E+03	2.27E+00
Mass Flows	kg/hr	4.25E+02	7.30E+01	4.69E+01	2.08E+03	3.77E+04	4.18E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	7.30E+01	0.00E+00	0.00E+00	5.07E+01	1.56E-02
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.15E+01	1.58E-02
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.23E+03	9.90E-01
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.22E+03	4.17E-24
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.80E+01	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	4.69E+01	0.00E+00	4.56E+01	1.40E-02
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.08E+03	2.31E+03	3.42E-19
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E+01	5.96E-03
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.38E+00	2.14E-30
H2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.86E-03	2.83E+04	4.07E+01
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.40E+00	6.38E-28
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.06E+00	2.17E-27
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.69E+00	7.33E-19
CSL	kg/hr	4.25E+02	0.00E+00	0.00E+00	0.00E+00	4.21E+02	1.29E-01
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E+02	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E+02	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E+02	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E+02	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	H2OIN	H2OOUT	H2SO4	HCL	HEAVY	K02-H20
Temperature	C	101.10	51.48	25.00	4.00	81.68	23.89
Pressure	bar	1.03	1.03	1.01	1.01	0.51	20.68
Molar Vapor Fraction		0.00	0.00	0.00	1.00	0.00	0.00
Mole Flows	kmol/hr	1.24E+03	1.24E+03	8.24E+01	4.92E-02	3.33E+02	4.14E-01
Mass Flows	kg/hr	2.62E+04	2.62E+04	6.86E+03	1.79E+00	6.00E+03	1.41E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	5.07E+01	5.07E+01	0.00E+00	0.00E+00	1.56E-02	0.00E+00
FRUCTOSE	kg/hr	5.15E+01	5.15E+01	0.00E+00	0.00E+00	1.58E-02	0.00E+00
H2SO4	kg/hr	3.23E+03	3.23E+03	6.59E+03	0.00E+00	9.90E-01	0.00E+00
CO2	kg/hr	2.83E-21	2.83E-21	0.00E+00	0.00E+00	7.31E-63	1.67E+00
ZYMO	kg/hr	7.80E+01	7.80E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	4.56E+01	4.56E+01	0.00E+00	0.00E+00	1.40E-02	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.57E-18	1.57E-18	0.00E+00	0.00E+00	3.62E-11	9.23E+00
GLYCEROL	kg/hr	1.94E+01	1.94E+01	0.00E+00	0.00E+00	5.96E-03	0.00E+00
O2	kg/hr	7.03E-26	7.03E-26	0.00E+00	0.00E+00	3.18E-88	1.71E-04
H2O	kg/hr	2.14E+04	2.14E+04	2.75E+02	0.00E+00	6.00E+03	3.14E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	5.10E-24	5.10E-24	0.00E+00	0.00E+00	1.04E-18	4.19E-02
1-PROP	kg/hr	1.88E-19	1.88E-19	0.00E+00	0.00E+00	6.87E-18	2.78E-03
METHANOL	kg/hr	7.87E-18	7.87E-18	0.00E+00	0.00E+00	2.70E-11	5.61E-03
CSL	kg/hr	4.20E+02	4.20E+02	0.00E+00	0.00E+00	1.29E-01	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	2.27E+02	2.27E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	2.27E+02	2.27E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	2.27E+02	2.27E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	2.27E+02	2.27E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.79E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	KO2-VAP	LIGHT	MIXTURE	MOL-ETOH	MOLASSES	MS2
Temperature	C	21.11	66.56	25.00	29.71	25.00	49.63
Pressure	bar	4.83	0.51	1.01	1.01	1.01	0.01
Molar Vapor Fraction		1.00	1.00	0.00	0.00	0.00	0.92
Mole Flows	kmol/hr	5.08E+01	8.50E+01	3.08E+03	1.65E+03	5.88E+02	4.04E+01
Mass Flows	kg/hr	2.23E+03	2.80E+03	6.55E+04	3.72E+04	2.06E+04	1.87E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	7.21E+03	0.00E+00	7.21E+03	0.00E+00
GLUCOSE	kg/hr	0.00E+00	1.19E-108	1.02E+03	2.36E+03	1.02E+03	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	1.20E-108	1.10E+03	2.40E+03	1.10E+03	0.00E+00
H2SO4	kg/hr	6.89E-12	5.09E-55	0.00E+00	3.23E+03	0.00E+00	0.00E+00
CO2	kg/hr	2.21E+03	1.03E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.35E+01	2.08E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	4.68E-13	2.23E-55	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	3.38E+00	7.46E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	4.06E+00	7.14E+02	5.43E+04	2.83E+04	9.42E+03	5.50E+02
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	5.71E-02	6.34E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	3.20E-03	9.33E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	9.91E-03	1.55E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	9.83E-108	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	4.63E+02	2.27E+02	4.63E+02	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	4.63E+02	2.27E+02	4.63E+02	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	4.63E+02	2.27E+02	4.63E+02	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	4.63E+02	2.27E+02	4.63E+02	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.26E+03
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.39E+01
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	NAOH	NH3	OCTANOL	PRODUCT	RAFF	RCL
Temperature	C	20.00	20.00	50.00	83.30	62.72	93.32
Pressure	bar	1.01	1.01	1.01	1.03	1.01	1.52
Molar Vapor Fraction		0.00	1.00	0.00	0.00	0.00	0.96
Mole Flows	kmol/hr	8.07E-01	4.70E-01	2.00E+01	4.16E+02	1.56E+03	1.69E-01
Mass Flows	kg/hr	3.23E+01	8.00E+00	4.40E+02	8.76E+03	2.88E+04	5.58E+00
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.49E-29	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.57E-28	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.08E-29	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.03E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	5.49E-29	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.08E+03	0.00E+00	4.15E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	5.17E-27	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.46E-06	0.00E+00	0.00E+00
H2O	kg/hr	0.00E+00	0.00E+00	3.48E+02	6.67E+03	2.79E+04	1.43E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	6.34E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	9.33E-01	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.55E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.68E-19	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.35E+02	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	8.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	9.24E+01	0.00E+00	3.33E+02	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.37E+01	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	3.23E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	S1	S3	S6	S8	SOLID-1	SOLID-2
Temperature	C	100.00	29.71	30.00	25.26	29.71	38.46
Pressure	bar	1.01	1.01	1.01	4.14	1.01	1.01
Molar Vapor Fraction		0.02	0.00	0.00	0.00	0.00	0.00
Mole Flows	kmol/hr	5.90E+02	1.65E+03	3.16E+03	1.00E+00	6.72E+01	3.78E+01
Mass Flows	kg/hr	3.26E+04	3.72E+04	7.24E+04	1.80E+01	1.52E+03	8.38E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	1.80E+03	2.36E+03	4.81E+03	0.00E+00	9.63E+01	9.17E+00
FRUCTOSE	kg/hr	1.78E+03	2.40E+03	4.89E+03	0.00E+00	9.78E+01	9.06E+00
H2SO4	kg/hr	1.27E+04	3.23E+03	6.59E+03	0.00E+00	1.32E+02	6.46E+01
CO2	kg/hr	1.15E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.87E-01
ZYMO	kg/hr	3.88E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.75E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.65E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.42E-02
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	1.23E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.25E-05
H2O	kg/hr	5.51E+03	2.83E+04	5.42E+04	1.80E+01	1.16E+03	6.44E+02
ACETIC	kg/hr	6.80E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.47E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	5.84E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-04
1-PROP	kg/hr	1.61E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.23E-06
METHANOL	kg/hr	1.66E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.49E-05
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	3.58E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.39E+01
MGO	kg/hr	8.90E+02	2.27E+02	4.63E+02	0.00E+00	9.27E+00	4.54E+00
CAO	kg/hr	8.90E+02	2.27E+02	4.63E+02	0.00E+00	9.27E+00	4.54E+00
K2O	kg/hr	8.90E+02	2.27E+02	4.63E+02	0.00E+00	9.27E+00	4.54E+00

