COST ANALYSIS OF LOCAL BIOPRODUCTS PROCESSING PLANT USING MICROALGAE BIOMASS AS FEEDSTOCK

By

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Abstract

The need to produce bioproducts useful for the human wealth derived from microalgae, such as proteins, lipid and carbohydrates is gaining importance in recent years. In spite of the broad availability of technologies for these kinds of processes there are uncertainties regarding the investment required to build a microalgae processing plant in Puerto Rico. To address this issue, economic analysis for five selected process case scenarios able to produce 222 million pounds of microalgae-derived paste per year were performed. Results indicate that operational costs are predominant in our analysis due primarily to the cost of utilities. In addition, the combination of pond site, dewatering, freeze drying and supercritical CO_2 extraction were the most effective in terms of investment (\$80 million) and operational costs with an annual cost of manufacturing of \$0.65/lb for the microalgae paste.

Resumen

La necesidad de producir bio-productos para el bienestar humano derivados de microalgas como lo son las proteínas, lípidos y carbohidratos ha cobrado importancia en años recientes. A pesar de la amplia disponibilidad de tecnologías para estos tipos de procesos, aún existen incertidumbres respectó a la inversión requerida para construir una planta de procesamiento de microalgas en Puerto Rico. Para atender este asunto se realizó un estudio económico de cinco casos diseñados para la producción de 222 millones de libra de pasta derivada de microalgas. Nuestros resultados indican que los costos operacionales son predominantes para efectos de nuestro estudio debido primeramente al costo de las utilidades. Además, la combinación de una charca, concentración por desaguado, liofilización y extracción de CO₂ supercrítico demostró ser la más efectiva en términos de inversión (\$80 millones) y costos operacionales con un costo de manufactura de \$0.65/lb de pasta de microalgas.

Author Right Declaration

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Dedication

To my parents Manuel García-Rivera and Altagracia Figueroa-Soto for teaching me the importance to culture a moral philosophy, as well as the rewards of being honest and hard-working. Thank you for teaching me to be determined and consistent in accomplishing my goals.

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Nomenclature

Variable or Term	Description	Unit and Dimensions
\$M	Million dollars	1 x 10 ⁶ dollars
Lb	Pound	Pound
Cost	Cost of item in terms of size	\$
Capacity	Capacity of item 'i'. Could be mass or energy	Dimensionless
Ι	Refers to the cost index (Section LR- 6)	Dimensionless
C _{TPI}	Total permanent investment	\$
C _{TCI}	Total Capital investment. Account 15 percent of working capital and 17 percent of general cost over C _{TPI}	\$
C _{p,i}	Purchase cost of item 'í'	\$
fL	Overall factor of Lang	Dimensionless
СОМ	Cost of manufacturing	\$
DMC	Direct manufacturing cost	\$
FMC	Fixed manufacturing cost	\$
GMC	General manufacturing cost	\$
FCI	Fixed capital investment sometimes referred as capital cost	\$
C _{OL} or C_OL	Cost of labors	\$/yr
C _{UT} or C_UT	Cost of utilities	\$/yr
C _{WT} or C_WT	Cost of waste treatment	\$/yr
C _{RM} or C_RM	Cost of raw materials	\$/yr
Ci	Cost of item 'i'	\$
C _p ⁰	Bare cost	\$
Ki	Constants for bare cost calculation	Dimensionless
Fp	Pressure factor	Dimensionless
F _m	Material factor	Dimensionless
N _{np}	Number of employees who work with non particulate equipments	# of workers
Р	Number of employees who work with particulate equipment	# of workers
R	Revenue from sales	\$/yr
A, B and C	Constants to calculate the R value (See Table 17)	See Table 17
t	Income tax rate	Dimensionless

CHAPTER 1: INTRODUCTION

Microalgae culture has been considered by several research groups as a potential renewable resource production activity to generate useful products for mankind. For instance, it has been estimated that 30-70% of the microalgae dry mass can be used to produce a diversity of commercial bioproducts (Sheenan et al., 1998; Brennan et al., 2010a, 2010b; McKendry et al., 2011). These bioproducts are generally composed of proteins, lipids and carbohydrates. Also, microalgae can be used as a potential feedstock in the cosmetic, pharmaceutical, nutraceutical and fuel industries. **Figure 1.1** summarizes an average composition of the bioproducts obtainable from microalgae.

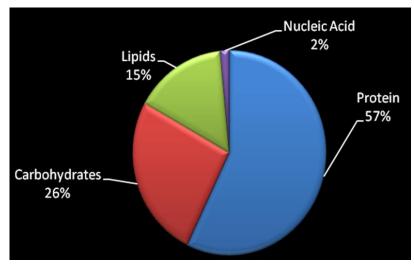


Figure 1.1. Weight composition of microalgae (<u>www.oilalgae.com</u>, 2012).

According to the National Algal Biofuels Technology Roadmap, microalgae technology is attributed to have four main advantages: (1) to produce a high yield of biomass per pond surface area, (2) they can be cultivated in non-arable land, (3) they can be grown in different sources of water, and (4) they can fix CO_2 which is contained at high concentrations in flue emissions from power plants. Finally, microalgae can be used to produce a variety of biofuels and valuable co-products (McKendry et al., 2011).

Moreover, the productivity of microalgae crops for oil production is approximately five times greater than that of palm oil, fifteen times greater than *Jatropha*, and sixty times greater than soybean oil. A representative data is illustrated in **Figure 1.2**.

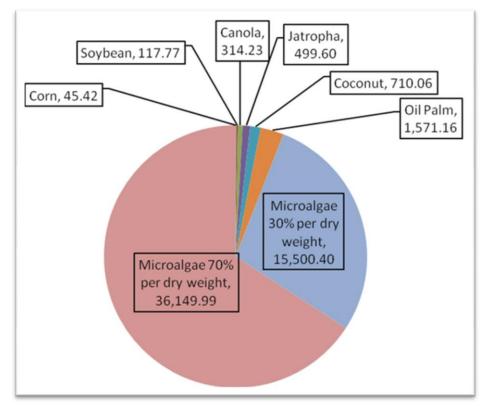


Figure 1.2. United States annual productivity of oil in gallons per hectare using different crops (Chisti et al., 2007).

Several groups believe that the production of biofuel can be obtained using microalgae containing 20% of lipid per dry mass. The bioproducts that are extracted from microalgae also include proteins and carbohydrates that can be used as a potential feedstock to produce high-demand value-added products for the cosmetic, human health, and aquaculture industry (Brennam et al., 2010b).

There are challenges regarding the use of microalgae as feedstock to produce bioproducts. First, there are external factors like potential contamination of bacteria or viruses during the growth stage and even during the harvesting process. Second, steady-state production is still a challenge. Third, there is a need to identify process technologies and schemes that can be implemented and proven to be cost-effective for the culture, harvest, and extraction stages in order to recover high yields of microalgal bio-oil at an industrial scale. An example of the third point is discussed in the article *Algae Plans Bloom* (Bomgardner et al., 2011). In the case of Puerto Rico, an added challenge is to consider local island factors at the time of doing a cost analysis for the production of bioproducts from microalgae.

At present, there are no economic analyses available to accelerate the commercialization of microalgae bioproducts in the island. In response to this, our focus is to perform an economic analysis that would provide a clear understanding

of the investment risks and uncertainties as a potential entrepreneurship activity in Puerto Rico. This analysis takes into account microalgae as a biomass feedstock in order to produce 220 million pounds per year of cell paste, which would contain the main bioproducts: lipids, protein, and carbohydrates. The yearly 220 million pounds of cell paste were fixed considering the local availability of culture land for microalgae. In addition, an estimate of the operational and capital costs to build and operate such process in Puerto Rico has been performed as part of this study.

CHAPTER 2: LITERATURE REVIEW

2.1 - The use of microalgae as a feedstock

Microalgae are photosynthetic micro-scale organisms that can grow in aquatic environments using available carbon sources and solar energy in an effective manner. In principle, microalgae's main distinctions are that they store their pigmentation within their cell wall, they have a simple life cycle and a simple cellular structure. The four classes of microalgae are: diatoms (*Bacillariophyceae*), green algae (*Chlorophyceae*), blue-green algae (*Cianophyceae*) and golden algae (*Chrysophyceae*). The literature confirms that the most abundant species are the diatoms and the green algae (Sheenan et al., 1998). They are also known as a third generation crop given that they are not a food or forest based derivative. Microalgae can be cultivated under autotrophic or heterotrophic conditions and are able to grow either in salt water (~70%) or freshwater (~30%) (Singh et al., 2010).

Research literature shows that microalgae biomass is mainly composed of proteins, lipids and carbohydrates as previously shown in Figure 1.1 (Harun et al., 2010). Moreover, according to the Aquatic Species Program report, microalgae is a potential feedstock to produce the right kind of oil that can be used for the production of fuel (Sheenan et al., 1998). Microalgae have between 30 and 70 percent of bioproduct content; however, several microalgae can reach almost 40 percent of free fatty acids, which are implicitly included in the general matter extracted from the microalgae biomass. This information is consistent with the data of annual oil productivity illustrated in Figure 1.2 (Mata et al., 2010; Ahmad et al., In addition, some authors like Brennan and Ahmad showed that oil 2011). produced from microalgae is richer in carbon content when it is compared to the oil obtained from wood via fast pyrolysis (refer to Figures 2.1.1 and 2.1.2). Most of the properties of biodiesel produced from microalgae are comparable with the properties of biodiesel produced by other different crops, as well as the standardized biodiesel for aviation (Figure 2.1.1). This fact was presented by Ahmad and coworkers in 2011.

Microalgae is not a feedstock that can be exclusively and potentially considered for the production of biodiesel only. Natural properties of the oil produced by microalgae make them suitable to produce other added-value chemical compounds instead of biofuels. Most of these chemicals are of great importance in the pharmaceutical, neutraceutical, human care, and fish food industries. **Figure 2.1.2** shows that oil produced from microalgae have favorable properties when compared with oil obtained from other crops (Brenan et al., 2010a; and Ahmad, et al., 2011). Note that oil coming from microalgae as well as wood

based sources does not contain sulfur, while petroleum oil contains 0.75-1.0 kg sulfur per liter of fuel (Breenan, 2010a, 2010b).

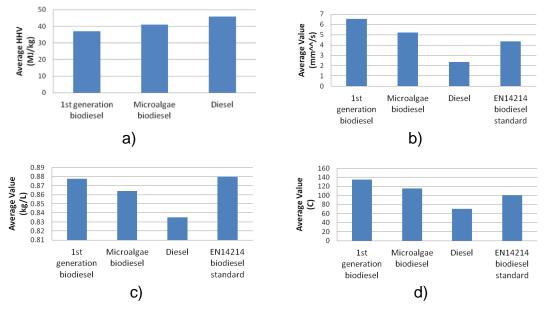


Figure 2.1.1. Physical properties of oil obtained from different crops and standardized biodiesel. a) Average heating value, b) average kinematic viscosity, c) average density, and d) average flash point. (Brennan et al., 2010b).

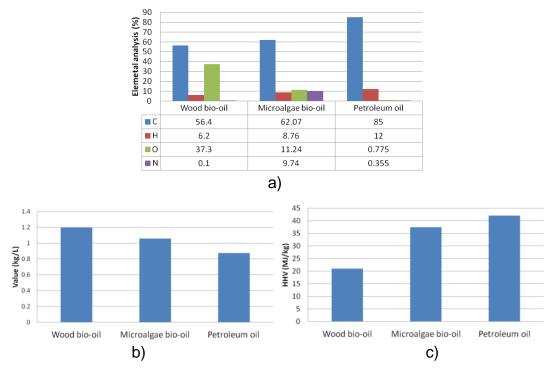


Figure 2.2.2. Properties of oil from different crops. a) Chemical composition analysis, b) density, and c) higher heating value. (Brennan et al., 2010 and Ahmad et al., 2011).

Table 2.1.1 shows common examples of chemicals used for human care, cosmetics, animal nutrition, and neutraceuticals. Among those, high-demand pigments like beta-carotene, docosahexanoic acid (DHA), astaxanthin, lutein, phycocyanin and phycoerythrin can also be obtained (Dufosse et al., 2005).

Microalgae	Annual Production	Application and Product
Spirulina	3000 tons dry weight	Human nutrition Animal nutrition Cosmetics Phycobiliproteins
Clorella	2000 tons dry weight	Human nutrition Cosmetics Aquaculture
Dunaliela salina	1200 tons dry weight	Human nutrition Cosmetics Betacarotene
Aphanizomenon flas- aquae	500 tons dry weight	Human nutrition
Haematococcus pluvialis	300 tons dry weight	Aquaculture Astaxanthin
Cryptecodinium cohnii	240 tons DHA oil	DHA for omega-3-supplement
shizochytrium	10 tons DHA oil	DHA omega-3-supplement

Table 2.1.1. Production by demand of microalgae and derivatives around the world (Brennan et al., 2010b).

In agreement with the aforementioned versatility of algae-based products, the idea of using microalgae as raw material to implement a biorefinery industry producing a variety of multiple products is more attractive than just producing biofuels only. Furthermore, these products can be sold in their raw form as specialty chemicals or raw materials to produce other specialty products. At the same time, the sales of these specialty chemicals would allow the production of other high-demand products, like commodity chemicals to be sold at a reasonable price in the local markets. Consequently, the potential lower costs of other chemicals by implementing the biorefinery approach may result in the development of a economically feasible microalgae-based industry. A general scheme of the potential products that can be obtained using biomass from microalgae is summarized in **Figure 2.1.3** (Singh et al., 2010).

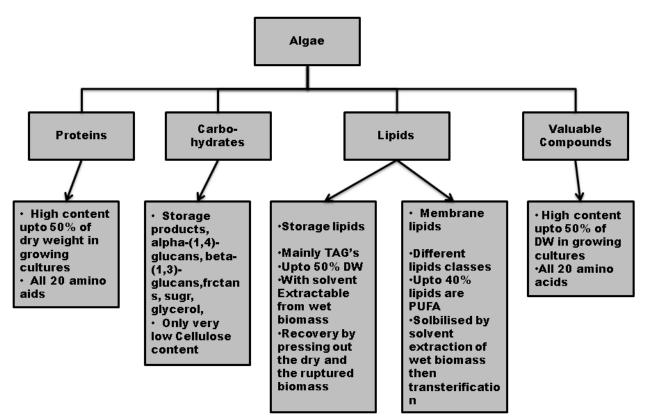


Figure 2.1.3. General potential extracts from microalgae (Singh et al., 2010).

2.2 – Bio-industry from microalgae

One of the earliest efforts of using microalgae as a mass culture was performed by Jorgen Jorgensen and his co-workers in 1968. They patented a procedure that focused on the use of microalgae to produce a wine-like alcoholic beverage via sucrose enzymatic fermentation. Later, Sheehan and co-workers from the National Renewable Energy Laboratories (NREL) prepared a closure report titled "A Look Back at the U.S. Department of Energy's Aquatic Species *Program: Biodiesel from Microalgae*" in 1998. They reported the interesting fact that microalgae have the ability to grow in open ponds using CO₂ under extreme pH and salinity conditions (Sheenan et al., 1998). They suggested three alternatives for the potential use of microalgae: (1) to produce methane via biological or thermal gasification, (2) to produce ethanol via fermentation, and (3) to produce biodiesel via a transesterification reaction.

Even though the report focused on the use of microalgae as a source of alternative and renewable fuels, the interest in using microalgae as a means of producing a new branch of products for the industry of medicine was also discussed. Moreover, the report suggested that building a biotechnology plant to produce non-fuel products as co-products may be more profitable than producing exclusively oil from microalgae. This suggests to conceptualize microalgae processing plants to produce oil as a commodity chemical in addition to generate proteins and carbohydrates as specialty chemicals (Sheenan et al., 1998).

Recently, Singh (2010) proposed the possibility of microalgae as feedstock to produce food supplements and fine chemicals for medicinal purposes and livestock feed. According to the authors, "the main components of a typical algae feedstock are proteins, carbohydrates, lipids, and other valuable components, e.g. pigments, antioxidants, fatty acids, vitamins, etc." This opens an opportunity to explore the possibility of producing biofuels from microalgae on a large-scale basis through a local biorefinery, which can also produce high-demand specialty chemicals (**Figure 2.2.1**).

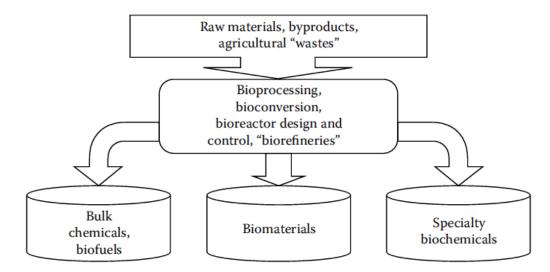


Figure 2.2.1. Biorefinery concept (Patterson et al., 1991; Carotenoids, 2002; Walker et al., 2006; Olivares et al., 2011; <u>www.emergingmarkets.com</u>, 2012).

Figure 2.2.2 shows a general microalgae processing flow diagram. It considers all the possible processes that can be applied to produce biofuels and other bioproducts from microalgae. Although this diagram is very detailed, it is lacking in terms of economical aspects. The reported production rates of oil from microalgae are between ~5,000 gal ac⁻¹ yr⁻¹ and ~38,000 gal ac⁻¹ yr⁻¹. This estimate was obtained based on expected looses, photosynthetic efficiency and other assumptions, like the availability of solar energy consistent with a higher percentage of clear weather conditions and 50% of oil content per microalgae (McKendry et al., 2011).

Moreover, microalgae crops are able to yield between 30% and 70% of lipid content per dry mass. This variability of yields for microalgae is due to the suitability of the selected crop, as well as the nutrients used in the growth process

(see Brennam et al., 2010; Moazami et al., 2011; Araujo et al., 2011; Chiu et al., 2008). There is also the need to consider the advantages and operability challenges of using either ponds or photo-bioreactors to design an adequate growth strategy (Scragg et al., 2011).

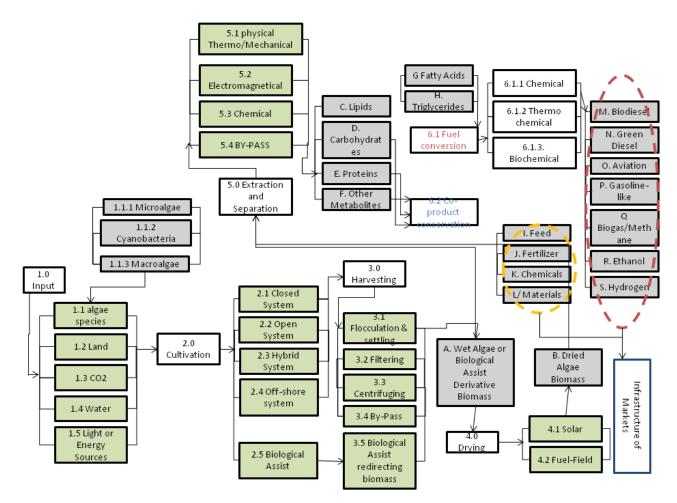


Figure 2.2.2. Multi-process diagram for microalgae processing (McKendry et al., 2011).

2.3 - Growth and harvesting of microalgae

There are several companies around the world dedicated to grow and harvest microalgae. A summary of worldwide distribution of these companies, as well as the main technologies used to grow microalgae are shown in **Figure 2.3.1**.

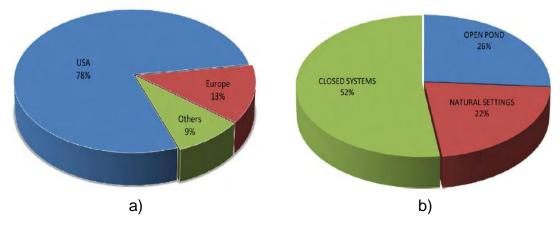


Figure 2.3.1. a) Region wide company distribution and b) technologies used to grow microalgae (Singh et al., 2010).

As shown above, there are two main types of technologies used to grow microalgae: (1) open ponds and (2) photo-bioreactors (closed systems). **Figure 2.3.2** below shows a representative scheme of both technologies: the open ponds (left) and the photo-bioreactors (right).

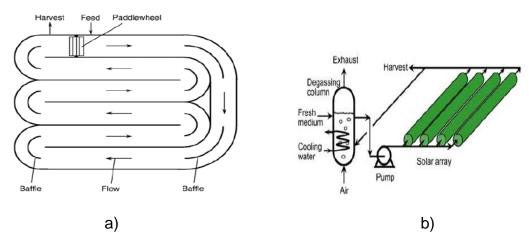


Figure 2.3.2. Schemes of the two main microalgae culture technologies: a) top view of an open pond and b) a photo-bioreactor (Singh et al., 2010).

Table 2.3.1 shows a comparison of open ponds versus photo-bioreactors. For the objectives of this project, the open pond technology will be considered due to various practical reasons: (1) the process technology is better known than the photo-bioreactor technology, (2) its construction and maintenance appears to be more cost attractive, (3) its operation on a large scale can be more easily manipulated, and (4) the technology is very simple, in terms of operation requirements.

Table 2.3.1. Comparison of open ponds versus photo-bioreactors (Harun et al., 2010; Rattanapoltee et al., 2008; Mata et al., 2010; Chisti et al., 2007).

Fact	Open Pond	Photobioreactor
Capital investment	Low	High
Difficult for scale-up	Good	High
Availability of	Available	Not demonstrated for
technology		large scale
Downstream processing	High	Low
cost		
Flexibility to strain	Low	High
selection		
Water use	High	Low

According to published literature, Jiménez and coworkers (2003) used a model to correlate the growth of microalgae as a function of variables such as pH, dissolved oxygen, temperature, media conductivity and solar irradiance. They reported that dissolved oxygen and pH are the main factors that control the microalgae growth. To support this hypothesis, they observed an increment in the inhibition of microalgae when the dissolved oxygen concentration was greater than 25 mg/L (Mendes et al., 2007). Moreover, the annually averaged microalgae growth rate was 8.2 g of dry weight/m²•day, yielding approximately 30 tons of microalgae per hectare per year (Jiménez et al., 2003).

Another empirical model developed by Moreno and coworkers in 2003 showed that sodium can inhibit the anaerobic digestion of microalgae. The study was done using Zarouk as growth media. According to Amaro and coworkers (2011), alkaline conditions promote an accelerated adsorption of CO_2 , which results in two main products depending on two un-catalyzed reaction paths. These paths are: (1) the hydration of CO_2 followed by subsequent acid-base reactions to form HCO_3^- , and (2) the direct reaction of CO_2 with OH^- to form HCO_3^- . The former is important at a pH lower than 8, where the latter is important at a pH higher than 10. Both reactions compete at pH levels between 8 and 10, respectively.

In addition, studies by Amaro and co-workers showed that lipid content and productivity can be inversely correlated to the nitrogen and phosphate deprivation conditions (Amaro et al., 2011). For example, *Chlorellla sp.* is a microalgae that grows in saline media. Its lipid content can be manipulated between 20% and 50% per algae dry mass by manipulating the nitrogen feed in the media (Brennan et al., 2010b; Li et al., 2007; Feng et al., 2005). A possible explanation for these results was offered by Amaro and coworkers. They suggested that insufficient nitrogen

inhibits protein synthesis. Therefore, the excess of carbon that remains in the media is channeled into storage molecules such as triacylglycerols via photosynthesis. Similar results have been found using wastewater as media (Sydney et al., 2011). In summary, the best alternative is to use a species with a higher C/N ratio as the carbon source with the pH between 8 and 10.

Sialve and coworkers (2009) established that the conditions mentioned in the previous paragraph could be employed to obtain microalgae with lipid content of about 40%. Of course, they did not consider the other potential by-products, such as proteins and carbohydrates (**Figure 2.3.3**). Other assumptions included algae steady-state concentration of 0.5 g/L. A factor of 10 for the growth rate was used to determine the initial concentration, $2.5g/m^2$. Three-hundred thirty days were established for the pond operation (Davis et al., 2011). The pond dimensions are 12 m wide x 82 m long x 0.3 m deep per each single pond. The calculated pond area available for crop is approximately 8.5 square miles. This is approximately 67 percent of the total area used by the pond site (12.7 square miles). This estimate takes into account other areas needed by the pond site in terms of facilities, in addition to the 8.5 square miles occupied directly by the ponds.

To harvest microalgae after the growth phase is finished requires technologies capable to deliver dry microalgae to the extraction phase. This is due to the fact that harvest of dry algae can achieve a higher fuel-energy ratio and an improvement of the production of valuable bioproducts (Sarada et al., 2009; Jorquera et al., 2010; Xu et al., 2011). The principal techniques considered for the harvesting of microalgae are centrifugation, flocculation, filtration, sedimentation, flotation, and electrophoresis (Brennam et al. 2011). Chitosan or chitosan-based flocculants show to be effective microalgae flocculation agents with concentrations of 40 ppm at pH levels between 7 and 8 (Davis et al., 2011).

It is important to mention that flocculation technology was seen as one of the most efficient and cost attractive means to process microalgae. In addition to flocculation, the processes of flotation, centrifugation, membrane filtration, dewatering and freeze-drying have been identified as alternatives to processing the final microalgae broth (Li et al., 2007; Brennam et al., 2010a, 2010b; Posten et al., 2009). **Table 2.3.2** summarizes the mainly identified harvesting techniques for microalgae-based processes.

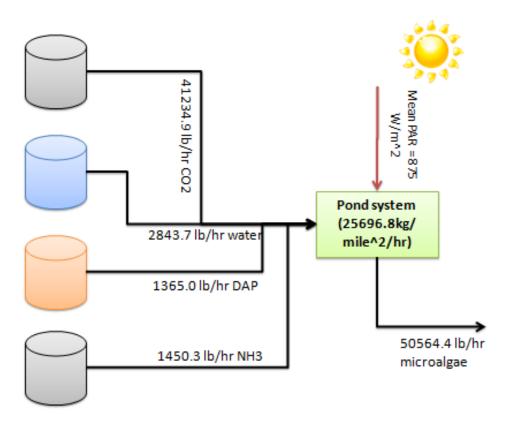


Figure 2.3.3: Propossed formulation and flow diagram to grow microalgae using open pond technology (Chisti et al., 2007; Davis et al, 2011).

Harvesting Technology	Uses or application
Centrifuge	Separation of sugar crystals from
Centinuge	mother liquid, Measure toll of soil
	stress, Removal of soil from drilling
	fluid, Water and wastewater
	treatment, Oil and sand treatment,
	Separation of cream from milk.
Flocculation	Colloidal chemistry, Emulsion
	formation, Separation of clay from
	slurries, Asexual aggregation of
	microorganisms, Cheese
	production, Water treatment from
	suspended particles.
Drying	Food industry, Preparation of
	oilseeds for extraction, Prevention
	of growth of microbial organisms,
	Reduction of volume and weight in
	wood based materials.
Dewatering	Aquifer testing, Groundwater
	drainage, Soil drainage and soil
	pore size control.
Freeze Drying	Drug preservation and production of
	tablets, Food preservation, Late
	state purification procedure in bio-
	separation, Conservation of
	bacterial strains, Recovery of paper
	documentation, Creation of spray
	slurry in ceramic industry.
Membrane Filtration	Dialysis, Concentration of milk to
	make cheese, Desalting and solvent
	exchange of proteins via
	diafiltration, Fractionation of
	proteins, Clarification of fruit juice,
	Recovery of vaccines and
	antibiotics.
	Water treatment and or purification.

Table 2.3.2. Microalgae harvesting technologies.

2.4 - Extraction of oil from microalgae

Herrero and coworkers (2006) presented a conceptual idea on how an oil extraction system from microalgae should be. A summary of different methods that are being contemplated for extraction is shown in **Table 2.4.1**. At the laboratory scale, microwave assisted extraction shows to be an effective technology to extract oil from microalgae (Lee et al., 2010). However, due to the concerns with the control of the microwave technology at a large scale, a solvent extraction strategy promises to be suitable due to the fact that it is a widely used technology at the industrial level. Literature also exposes that the use of a conventional extraction solvent, like hexane, could result in the destruction or degradation of the proteins and carbohydrates of the microalgae. Emergent green solvent technologies, which are able to extract the desired product while preserving the integrity of other constituents should be considered. In that case, supercritical fluid extraction represents an alternative for extracting the oil produced by microalgae.

Table 2.4.1.	Comparison	of differ	ent extrac	tion technolo	gies contemplat	ted to
extract oil from	m microalgae	(Reverce	on et al., 1	997; Mendes	et al., 2007; Si	ngh et
al., 2010; Wai	ng et al., 2011).				

Extraction Method	Advantages	Limitations
Oil press	Easy to use.	Large amount of sample
	No solvent is involved.	is required.
		Time consuming process.
Solvent	Solvent used can be relative	Most of the solvents are
extraction	inexpensive.	flammable or toxic.
	The results are reproducible.	Solvent recovery is
		expensive and energy
		intensive.
		Large volume of solvent
		is needed.
Super-	Results in the non-toxicity or absence	Need sufficient CO ₂ to
critical	of the organic residues in the extracts.	promote the interaction
fluid	The solvent can be considered a green	with the matrix.
extraction	solvent.	Need high pressure for
	Solvents for the operation are non-	operation.
	flammable, as well as of simple	Often fails for quantitative
	management.	extraction technique.
Ultra-	Reduced extraction time and solvent	High power consumption.
sound	consumption.	Difficult to scale-up.
	Greater penetration of the solvent into	
	the cellular materials.	
	Improves the release of cell content	
	into the medium.	

Carbon dioxide supercritical fluid (CO₂-SCF) extraction can be used to extract proteins, lipids and antioxidants from microalgae (Diaz-Reinoso et al., 2007; Wang et al., 2010; Sarada et al., 2011). CO₂-SCF also offers some considerable advantages. First, supercritical fluid extraction can be used instead of traditional organic solvent because it can preserve the extracted by-products. Second, CO₂ has a tunable solvating power, which can be manipulated with pressure and temperature. Third, CO₂ is a low-toxicity solvent and possesses favorable mass transfer rates due to diffusion coefficients in the order around 10^{-8} m²/s under supercritical conditions. Fourth, the viscosity properties between the solute and the solvent can be thermodynamically manipulated after a critical pressure (P_c) of 72.8 bar and a critical temperature (T_c) of 304.2 K. Finally, the resulting extract from microalgae will be free of solvent (Amaro et al., 2011). Below, Table 2.5 shows the variation of the dielectric constant and density of CO₂ as a function of temperature under supercritical condition. In summary, when the pressure is increased, the dielectric constant increases, promoting CO₂ to behave as a polar solvent. The fact that the density of CO₂ increases with temperature shows that CO₂ also behaves as a dense solvent, promoting the extraction of desired products by a forceddiffusion mechanism.

Extraction Pressure (MPa) @ <i>T</i> = 60°C	Density (kg/L)	Dielectric constant
10	0.32	1.17
20	0.73	1.43
30	0.83	1.49

Table 2.4.2. Physical properties of CO_2 when it is used as supercritical solvent (Wisniak et al., 2005; Amaro et al., 2011; Halim et al., 2011).

The principal disadvantages of supercritical fluid extraction are that large scale production demands a lot of energy requirements, and it is not cost-attractive due to the fact that it demands high pressure equipment to maintain the CO_2 in the supercritical dense region (Chan et al., 1995; Alvarez et al., 2009; Cooney et al., 2009). Even so, CO_2 -SCF shows to be more efficient than Soxhlet extraction apparatus with hexane as a solvent that takes almost six times longer to achieve with a comparable lipid yield (Amaro et al., 2011; Cheng et al., 2011; Halim et al., 2011). This observation is also sustained by Palavra and coworkers (2011), who observed that CO_2 at 313 K and 30 MPa can extract chlorophyll, as well as 60% of hydrocarbons, while Soxhlet hexane extraction yields only around 37% hydrocarbons. Improved hydrocarbon yields greater than or equal to 60% can be achieved at higher pressures.

Moreover, an extensive review regarding the evaluation of supercritical fluid has been done starting with the Natex Company from Australia for the 1980's. It has been determined that the pressure charging stage in a batch process at industrial scale should delay around 45 minutes. The total operation time for extraction is assumed to be 180 minutes (3 hours) on a batch run. At an industrial scale, the main evidence of the extraction of oil from matrixes other than microalgae using CO_2 -SCF was separately reported by Rodriguez and co-workers (2010) and Nyam and co-workers (2011). However, Cooney and coworkers showed that a temperature range of 40-50°C and pressures above 379 bars (around 38.4 MPa) are required to efficiently extract oil from microalgae (Cooney et al., 2009).

Other studies by Gamlieli-Bonshtein and coworkers (2002) show that the pressure used to extract most of the oils from microalgae, including the proteins and other by-products is 44.8 MPa and a temperature near to 40°C. This is also supported by other research articles (Macias-Sanchez et al., 2005; Tang et al., 2011; <u>www.natex.com</u>, 2012). Conveniently, the activity ratio carothenoid/chlorophyl was the best at 200 bar and 60°C. Therefore, all valuable compounds can be obtained at pressure of above 40 MPa between 35 and 45°C. **Figure 2.4.1** illustrates a general process scheme for a supercritical fluid extraction system.

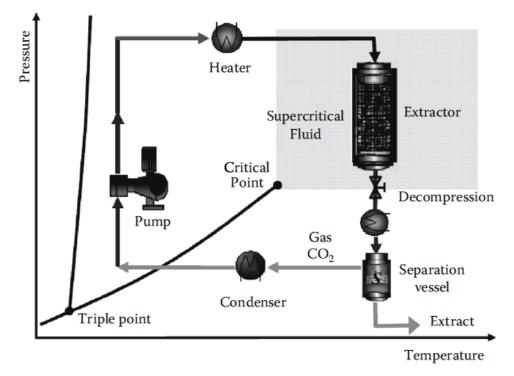


Figure 2.4.1. Operation scheme for supercritical fluid extraction (Mereiles et al, 2008).

Some other alternatives, such as the combination of CO_2 with methanol as a co-solvent and supercritical methanol as a solvent have been proven to achieve a high yield in the oil extraction from microalgae. However, concerns regarding the degradation of valuable by-products such as proteins are still of concern and these alternative solvent approaches need to be further evaluated (Hu et al., 2007; Buit et al., 2011; Liau et al., 2011).

2.5 - Alternative for processing microalgae

Beginning with the use of microalgae to produce alcoholic beverages by Jorgensen, some other researchers claim that microalgae can be used to produce sterols and antioxidants using greener technologies (Patterson, 1991; Rodrigues et al., 2011). Other researchers have proposed that microalgae can be used for CO_2 mitigation and methanation (Jorgensen et al., 1991; Brennen et al., 2010b; Zamalloa et al., 2011). Others, like Khan and coworkers (2009), discussed the composition of microalgae via CO_2 mitigation. Microalgal biomass can be used for either thermochemical or biochemical conversion to energy.

Figure 2.5.1 shows an example of the scheme proposed in the use of microalgae biomass via thermochemical or biochemical conversion. Alternatively, most researchers prefer pyrolysis and catalytic hydrothermal reactions, because their objectives were oriented to using the products for the oil industry (D'Oca et al., 2011; Amin et al., 2009; Biller et al., 2011).

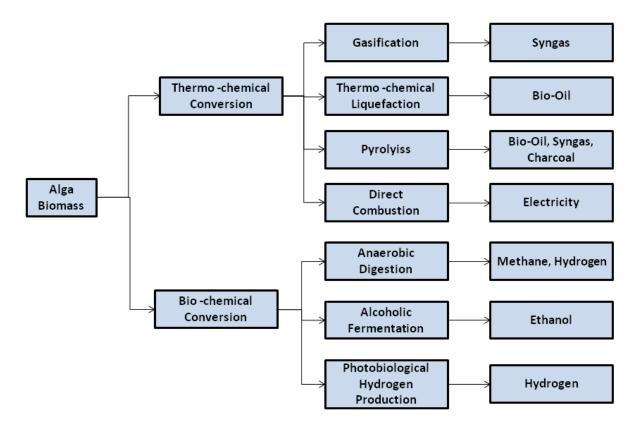


Figure 2.5.1. Summary of techniques available for conversion of microalgae (Brennan et al., 2010a, 2010b).

2.6 - Cost technique used for the analysis

There are different technologies that can be integrated to grow, harvest and extract bioproducts from microalgae. However, an analysis that evaluates how much it will cost to build and operate a microalgae biorefinery plant based in existing technologies and considering local factors remains unrevealed. This uncertainty represents a potential risk that is not acceptable for the investors. In response to this, it is imperative to make an economic analysis based on the evaluation of a preliminary process flow diagram, as well as to take into consideration local cost factors and challenges.

This analysis should involve both operational and capital cost estimates based in the plant layout and unit operations. Accurate capital cost estimates demand detailed equipment cost information. In some cases, the cost value of the units should be adjusted for equipment size, capacity and time (year) as the information is being collected. **Equations 2.6.1** and **2.6.2** are basic relations to make these adjustments. **Equation 2.6.1** is known as the "sixteenths rule." This equation is used to estimate the cost of desired equipment based in capacity. The subscripts 1 and 2 refer to the capacities and costs of the equipment at two scale levels: 1 and 2. The unknown cost of the equipment at its upscale level (for

instance, level 2) can be estimated based on the known capacity and cost of the equipment at level 1. **Equation 2.6.2** is used to update the equipment cost based on the year from which its cost is known. The normal index used to get these estimates is the Marshall & Swift (MS) equipment cost index; where *I*_{base} and *I* are the base cost and the late or actual cost indexes, respectively.

$$\frac{Cost_1}{Cost_2} = \left(\frac{Capacity_2}{Capacity_1}\right)^{0.6}$$
 Eq. 2.6.1

$$Cost = Base Cost \left(\frac{I}{I_{base}}\right)$$
 Eq. 2.6.2

$$\frac{Cost_1}{Cost_2} = \left(\frac{Capacity_2}{Capacity_1}\right)^{0.6} \left(\frac{I}{I_{base}}\right)$$
 Eq. 2.6.3

Equations 2.6.1 and 2.6.2 can be combined in the case that both equipment capacity and year are required for the analysis, obtaining Equation 2.6.3. For the equipment where the cost information is missing but the size/capacity information is available, the base cost estimate is required. The base cost can be estimated using equations available in Appendix B. Table 2.6.1 shows the most frequently used data of cost indexes for each year up to 2011, based in commercial-scale processes. Table 2.6.2 lists the sale price information for different raw materials. It must be pointed out that the equipment cost, as well as the cost index information is substantial to obtain an updated cost estimate. However, the chemical price cost index and labor cost index are two other indexes that should be considered in our cost analysis (Tables 2.6.3 and 2.6.4).

Cost estimates can be complemented in order to fine-tune and release a thorough and confident analysis. An approach to do this is to apply the complementary method. For the purpose of this project, the two methods that will be used for cost analysis will be: (1) the Lang factor method integrated with the set of equations of manufacturing costs (shown in **Equations 3.1** to **3.4** on the Research Methodology) and (2) using a computer-based spreadsheet capital and operational costs (CAPCOST) for the analysis developed by Turton and Seider in 2008.