NA2O	kg/hr	8.90E+02	2.27E+02	4.63E+02	0.00E+00	9.27E+00	4.54E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	2.78E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.42E-01
FORMIC	kg/hr	2.17E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E-01
1-OCT	kg/hr	2.32E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	9.15E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	1.26E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.45E-01
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	3.30E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	SUBSTRAT	TMA	TOA	TOWERIN
Temperature	C	29.71	25.00	25.00	59.00
Pressure	bar	1.01	1.01	1.01	1.03
Molar Vapor Fraction		0.00	0.00	0.00	0.00
Mole Flows	kmol/hr	3.29E+03	6.06E+01	2.02E+01	1.66E+03
Mass Flows	kg/hr	7.44E+04	1.32E+03	4.15E+02	3.51E+04
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	4.72E+03	0.00E+00	0.00E+00	5.07E+01
FRUCTOSE	kg/hr	4.79E+03	0.00E+00	0.00E+00	5.15E+01
H2SO4	kg/hr	6.46E+03	0.00E+00	0.00E+00	3.23E+03
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.17E+01
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	7.80E+01
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.56E+01
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.16E+03
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.94E+01
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.86E-03
H2O	kg/hr	5.66E+04	9.91E+02	3.61E+02	2.81E+04
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	6.69E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	9.73E-01
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.60E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.21E+02
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	4.54E+02	0.00E+00	0.00E+00	2.27E+02
CAO	kg/hr	4.54E+02	0.00E+00	0.00E+00	2.27E+02
K2O	kg/hr	4.54E+02	0.00E+00	0.00E+00	2.27E+02

NA2O	kg/hr	4.54E+02	0.00E+00	0.00E+00	2.27E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	5.39E+01	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	3.30E+02	0.00E+00	0.00E+00

Stream Name	Units	WATER	WATER3	WATER-1	WATER-2
Temperature	C	25.00	25.00	25.00	25.00
Pressure	bar	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00	0.00	0.00	0.00
Mole Flows	kmol/hr	2.49E+03	1.00E+00	1.99E+02	1.99E+02
Mass Flows	kg/hr	4.49E+04	1.80E+01	3.58E+03	3.58E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	4.49E+04	1.80E+01	3.58E+03	3.58E+03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Appendix E

Process flow diagram and stream summary of Int. ETOH+SA 75:25 production.