The Lang factor methodology is used to estimate the amount, as well as the contribution in terms of magnitude of the operational costs versus the capital costs to the production costs of a commercial processing plant. This methodology, also known as the "overall factor method of Lang", developed in 1948 is a tool used to estimate the fixed capital investment of the overall plant. The method requires a plant design diagram, which includes the major equipment with their respective mass and energy balances. The accuracy of the cost estimates will be around plus or minus 35 percent (Seider et al., 2004), depending on the quantity and quality of

the technical information available to construct the process flow diagram. **Equations 2.6.4** and **2.6.5** are used to estimate the fixed capital investment (**FCI**) and total capital investment (**TCI**), respectively.

Table 2.6.1. Cost index for industrial processes (Vatavuk et al., 2002; Turton et al., 2009; Economic Indicators, 2011; Lozowski et al., 2011).

Year	Chemical Engineering Plant Cost Index	Marshall and Swift Equipment Cost Index
1991	361	931
1992	358	943
1993	359	964
1994	368	993
1995	381	1028
1996	382	1039
1997	387	1057
1998	390	1062
1999	391	1068
2000	394	1089
2001	394	1094
2002	396	1104
2003	402	1124
2004	444	1179
2005	468	1245
2006	500	1302
2007	525	1373
2008	575	1449
2009	521	1469
2010	550	1457
2011	580	1520

Table 2.6.2. Sale price of different materials required in the microalgae processing plant (Borowitzka et al., 1992; Sialve et al., 1992; Davis et al., 2011).

Material	Cost (\$/unit	Year
CO2	\$0.02/lb	2011
NH3	\$0.18/lb	2011
Diammonium phosphate (DAP)	\$0.20/lb	2011
Microalgae	\$14.34/lb	2011
Water	\$0.006/lb	2012
Flocculant	\$4.84/lb	2003
Land	\$300/acre/yr	2012

Year	Cost Index		
2002	127.3		
2003	141.7		
2004	162.8		
2005	188.5		
2006	212.4		
2007	226.4		
2008	274.6		
2009	234.1		
2010	269.2		
2011	326.3		

Table 2.6.3. Chemical price cost index (Industrial Chemical Cost index, 2012).

Table 2.6.4. Annual labor cost index (Employment Cost Index, 2012).

Year	Labor Cost Index	Year	Labor Cost Index
1975	26.9	1994	70.2
1976	28.9	1995	72.2
1977	30.9	1996	74.7
1978	33.2	1997	77.6
1979	36.1	1998	80.6
1980	39.4	1999	83.5
1981	42.8	2000	86.7
1982	45.5	2001	90.0
1983	47.8	2002	92.4
1984	49.8	2003	95.2
1985	51.8	2004	97.5
1986	53.5	2005	100.0
1987	55.2	2006	103.2
1988	57.5	2007	106.6
1989	59.9	2008	109.4
1990	62.3	2009	110.8
1991	64.6	2010	112.8
1992	66.3	2011	114.6
1993	68.3		

$$C_{TPI} = 1.05 f_{L_{TPI}} \sum_{i} \left(\frac{I_i}{I_{b_i}}\right) C_{P_i}$$
 Eq. 2.6.4

$$C_{TCI} = 1.05 f_{L_{TCI}} \sum_{i} \left(\frac{I_i}{I_{b_i}}\right) C_{P_i}$$
 Eq. 2.6.5

 C_{TPI} is the total permanent investment, also known as fixed capital investment. C_{TPI} does not take into account the working capital or additional expenses at exception of mount the equipment. However, C_{TCI} is the total capital investment that includes the 15 percent for the working capital used to operate the equipment from the total capital investment or even a 17.6 percent in additional overhead and other expenses to the total permanent investment. The corresponding Lang factors of the above equations are $f_{\text{L TPI}}$ and $f_{\text{L TCI}}$, which are the fixed and the total capital investment Lang factors, respectively. These two factors were obtained based in the original Lang study and were incorporated to the data of fourteen different kinds of chemicals plants.

The CAPCOST analysis can be applied with the purpose to use operational as well as capital cost data to predict the effect of the financing period in the production costs of products at different project time frames. Once the capital and operational costs are obtained, these data can be input to the CAPCOST spreadsheet. CAPCOST then can be used to estimate the effects of the inflation in the production costs of the designed plant at different project time spans that can range from five to twenty years. CAPCOST is also capable to provide estimates of cost data like net present value (NPV), the return of return (ROR), cash flow diagrams, and Monte Carlo analyses (Turton et al., 2009).

The use of these factors depends on the nature of the processing plant (if the plant is designed to process solids, fluids, or a mixture of both), and if the working capital is included or not. **Table 2.6.5** shows the Lang factors corresponding to the mentioned processing plants. *I* is the late cost index or the cost index corresponding to the current year of analysis. I_{base} is the base cost index, which corresponds to the year in which the equipment was purchased. C_p is the purchase cost which excludes the delivery of the equipment to the plant site. This delivery is taken into account by applying a multiplying factor of 1.05 in the **Equations 2.6.1** and **2.6.2**.

	tors of uncrent processes		<i>s</i> .).
Type of Plant	Original Lang factor (working capital not included)	f _{L,TPI} including working capital	f _{L,TCI} including working capital
Solids processing plant	3.10	3.9	4.8
Solids-fluids processing plant	3.63	4.1	4.9
Fluids processing plant	4.74	4.6	5.7

Table 2.6.5. Lang factors of different processes (Seider et al., 2004).

2.7 - Mass and energy balances, equipment size estimation and energy consumption as tools to complement our analysis

In the previous section we mentioned the necessity to have realistic information of the process to perform a reliable economic analysis. The development of a validated process scheme with realistic conditions, as well as mass and energy balances that correspond to each case scenario is mandatory. This task achieved by hand calculations can be tedious in terms of working as well as time-consuming. Process simulators like ASPEN ONE, developed by ASPEN Tech Inc. (http://www.aspentech.com, 2012) can be used to verify the process reliability and operability conditions. In other words, ASPEN ONE can be used as a validation tool for all process units mass and energy balances.

ASPEN ONE can also provide information that can be used to determine other important design requirements, such as equipment size that at the same time will support our economical analysis in terms of scaling-up. Previous researchers have used ASPEN ONE in an efficient manner to simulate the conversion of oil to biodiesel, as well as a supplementary tool to develop a block diagram to estimate costs of production of diesel using microalgae oil (Sanchez et. al., 2011; Davis et al., 2011). Our project incorporated the ASPEN ONE results to sustain and complement our economic analysis in terms of the production of microalgal paste which contains lipids, proteins and carbohydrates.

CHAPTER 3: RESEARCH METHODOLOGY

Five case scenarios were developed in order to consider potential green technologies (**Figure 3.1**). These technologies were mainly considered because they promote the integrity of the extracted protein, lipids, and carbohydrates. **Table 3.1** shows the path of these scenarios that were summarized in terms of unit steps.

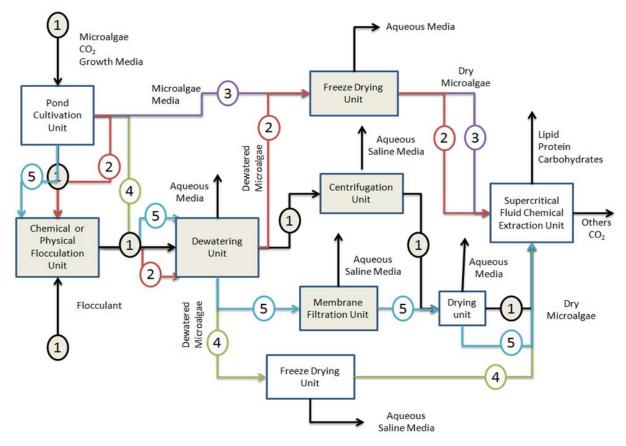


Figure 3.1. Schematic scenario of process diagram for microalgae processing.

All routes in **Figure 3.1** include a pond site to grow the microalgae, as well as a supercritical extraction step to extract the paste from the microalgae. The difference is in the harvesting steps that are between the growth and extraction steps. In Route 1, the microalgae is flocculated and the broth is dewatered. The remaining solid part is centrifuged and conventionally dried before the paste can be extracted. Routes 2 and 5 have the same flocculation and dewatering steps. However, route 2 uses a freeze drying unit to prepare the microalgae, while route 5 uses a combination of membrane filtration followed by a conventional drying unit to prepare the microalgae for the extraction step. Route 4 uses a dewatering unit followed by a freeze drying unit to prepare the microalgae for extraction. Finally, route 3 only uses a freeze drying unit to harvest the microalgae prior to the extraction step.

The reference frameworks provided in **Figure 3.1** were used to generate a mass balance spreadsheet corresponding to the five different possible scenarios using Microsoft Excel 2007 (refer to **Tables 5.1.1 to 5.1.10** of Section 5.1). The generated spreadsheets were used to construct and validate a preliminary process layout for each case scenario using ASPEN ONE. A conversion of microalgae to bulk paste that contains proteins, lipids, and carbohydrates was assumed as 50 percent (according to Sections 2.1 to 2.4). Then, preliminary process flow diagrams for each scenario were obtained (**Figures 5.1.1 to 5.1.5** of Section 5.1). Data gathered from the simulator (**Appendix C**) and balance spreadsheet information were combined to identify appropriate equipment sizes on the plant site (A**ppendix B**), depending on the case scenario.

Case Scenario	Unit Operation Sequence
1	Pond \rightarrow Flocculation \rightarrow Dewatering \rightarrow Centrifugation \rightarrow Drying \rightarrow SC Extraction
2	Pond \rightarrow Flocculation \rightarrow Dewatering \rightarrow Freeze Drying \rightarrow SC Extraction
3	Pond \rightarrow Freeze Drying \rightarrow SC Extraction
4	Pond \rightarrow Dewatering \rightarrow Freeze Drying \rightarrow SC Extraction
5	Pond \rightarrow Flocculation \rightarrow Membrane Filtration \rightarrow Drying \rightarrow SC Extraction

Table 3.1.	Summary of	chosen	scenarios.
------------	------------	--------	------------

Cost of utilities (C_{UT}), labor (C_{OL}), raw materials (C_{RM}), waste treatment (C_{WT}) and fixed capital investment (*FCI*) for plants and ponds were calculated on different basis (see Section 4.1 and 4.2). Cost of manufacture (*COM*) (Equation 3.1), direct manufacturing cost (*DMC*) (Equation 3.2), fixed manufacturing cost (*FMC*) (Equation 3.3), general manufacturing cost (*GMC*) (Equation 3.4), fixed capital investment (*FCI*), working capital (*WC*), and cost of land (C_{Iand}) were calculated and used to obtain the production cost of bulk paste. This was done considering the effect of financing period in the production cost at project terms of: 5, 10, and 20 years. A high-risk annual interest rate of 10% and a taxation of 42% (Hills, 2011) were chosen in conjunction with the Method Accelerated Cost Reduction System (MACRS) (Seider et al., 2004) for the cash flow analysis. The construction period was assumed to be two years. The information was used to feed the CAPCOST economic spreadsheet.

$$COM = 0.180FCI + 2.73C_{OL} + 1.23(C_{UT} + C_{WT} + C_{RM})$$
 Eq. 3.1

$$DMC = C_{RM} + C_{WT} + C_{UT} + 1.33C_{OL} + 0.03COM_d + 0.069FCI$$
 Eq. 3.2

$$FMC = 0.708C_{OL} + 0.068FCI + depreciation$$
 Eq. 3.3

$$GMC = 0.177C_{OL} + 0.009FCI + 0.16COM$$
 Eq. 3.4

Heat duty as well as power data provided by ASPEN Plus and Excel spreadsheet calculations were used to perform the economic analysis. UNIQUAQ was chosen as the thermodynamic model due to its versatility with respect to the analysis of solid and liquid interaction within processing plants. Examples of other calculations that were relevant to support our economic analysis are shown in Sections 4.1 to 4.3. Finally, the preliminary plant site process flow diagrams (**PFD**), are shown in **Figures 5.1.6** to **5.1.10** of Section 5.1. The cost analysis information pertinent to building a facility to produce approximately 222.1 million pounds of bulk paste (depending on the five possible scenarios) in an annual basis is also provided in Sections 5.2, and 5.3.

CHAPTER 4: COST ANALYSIS CALCULATIONS

4.1 - Cost related to open pond construction

According to Welssmen and coworkers in 1987, the total cost to build a pond facility of 192 hectares was approximately \$4,932,147. Based in the information provided in Section 2.3, the area estimated to grow microalgae for a production of 222.1 million of paste is around of 2,207 hectares. Assuming that a microalgae pond site can be considered as a chemical plant and that the cost index of 1987 value should be close to the cost index of 1991 (with a value of 361), the cost of a pond site in year 2011 (with an index of 580) can be estimated using **Equation 2.6.3**:

$$C_{Pond,2011} = \$4,932,147x \left(\frac{2207.2 ha}{192 ha}\right)^{0.6} \left(\frac{580}{361}\right)$$
$$C_{Pond,2011} = \$34,298,821.93$$

The cost of land was calculated on basis of the total required land for site construction, instead of the land needed for pond construction, as expressed in the equations of Section 2.3. According to Davis and coworkers (2011), for each 12.71 square miles used for total operation facilities, 8.52 square miles are needed for multiple ponds in the pond site. From data provided in April 13, 2012 by agronomist Cristian Martes Camacho from the 'Autoridad de Tierras de Puerto Rico' (personal communication), a cost of subsidized land rental was estimated as \$300 per acre per year. The yearly cost of subsidized land rent is estimated as:

$$C_{land,2011} = 2207.2 \ ha \ x \left(\frac{1000 \ acre}{404.86 \ ha}\right) \ x \left(\frac{12.71 \ sqrt \ miles}{8.52 \ sqrt \ miles}\right) \ x \ \$300 \frac{1}{acre \ yr}$$

$$C_{land,2011} = \$2,439,702 \ per \ yr$$

The cost of water was calculated using data taken from Section 2.3. Based on Welssmen for 1987, an equivalent volume capacity of 22,430 ponds of 82 m long, 12 m wide and 0.3 m deep should be used to obtain the desired annual production rate. Taking the cost of water provided in Section 2.6, the cost to fill the pond site with water results in:

$$C_{water,2011} = 12 \ m \ x82 \ m \ x0.3 \ m \ \frac{1}{pond \ yr} \left(\frac{3.787 gal}{1000 \ m^3}\right) 22430.73 \ pond \ \frac{\$0.00525}{gal}$$
$$C_{water,2011} = \$9,140,767 \ per \ year$$

This result was taken into consideration in the working capital calculation. The annual cost of makeup water based in an evaporation rate of 1,200 m³ per day was \$606,814 per year. Cost of DAP, NH_3 , CO_2 and microalgae were estimated using the sales value and the information provided in Section 2.3.

$$C_{DAP,2011} = 1365.02 \frac{lb}{hr} x \frac{24 x 365.25 hr}{yr} x \frac{\$0.20}{lb}$$

$$C_{DAP,2011} = \$2,399,009 \text{ per year}$$

$$C_{NH3,2011} = 1450.33 \frac{lb}{hr} x \frac{24 x 365.25 hr}{yr} x \frac{\$0.18}{lb}$$

$$C_{NH3,2011} = \$2,347,108 \text{ per year}$$

$$C_{CO2,2011} = 41234.88 \frac{lb}{yr} x \frac{24 x 365.25hr}{yr} x \frac{\$0.02}{lb}$$

$$C_{CO2,2011} = \$6,558,378 \text{ per year}$$

 $C_{microalgae,2011} = 121,800.3 \frac{lb}{yr} x \frac{\$14.34}{lb}$

$$C_{microalgae,2011} =$$
\$1,747,020 per year

According to the information from Section 2.3, the amount of CO₂, NH₃ and DAP were assumed as being totally consumed. Adding the cost of the land, makeup water, CO₂, NH₃, DAP, and initial microalgae culture costs for raw materials consumption, C_{RM} , is equal to \$16,098,032 per year. The cost of waste treatment, C_{WT} , was assumed \$0 per year in the pond site because we are not disposing any material from over there. The cost of utilities was calculated based on the pond's paddle wheels energy consumption. Welssmen in 1987 established that a pond area of 192 hectares demands 24 paddle wheels. Each paddle wheel has 0.42 of efficiency that results in a shaft power requirement of 8.28 kW. In our case, we need approximately 276 paddle wheels. Assuming that the paddles are operated during the whole year, then a total of 20,021,907 kW-hr per year is required. In Puerto Rico, the electricity cost is around \$0.24/kW-hr for the industrial sector. Therefore, the cost of utilities consumed by the pond (C_{UT}) is around \$4,813,647 per year.

Costs of labor were estimated using the data from **Table 4.1.1** and adjusted to the actual salaries and pond area. For the objectives of this project, all the facility workers were counted as operating labors.

Table 4.1.1. Itemization of cost salary work in a 1,000 acre pond site.

Position Title	Quantity	Time (hrs)	N \$/hr	loney \$/yr
Plant Manager	1	2080	25	52000
Shift Supervisor	4	2080	17	35360
Pond Operators	10	2080	10	20800
Centrifuge Operators	5	2080	12	24960
Laboratory Manager	1	2080	17	35360
Laboratory Technicians	2	2080	10	20800
Total (\$)				603200

$$C_{OL,2011} = \frac{\$603,200}{yr} x \left(\frac{2207.18 ha}{404.86 ha}\right) x \left(\frac{114.6}{55.2}\right)$$

 $C_{OL,2011} =$ \$6,827,167.59 per year

Note that the pond construction costs were used in **Equations 3.1** to **3.4** to calculate *COM*, *DMC*, *FMC*, and *GMC*. All of these calculations are summarized in **Table 4.1.2** below.

ltem	Cost (\$)
COM (\$/yr)	50,533,321
DMC	33,874,430
DMC (%)	67.0
FMC	7,165,955
FMC (%)	14.18065243
GMC	9,602,429
GMC (%)	19.0

4.2 - Cost related to plant construction

Most of the calculations corresponding to this section were done using **Equation 2.6.3** from section 2.6. Tables were constructed to estimate the cost of the equipment or unit operations (**Appendix B**). For example, the shaft power required for a pumping system, P-103, of Case 1 was estimated as 234.78 kW.

This value exceeds 200 kW, which is the maximum shaft power allowed by the equation of bare/basis cost (**Equation 4.2.1**).

 C_p^0 is the bare cost in dollars at standard pressure and temperature conditions; **A** is the attribute (200 kW) of the system; and K_1 , K_2 , and K_3 are the constants relative to the chosen equipment. P-103 was analyzed as a centrifugal pump with K_1 , K_2 , and K_3 equal to 3.3892, 0.0536, and 0.1538, respectively, resulting in a bare cost of \$21,226 per pump.

$$C_p^0 = 10^{(K_1 + K_2 \log_{10}(A) + K_3 (\log_{10}(A))^2)}$$
 Eq. 4.2.1

For this case, the pressure factor F_p and the material factor F_m were set equal to 1. Therefore, the purchase cost in the year 2001 was:

$$C_{p,2001} = C_p^0 x F_p x F_m$$
$$C_{p,2001} = \$21,226 x 1 x 1 = \$21,226$$

Using this value, the cost for the actual size and year is an amount of:

$$C_{p,2011} = \$21,226 \ x \left(\frac{234..78kW}{200kW}\right)^{0.6} \ x \ \frac{1520}{1094}$$
$$C_{p,2011} = \$32,469$$

Table 4.2.1 shows the summary of units considered to calculate the capital cost of plant for case scenario 1 using **Equation 2.6.5**. Adding the purchase cost of the equipment and multiplying it by 1.05 and 4.1 to account an adjustment of the cost index relation from plant and equipment, a capital cost (C_{TCI}) of \$67,463,816 was estimated.

ltem	Description	С _{р,2011} (\$)
P-101	Pump or Pump System	21,463
P-102	Pump or Pump System	28,652
P-103	Pump or Pump System	32,469
P-104	Pump or Pump System	8,756
P-105	Pump or Pump System	12,830
P-106	Pump or Pump System	6,835
P-107	Pump or Pump System	8,126
P-108	Pump or Pump System	5,279
P-109	Pump or Pump System	9,071
P-110	Pump or Pump System	80,318
Tk-101	Flocculation Tank	78,747
Z-101	Dewatering system	43,249
Z-102	Centrifuge System	1,200,886
Z-103	Drying System	4,015,288
Z-104	CO2 Compressor	1,680,936
Z-105	SCF - Extraction Vessel	17,879
Z-106	SCF - Separation Vessel	7,951,428
Z-108	CO2 - Stripping System	468,825

 Table 4.2.1.
 Summary of purchase cost for equipment in Case Scenario 1.

Continuing with case scenario 1, **Table 4.2.2** shows a summary of utility costs and number of operators used for each unit. This information was used to estimate the cost of utilities for the plant site in Case 1. Overall, the electricity consumed by the plant was calculated taking the sum the electricity of all individual equipments (~19,700 kW) and multiplied by 24 hours per day of operation, and using the factor of 365.25 days per year. This gave an energy consumption of 1.73 x 10^8 kW-hr per year. In Puerto Rico, the actual electricity cost was approximately \$0.24 per year for the industrial sector in 2011. Therefore the annual electricity cost amount was determined as:

$$C_{electricity} = \frac{1.73 \ x \ 10^8 kWhr}{yr} \ x \ \frac{\$0.24}{kWhr}$$

$$C_{electricity} = $41,600,000 \, per \, year$$

	Uti	lity	
Item	Electricity (kW)	Water (kg/s)	# of Labors
P-101	129.6		
P-102	192.3		
P-103	234.78		
P-104	12.58		
P-105	58.77		
P-106	6.916		
P-107	25.28		
P-108	3.14		
P-109	31.51		
P-110	303.83		
Tk-101			1
Z-101	13.1		1
Z-102	2,644.94		1
Z-103	3.15		1
Z-104	16,082.52		1
Z-105		250.61	1
Z-106			
Z-108			1

Table 4.2.2. Amount of utilities and of labors per system in Case Scenario 1.

Water consumption was estimated around 552.48 lb/s, which equals to 17.4 x 10^9 pounds per year. The price of water was assumed to be \$0.0006 per pound of water. The annual cost of water is therefore \$10,948,445 per year. This analysis makes a total cost of utilities (C_{UT}), of approximately \$52,600,000 per year. The cost of labor was estimated from **Equation 4.2.2**.

$$C_{OL} = \frac{\$39,931.73}{yr} x \ln \{ 4.5(6.29 + 31.7P^2 + 0.23N_{np})^{0.5} \}$$
 Eq. 4.2.2

The amount of \$39,931.73 is the annual salary for regular operators during 2011. **4.5** is the shift number factor per work per each year, *Int* is the integer number, *P* is the number of operators who are assumed to work with solids or solid particles and fluids, and N_{np} is the number of operators that work with powder or particulate material. For Case 1, *P* is equal to 7 and N_{np} is equal to 0. Then, the cost of operating labor is approximately to \$9,330,030 per year. The cost of waste disposal was estimated as \$36 per ton for the year 2001. Assuming that half of microalgae mass is being disposed as a non-hazardous waste, the cost for waste disposal is:

$$C_{WT} = \frac{22.98293 \, Ton}{hr} x \, \frac{24 \, x \, 365.25 \, hr}{yr} \, x \frac{\$36}{Ton} x \frac{\$80}{397}$$

$$C_{WT} =$$
\$5,298,060 per year

The cost of CO_2 was estimated at \$2,647,660 per year using a similar methodology as described to calculate the amount of water for the pond site. The makeup CO_2 was based in the loss of one day with an equivalent cost of \$794,298 per year. The cost of flocculant is about \$1,980,129 per year. Adding these values to the cost of land, the total cost of raw materials was estimated as \$5,214,130 per year. Cost of manufacturing for case scenario 1 was calculated and is summarized below.

ltem	Cost (\$)
COM (\$/yr)	109,340,080
DMC	74,144,485
DMC (%)	75.16
FMC	7,480,437
FMC (%)	7.6
GMC	17,283,807
GMC (%)	17.52

 Table 4.2.3.
 Summary for cost of manufacturing in Case Scenario 1.

4.3 - Adjusted value and the use of CAPCOST

In addition to the chemical plant cost index value required in CAPCOST, some other values from the 'user options' spreadsheet of each case were modified. This section explains how these values were obtained. The electricity cost in \$/GJ amount calculated by **Equation 4.3.1** is:

Electricity
$$Cost = \frac{\$0.24}{kWhr} x \frac{1hr}{3600s} x \frac{1x10^6 kJ}{1GJ}$$
 Eq. 4.3.1
Electricity $Cost = \frac{\$66.78}{GJ}$

The cost of water in **\$/GJ** was calculated by dividing the value of the annual utility cost between the needed heat duty for the extraction vessel of Case 1, Z-105, from APEN ONE simulator (**Appendix C**), resulting in a value of **\$16.60/GJ**. In 2001, the cost for waste treatment was \$36/ton for non-hazardous waste. Using the chemical plant cost index, the actual cost for waste disposal was determined to be \$52.59/ton for non-hazardous waste.

The pump efficiency was adjusted to a justifiable normal minimum of 0.6 and the average operator salary was estimated to be \$16/hr. Assuming that one operator works 40 hours per week and 49 weeks per year, the annual salary would have been \$31,360 in 2001. Using this and the labor cost index, the annual salary for labor would be \$39,931 in 2011. The time for production was considered to be 8,766 hours annually.

Working capital was estimated based on the materials needed to start up the plant for the first month of operation. For Case scenario 1, the sum of \$9.14 million to fill the ponds with water, \$2.65 million for CO₂, and \$2.18 million for raw materials C_{RM} , of \$5.88 million in utilities, \$0.54 million in waste treatment and \$3.19 million for labor, C_{OL} , are needed to start the project during the first month. The addition of all these values gives an estimated working capital of approximately \$23.6 million. Fixed capital investment (*FCI*) is the sum of the capital cost of the processing plant and pond site. The cost of land was estimated based on two years of construction. To obtain the production costs of bulk microalgae paste, the revenue from sales value R, was calculated assuming a break-even scenario for each case using **Equation 4.3.2**.

$$R = COM + AC_{Land} + B FCI - Ct$$
 Eq. 4.3.2

The parameter t is known as the taxation rate, which is equal to 0.42 in this analysis. The annual interest or discount rate was assumed to be 10 percent which is normally considered a high risk for purposes of investment. **Table 4.3.1** shows the respective values of A, B, and C in order to calculate the production costs, R value, in 2011 for each case scenario, as well as for considering effects in production costs at three different financing periods: 5, 10, and 20 years.

Case		5 years	5		10 year	S		20 years	S
Scena- rio	Α	В	C (1 x 10 ⁶)	Α	В	C (1 x 10 ⁶)	Α	В	C (1 x 10 ⁶)
Case 1	0.268	0.511	38.519	0.231	0.330	23.764	0.215	0.249	17.151
Case 2	0.268	0.519	30.544	0.231	0.338	18.844	0.215	0.256	13.600
Case 3	0.268	0.526	33.498	0.231	0.345	20.666	0.215	0.264	14.916
Case 4	0.268	0.519	30.568	0.231	0.338	18.859	0.215	0.257	13.611
Case 5	0.268	0.513	36.626	0.231	0.332	22.596	0.215	0.250	16.308

Table 4.3.1. Summary of *A*, *B*, and *C* to calculate the *R* value.

Factor **A** accounts for the project life, the income tax rate and the depreciation. Factor **B** accounts for the income tax, annual interest and the working capital. Factor **C** accounts for the annual interest, the income tax rate and the depreciation. For example, the production cost value of microalgae oil for five years

of project life using case scenario 1 was calculated. Land should be rented for two years during the construction period. Using the values of **COM Equation 4.3.2**, an *R* value of \$198,327,942 per year was obtained. The calculated density of microalgae (as shown in **Appendix A**) was assumed to be 1.33 kg/L. Then, the *R* value means that for a production of 222.1 million pounds of bioproducts per year, the break-even sale value based on revenue from sales should be \$0.89 per pound. These results were used to feed CAPCOST and perform the cash flow and uncertainty analyses for projects of 5, 10, and 20 years for each case scenario. The values used for case scenario 1 are shown as an example in **Table 4.3.2**.

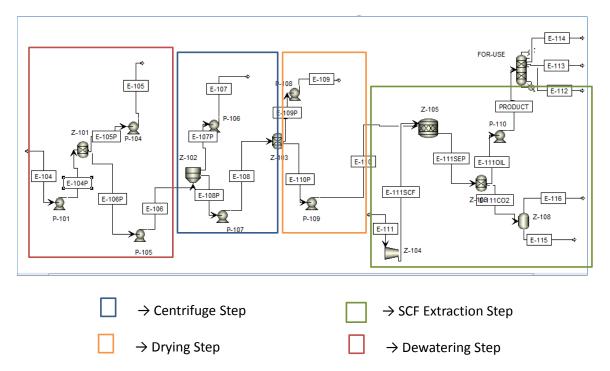
Item	Cost (\$)
Cost of Land	9,758,808
Fixed Capital Investment	101,76,2638
Working Capital	23,584,681
СОМ	159873401.4
Salvage Value	0
Taxation Rate	0.42
Annual Interest Rate	0.10

Table 4.3.2. Values used in CAPCOST for Case Scenario 1.
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CHAPTER 5: RESULTS AND DISCUSSION

5.1 - General process description, ASPEN ONE complementary information and plant site process flow diagram

Five different case scenarios were designed and analyzed in this project. Each case scenario process scheme is described in this section. ASPEN ONE was used to generate the plant site simulation diagrams shown in Figures 5.1.1, 5.1.3, 5.1.5, 5.1.7, and 5.1.9 below (see Appendix C). Also, Figures 5.1.2, 5.1.4, 5.1.6, 5.1.8, and 5.1.10 shown below are the process flow diagrams obtained for each of the five case scenarios that were analyzed. Finally, process stream conditions and equipment specifications and costs for each case scenario results are summarized in Tables 5.1.1 to 5.1.10.





Case Scenario 1 – Process Description

Microalgae broth of approximately 9.1% wt. biomass is pumped from the pond site to flocculation tank **Tk-101**. In **Tk-101**, part of the water is recycled to the pond thorough **E-103** increasing the microalgae concentration up to 50% wt. Then the microalgae mixture flows to the dewatering system **Z-101**. In **Z-101** more water is recycled to the pond site, achieving a concentration of approximately 33% wt. water. Then, water is removed in the centrifugation unit **Z-102**, concentrating the microalgae broth to approximately 10% wt. water. This residual water is removed using a drying system **Z-103** before entering the cell paste to the supercritical fluid

extraction unit (**SC-Extraction**). In the **SC-Extraction**, 50% of microalgae composed by lipid, proteins and carbohydrates (bulk paste, as mentioned in Section LR-1), is extracted at an operating pressure of 40 MPa and temperature of 121°F in **Z-105** using supercritical CO₂. Bulk paste extracted from the **SC-Extraction** is transported to storage for sale or to be used (**FOR USE**) through **Z-106** at approximately 870 psia and 80°F. The carbon dioxide and the remaining biomass are separated in **Z-108**, where carbon dioxide is recycled to the extraction unit and the residual biomass is sent to a waste treatment plant.

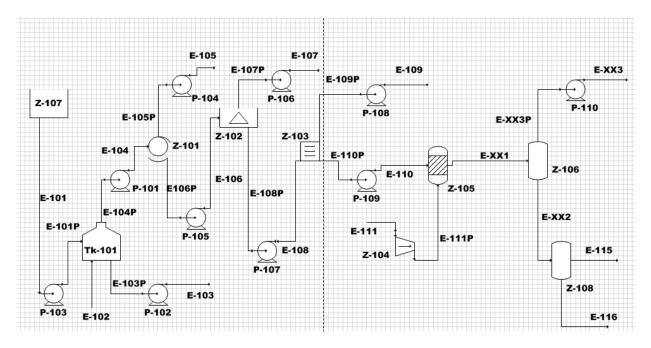


Figure 5.1.2. Preliminary process flow diagram for Case Scenario 1.

Stream ID	E-101	E-102	E-103	E-104	E-105	E-106
From	Pond		Flocculation Tank	Flocculation Tank	Dewatering System	Dewatering System
То	Flocculation Tank	Flocculation Tank		Dewatering System		Centrifuge system
T (F)	76.9	76.9	76.9	76.9	76.7	76.9
P (psia)	30.0		30.0	90.0	30.0	30.0
Microalgae (LB/HR)	50668.7			50668.7		50668.7
Water (LB/HR)	506686.9		456018.2	50668.7	30401.0	20267.7
Chitosan Base (LB/HR)		20.3	18.2	2.0	1.2	0.8
C6H12 (CARB) (LB/HR)						
C2H5N (PROTEIN) (LB/HR)						
C3H8O (LIPID)(LB/HR)						
OTHER (LB/HR)						
CO2 (LB/HR)						
TOTAL (LB/HR)	557355.6	20.3	456036.4	101339.4	30402.2	70937.2

 Table 5.1.1. Process stream conditions for Case Scenario 1.

STREAM ID	E-107	E-108	E-109	E-110	E-111	E-112			
From	Centrifuge System	Centrifuge System	Dryer	Dryer		SC Extraction System			
То		Dryer		SC - Extraction System	SC Extraction system	For use			
T (F)	76.9	76.9	76.9	76.9	80.5	121.9			
P (psia)	30.0	30.0	45.0	45.0	870.2	870.2			
Microalgae(LB/HR)		50668.7		50668.7					
Water (LB/HR)	15201.0	5066.7	5066.7						
Chitosan Base (LB/HR)	0.6	0.2	0.2						
C6H12 (CARB) (LB/HR)						6662.9			
C2H5N (PROTEIN) (LB/HR)									
C3H8O (LIPID) (LB/HR)									
OTHER (LB/HR)									
CO2 (LB/HR)					2026747.5				
TOTAL (LB/HR)	15201.6	55735.6	5066.9	50668.7	2026747.5	6662.9			

Table 5.1.1. Continued

Table 5.1.1 Continued

STREAM ID	E-113	E-114	E-115	E-116
From	SC Extraction system	SC Extraction System	SC Extraction System	SC Extraction system
То	For use	For use	Waste Treatment Plant	
T (F)	121.9	121.9	121.3	121.6
P (psia)	870.2	870.2	870.2	870.2
Microalgae (LB/HR)				
Water (LB/HR)				
Chitosan Base (LB/HR)				
C6H12 (CARB) (LB/HR)				
C2H5N (PROTEIN) (LB/HR)	14719.3			
C3H8O (LIPID) (LB/HR)		3952.2		
OTHER (LB/HR)			25334.3	
CO2 (LB/HR)				2026747.5
TOTAL (LB/HR)	14719.3	3952.2	25334.3	2026747.5

Equipment ID	Specification	Purchase Cost (\$)
P-101	Centrifugal pump system of 129.6kW	21,462
P-102	Centrifugal Pump system of 192.53kW	28,651
P-103	Centrifugal Pump system of 234.78kW	32,469
P-104	Positive displacement pump system 12.58kW	8,755
P-105	Centrifugal Pump system of 58.77kW	12,830
P-106	Positive displacement pump system 6.916kW	6,834
P-107	Centrifugal pump system of 25.28kW	8,125
P-108	Positive displacement pump system of 3.14kW	5,278
P-109	Centrifugal pump system of 31.51kW	9,071
P-110	Centrifugal pump system of 303.83kW	80,318
Tk-101	Flocculation Tank of 300m ³	78,747
Z-101	Dewatering Press Filter of cake volume 3764m ³	43,249
Z-102	Centrifuge system of process capacity 70,937.19lb/hr	1,200,886
Z-103	Drying unit with capacity of 25282 kg	4,015,288
Z-104	CO2 Compressor of 16082.52kW	1,680,936
Z-105	Supercritical Extraction Vessel of 6092.24m ³	17,879
Z-106	SC Separation Vessel unit of 1581.21m ³	7,951,428
Z-108	SC trip Tank with capacity of 8695.76m ³	468,825

Table 5.1.2. Equipment specifications and costs for Case Scenario 1.

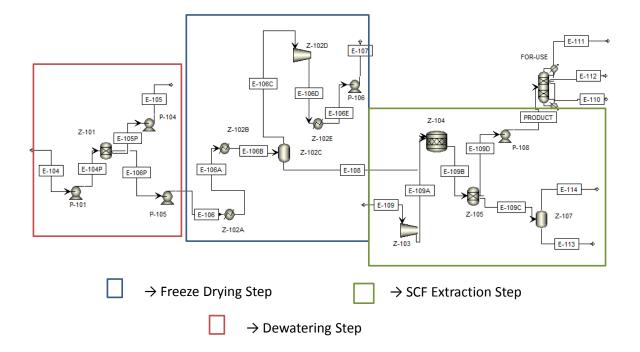


Figure 5.1.3. Simulation diagram for Case Scenario 2 using ASPEN ONE.

Case Scenario 2 – Process Description

Microalgae broth with approximately 10% wt. biomass is sent from the pond site to the flocculation tank (**Tk-101**), where part of the water is recycled to the pond through **E-103**. The microalgae mixture of approximately 50% wt. water content goes to the dewatering system **Z-101**, where broth is concentrated up to 33% wt. water. Then the excess water is extracted using a freeze dryer system, **Z-102**, operated at a temperature range between -40°C to -50°C and 1.45 psia before it enters the supercritical fluid extraction unit (**SC-Extraction**). In the **SC-Extraction** unit, 50% of the microalgae, composed by lipid, proteins and carbohydrates, is extracted at 40 MPa and 121.9°F in unit **Z-104** using supercritical CO₂. The bulk paste extracted from the supercritical fluid extraction unit is stored for sale or can be used (**FOR USE**), through **Z-106**. Carbon dioxide and residual biomass are separated in **Z-107**, where the biomass is disposed as waste.

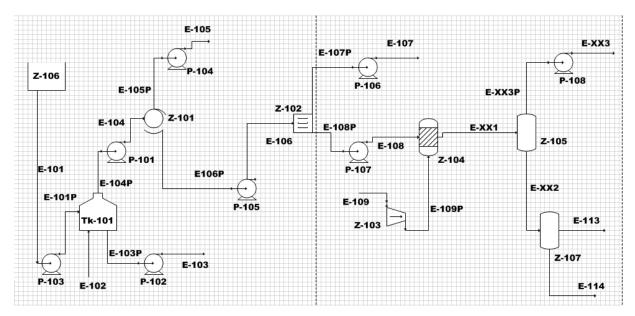


Figure 5.1.4. Preliminary process flow diagram for Case Scenario 2.

STREAM ID	E-101	E-102	E-103	E-104	E-105	E-106
From	Pond		Flocculation Tank	Flocculation Tank	Dewatering Unit	Dewatering Unit
То	Flocculation Tank	Flocculation Tank		Dewatering Unit		Freeze Dryer
T (F)	76.9	76.9	76.9	76.9	76.8	76.9
P (psia)	30.0		30.0	90.0	30.0	60.0
Microalgae (LB/HR)	50668.7			50668.7		50668.7
Water (LB/HR)	506686.9		456018.2	50668.7	30401.0	20267.7
Chitosan Base (LB/HR)		20.3	18.2	2.0	1.2	0.8
C6H12 (CARB) (LB/HR)						
C2H5N (PROTEIN) (LB/HR)						
C3H8O (LIPID) (LB/HR)						
OTHER (LB/HR)						
CO2 (LB/HR)						
TOTAL (LB/HR)	557355.6	20.3	456036.4	101339.4	30402.2	70937.2

 Table 5.1.3: Process stream conditions for Case Scenario 2.