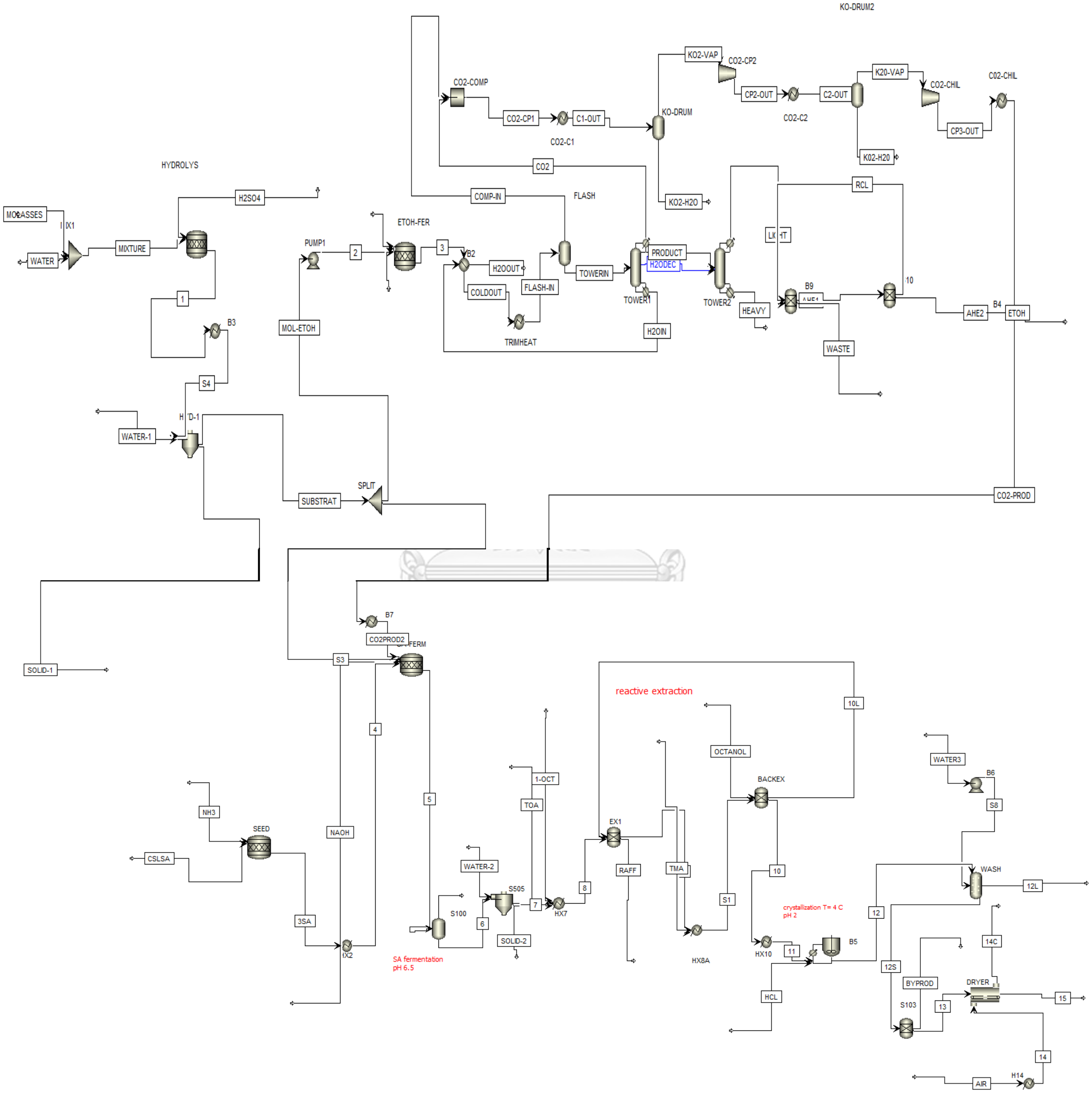

Figure E. 1 Process flow diagram of Int.ETOH+SA 75:25

Table E 1 Stream summary of Int. ETOH+SA 75:25

Stream Name	Units	1	1-oct	2	3	3SA	4
Temperature	C	40.00	25.00	25.18	41.00	30.00	40.00
Pressure	bar	1.01	1.00	5.15	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	3.18E-02	3.41E-01	3.60E-01
Mole Flows	kmol/hr	3.16E+03	2.04E+01	2.47E+03	2.59E+03	1.10E+00	1.10E+00
Mass Flows	kg/hr	7.24E+04	1.47E+03	5.58E+04	5.63E+04	8.10E+01	8.10E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	4.81E+03	0.00E+00	3.54E+03	7.61E+01	6.68E+01	6.68E+01
FRUCTOSE	kg/hr	4.89E+03	0.00E+00	3.59E+03	7.73E+01	0.00E+00	0.00E+00
H2SO4	kg/hr	6.59E+03	0.00E+00	4.84E+03	4.84E+03	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.33E+03	4.33E-01	4.33E-01
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.17E+02	4.85E+00	4.85E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.50E+01	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	3.47E+03	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.92E+01	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	5.07E+00	0.00E+00	0.00E+00
H2O	kg/hr	5.42E+04	1.90E+02	4.25E+04	4.25E+04	1.60E+00	1.60E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.11E+01	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.59E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.54E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.18E+02	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	4.63E+02	0.00E+00	3.41E+02	3.41E+02	0.00E+00	0.00E+00
CAO	kg/hr	4.63E+02	0.00E+00	3.41E+02	3.41E+02	0.00E+00	0.00E+00