STREAM ID	E-107	E-108	E-109	E-110	E-111	E-112
From	Freeze	Freeze		SC Extraction	SC Extraction	SC Extraction
	Dryer	Dryer	60	EXITACTION	EXITACTION	EXITACTION
То		SC Extraction	SC Extraction	For use	For use	For use
Т (F)	86.1		80.5	121.9	121.9	121.9
P (psia)	45.0	1.5	870.2	870.2	870.2	870.2
Microalgae (LB/HR)		50668.7				
Water (LB/HR)	20267.7					
Chitosan Base (LB/HR)	0.8					
C6H12 (CARB) (LB/HR)				6662.9		
C2H5N (PROTEIN) (LB/HR)					14719.3	
C3H8O (LIPID) (LB/HR)						3952.2
OTHER (LB/HR)						
CO2 (LB/HR)			2026747.5			
TOTAL (LB/HR)	20268.5	50668.7	2026747.5	6662.9	14719.3	3952.2

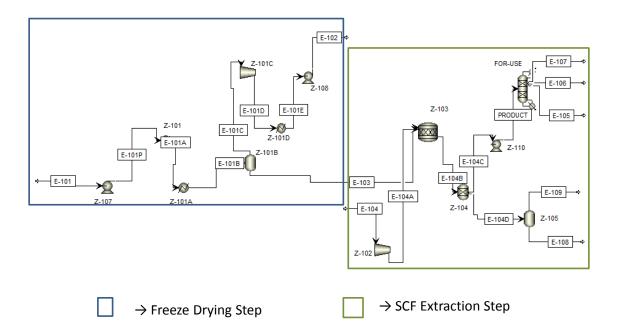
Table 5.1.3 Continued.

Table 5.1.3. Continued.

STREAM ID	E-113	E-114
From	SC	SC
	Extraction	Extraction
То	Waste	
10	Treatment	
T (F)	121.9	121.9
P (psia)	870.2	870.2
Microalgae (LB/HR)		
Water (LB/HR)		
Chitosan Base (LB/HR)		
C6H12 (CARB) (LB/HR)		
C2H5N (PROTEIN)		
(LB/HR)		
C3H8O (LIPID) (LB/HR)		
OTHER (LB/HR)	25334.3	
CO2 (LB/HR)		2026747.5
TOTAL (LB/HR)	25334.3	2026747.5

Equipment ID	Specification	Purchase Cost (\$)
P-101	Centrifugal pump system of 129.6kW	21,462
P-102	Centrifugal Pump system of 192.53kW	28,651
P-103	Centrifugal Pump system of 234.78kW	32,469
P-104	Positive displacement pump system 12.58kW	8,755
P-105	Centrifugal Pump system of 58.77kW	12,830
P-106	Positive displacement pump system 12.56kW	8,749
P-107	Centrifugal pump system of 31.51kW	9,071
P-108	Centrifugal pump system of 303.83kW	80,318
Tk-101	Flocculation Tank of 300m ³	78,747
Z-101	Dewatering Press Filter of cake volume 1605.07ft ³ /hr	43,249
Z-102	Freeze Dryer for 8200kg of ice capacity	333,670
Z-103	CO2 Compressor of 16082.52kW	1,680,936
Z-104	Supercritical Extraction Vessel of 6092.24m ³	17,879
Z-105	SC Separation Vessel unit of 1581.21m ³	7,951,428
Z-107	SC trip Tank with capacity of 8695.76m ³	468,825

Table 5.1.4. Equipment specifications and costs for Case Scenario 2.





Case Scenario 3 – Process Description

Microalgae broth of approximately 9% wt. biomass is directly fed into a Freeze Dryer **Z-101** operated between -40.9°C and -50°C with a pressure of 1.45 psia. All the water from the dryer is recycled to the pond. Dry microalgae enters the supercritical fluid extraction unit (**SC-Extraction**), were 50% of the microalgae is

extracted at 40 MPa and 121.9°F (**Z-103**) using dense supercritical CO_2 . The bulk paste extracted from the supercritical fluid extraction unit is stored for sale or to be used (**FOR USE**) through **Z-104**. Carbon dioxide and the residual biomass are separated in **Z-105**, where the biomass is disposed as waste.

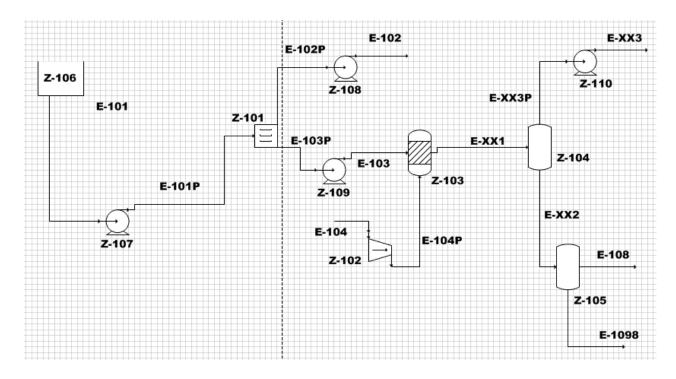


Figure 5.1.6. Preliminary process flow diagram for Case Scenario 3.

STREAM ID	E-101	E-102	E-103	E-104	E-105	E-106
From	Pond	Freeze Dryer	Freeze Dryer		SC Extraction	SC Extraction
То	Freeze Dryer		SC Extraction	SC Extraction	For use	For use
T (F)	76.90	86.10	86.10	121.91	121.91	121.91
P (psia)	45.00	45.00	1.45	870.23	870.23	870.23
Microalgae (LB/HR)	50668.69		50668.69			
Water (LB/HR)	506686.87	506686.87				
Chitosan Base (LB/HR)					6662.93	
C6H12 (CARB) (LB/HR)						14719.25
C2H5N (PROTEIN) (LB/HR)						
C3H8O (LIPID) (LB/HR)						
OTHER (LB/HR)				2026747.50		
CO2 (LB/HR)	557355.56	506686.87	50668.69	2026747.50	6662.93	14719.25
TOTAL (LB/HR)	20268.5	50668.7	2026747.5	6662.9	14719.3	3952.2

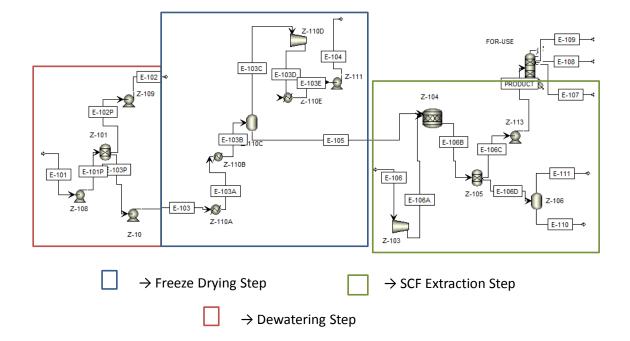
Table 5.1.5. Process stream conditions for Case Scenario 3.

Table 5.1.5. Continued.

STREAM ID	E-107	E-108	E-109
From	SC	SC	SC
FIOIII	Extraction	Extraction	Extraction
То	For use	Waste	
10	FOI USE	Treatment	
Т (F)	121.91	121.91	121.91
P (psia)	870.23	870.23	870.23
Microalgae (LB/HR)			
Water (LB/HR)			
Chitosan Base (LB/HR)			
C6H12 (CARB) (LB/HR)			
C2H5N (PROTEIN)	3952.16		
(LB/HR)	3932.10		
C3H8O (LIPID) (LB/HR)		25334.34	
OTHER (LB/HR)			2026747.50
CO2 (LB/HR)	3952.16	25334.34	2026747.50
TOTAL (LB/HR)	20268.5	50668.7	2026747.5

Equipment ID	Specification	Purchase Cost (\$)
Z-107	Centrifugal pump system of 463.53kW	40,950
Z-108	Centrifugal Pump system of 323.90kW	39,384
Z-109	Centrifugal Pump system of 28.73kW	8,600
Z-101	Freeze Dryer for 229,832 kg of ice capacity	2,301,808
Z-102	CO2 Compressor of 16082.52kW	1,680,936
Z-103	Supercritical Extraction Vessel of 6092.24m ³	17,879
Z-104	SC Separation Vessel unit of 1581.21m ³	7,951,428
Z-105	SC trip Tank with capacity of 8695.76m ³	468,825
Z-110	Centrifugal Pump system of 303.83kW	80,318

Table 5.1.6. Equipment specifications and costs for Case Scenario 3.





Case 4 – Process Description

Microalgae broth of approximately 9% wt. biomass is collected from the pond site and moved thorough **E-103** to the dewatering system **Z-101**, where broth is concentrated to 33% wt. water. Then, microalgae is moved to the freeze dryer system operated at a range between -40.9°C and -50°C at 1.45 psia, where the balance of the water is removed. Then, dry microalgae is fed to the supercritical fluid extraction unit (**SC-Extraction**) where 50% of microalgae extracted at a pressure of 40 MPa and a temperature of 121.9°F (**Z-104**) using dense supercritical CO₂. Bulk paste extracted from the supercritical fluid unit is stored for

sale or to be used (FOR USE) through Z-105. Carbon dioxide and residual biomass are separated in Z-106, where the biomass is disposed as waste.

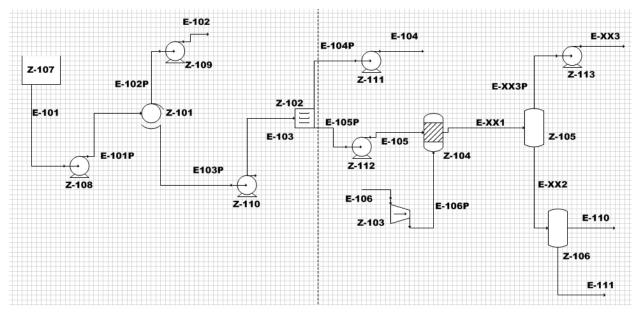


Figure 5.1.8. Preliminary process flow diagram for Case Scenario 4.

STREAM ID	E-101	E-102	E-103	E-104	E-105	E-106
From	Pond	Dewatering	Dewatering	Freeze	Freeze	
		system	System	Dryer	Dryer	
То	Dewatering		Freeze		SC	SC
	System		Dryer		Extraction	Extraction
T (F)	76.9	76.9	76.9	86.1	86.1	121.9
P (psia)	90.0	30.0	45.0	45.0	1.5	870.2
Microalgae (LB/HR)	50668.7		50668.7		50668.7	
Water (LB/HR)	506686.9	486419.2	20267.7	20267.7		
Chitosan Base						
(LB/HR)						
C6H12 (CARB)						
(LB/HR)						
C2H5N (PROTEIN)						
(LB/HR)						
C3H8O (LIPID)						
(LB/HR)						
OTHER (LB/HR)						2026747.5
CO2 (LB/HR)	557355.6	486419.2	70936.4	20267.7	50668.7	2026747.5
TOTAL (LB/HR)	20268.5	50668.7	2026747.5	6662.9	14719.3	3952.2

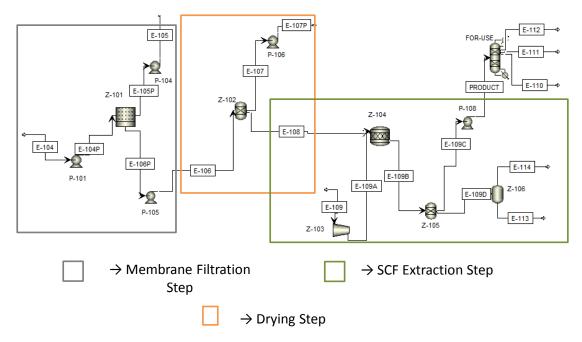
 Table 5.1.7.
 Process stream conditions for Case Scenario 4.

STREAM ID	E-107	E-108	E-109	E-110	E-111
From	SC	SC	SC	SC	SC
From	Extraction	Extraction	Extraction	Extraction	Extraction
То	For use	For use	For use	Waste	
	TOT USE TOT USE		101 030	Treatment	
T (F)	121.9	121.9	121.9	121.9	121.9
P (psia)	870.2	870.2	870.2	870.2	870.2
Microalgae (LB/HR)					
Water (LB/HR)					
Chitosan Base (LB/HR)	6662.9				
C6H12 (CARB) (LB/HR)		14719.3			
C2H5N (PROTEIN)			3952.2		
(LB/HR)			5552.2		
C3H8O (LIPID) (LB/HR)				25334.3	
OTHER (LB/HR)					2026747.5
CO2 (LB/HR)	6662.9	14719.3	3952.2	25334.3	2026747.5
TOTAL (LB/HR)	20268.5	50668.7	2026747.5	6662.9	14719.3

Table 5.1.7. Continued.

Table 5.1.8.	Equipment specifications and costs for Case Scenario 4.	

Equipment ID	Specification	Purchase Cost (\$)
Z-108	Centrifugal pump system of 690.05KW	62,001
Z-109	Positive displacement pump system 201.44 kW	49,410
Z-110	Centrifugal Pump system of 44.08kW	10,863
Z-111	Positive displacement pump system 12.56kW	8,749
Z-112	Centrifugal Pump system of 31.46kW	9,064
Z-113	Centrifugal pump system 30k3.83kW	80318
Z-101	Dewatering Press Filter of cake volume 8667.72ft ³ /hr	180,889
Z-102	Freeze Dryer for 8200kg of ice capacity	333,670
Z-103	CO2 Compressor of 16082.52kW	1,680,936
Z-104	Supercritical Extraction Vessel of 6092.24m ³	17,879
Z-105	SC Separation Vessel unit of 1581.21m ³	7,951,428
Z-106	SC trip Tank with capacity of 8695.76m ³	468,825





Case 5 – Process Description

Microalgae broth of approximately 9% wt. biomass is collected from the pond site through **E-104** to a flocculation tank **Tk-101**, where the broth is concentrated up to 50% wt. of biomass. The remaining broth is pumped to a membrane filtration system **Z-101**, where it is concentrated up to 10% wt. water content. Then microalgae is totally dried in a fluidized dryer system, **Z-102** and moved to the supercritical fluid extraction unit (**SC-Extraction**) where 50% of microalgae is extracted at a pressure of 40 MPa and a temperature of 121.9°F in **Z-104** using dense supercritical CO₂. The bulk paste extracted from the supercritical fluid extractor is stored for sale or to be used (**FOR USE**) through **Z-105**. Carbon dioxide and residual biomass are separated in **Z-106**, where the biomass is disposed as waste.

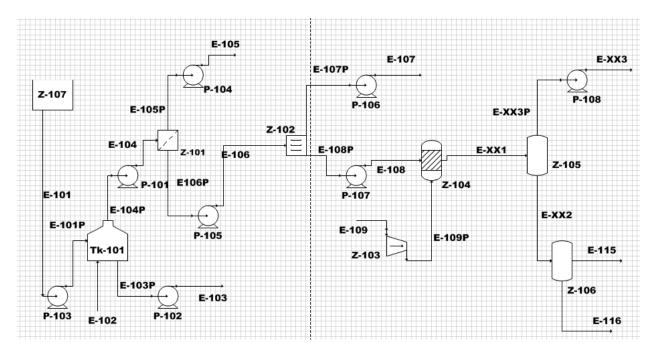


Figure 5.1.10: Preliminary process flow diagram for Case Scenario 5.

STREAM ID	E-101	E-102	E-103	E-104	E-105	E-106
From	Pond		Flocculation Tank	Flocculation Tank	Membrane Filtration	Membrane Filtration
То	Flocculation Tank	Flocculation Tank		Membrane Filtration		Dryer
T (F)	76.90	76.90	76.90	76.90	77.00	76.90
P (psia)	30.00		30.00	90.00	100.00	45.00
Microalgae (LB/HR)	50668.69			50668.69		50668.69
Water (LB/HR)	506686.87		456018.19	50668.69	45601.82	5066.87
Chitosan Base (LB/HR)		20.27	18.24	2.03	1.82	0.20
C6H12 (CARB) (LB/HR)						
C2H5N (PROTEIN) (LB/HR)						
C3H8O (LIPID) (LB/HR)						
OTHER (LB/HR)						
CO2 (LB/HR)						
TOTAL (LB/HR)	557355.56	20.27	456036.43	101339.40	45603.64	55735.76

 Table 5.1.9.
 Process stream conditions for Case Scenario 5.

STREAM ID	E-107	E-108	E-109	E-110	E-111	E-112
From	Dryer	Dryer		SC Extraction	SC Extraction	SC Extraction
То		SC Extraction	SC Extraction	For use	For use	For use
T (F)	76.90	76.90	121.91	121.91	121.91	121.91
P (psia)	45.00	45.00	870.23	870.23	870.23	870.23
Microalgae (LB/HR)		50668.69				
Water (LB/HR)	5066.87					
Chitosan Base (LB/HR)	0.20					
C6H12 (CARB) (LB/HR)				6662.93		
C2H5N (PROTEIN) (LB/HR)					14719.25	
C3H8O (LIPID) (LB/HR)						3952.16
OTHER (LB/HR)						
CO2 (LB/HR)			2026747.50			
TOTAL (LB/HR)	5067.07	50668.69	2026747.50	6662.93	14719.25	3952.16

Table 5.1.9. Continued.

Table 5.1.9. Continued.

STREAM ID	E-113	E-114
From	SC Extraction	SC Extraction
То	Waste Treatment	
T (F)	121.91	121.91
P (psia)	870.23	870.23
Microalgae (LB/HR)		
Water (LB/HR)		
Chitosan Base (LB/HR)		
C6H12 (CARB) (LB/HR)		
C2H5N (PROTEIN) (LB/HR)		
C3H8O (LIPID) (LB/HR)		
OTHER (LB/HR)	25334.34	
CO2 (LB/HR)		2026747.50
TOTAL (LB/HR)	25334.34	2026747.50

Equipment ID	Specification	Purchase Cost (\$)
P-101	Centrifugal pump system of 129.6kW	21,462
P-102	Centrifugal Pump system of 192.53kW	28,651
P-103	Centrifugal Pump system of 234.78kW	32,469
P-104	Positive displacement pump system 628.93kW	58,645
P-105	Centrifugal Pump system of 34.63kW	9528
P-106	Positive displacement pump system 6.29kW	6598
P-107	Centrifugal pump system of 31.46kW	9,064
P-108	Centrifugal pump system of 303.83kW	80,318
Tk-101	Flocculation Tank of 300m ³	78,747
Z-101	Membrane Filtration of 2490.39gal/min	31,915
Z-102	Drying unit with capacity of 25282 kg	4,015,295
Z-103	CO2 Compressor of 16082.52kW	1,680,936
Z-104	Supercritical Extraction Vessel of 6092.24m ³	17,879
Z-105	SC Separation Vessel unit of 1581.21m ³	7,951,428
Z-106	SC trip Tank with capacity of 8695.76m ³	468,825

Table 5.1.10. Equipment specifications and costs for Case Scenario 5.

5.2 - Economic analysis for each case scenario

Costs of manufacturing (COM) that are equivalent to the operational costs for the five different case scenarios to obtain the bioproducts from the microalgae growth process to the paste extraction phase are displayed in Table 5.2.1. These COM are divided in direct manufacturing costs (DMC) that depend on the associated facts, and fixed manufacturing costs (FMC) regarding the direct processing of microalgae (see Tables 5.2.2 and 5.2.3), such like the costs of raw materials, labor and utilities. General manufacturing costs (GMC) (Table 5.2.4) include costs of distribution, selling, research and development.

general man	alaotaning ooo				
Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
DMC (\$/yr)	114,437,700	108,018,916	164,342,105	105,530,851	108,338,952
FMC (\$/yr)	16,842,394	14,646,392	13,791,843	14,028,801	15,740,526
GMC (\$/yr)	28,976,242	26,886,237	37,084,342	26,111,730	27,327,981
COM (\$/yr)	159,873,401	149,188,692	214,652,352	145,316,237	151,044,518

Table 5.2.1. Breakdown of manufacturing costs in terms of direct, fixed and general manufacturing costs.

Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5	
DMC	114,437,700	108,018,916	164,342,105	105,530,851	108,338,952	
Raw Materials	21,312,162	21,312,162	19,332,032	19,332,032	21,312,162	
Waste Treatment	5,298,060	5,298,060	5,298,060	5,298,060	5,298,060	
Utilities	57,369,864	54,159,306	112,562,498	54,931,497	53,313,443	
Operating Labor	14,014,880	12,936,723	10,980,068	12,058,225	12,936,723	
Direct Supervisor and clerical labor	2,522,678	2,328,610	1,976,412	2,170,480	2,328,610	
Maintenance and repairs	6,105,758	4,841,640	5,309,960	4,845,510	5,807,052	
Operating supplies	915,864	726,246	796,494	726,826	871,057	
Laboratory Charges	2,102,232	1,940,508	1,647,010	1,808,734	1,940,508	
Patent & Royalties	4,796,202	4,475,661	6,439,571	4,359,487	4,531,335	

Table 5.2.2. Breakdown of direct manufacturing costs (DMC) in \$/yr.

Table 5.2.3. Breakdown of fixed manufacturing costs (FMC) in \$/yr.

Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
FMC	16,842,394	14,646,392	13,791,843	14,028,801	15,740,526
Local Taxes and insurance	3,256,404	2,582,208	2,831,979	2,584,272	3,097,094
Plant Overhead	13,585,990	12,064,184	10,959,864	11,444,529	12,643,431

Table 5.2.4. Breakdown of general manufacturing costs (GMC) in \$/yr.

Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
GMC	28,976,242	26,886,237	37,084,342	26,111,730	27,327,981
Administration	3,396,497	3,016,046	2,739,966	2,861,132	3,160,858
Distribution and selling	17,586,074	16,410,756	23,611,759	15,984,786	16,614,897
Research and Development	7,993,670	7,459,435	10,732,618	7,265,812	7,552,226

Table 5.2.5 shows the costs of manufacturing divided into the costs associated to the fixed capital investment, the operating labor, raw materials, utilities, and waste treatment. The factor 0.18 accounts for all contingencies associated to equipment in the facilities, such as equipment tax insurance and maintenance operations over the equipment used to manufacture the product. The factor 2.73 accounts for influence of all additional labor efforts required in addition

to operating labor such as overhead, and marketing over the cost of the estimated labor to manufacture the products. The factor 1.23 accounts for additional costs of other materials. Notice in **Table 5.2.5** and **Table 5.2.1** to **Table 5.2.4** that the breakeven operational cost is dominated by the cost of utilities.

Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
0.18FCI (\$/yr)	18,317,275	14,524,920	15,929,881	14,536,529	17,416,928
2.73C_OL (\$/yr)	38,260,621	35,317,253	29,975,585	32,918,953	35,317,253
1.23C_RM (\$/yr)	26,213,960	26,213,960	23,778,399	23,778,399	26,213,960
1.23C_WT (\$/yr)	6,516,613	6,516,613	6,516,613	6,516,613	6,516,613
1.23C_UT (\$/yr)	70,564,932	66,615,946	138,451,872	67,565,740	65,575,535
COM (\$/yr)	159,873,401	149,188,692	214,652,352	145,316,237	151,044,518

Table 5.2.5. Summary for cost of manufacturing in terms of operating labor, raw materials, utilities, waste treatment, and fixed capital investment.

For any case scenario, the supercritical extraction unit shows high consumption in terms of utilities (**Table 5.2.6**) due to the water required in the extraction vessel (**Figure 5.2.1**) and a great amount of energy associated to the CO_2 compression system (**Figure 5.2.2**). The pond site requires 126 operation personnel for all the cases. **Figure 5.2.3** shows the variability in the number of operating personnel required in the plant site. These results of direct impact in costs of operating labor are shown in **Figure 5.2.4** below.

			•		
Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
Flocculation	1,443,644	1,443,645	2,114,750		1,411,138
Dewatering	218,795	214,272		2,607,961	
Centrifugation	6,939,771	3,093,286			
Membrane Filtration					2,188,203
Drying	97,977				111,450
Freeze Drying		3,093,286	2,114,750	3,093,037	
SC Extraction	42,477,369	42,477,370	42,477,370	42,477,370	42,477,370
Subtotal Energy	51,177,558	47,228,572	44,592,120	48,178,367	46,188,161
Pond Energy	5,920,785	5,920,786	5,920,786	5,920,786	5,920,786
Water for SC Extraction	13,466,587	13,466,588	13,466,588	13,466,588	13,466,588
Total Utilities	70,564,932	66,615,946	63,979,493	67,565,741	65,575,535

Table 5.2.6. Breakdown for utilities per unit in \$/yr.

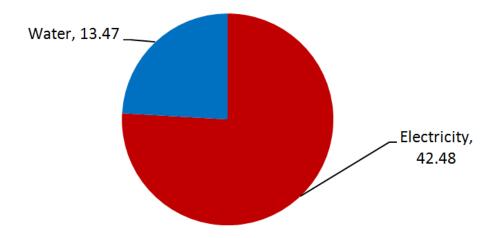


Figure 5.2.1. Cost of utilities consumed by the supercritical fluid extraction unit.

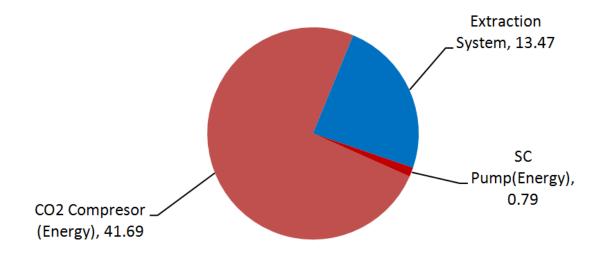


Figure 5.2.2. Breakdown of cost of utilities used by the supercritical extraction unit.



Figure 5.2.3. Operating labor workers required in the plant site.

Table 5.2.7. Breakdown of labo	r workers in percent effort.
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Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
Flocculation (%)	8.40	9.14			9.14
Dewatering (%)	8.40	9.14		10.19	
Centrifugation (%)	8.40				
Membrane Filtration (%)					9.14
Drying (%)	8.40				9.14
Freeze Drying (%)		9.14	11.30	10.19	
SC Extraction (%)	25.21	27.42	33.91	30.58	27.42
Subtotal Energy (%)	58.82	54.84	45.22	50.97	54.84
Pond (%)	41.18	45.16	54.78	49.03	45.16
Total Workers	306	279	230	257	279



Figure 5.2.4. Cost of operating labor workers in million dollars per year.

In summary, the costs of manufacturing for a production of 222.1 million pounds of bulk paste is in the range of \$0.65/lb to \$0.97/lb, which are equivalent to \$4.92/gal oil to \$7.26/gal oil (**Table 5.2.8**). In terms of the needed investment, **Table 5.2.9** is divided in cost of land, working capital and the fixed capital investment. Fixed capital investment refers to the capital cost of the plant and pond sites. Land costs were assumed the same for all cases. Working capital (**Table 5.2.10**) is the quantity needed to operate the plant during the first month of operation.

Table 5.2.8. Production cost of 222.1 million pounds of bulk paste and equivalence in oil gallon.

Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
Bulk Paste (\$/lb)	0.72	0.67	0.97	0.65	0.68
Oil (\$/gal)	5.41	5.05	7.26	4.92	5.11

Table 5.2.9. Breakdown of total investment in terms of fixed capital investment, land and working capital.

Item	Case 1	Case 2	Case 3	Case 4	Case 5
FCI (\$M)	101.76	80.69	88.50	80.76	96.76
Land (\$M)	9.76	9.76	9.76	9.76	9.76
Working Capital (\$M)	23.58	23.01	28.35	22.69	22.92
Total Investment (\$M)	135.11	113.46	126.61	113.20	129.47

Case Scenario	Water for pond (\$M)	CO₂ of SCE (\$M)	RM (\$M)	UT (\$M)	WT (\$M)	OL (\$M)	Working Capital (\$M)	% in FCI (%)	Equivalent startup days @ 15% FCI
Case 1	9.14	2.65	2.18	5.88	0.54	3.19	23.58	23.1 8	20
Case 2	9.14	2.65	2.18	5.55	0.54	2.94	23.01	28.5 2	16
Case 3	9.14	2.65	1.98	11.5 4	0.54	2.50	28.35	32.0 3	14
Case 4	9.14	2.65	1.98	5.63	0.54	2.74	22.69	28.0 9	16
Case 5	9.14	2.65	2.18	5.46	0.54	2.94	22.92	23.6 9	19

Table 5.2.10. Breakdown of working capital for each case scenario.

According to the 2011Puerto Rico Tax Guide, taxation rates vary from 20% to 40.95%, plus minor uncertainties due to the volume of production scale (Hills et al., 2011). This makes a rate of 42% appropriate as the income tax rate. Production costs of bulk paste considering a project life of 5, 10 and 20 years at an annual interest of 10% are shown in **Figure 5.2.5**. **Figure 5.2.6** shows the equivalent cost of the oil in terms of dollars per gallon. Breakdown for production costs of bulk paste for 5, 10 and 20 years (**Table 5.2.11** to **5.2.13**) shows that costs of manufacturing remain the same. However, as expected, the fixed capital contribution decreases with time.

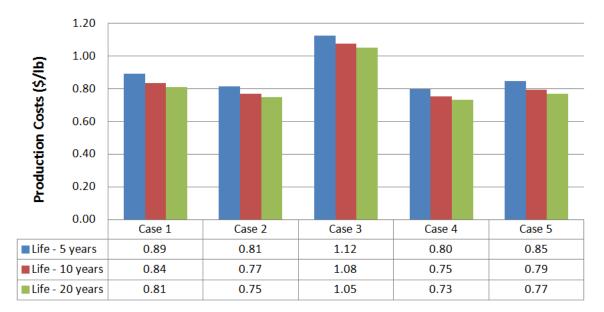


Figure 5.2.5. Production costs of bulk microalgal paste for each case scenario.

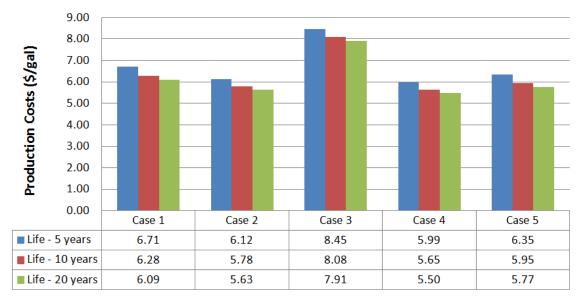


Figure 5.2.6. Production costs in equivalence of oil gallon for each case scenario.

Table 5.2.11. Breakdown of production costs for a 5-year project in \$/lb.

Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
Production cost	0.89	0.81	1.12	0.80	0.85
СОМ	0.72	0.67	0.96	0.65	0.68
Land	0.01	0.01	0.01	0.01	0.01
Fixed Capital	0.16	0.13	0.15	0.14	0.16

Table 5.2.12. Breakdown of production costs for a 10-year project in \$/lb.

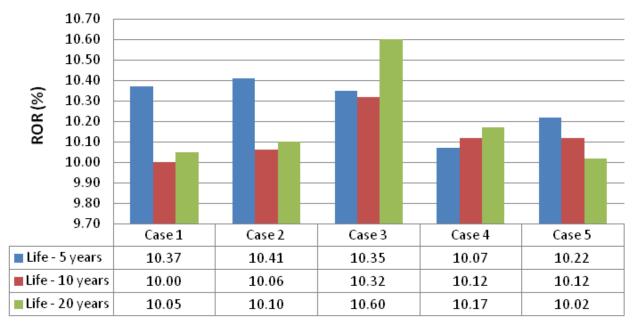
Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
Production cost	0.84	0.77	1.08	0.75	0.79
СОМ	0.72	0.67	0.96	0.65	0.68
Land	0.01	0.01	0.01	0.01	0.01
Fixed Capital	0.11	0.09	0.11	0.09	0.10

Table 5.2.13. Breakdown of production costs for a 20-year project in \$/lb.

Case Scenario	Case 1	Case 2	Case 3	Case 4	Case 5
Production cost	0.81	0.75	1.05	0.73	0.77
СОМ	0.72	0.67	0.96	0.65	0.68
Land	0.01	0.01	0.01	0.01	0.01
Fix Capital	0.08	0.07	0.08	0.07	0.08

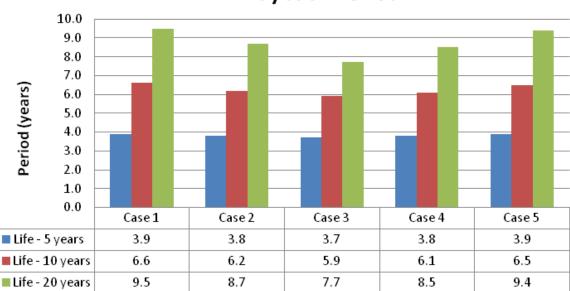
The estimated rate of return (Figure 5.2.7) validates our analysis due to its proximity to a 10%, that is equal to the annual interest used for the analysis

assuming breakeven situation. It is important to remember that 10% is a fair value for investment. However, the payback period (**Figure 5.2.8**) shows to have a lower value than the value that was expected, which should approximate a value close to the project life. An explanation for this is that the payback period only considers the time to pay a loan for the fixed capital investment. Payback period does not consider the cash flow movement or the effect of the operational costs. This results in a shorter payback period than the one expected, that should be the closest to the project life.



ROR

Figure 5.2.7. Rate of return (ROR) for each case scenario using CAPCOST.



Payback Period

Figure 5.2.8. Payback period for each case scenario using CAPCOST.

5.3 - Facts and recommendations based in our economic analysis

The economic analysis results displayed in Section 5.2 show that our preferences in terms of investment should be in the following order: Case $4 \rightarrow$ Case $2 \rightarrow$ Case $5 \rightarrow$ Case $1 \rightarrow$ Case 3. Case 4 is the preferred due to low fixed capital investment and costs of operating labor, as well as a lower cost of raw materials and a considerable cost of utilities. Case 2 has a lower cost of utilities and fixed capital cost, but a higher cost of raw materials and operating labor as compared to Case 4. Case 5 has the same cost of operating labor and raw materials as Case 2, and a lower cost of utilities. However, the fixed capital investment for Case 5 shows to be higher than Cases 2 and 4. Cases 1 and 3 were shown to have the higher costs of utilities, operating labor and raw materials, as well as fixed capital, which is equivalent to higher capital and operational costs. According to these observations, as the fixed capital investment becomes higher; the higher will be the added-value production costs due to income tax and annual interest rates.

According to this project, the cost of disposing the remaining microalgal biomass is \$0.03/lb from our cost of manufacturing. The remaining biomass still has properties that make it suitable to use as fertilizer, fish food, as well as for other emerging applications. Actually, urea- and phosphate-based fertilizers have prices between \$0.30/lb to \$0.33/lb (fertilizer cost, 2012). If the remaining biomass

can be sold at a value of \$0.30/lb as fertilizer, this could have a positive effect of \$0.30/lb, or at least a reduction of \$0.03/lb waste in the actual manufacturing costs.

Supercritical fluid extraction increases considerably the operational cost, especially in utilities and operating labor. The process also requires at least 45 minutes to pressurize the extraction chamber and three additional hours to extract the paste per each batch. At least, this will cause an increment in the utilities needed to operate the plant. Thereupon, it is imperative that a detailed design study be done in order to: 1) optimize the use of resources, such as utilities and equipment operation, considering the schedule effect in the annual cost of manufacturing, and 2) determine if it is reasonable to produce the paste using supercritical fluid extraction or by implementing another emerging technology that preserves the integrity of proteins, lipids and carbohydrates in the extracted paste.

According to the Lang factor technique, the additional unit composed of one centrifugation system, one separation tank and five centrifugal pumps to separate lipids, proteins and carbohydrates will add around \$3,175,455 to the capital investment (**Appendix B**). This is equivalent to the addition of \$0.04 per pound each year to the actual cost of manufacturing the paste, which also will influence the operational costs (**Table 5.3.1**). However, note that the added value to produce proteins relative to the actual manufacturing cost may not be too high. Moreover, the sale value of proteins, lipids and carbohydrates could be \$653/lb, \$0.24/lb and \$0.06/lb, respectively (Lever1diet, 2012; Monthly Data – Monthly Lactose Price, 2012; Arifeen et al., 2007; Haas et al., 2006). If this is true, maybe the cost production can be justified based in the production of proteins from microalgae, instead of from the paste itself. A much better idea would be the sale of proteins in little quantities and sell the remaining of bulk paste as supplement compounds for the food industry as well as feedstock to produce biofuels or fuel derivatives.

Table 5.3.1. Breakdown of costs of manufacturing for an additional separation unit for the proteins, lipids and carbohydrates contained in the microalgal biomass.

Unit	PLC Separation
COM (\$/yr)	90,053,93
COM (\$/lb)	0.04
0.18*FCI	571,581.9
2.73*C_OL	5,886,736
1.23*C_RM	0
1.23*C_UT	2,547,075
1.23*C_WT	0

CHAPTER 6: FINDINGS AND RECOMMENDATIONS

An economic analysis was performed for five different case scenarios maintaining a fixed pond site, a supercritical extraction unit, with various technologies to harvest the bioproduct for a design of an annual production of 222.1 million pounds of bulk paste with a high protein content from microalgae. Flocculation, dewatering, drying, centrifugation, freeze-drying and membrane filtration were the considered technologies. Case 4, which considers the use of pond \rightarrow dewatering \rightarrow freeze dryer \rightarrow supercritical fluid extraction shows to be the most attractive in terms of investment due to a low cost of fixed capital (80 million dollars), as well as lower annual operational costs (132.5 million dollar). This results in a production cost of \$0.74/lb, \$0.69/lb and \$0.67/lb to produce the bulk paste equivalent to \$5.56/gal, \$5.22/gal and \$5.06/gal of oil considering an annual interest of 10% and an income tax of 42% at 5, 10 and 20 years of financing, respectively.

In all the cases, operational costs were the predominant factor due to the high costs associated to the operating labor, raw materials and utilities required to operate the supercritical fluid extraction unit. It is recommended to perform a detailed analysis in order to find strategies to reduce the associated operational costs to this unit, as well as to identify emerging technologies to replace the supercritical fluid extraction without affecting the yield and integrity of the proteins, lipids and carbohydrates contained by the paste.

Selling the residual microalgal biomass as a bio-fertilizer or fish food versus disposing it as a waste could result in a positive effect in terms of the production costs of \$0.30/lb to our analysis. In summary, our results indicate that microalgae-based production facility requires a biorefinery operation philosophy. Especially, a variety of products must be produced efficiently and sold in a wide variety of markets such as commodities (biofuels) and value-added specialties (proteins, lipids). A single product approach will not justify either the investment or operational costs of similar processing plants.