K2O	kg/hr	4.63E+02	0.00E+00	3.41E+02	3.41E+02	0.00E+00	0.00E+00
NA2O	kg/hr	4.63E+02	0.00E+00	3.41E+02	3.41E+02	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E+00	7.33E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	1.27E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	5	6	6G	7	8	9
Temperature	C	37.00	37.00	37.00	34.76	50.00	51.55
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		7.71E-02	0.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	9.09E+02	8.39E+02	7.01E+01	1.02E+03	1.05E+03	1.62E+02
Mass Flows	kg/hr	2.20E+04	1.91E+04	2.98E+03	2.22E+04	2.39E+04	6.56E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	2.36E+02	2.36E+02	1.54E-11	2.31E+02	2.31E+02	0.00E+00
FRUCTOSE	kg/hr	2.26E+02	2.26E+02	1.49E-11	2.22E+02	2.22E+02	0.00E+00
H2SO4	kg/hr	1.61E+03	1.61E+03	4.14E-05	1.58E+03	1.58E+03	0.00E+00
CO2	kg/hr	2.91E+03	1.58E+01	2.89E+03	1.55E+01	1.55E+01	0.00E+00
ZYMO	kg/hr	4.85E+00	4.85E+00	0.00E+00	9.69E-02	9.69E-02	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	6.40E+00	6.08E+00	3.18E-01	5.96E+00	5.96E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	5.07E+00	1.18E-03	5.06E+00	1.16E-03	1.16E-03	0.00E+00
H2O	kg/hr	1.43E+04	1.42E+04	7.52E+01	1.75E+04	1.78E+04	2.32E+03
ACETIC	kg/hr	8.80E+01	8.77E+01	2.76E-01	8.60E+01	8.60E+01	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	2.29E-02	2.14E-02	1.51E-03	2.09E-02	2.09E-02	0.00E+00
1-PROP	kg/hr	6.32E-04	5.96E-04	3.65E-05	5.84E-04	5.84E-04	0.00E+00
METHANOL	kg/hr	6.40E-03	6.14E-03	2.67E-04	6.01E-03	6.01E-03	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	2.13E+03	2.13E+03	9.92E-06	2.09E+03	2.09E+03	1.81E+03
MGO	kg/hr	1.14E+02	1.14E+02	0.00E+00	1.11E+02	1.11E+02	0.00E+00
CAO	kg/hr	1.14E+02	1.14E+02	0.00E+00	1.11E+02	1.11E+02	0.00E+00

K2O	kg/hr	1.14E+02	1.14E+02	0.00E+00	1.11E+02	1.11E+02	0.00E+00
NA2O	kg/hr	1.14E+02	1.14E+02	0.00E+00	1.11E+02	1.11E+02	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	7.33E+00	6.55E+00	7.82E-01	6.42E+00	6.42E+00	0.00E+00
FORMIC	kg/hr	2.81E+00	2.79E+00	2.32E-02	2.73E+00	2.73E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.27E+03	2.21E+03
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.73E+01	2.19E+02
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	3.23E+01	3.23E+01	3.98E-79	3.16E+01	3.16E+01	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	10	10L	11	12	12L	12S
Temperature	C	99.66	99.66	4.00	4.00	4.08	4.08
Pressure	bar	1.01	1.01	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	1.92E+02	1.03E+01	1.92E+02	1.92E+02	4.08E+01	1.53E+02
Mass Flows	kg/hr	6.02E+03	1.49E+03	6.02E+03	6.03E+03	9.93E+02	5.05E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	3.04E+03	0.00E+00	3.04E+03	3.04E+03	6.97E+02	2.36E+03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	1.81E+03	0.00E+00	1.81E+03	1.30E+02	2.97E+01	1.01E+02
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	9.92E+02	1.26E+03	9.92E+02	9.92E+02	2.26E+02	7.66E+02
TOA	kg/hr	1.76E+02	2.24E+02	1.76E+02	1.76E+02	4.01E+01	1.36E+02
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.68E+03	0.00E+00	1.68E+03
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.79E+00	4.08E-01	1.38E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	13	14	14C	15	AHE1	AHE2
Temperature	C	4.08	100.00	100.00	100.00	66.13	66.13
Pressure	bar	1.01	1.01	1.01	1.01	0.51	0.51
Molar Vapor Fraction		0.00E+00	1.00E+00	1.00E+00	0.00E+00	1.00E+00	1.00E+00
Mole Flows	kmol/hr	2.74E+01	1.24E+00	1.44E+01	1.43E+01	4.91E+01	4.89E+01
Mass Flows	kg/hr	1.92E+03	3.58E+01	2.72E+02	1.68E+03	2.26E+03	2.25E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.26E+03	2.25E+03
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	8.96E+00	8.96E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	2.36E+02	0.00E+00	2.36E+02	0.00E+00	1.47E+00	2.94E-03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	2.69E+01	2.69E+01	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	1.68E+03	0.00E+00	0.00E+00	1.68E+03	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	AIR	BYPROD	C1-OUT	C2-OUT	CO2	CO2-CP1
Temperature	C	20.00	4.08	23.89	150.00	83.42	191.65
Pressure	bar	1.01	1.01	4.83	20.68	1.03	3.45
Molar Vapor Fraction		1.00E+00	0.00E+00	7.29E-01	1.00E+00	1.00E+00	1.00E+00
Mole Flows	kmol/hr	1.24E+00	1.25E+02	1.05E+02	7.61E+01	6.29E+00	1.05E+02
Mass Flows	kg/hr	3.58E+01	3.13E+03	4.07E+03	3.34E+03	2.03E+02	4.07E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	1.33E-10	0.00E+00	1.59E-39	1.33E-10
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	1.35E-10	0.00E+00	1.59E-39	1.35E-10
H2SO4	kg/hr	0.00E+00	0.00E+00	5.58E-04	1.10E-11	1.20E-35	5.58E-04
CO2	kg/hr	0.00E+00	0.00E+00	3.32E+03	3.31E+03	3.01E+01	3.32E+03
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	8.31E-66	0.00E+00	8.31E-66	8.31E-66
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	3.60E+02	2.02E+01	1.18E+02	3.60E+02
GLYCEROL	kg/hr	0.00E+00	0.00E+00	6.38E-06	7.30E-13	1.65E-35	6.38E-06
O2	kg/hr	8.96E+00	0.00E+00	5.07E+00	5.07E+00	2.72E-03	5.07E+00
H2O	kg/hr	0.00E+00	2.13E+03	3.81E+02	6.09E+00	5.47E+01	3.81E+02
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	1.67E+00	8.57E-02	5.26E-01	1.67E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	1.96E-01	4.81E-03	6.08E-02	1.96E-01
METHANOL	kg/hr	0.00E+00	0.00E+00	2.14E-01	1.48E-02	7.35E-02	2.14E-01
CSL	kg/hr	0.00E+00	0.00E+00	7.30E-10	9.07E-24	9.03E-30	7.30E-10
SA	kg/hr	0.00E+00	1.01E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	7.66E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	1.36E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	2.69E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	1.38E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	CO2-PROD	CO2PROD2	COLDOUT	COMP-IN	CP2-OUT	CP3-OUT
Temperature	C	48.58	25.00	69.48	60.00	243.01	149.88
Pressure	bar	68.95	2.00	1.01	1.03	34.47	68.95
Molar Vapor Fraction		1.00E+00	1.00E+00	4.59E-02	1.00E+00	1.00E+00	1.00E+00
Mole Flows	kmol/hr	7.55E+01	7.55E+01	2.59E+03	9.84E+01	7.61E+01	7.55E+01
Mass Flows	kg/hr	3.32E+03	3.32E+03	5.63E+04	3.87E+03	3.34E+03	3.32E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	7.61E+01	1.33E-10	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	7.73E+01	1.35E-10	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	4.84E+03	5.58E-04	1.10E-11	0.00E+00
CO2	kg/hr	3.31E+03	3.31E+03	3.33E+03	3.29E+03	3.31E+03	3.31E+03
ZYMO	kg/hr	0.00E+00	0.00E+00	1.17E+02	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	4.50E+01	2.40E-79	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	6.40E+00	6.40E+00	3.47E+03	2.42E+02	2.02E+01	6.40E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	2.92E+01	6.38E-06	7.30E-13	0.00E+00
O2	kg/hr	5.07E+00	5.07E+00	5.07E+00	5.06E+00	5.07E+00	5.07E+00
H2O	kg/hr	1.37E+00	1.37E+00	4.25E+04	3.27E+02	6.09E+00	1.37E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	2.29E-02	2.29E-02	1.11E+01	1.14E+00	8.57E-02	2.29E-02
1-PROP	kg/hr	6.32E-04	6.32E-04	1.59E+00	1.35E-01	4.81E-03	6.32E-04
METHANOL	kg/hr	6.40E-03	6.40E-03	2.54E+00	1.40E-01	1.48E-02	6.40E-03
CSL	kg/hr	0.00E+00	0.00E+00	4.18E+02	7.30E-10	9.07E-24	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	3.41E+02	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	3.41E+02	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	3.41E+02	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	3.41E+02	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	CSL	CSLSA	DAP	ETOH	FLASH-IN	H2ODEC
Temperature	C	25.00	25.00	25.00	25.00	60.00	100.76
Pressure	bar	1.01	1.01	1.01	1.01	1.03	1.03
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.80E-02	0.00E+00
Mole Flows	kmol/hr	2.36E+00	4.05E-01	3.55E-01	4.89E+01	2.59E+03	2.27E+00
Mass Flows	kg/hr	4.25E+02	7.30E+01	4.69E+01	2.25E+03	5.63E+04	4.18E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	7.30E+01	0.00E+00	0.00E+00	7.61E+01	1.56E-02
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.73E+01	1.58E-02
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.84E+03	9.91E-01
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.33E+03	7.77E-24
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.17E+02	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	4.69E+01	0.00E+00	4.50E+01	9.21E-03
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.25E+03	3.47E+03	3.38E-19
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.92E+01	5.97E-03
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.07E+00	2.40E-27
H2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	2.94E-03	4.25E+04	4.07E+01
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+01	9.78E-28
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.59E+00	2.10E-26
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.54E+00	7.30E-19
CSL	kg/hr	4.25E+02	0.00E+00	0.00E+00	0.00E+00	4.18E+02	8.56E-02
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E+02	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E+02	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E+02	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.41E+02	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	H2OIN	H2OOUT	H2SO4	HCL	HEAVY	K02-H20
Temperature	C	101.09	51.46	25.00	4.00	74.90	23.89
Pressure	bar	1.03	1.03	1.01	1.01	0.51	20.68
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	1.00E+00	4.89E-06	0.00E+00
Mole Flows	kmol/hr	1.86E+03	1.86E+03	8.24E+01	4.92E-02	5.35E+02	6.20E-01
Mass Flows	kg/hr	3.90E+04	3.90E+04	6.86E+03	1.79E+00	1.02E+04	2.11E+01
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	7.61E+01	7.61E+01	0.00E+00	0.00E+00	1.56E-02	0.00E+00
FRUCTOSE	kg/hr	7.73E+01	7.73E+01	0.00E+00	0.00E+00	1.58E-02	0.00E+00
H2SO4	kg/hr	4.84E+03	4.84E+03	6.59E+03	0.00E+00	9.91E-01	0.00E+00
CO2	kg/hr	7.96E-21	7.96E-21	0.00E+00	0.00E+00	1.02E-88	2.50E+00
ZYMO	kg/hr	1.17E+02	1.17E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	4.50E+01	4.50E+01	0.00E+00	0.00E+00	9.21E-03	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	2.19E-18	2.19E-18	0.00E+00	0.00E+00	8.49E+02	1.38E+01
GLYCEROL	kg/hr	2.92E+01	2.92E+01	0.00E+00	0.00E+00	5.97E-03	0.00E+00
O2	kg/hr	2.66E-26	2.66E-26	0.00E+00	0.00E+00	6.18E-131	2.56E-04
H2O	kg/hr	3.21E+04	3.21E+04	2.75E+02	0.00E+00	9.31E+03	4.72E+00
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	1.85E-26	1.85E-26	0.00E+00	0.00E+00	2.40E-01	6.28E-02
1-PROP	kg/hr	2.29E-22	2.29E-22	0.00E+00	0.00E+00	2.62E-01	4.18E-03
METHANOL	kg/hr	1.17E-17	1.17E-17	0.00E+00	0.00E+00	8.91E-01	8.35E-03
CSL	kg/hr	4.18E+02	4.18E+02	0.00E+00	0.00E+00	8.56E-02	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	3.41E+02	3.41E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	3.41E+02	3.41E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	3.41E+02	3.41E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	3.41E+02	3.41E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.79E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	K20-VAP	KO2-H2O	KO2-VAP	LIGHT	MIXTURE	MOL-ETOH
Temperature	C	23.89	21.11	21.11	66.14	25.00	25.00
Pressure	bar	20.68	4.83	4.83	0.51	1.01	1.01
Molar Vapor Fraction		1.00E+00	0.00E+00	1.00E+00	1.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	7.55E+01	2.86E+01	7.61E+01	9.00E+01	3.08E+03	2.47E+03
Mass Flows	kg/hr	3.32E+03	7.32E+02	3.34E+03	3.00E+03	6.55E+04	5.58E+04
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.21E+03	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.47E-162	1.02E+03	3.54E+03
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	1.50E-162	1.10E+03	3.59E+03
H2SO4	kg/hr	0.00E+00	5.58E-04	1.10E-11	2.99E-79	0.00E+00	4.84E+03
CO2	kg/hr	3.31E+03	1.54E+01	3.31E+03	1.50E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	6.40E+00	3.40E+02	2.02E+01	2.26E+03	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	6.38E-06	7.30E-13	7.08E-77	0.00E+00	0.00E+00
O2	kg/hr	5.07E+00	1.20E-03	5.07E+00	1.09E-05	0.00E+00	0.00E+00
H2O	kg/hr	1.37E+00	3.75E+02	6.09E+00	7.34E+02	5.43E+04	4.25E+04
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	2.29E-02	1.58E+00	8.57E-02	9.19E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	6.32E-04	1.91E-01	4.81E-03	1.13E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	6.40E-03	1.99E-01	1.48E-02	1.43E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	7.30E-10	9.07E-24	8.09E-162	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.63E+02	3.41E+02
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.63E+02	3.41E+02
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.63E+02	3.41E+02