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APPENDIX APPENDIX A: YIELD CALCULATIONS FOR POND SITE

TO PRODUCE MICROALGAE

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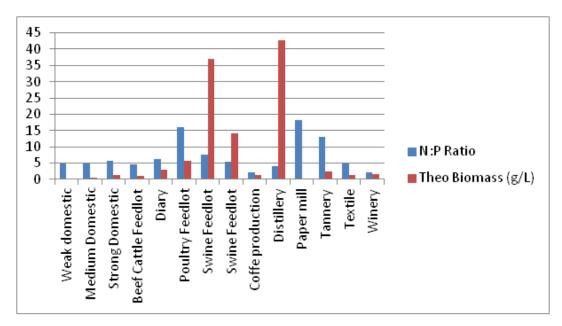
A.1 - Yield calculations for pond site to produce microalgae

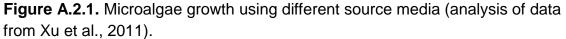
Chisti reported in 2007, that microalgae cultured using a photobioreactor system can yield 30-70% of bio-oil, equivalent to 15,500-36,150 gallons of oil per hectare (ha) in an annual basis. Assuming that an annual production of 20 million gallons of oil with a specific gravity of 0.85 is desired, an area between 1,290-553 ha should be used, depending if oil content is either 30 or 70 percent. Chisti also showed that the equivalence in terms of a growth area of 5,681 m² of photobioreactor equals 7,828 m² of an open raceway pond site. Therefore, the area of pond site should be between 1,778-762 ha, with an average area of 1,270 ha (5 square miles), considering oil with a specific gravity of 0.85, which represents an annual biomass of 153,283,333 kg microalgae.

Literature shows that microalgae biomass is composed of lipids, proteins and carbohydrates with a characteristic specific gravity around 1.2. We chose a monomer of protein (glycine), lipid (glycerol) and carbohydrate (glucose derivative) to simulate our sample with an average paste bulk specific gravity of 1.33, assuming a microalgae conversion of 50 percent (refer to Introduction). To produce 20 million gallons of bulk paste per year, the production of microalgae was estimated to be 201,468,400 kg microalgae per year. This tells us that we need 22,982.93 kg of microalgae per hour to obtain 20 million gallons of bulk paste per year (222 lb/yr). Details of recipe are given in **Section A.1**.

Section A.2 - General aspects for microalgae broth formulation

Christenson in 2011 showed the N/P ratio is not a significant parameter for microalgae growth (**Figure A.2.1**). However, the C/N ratio shows to be an important factor to grow microalgae (**Section 2.3**).





A microalgae growth medium was formulated using the data of Welssmen, et al., 1987; Chisti et al., 2007; and Davis et al., 2011 (**Tables A.2.1** and **A.2.2**). PAR-radiation data was assumed by this author based on empirical data. Pond dimensions (**Table A.02**), as well as complimentary data of required labor workers and energy consumed from paddle wheels was reported by Welssmen et al., 1987 and Davis et al., 2011 (**Figures A.2.2 to A.2.5**).

Table A.2.1. Medium composition for growth of microalgae (adjusted from Chisti et al., 2007; Davis et al., 2011).

Parameter	Value	Unit
Algae production rate	50,654.37772	lb/hr
Land use	2207.184114	ha
Land use	8.522451515	mile ²
Total land use	12.71295153	mile ²
Net water Demand	2,843.785114	lb/hr
Fresh CO₂ demand	41,234.88416	lb/hr
Fresh NH₃ Demand	1,450.330408	lb/hr
Fresh DAP required	1,365.016855	lb/hr
Reported algae productivity	2,696.751042	kg/mile²/hr
Initial algae	2.5031104	g/m ²
PAR-Radiation (400-700 nm)	2.32 -04 - 4.44 -04	(W/mile ²)
Incident solar power	2.65858E-05	(W)
Radiation time	8 – 12	(hr/day)
Operating days	330	Days
Year	2011	Year

Table A.2.2. Pond dimensions (adjusted from Welssmen et al., 1987).

Parameter	Value	Units
Long	269.0256	ft
Wide	39.3696	ft
Deep	0.981435897	ft
Area	0.000380087	mile ²
Needed ponds	22,422.37073	No ponds
Needed area	2207.1841	ha
Cost to build a pond	32,300,798	\$

LABOR REQU	JIRED PER 1	000 ACRE									FROM 1	28 PAGE 110
POSITION TIT	FLE	QUANTITY	Time	Salary								
			HR/YR	\$/hr	\$/yr							
Plant Manag	ger	1	2080	25	52000			Total Labor	23	1000 acr	e	
Shift Supervi	isors	4	2080	17	35360			Total Labor	126			
Pond Operat	tors	10	2080	10	20800							
Centrifuge C	Operators	5	2080	12	24960							
Laboratory N	Manager	1	2080	17	35360							
Laboratory T	echnicians	2	2080	10	20800							
Total (\$)					189280							
Area (acre)		1000										
Area (ha)		404.86										
Required Arr	rea (ha)	2207.1841										
Needed Labor Cost (\$)		1031901.9				Cost for the year 1987		look on 129 for the labor cost indexes on Dec of each year				
Updated Labor Cost (\$		2142318.1				Cost for the Year 2011		look on 129				

Figure A.2.2. Labor information for pond site (adjusted from Welssmen et al., 1987).

WATER COST FOR ALGA	E GROWTH							
Needed Water (gal)	1.744E+09					Evap (m^3/day) Cost of make up (\$/yr)		1200
Cost of Water (\$/gal)	0.0052427							606815
Cost of Water (\$)	9140676.3	Esto	to lo necesitas solo para llenar las charcas					
LAND COST								
Required Land (acre)	8132.3403							
Cost of Land (\$/acre/yr	300							
Cost of Land (\$/yr)	2439702.1							

Figure A.2.3. Water and land information for pond site (adjusted from Welssmen et al., 1987 and Davis et al., 2011).

RAW MATERIALS						
		CO2	NH3	DAP	MICROALO	GΑ
		(1/yr)	(1/yr)	(1/yr)	1/yr	
Needed (lb)		361464995	1.3E+07	11965738	121800	
Class		Variable	Variable	Variable	Variable	
Material Cos	t (\$/lb)	0.0181439	0.18461	0.20049	14.3433	
Cost (\$)		6558377.8	2347108	2399009	1747020	

Figure A.2.4. Raw materials information for pond site (adjusted from Davis et al., 2011).

192
24
0.42
3.477
8.278571
2207.184
275.898
2284.041
24
54816.99
20021907
0.240419
4813647

Figure A.2.5. Utilities information for pond site (adjusted from Welssmen et al., 1987).

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APPENDIX B: TABULATED INFORMATION FOR PLANT

SITE USING EXCEL SPREASHEETS

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B.1 – Introduction to equipment cost information tables

Tables B.1.1 to **B.1.5** show the relevant information regarding the equipment involved for each case scenario considered in this project. Parameters for pumps, turbines and compressors were calculated using the hydraulic equation and the turbine equation. Parameters for other specialized equipment, such as freeze dryers, fluidized bed dryers, supercritical fluid extraction systems (SC-Extraction), dewatering, and centrifugation systems were determined according to related literature.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
Flocculation tank (Tk-101) 1 Labor	Flocculation	SS or CS Tank P = ambient pressure T = ambient or near Tank Capacity (Ib) Volume (m ³) Used volume (m ³)	 557375.8288 247.1250204 300	56677.47 (2001) 78747.49 (2011)
CLTALGAE Pump (P-101) 129.6kW	Flocculation	Fluid density kg/L Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.030345212 45.45214893 9.81 602.0868184 0.6 77.76 104.28 129.6 173.8 	15447.58 (2001) 21462.81 (2011)
RE-WATER Pump system (P-102) 192.53kW	Flocculation	Fluid density kg/L Flow capacity (m ³ /h) Specific gravity (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.030345212 204.5478511 9.81 200.6956061 0.6 115.53 154.91 192.53 258.18 	20621.54 (2001) 28651.49 (2011)

Table B.1.1. Equipment and cost information of plant site for Case Scenario 1.

Table B.1.1.	Continued.
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Equipment	Unit	Description	Description Value	Cost (\$) (year)
PONDFEED Pump system P-103) 234.78kW	Flocculation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Ratio of required/pilot capacity Centrifugal pump	1.030345212 250 9.81 200.6956061 0.6 140.87 188.9 200 234.78 314.83 1.1739 	21225.9 (2001) 23369.25 (2001) 32469.16 (2011)
Dewatering press filter (Z-101) 1 Labor 13.1kW	Dewatering	Filter presses system - Pressure leaf Operating pressure Operating temperature (°F) Initial estimated capacity (ft ³ /hr) Total volume feed batch (gal) Solid concentration product feed (%) Specific gravity of process solid Mass of the cake (lb/hr) Volume of the cake (lb/hr) Volume of the cake (ft ³ /hr) Weight of cake (lb/ft ³) Percent of dry solids in cake (%) Desired cycles per day of filter Estimated time for one batch (day) Cake required volume (ft^3) Application volume requirement (ft ³) Cake thickness (m) Estimated filter area (ft ²) Quote index for the current year	90 76.9 1605.068937 12002.15182 49.99900002 1.33 70937.1855 934.905853 75.87628772 71.4275412 24 0.042 3763.63 156.81795 1.5 31.86579493 394	11210.68 (2001) 43249.31 (2011)
DEWAT Pump system (P- 104)123.58kW	Dewatering	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic	1.00++00 1.38E+01 9.81 200.6956061 0.6 7.55	6301.644 (2001) 8755.484 (2011)

Equipment	Unit	Description	Description Value	Cost (\$) (year)
		power (bph)	10.12	
		Calculated shaft power		
		(kW)	12.58	
		Calculated shaft power		
		(bph)	16.87	
		Positive displacement		

Table B.1.1. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
WETALGAE Pump system 58.77kW	Dewatering	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.24E+00 2.60E+01 9.81 401.3912122 0.6 35.26 47.29 58.77 78.81	9234.368 (2001) 12830.2 (2011)
Centrifuge system (Z-102) 1 Labor 2644.94kW	Centrifugation	Perforated Basket Centrifuge Type solid bowl with motor Speed (rpm) Diameter (inch) Drum height (inch) Electrical supply Capacity (lb) Process capacity (lb) Ratio of required/pilot capacity	 1020-4000 20 14 460 VAC with 3ph 60 70937.1855 1182.286425	16500 (2001) 1151112 (2001) 1200886 (2011)
Water Pump (P-106) 6.92kW	Centrifugation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Positive displacement	1.00E+00 6.90E+00 9.81 200.6956061 0.6 4.15 5.565 6.916 9.274 	4919.383 (2001) 6834.975 (2011)

Table B.1.1. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
CNTMATTER Pump system (P-107) 25.28kW	Centrifugation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.30E+00 1.94E+01 9.81 200.6956061 0.6 15.17 20.34 25.28 33.9 	5848.358 (2001) 8125.689 (2011)
Dryer (Z-103) 1 Labor 3.15kW	Drying	Model from International Process Plants Type Fluid Bed Dryer SS Model capacity (kg) Speed (rpm) Det. Pressure Range (psia) Model drum deep (in) Model drum diameter (in) Surface area (m ²) Required capacity (kg) Ratio of required/pilot capacity	 70 1725 50 -80 16 34 0.350975576 25281.49209 361.1641727	84385.45 (2001) 2889950 (2001) 4015288 (2011)
Water Pump system (P-108) 3.14kW	Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated Hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Positive displacement	1.00E+00 2.30E+00 9.81 301.0434092 0.6 1.89 2.53 3.14 4.22 	3799.228 (2001) 5278.635 (2011)

Table B.1.1. (Continued.
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Equipment	Unit	Description	Description Value	Cost (\$) (year)
DRYMATTER Pump system (P-109) 31.46kW	Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 17.28058 9.81 301.0434 0.6 18.88 25.31 31.46 42.19	6523.738 (2001) 9064.06 (2011)
CO ₂ Compression system (Z-104) 1 Labor 16082.52kW	SC-Extraction	Axial gas compressor Inlet pressure (psia) Inlet temperature (°F) Outlet pressure (psia) Outlet temperature (°F) Mass capacity (kg/hr) Pressure change (kPa) CO ₂ density (lb/ft ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volumetric flow rate (m ³ /s) Fluid power (kW) Pilot turbine fluid power (kW) Ratio of required/pilot capacity	870.23 80.51 1450.37 169.92 919326.6 3998.822 6.6067 105.8264 2.413089 9649.513 3000 3.216504	600198 (2001) 1209832 (2001) 1680936 (2011)
Extraction system (Z-105) 1 Labor 250 kg/s	SC-Extraction	Jacketed non agitated Operating pressure (MPa) Range of temperature (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) SC volume capacity (m ³) Pilot reactor volume (m ³) Ratio of required/pilot capacity	40 95 - 131 1.33 1330 9.4475 151.3305 6092.241 54 112.8193	755.2593 (2001) 12868.45 (2001) 17879.38 (2011)

Table B.1.1. C	Continued.
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Equipment	Unit	Description	Description Value	Cost (\$) (year)
Separation vessel (Z-106)	SC-Extraction	Process Vessel - Vertical Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volume capacity (m ³) Pilot vessel volume (m ³ 3) Ratio of required/pilot capacity	 5801.51 121.9 870.23 130.9 1.33 1330 36.6995 587.8542 1581.208 520 3.040784	2936483 (2001) 5722936 (2001) 7951428 (2011)
Material Pump system (P-110) 303.83kW	SC-Extraction	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 8.640288 9.81 5821.711 0.6 182.3 244.46 303.83 407.44 	57808.08 (2001) 80318.36 (2011)
CO₂ Strip vessel (Z- 108) 1 Labor	SC-Extraction	Storage - Tank area Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 870.23 121.9 870.23 121.9 1.33 1330 6.6067 105.8264 8695.76 8695.76 1	337430.9 (2001) 337430.9 (2001) 468825.4 (2011)

Table B.1.2.	Technical	equipment	and	cost	information	of	plant	site	for	Case
Scenario 2.										

Equipment	Unit	Description	Description Value	Cost (\$) (year)
Flocculation tank (TK-101) 1 Labor	Flocculation	SS or CS Tank P = ambient pressure T = ambient or near Temperature Capacity (lb) Volume (m ³) Used volume (m ³)	 557375.8 247.1276 300	56677.47 (2001) 78747.49 (2011)
CLTALGAE Pump system (P-101) 129.6kW	Flocculation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 39.45725 9.81 602.0868 0.6 77.76 104.28 129.6 173.8	15447.58 (2001) 21462.81 (2011)

Table B.1.2. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
RE-WATER Pump system (P-102) 192.53kW	Flocculation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	0.999984 210.5427 9.81 200.6956 0.6 115.53 154.91 192.53 258.18 	20621.54 (2001) 28651.49 (2011)
PONDFEED Pump system (P-103) 234.78kW	Flocculation	Fluid density (kg/L) Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic Power (bph) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Ratio of required/pilot capacity Centrifugal pump	1.03 250 9.81 200.6956 0.6 140.87 188.9 200 234.78 314.83 1.1739	21225.9 (2001) 23369.25 (2001) 32469.16 (2011)
Dewatering Press Filter (Z-101) 1 Labor 11.31kW	Dewatering	Filter presses system - Pressure leaf Operating pressure (psia) Operating temperature (°F) Initial estimated capacity (ft ³ /hr) Total volume feed batch (gal) Solid concentration product feed (%) Specific gravity of process solid Mass of the cake (lb/hr) Volume of the cake (lb/hr) Volume of the cake (lb/hr) Volume of the cake (ft ³ /hr) Weight of cake (lb/ft ³) Percent of dry solids in cake (%) Desired cycles per day of filter Estimated time for one batch Cake required volume (ft ³) Application volume requirement (ft ³)	90 76.9 1605.069 12002.15 49.999 1.33 70937.19 934.9059 75.87629 71.42754 24 0.042 3763.63 156.818	11210.68 (2001) 43249.31 (2011)

Equipment	Unit	Description	Description Value	Cost (\$) (year)
		Cake thickness (m)	1.5	
		Estimated filter area (ft ²) Quote index for the	31.86579	
		current year	394	

Table B.1.2. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
WETALGAE Pump system (P-104) 12.58kW	Dewatering	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.24E+00 2.60E+01 9.81 401.3912 0.6 35.26 47.29 58.77 78.81	9234.368 (2001) 12830.2 (2011)
Freeze Dryer system (Z-102) 1 Labor 1169.26kW	Freeze Drying	Assumed Drum Dryer Model area capacity (m ²) 304SS VAC freeze dryer Number of shelves Shelve wide (m) Shelve long (m) Shelve distance (mm) Temperature range (°C) Shell dimensions, h w deep, (m) Ice capacity (kg) Ratio of required/pilot capacity	 3.8 5 0.81 0.79 80 -40 to 60 1.2 x 1.0 x0.95 80 114.9216	13939.62 (2001) 240155.2 (2001) 333670.9 (2011)
Water Pump (P-106) 12.56kW	Freeze Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Positive displacement pump	1.00E+00 9.19E+00 9.81 301.0434 0.6 7.54 10.11 12.56 16.85 	6297.122 (2001) 8749.201 (2011)

Table B.1.2. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
DRYMATTER Pump system (P-107) 31.46kW	Freeze Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 17.28058 9.81 301.0434 0.6 18.88 25.31 31.46 42.19 	6523.738 (2001) 9064.06 (2011)
CO ₂ Compression system (Z-103) 1 Labor 16082.52kW	SC-Extraction	Axial gas compressor Inlet pressure (psia) Inlet temperature (°F) Outlet pressure (psia) Outlet temperature (°F) Mass capacity (kg/hr) Pressure change (kPa) CO ₂ density (lb/ft ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volumetric flow rate (m ³ /s) Fluid power (kW) Pilot turbine fluid power (kW) Ratio of required/pilot capacity	870.23 80.51 1450.37 169.92 919326.6 3998.822 6.6067 105.8264 2.413089 9649.513 3000 3.216504	600198 (2001) 1209832 (2001) 1680936 (2011)
Extraction system (Z-104) 1 Labor 250 kg/s	SC-Extraction	Jacketed non agitated Operation pressure (MPa) Range of temperature (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (lb/ft ³) SC volume capacity (m ³) Pilot reactor volume (m ³) Ratio of required/pilot capacity	 40 95 - 131 1.33 1330 9.4475 151.3305 6092.241 54 112.8193	755.2593 (2001) 12868.45 (2001) 17879.38 (2011)

Table B.1.2. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
Separation vessel (Z-105)	SC-Extraction	Process Vessel – Vertical Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/M ³) CO ₂ density (kg/M ³) CO ₂ density (kg/M ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 5801.51 121.9 870.23 130.9 1.33 1330 36.6995 587.8542 1581.208 520	2936483 (2001) 5722936 (2001) 7951428 (2011)
Material Pump system (P-108) 303.83kW	SC-Extraction	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	3.040784 1.33 8.640288 9.81 5821.711 0.6 182.3 244.46 303.83 407.44 	57808.08 (2001) 80318.36 (2011)
CO₂ Strip vessel (Z- 107) 1 Labor	SC-Extraction	Storage - Tank Area Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/M ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/M ³) Volume Capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 870.23 121.9 870.23 121.9 1.33 1330 6.6067 105.8264 8695.76 8695.76 1	337430.9 (2001) 337430.9 (2001) 468825.4 (2011)

Table B.1.3.	Technical	equipment	and	cost	information	of	plant	site	for	Case
Scenario 3.										