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.63E+02	3.41E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	MOLASSES	NAOH	NH3	OCTANOL	PRODUCT	RAFF
Temperature	C	25.00	20.00	25.00	50.00	83.42	51.55
Pressure	bar	1.01	1.01	1.01	1.01	1.03	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	1.00E+00	0.00E+00	0.00E+00	4.74E-05
Mole Flows	kmol/hr	5.88E+02	8.07E-01	4.70E-01	1.02E+01	6.23E+02	8.96E+02
Mass Flows	kg/hr	2.06E+04	3.23E+01	8.00E+00	2.25E+02	1.31E+04	1.88E+04
SUCROSE	kg/hr	7.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	1.02E+03	0.00E+00	0.00E+00	0.00E+00	1.12E-28	2.31E+02
FRUCTOSE	kg/hr	1.10E+03	0.00E+00	0.00E+00	0.00E+00	1.12E-28	2.22E+02
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.11E-29	1.58E+03
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+00	1.55E+01
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.69E-02
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.23E-29	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.11E+03	5.96E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.74E-29	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E-05	1.16E-03
H2O	kg/hr	9.42E+03	0.00E+00	0.00E+00	1.78E+02	1.00E+04	1.55E+04
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.60E+01
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.43E+00	2.09E-02
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.39E+00	5.84E-04
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.32E+00	6.01E-03
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.36E-19	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.71E+02
MGO	kg/hr	4.63E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+02
CAO	kg/hr	4.63E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+02
K2O	kg/hr	4.63E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+02

NA2O	kg/hr	4.63E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.11E+02
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	8.00E+00	0.00E+00	0.00E+00	6.42E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.73E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	4.73E+01	0.00E+00	3.30E+02
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.27E+01
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	3.23E+01	0.00E+00	0.00E+00	0.00E+00	3.16E+01
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	RCL	S1	S3	S4	S8	SOLID-1
Temperature	C	66.13	100.00	25.00	25.00	25.26	25.00
Pressure	bar	0.51	1.01	1.01	1.01	4.14	1.01
Molar Vapor Fraction		9.96E-01	3.42E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	1.79E-01	1.92E+02	8.23E+02	3.16E+03	1.00E+00	6.72E+01
Mass Flows	kg/hr	5.98E+00	7.29E+03	1.86E+04	7.24E+04	1.80E+01	1.52E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	1.18E+03	4.81E+03	0.00E+00	9.63E+01
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	1.20E+03	4.89E+03	0.00E+00	9.78E+01
H2SO4	kg/hr	0.00E+00	0.00E+00	1.61E+03	6.59E+03	0.00E+00	1.32E+02
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	4.51E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	1.47E+00	2.86E+03	1.42E+04	5.42E+04	1.80E+01	1.16E+03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	1.81E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	1.14E+02	4.63E+02	0.00E+00	9.27E+00
CAO	kg/hr	0.00E+00	0.00E+00	1.14E+02	4.63E+02	0.00E+00	9.27E+00
K2O	kg/hr	0.00E+00	0.00E+00	1.14E+02	4.63E+02	0.00E+00	9.27E+00

NA2O	kg/hr	0.00E+00	0.00E+00	1.14E+02	4.63E+02	0.00E+00	9.27E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	2.21E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	4.00E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	SOLID-2	SUBSTRAT	TMA	TOA	TOWERIN	WASTE
Temperature	C	34.76	25.00	25.00	25.00	60.00	66.13
Pressure	bar	1.01	1.01	1.01	1.01	1.03	0.51
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.81E-03
Mole Flows	kmol/hr	2.10E+01	3.29E+03	3.07E+01	1.02E+01	2.49E+03	4.11E+01
Mass Flows	kg/hr	4.58E+02	7.44E+04	7.26E+02	2.10E+02	5.24E+04	7.52E+02
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	4.71E+00	4.72E+03	0.00E+00	0.00E+00	7.61E+01	0.00E+00
FRUCTOSE	kg/hr	4.53E+00	4.79E+03	0.00E+00	0.00E+00	7.73E+01	0.00E+00
H2SO4	kg/hr	3.23E+01	6.46E+03	0.00E+00	0.00E+00	4.84E+03	0.00E+00
CO2	kg/hr	3.17E-01	0.00E+00	0.00E+00	0.00E+00	3.16E+01	1.50E+00
ZYMO	kg/hr	4.75E+00	0.00E+00	0.00E+00	0.00E+00	1.17E+02	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.50E+01	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	1.22E-01	0.00E+00	0.00E+00	0.00E+00	3.22E+03	4.52E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.92E+01	0.00E+00
O2	kg/hr	2.36E-05	0.00E+00	0.00E+00	0.00E+00	2.73E-03	1.09E-05
H2O	kg/hr	3.57E+02	5.66E+04	5.44E+02	1.83E+02	4.22E+04	7.34E+02
ACETIC	kg/hr	1.75E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	4.27E-04	0.00E+00	0.00E+00	0.00E+00	9.96E+00	9.19E+00
1-PROP	kg/hr	1.19E-05	0.00E+00	0.00E+00	0.00E+00	1.45E+00	1.13E+00
METHANOL	kg/hr	1.23E-04	0.00E+00	0.00E+00	0.00E+00	2.40E+00	1.43E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.18E+02	0.00E+00
SA	kg/hr	4.26E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	2.27E+00	4.54E+02	0.00E+00	0.00E+00	3.41E+02	0.00E+00
CAO	kg/hr	2.27E+00	4.54E+02	0.00E+00	0.00E+00	3.41E+02	0.00E+00
K2O	kg/hr	2.27E+00	4.54E+02	0.00E+00	0.00E+00	3.41E+02	0.00E+00

NA2O	kg/hr	2.27E+00	4.54E+02	0.00E+00	0.00E+00	3.41E+02	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	1.31E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	5.57E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	1.81E+02	2.73E+01	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	6.45E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Stream Name	Units	WATER	WATER3	WATER-1	WATER-2
Temperature	C	25.00	25.00	25.00	25.00
Pressure	bar	1.01	1.01	1.01	1.01
Molar Vapor Fraction		0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mole Flows	kmol/hr	2.49E+03	1.00E+00	1.99E+02	1.99E+02
Mass Flows	kg/hr	4.49E+04	1.80E+01	3.58E+03	3.58E+03
SUCROSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLUCOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FRUCTOSE	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ZYMO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DAP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
LACACID	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ETHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
GLYCEROL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
O2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
H2O	kg/hr	4.49E+04	1.80E+01	3.58E+03	3.58E+03
ACETIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BUTANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-PROP	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANOL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CSL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CAO	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00

NA2O	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
MGSO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
K2SO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CASO4	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NH3	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORMIC	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1-OCT	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
N2	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SA(S)	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NAOH	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCL	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TMA	kg/hr	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Appendix F

Equipment sizing calculation.

1. Determine volume of fermenter per 1 tank for ethanol production
   - Volumetric flow rate entering fermenter (Qtot) = 1,132.0 L/min
   - Number of tank (N)= 6
   - Residence time = 36 hours

$$\text{V } per\ tank = \frac{Qtot}{Number\ of\ tank} = \frac{1{,}132.0\ L/min}{6} \times 36\ hours \times \frac{60\ min}{1\ hour} = 407.54\ \text{m}^3$$

2. Determine working volume of fermenter.

Based on the geometry characteristics and aspect ratios of ethanol fermenter from Mohammad E. Q. (2016)

- Working volume (Vw) of 1 tank = 75% of the total tank volume

$$Vw = 407.54\ m^3 \times 0.75 = 305.65\ m^3$$

3. **Determine height and diameter of the reactor**
   - Height of reactor (H_R): Diameter of the reactor (D_R) = 3:1
   - Stirred diameter/Impeller Diameter (D_s): Diameter of the reactor (D_R) = 1:3.2
   - Impeller type = Ruston Turbine

$$V_R = \frac{\pi D^2 H}{4}$$

$$2{,}445.22\ \text{m}^3 = \frac{3\pi D^3}{4}$$

$$D_R = 10.53\ m,\ H_R = 31.59\ m.$$

4. **Determine impeller diameter**

$$\frac{D_s}{D_R} = \frac{1}{3.2}$$

$$D_s = \frac{1}{3.2} D_R = 9.\ 87\ \mathrm{m}$$

5. Determine impeller diameter and tank diameter of hydrolysis.

- Geometry characteristic of hydrolysis tank can be determined as the fermenter.
- Using the default aspect ratio HR/DR = 5.4864:1.3716
- The volumetric flow rate = 65.9988 m^3/hr.
- Residence time = 4 hours [31]

6. Dehydration column scale up

- Distillation column adjustment using distillation column's configuration D. G. et al (2007)
- By this distillation set up, it is able to achieve maximum ethanol purity of 72% by weight.
- distillate rate range (180-200 kmol/hr) and reflux ratio = 0.3

7. Dehydration columns scale up calculation

- Determine length (Llab) and diameter (Dlab) of a lab scale reactor from literature reviews.
- Determine volume of lab (Vlab) scale reactor from equation (1)

$$\mathrm{Vlab} = \frac{\pi Dlab^2 \times Llab}{4} \quad (1)$$

8. Determine volume of a large-scale reactor from equation **(2)**

$$Vlarge = Residence\ time\ c \times Volumetric\ flow\ rate\ (Q) \qquad \mathbf{(2)}$$

9. Determine a diameter of reactor in large scale reactor using an aspect ratio (L/D) from lab scale reactor from **(3)**

$$Dlarge = Dlab \times (\frac{Vlarge}{Vlab})^{1/3}$$

(3)

10. Determine a length of the reactor from the aspect ratio of lab scale reactor from equation **(4)**

$$Llarge = \frac{L}{D} \times \mathrm{Dlarge}$$

(4)

11. Determine volume of bed from void fraction (**ε**) and total volume (Vtot) from equation (7)

$$V_{bed} = V_{tot} - V_{void} \qquad (5)$$

$$V_{void} = \varepsilon \times V_{tot} \qquad (6)$$

Substitute (6) into (5) then we will obtain (7)

$$V_{bed} = V_{tot} - \varepsilon \times V_{tot} \qquad (7)$$

$$\therefore \qquad V_{bed} = V_{tot}(1 - \varepsilon)$$

7. Determine the height of bed from equation (8)

$$L_{bed} = {V_b}/{A} \qquad (8)$$

$$A = \frac{\pi D^2}{4}$$

Table F-1 Details regarding equipment of interested in each biochemical production

Scenarios	No. of Seed fermenter	No. hydrolysis reactor	No. of SA fermenter	No. of ethanol fermenter	Dehydration unit details.
Ethanol	-	1	-	6	D=10.35 m, H=31.36 m, Packing height = 18.82 m
Bio-Succinic acid	1	1	26	-	-
1G+SA 25:75	1	1	20	2	D=7.89m, H=23.92m, Packing height = 14.35 m
1G+SA 50:50	1	1	13	3	D = 9.987m, H = 30.26m, Packing height = 18.16m.
1G+SA 75:25	1	1	7	5	D=10.15m, H=30.77m, packing height=18.46m