Equipment	Unit	Description	Description Value	Cost (\$) (year)
CLTALGAE Pump system (Z-107) 345.66Kw	Freeze Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic Power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (bph) Ratio required/pilot centrifugal pump	1.03+00 245 9.81 301.04 0.6 207.39 278.12 200 345.66 464 1.73 	21225.89797 (2001) 29473.89624 (2001) 40950.93444 (2011)
Freeze Dryer system (Z-101) 1 Labor 28728.96Kw	Freeze Drying	Assumed Drum Dryer Model area capacity (m ²) 304SS VAC freeze dryer number of shelves Shelve wide (m) Shelve long (m) Shelve distance (mm) Temperature range (°C) Shell dimensions , h w deep, (m) Ice capacity (kg) Ratio of required/pilot capacity	 3.8 5 0.81 0.79 80 -40 to 60 1.2 x 1.0 x0.95 80 2872.895729	13939.62149 (2001) 1656696.289 (2001) 2301808.373 (2011)
Water Pump (Z-108) 323.9Kw	Freeze Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (bph) Ratio required/pilot Positive displacement pump	1.00E+00 2.30E+02 9.81 301.0434092 0.6 194.34 260.61 200 323.9 434.35 1.6195 	21225.89797 (2001) 28346.18673 (2001) 39384.09856 (2011)

Table B.1.3. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
DRYMATTER Pump system (Z-109) 31.46kW	Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 17.28058 9.81 301.0434 0.6 18.88 25.31 31.46 42.19	6523.738 (2001) 9064.06 (2011)
CO ₂ Compression system (Z-102) 1 Labor 16082.52kW	SC-Extraction	Axial gas compressor Inlet pressure (psia) Inlet temperature (°F) Outlet pressure (psia) Outlet temperature (°F) Mass capacity (kg/hr) Pressure change (kPa) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volumetric flow rate (m ³ /s) Fluid power (kW) Pilot turbine fluid Power (kW) Ratio of required/pilot capacity	870.23 80.51 1450.37 169.92 919326.6 3998.822 6.6067 105.8264 2.413089 9649.513 3000 3.216504	600198 (2001) 1209832 (2001) 1680936 (2011)
Extraction system (Z-103) 1 Labor 250 kg/s	SC-Extraction	Jacketed non agitated Operating pressure (MPa) Range of temperature (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) SC volume capacity (m ³) Pilot reactor volume (m ³) Ratio of required/pilot capacity	 40 95 - 131 1.33 1330 9.4475 151.3305 6092.241 54 112.8193	755.2593 (2001) 12868.45 (2001) 17879.38 (2011)

Equipment	Unit	Description	Description Value	Cost (\$) (year)
Separation vessel (Z-104)	SC-Extraction	Process Vessel - Vertical Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/M ³) CO ₂ density (lb/ft ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 5801.51 121.9 870.23 130.9 1.33 1330 36.6995 587.8542 1581.208 520 3.040784	2936483 (2001) 5722936 (2001) 7951428 (2011)
Material Pump system (Z-110) 303.83kW	SC-Extraction	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft Power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 8.640288 9.81 5821.711 0.6 182.3 244.46 303.83 407.44	57808.08 (2001) 80318.36 (2011)
CO₂ Strip vessel (Z- 105) 1 Labor	SC-Extraction	Storage - Tank Area Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/M ³) CO ₂ density (kg/M ³) CO ₂ density (kg/M ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 870.23 121.9 870.23 121.9 1.33 1330 6.6067 105.8264 8695.76 8695.76 1	337430.9 (2001) 337430.9 (2001) 468825.4 (2011)

 Table B.1.4.
 Technical equipment and cost information of plant site for Case

 Scenario 4.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
PONPFEED Pump system (Z-108) 690.05W	Flocculation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (bph) Ratio required/pilot centrifugal pump	1.03 245 9.81 602.08 0.6 414.03 555.21 200 690.05 925.35 3.45 	21225.90 (2001) 44624.81 (2001) 62001.57 (2011)
DEWAT Pump system (Z-109) 201.44kW	Dewatering	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Ratio of required/pilot capacity Centrifugal pump	1.00 221 9.81 200.6956 0.6 120.86 162.08 200 201.44 270.13 1.0072	35409.72 (2001) 35562.47 (2001) 49410.38 (2011)
Dewatering Press Filter (Z-101) 1 Labor 70.49kW	Dewatering	Filter presses system - Pressure leaf Operating pressure (psia) Operating temperature (°F) Initial estimated capacity (ft ³ /hr) Total volume feed batch (gal) Solid concentration product feed (%) Specific gravity of process solid Mass of the cake (lb/hr) Volume of the cake (ft ³ /hr) Weight of cake (lb/ft ³) Percent of dry solids in cake (%) Desired cycles per day of filter	90 76.9 8668 64814 9.10 1.33 70936.19 919.50 77.14 71.43 24	46888.43 (2001) 180889.4 (2011)

Equipment	Unit	Description	Description Value	Cost (\$) (year)
		Estimated time for one		
		batch	0.042	
		Cake required volume		
		(ft ³)	1186.1	
		Application volume		
		requirement (ft ³)	1176.7	
		Cake thickness (m)	1.5	
		Estimated filter area		
		(ft ²)	239.1	
		Quote index for the		
		current year	394	

Table B.1.4. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
WETALGAE Pump system (Z-110) 44.08kW	Dewatering	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.24E+00 2.60E+01 9.81 301.04 0.6 26.45 35.47 44.08 59.11 	7818.696 (2001) 10863.27 (2011)
Freeze Dryer system (Z-102) 1 Labor 1169.26kW	Freeze Drying	Assumed Drum Dryer Model area capacity (m ²) 304SS VAC freeze dryer Number of shelves Shelve wide (m) Shelve long (m) Shelve distance (mm) Temperature range (°C) Shell dimensions, h w deep, (m) Ice capacity (kg) Ratio of required/pilot capacity	 3.8 5 0.81 0.79 80 -40 to 60 1.2 x 1.0 x0.95 80 114.9216	13939.62 (2001) 240155.2 (2001) 333670.9 (2011)
Water Pump (Z-111) 12.56kW	Freeze Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Positive displacement pump	1.00E+00 9.19E+00 9.81 301.0434 0.6 7.54 10.11 12.56 16.85	6297.122 (2001) 8749.201 (2011)

Equipment	Unit	Description	Description Value	Cost (\$) (year)
DRYMATTER Pump system (Z-112) 31.46kW	Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal Pump	1.33 17.28058 9.81 301.0434 0.6 18.88 25.31 31.46 42.19 	6523.738 (2001) 9064.06 (2011)
CO ₂ Compression system (Z-103) 1 Labor 16082.52kW	SC-Extraction	Axial gas compressor Inlet pressure (psia) Inlet temperature (°F) Outlet pressure (psia) Outlet temperature (°F) Mass capacity (kg/hr) Pressure change (kPa) CO ₂ density (lb/ft ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volumetric flow rate (m ³ /s) Fluid power (kW) Pilot turbine fluid Power (kW) Ratio of required/pilot capacity	870.23 80.51 1450.37 169.92 919326.6 3998.822 6.6067 105.8264 2.413089 9649.513 3000 3.216504	600198 (2001) 1209832 (2001) 1680936 (2011)
Extraction system (Z-104) 1 Labor 250 kg/s	SC-Extraction	Jacketed non agitated Operating pressure (MPa) Range of temperature (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) SC volume capacity (m ³) Pilot reactor volume (m ³) Ratio of required/pilot capacity	 40 95 - 131 1.33 1330 9.4475 151.3305 6092.241 54 112.8193	755.2593 (2001) 12868.45 (2001) 17879.38 (2011)

Table B.1.4.	Continued.
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Equipment	Unit	Description	Description Value	Cost (\$) (year)
Separation vessel (Z-105)	SC-Extraction	Process Vessel - Vertical Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 5801.51 121.9 870.23 130.9 1.33 1330 36.6995 587.8542 1581.208 520 3.040784	2936483 (2001) 5722936 (2001) 7951428 (2011)
Material Pump system (Z-113) 303.83kW	SC-Extraction	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 8.640288 9.81 5821.711 0.6 182.3 244.46 303.83 407.44	57808.08 (2001) 80318.36 (2011)
CO ₂ Strip vessel (Z- 106) 1 Labor	SC-Extraction	Storage - Tank Area Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 870.23 121.9 870.23 121.9 1.33 1330 6.6067 105.8264 8695.76 8695.76 1	337430.9 (2001) 337430.9 (2001) 468825.4 (2011)

Table B.1.5.	Technical	equipment	and	cost	information	of	plant	site	for	Case
Scenario 5.										

Equipment	Unit	Description	Description Value	Cost (\$) (year)
Flocculation Tank (Tk-101) 1 Labor	Flocculation	SS or CS Tank P = ambient pressure T = ambient or near temperature Capacity (lb) Volume (m ³) Used volume (m ³)	 557375.8 245.4639 300	56677.47 (2001) 78747.49 (2011)
CLTALGAE Pump System (P-101) 126.15kW	Flocculation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.164989 39.45725 9.81 602.0868 0.6 75.69 101.5 126.15 169.17 	15157.89 (2001) 21060.33 (2011)
RE-WATER Pump System (P-102) 187.77kW	Flocculation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.00 206.0067 9.81 200.6956 0.6 112.66 151.08 187.77 251.8 	33681.84 (2001) 46797.44 (2011)

Table B.1.5. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
PONDFEED Pump System (P-103) 230.45kW	Flocculation	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (bph) Ratio required/pilot centrifugal pump	1.03 245.4639 9.81 200.6956 0.6 138.27 185.42 200 230.45 309.03 1.15225 	21225.9 (2001) 23109.69 (2001) 32108.53 (2011)
Membrane Filtration system 1 Labor (Z-101) 180.58kW	Membrane Filtration	Ultra filtration Membrane Model Operation Pressure (psia) Capacity (gal/min) Bed length (inch) Diameter (inch) Diameter (m) Area (m ²) Required capacity (gal/min) Ratio plant/pilot	100 28 96 30 0.762009 0.455817 2490.386 88.94236 1	560 (2000) 8272.813 (2000) 31915.42 (2011)
DEWAT Pump system (P-104) 628.93kW	Membrane Filtration	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Required shaft power (kW) Calculated shaft power (bph) Ratio required/pilot centrifugal pump	1.00E+00 2.07E+01 9.81 668.9854 0.6 377.36 506.04 200 628.93 843.39 3.14465	21225.9 0(2001) 42209.43 (2001) 58645.64 (2011)

Table B.1.5. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
FILTRATE Pump system (P-105) 34.63kW	Membrane Filtration	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.299997 19.4474 9.81 301.0434 0.6 20.78 27.87 34.63 46.44	6858.157 (2001) 9528.701 (2011)
Dryer (Z-102) 1 Labor 5.24kW	Drying	Model from International Process Plants Type fluid bed dryer SS type drum Model capacity (kg) Speed (rpm) Pressure range (psia) Model drum deep (in) Model drum diameter (in) Surface area (m ²) Required capacity (kg) Ratio of required/pilot capacity	 70 1725 50 -8 16 34 0.350976 25281.57 361.1653	84385.45 (2001) 2889956 (2001) 4015295 (2011)
Water Pump System (P-106) 6.29kW	Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated shaft power (kW) Calculated shaft power (kW) Calculated shaft power (bph) Positive displacement	1 2.298409 9.81 602.0868 0.6 3.77 5.06 6.29 8.43 	4749.41 (2001) 4749.41 (2011)

Table B.1.5. Continued.

Equipment	Unit	Description	Description Value	Cost (\$) (year)
DRYMATTER Pump system (P-107) 31.46kW	Drying	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 17.28058 9.81 301.0434 0.6 18.88 25.31 31.46 42.19 	6523.738 (2001) 9064.06 (2011)
CO ₂ Compression system (Z-103) 1 Labor 16082.52kW	SC-Extraction	Axial gas compressor Inlet pressure (psia) Inlet temperature (°F) Outlet pressure (psia) Outlet temperature (°F) Mass capacity (kg/hr) Pressure change (kPa) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volumetric flow rate (m ³ /s) Fluid power (kW) Pilot turbine fluid Power (kW) Ratio of required/pilot capacity	870.23 80.51 1450.37 169.92 919326.6 3998.822 6.6067 105.8264 2.413089 9649.513 3000 3.216504	600198 (2001) 1209832 (2001) 1680936 (2011)
Extraction system (Z-104) 1 Labor 250 kg/s	SC-Extraction	Jacketed non agitated Operating pressure (MPa) Range of temperature (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) SC volume capacity (m ³) Pilot reactor volume (m ³) Ratio of required/pilot capacity	40 95 - 131 1.33 1330 9.4475 151.3305 6092.241 54 112.8193	755.2593 (2001) 12868.45 (2001) 17879.38 (2011)

Table B.1.5.	Continued.
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Equipment	Unit	Description	Description Value	Cost (\$) (year)
Separation vessel (Z-105)	SC-Extraction	Process vessel - vertical Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/m ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 5801.51 121.9 870.23 130.9 1.33 1330 36.6995 587.8542 1581.208 520 3.040784	2936483 (2001) 5722936 (2001) 7951428 (2011)
Material pump system (P-108) 303.83kW	SC-Extraction	Fluid density (kg/L) Flow capacity (m ³ /h) Gravity constant (m/s ²) Differential head (m) Pump efficiency Calculated hydraulic power (kW) Calculated hydraulic power (bph) Calculated shaft power (kW) Calculated shaft power (bph) Centrifugal pump	1.33 8.640288 9.81 5821.711 0.6 182.3 244.46 303.83 407.44	57808.08 (2001) 80318.36 (2011)
CO₂ Strip vessel (Z- 106) 1 Labor	SC-Extraction	Storage - tank area Pressure inlet (psia) Temperature inlet (°F) Pressure outlet (psia) Temperature outlet (°F) Algae density (kg/L) Algae density (kg/M ³) CO ₂ density (lb/ft ³) CO ₂ density (kg/m ³) Volume capacity (m ³) Pilot vessel volume (m ³) Ratio of required/pilot capacity	 870.23 121.9 870.23 121.9 1.33 1330 6.6067 105.8264 8695.76 8695.76 1	337430.9 (2001) 337430.9 (2001) 468825.4 (2011)

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APPENDIX C: ASPEN SIMULATION EXAMPLE - CASE SCENARIO 3 AND SIMULATIONS OUTPUT

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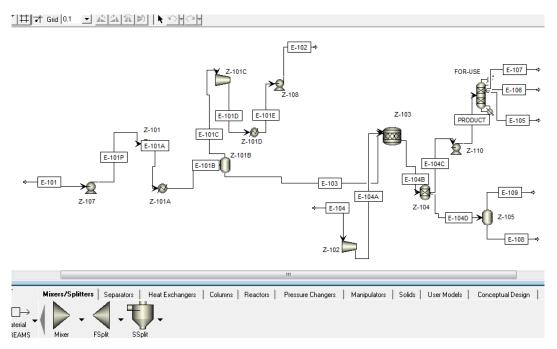


Figure C.1.1. Case 3 process flow diagram window (after building the diagram click the next icon).

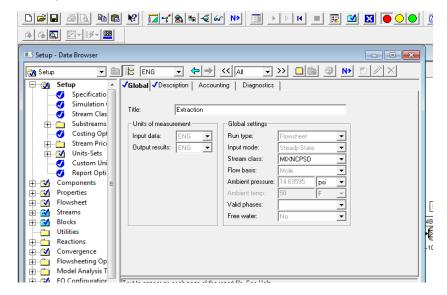


Figure C.1.2. Setup window.

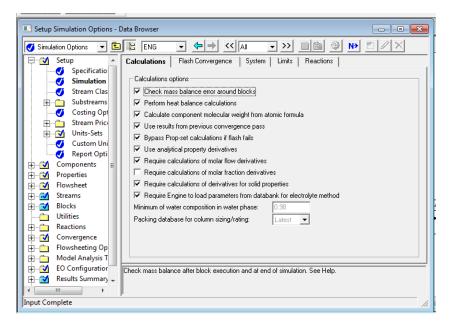


Figure C.1.3. Simulation window.

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The convergence
Flowsheeting Op
Hondel Analysis T
EO Configuration
🗄 🗹 Results Summary 👻
Input Complete

Figure C.1.4. Stream class window (define mixture with non conventional solid with particle size distribution).

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Flowsheeting Op	Generate/suppress the report file generation for batch runs.

Figure C.01.05. Report Options window (choose the options that you which to be displayed in the report output).

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	Petro Chara	ш	<u>▶</u>					
<u><u></u></u>	Petro Criara Pseudocom		_	C2H5N-01	-		C2H5N02-D1	
	Attr-Comps	ш		C3H80-01			C3H8O3	
	Henry Com			C02	Conventional	CARBON-DIOXIDE	CO2	
	Moisture Co	Ξ		ALGAE	Nonconventiona			
—ŏ	UNIFAC Grc		-	H20	Conventional	WATER	H2O	
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	actions		Compo	mont ID. If data as	a to be retrieved fr	om databanko, onto	r either Component	Name or Formula. See Help
	nvergence	-	Compo	nentitu, ir datā ar	e to pe retrieved fi	om databanks, ente	a earlier Component	wane of Formula, see Help
↓		-						
nput Comple	ete	,						

Figure C.1.6. Components window (all the components that will be used in the simulation were specified).

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Figure C.1.7. Global component list window (verify that all the components were included in the global section).

Properties - Data Browser	
Properties	
Components Property methods & models Process type:	Data set: 1 Liquid enthalpy: HLMX88 Liquid volume: VLMX01 V Heat of mixing Poynting correction Use liq: reference-state enthalpy

Figure C.1.8. Properties Specification window (make sure that you choose UNIQUAC as base method).

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Figure C.1.9: Binary window in parameters tab.

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🗄 🔼 Stre	ams		Component ID.	
🕂 🔂 Bloc	:ks	-		
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nput Complet	e			

Figure C.1.10. Advance section in properties window (choose the methods of enthalpy and density calculation).

Flowsheet Section - Data Bro	wser	x
😪 Section 💌 🖻		
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	Rename Make Current	
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Input Complete		1.

Figure C.1.11. Flowsheet window.

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Adva	anced Routes	Z-110	Pump	E-104C	F(IN)		PRODUCT	P(OU	
	User Pa NC Prc	Z-104	Sep	E-104B	F(IN)	† †	E-104C	P(OU'	
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Figure C.1.12. Global Flowsheet window (here the connectivity can be verified).

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🕂 🔂 E-108				
🗄 🔂 E-109				
🗄 🔂 PRODUCT 🚽				

Figure C.1.13. Streams window (here are all the streams already named according to Case 3).

Stream E-101 (MATERIAL) - I	Data Browser
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⊕ ∩ E-101C ⊕ ∩ E-101D ⊕ ∩ E-101P ⊕ ∩ E-102 ≡ ⊕ ∩ E-103 ≡ ⊕ ∩ E-104 ≡	45 psia Total flow: Mass kg/hr Solvent:
E-104B C E-104C E-104C E-104D E-104D E-105 E-105 E-105 F-106 ←	Lets you select the substream name.

Figure C.1.14. E-101 mixed tab (inlet stream should be the only one defined).

E Stream E-101 (MATERIAL) -	Data Browser	- 0 <mark>×</mark>
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	Solvent:	
	Total: [22982.9334	
	Lets vou select the substream name.	
€-106 -		
Input Changed, Unreconciled.		

Figure C.1.15. E-101 nonconventional compound tab for microalgae (inlet stream should be the only one defined).

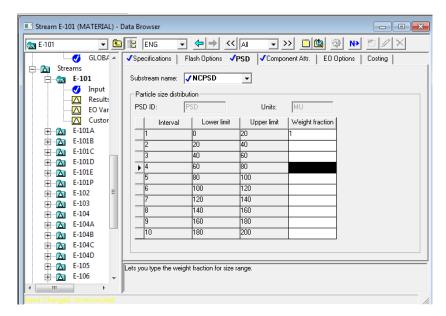


Figure C.1.16. Particle size distribution in E-101 (microalgae has between 10 μ m to 30 μ m).

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⊕ ⊡	FC VM ASH 18.4
	Lets you select the substream name.
Input Changed. Unreconciled.	

Figure C.1.17. E-101 Proxanal component properties for microalgae based on literature (sulfanal and ultanal component properties should be entered).

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	Results EO Var Custor	Pressure C6H12-01	
· · ·	01C 01D 01E	C3H80-01	
	02 ≡	lotal How: Mole bmol/hr ▼	
		Solvent:	
Ē 🔂 E-10	04B 04C 04D	Total: 0	
	05	ets you select the substream name.	
< III Input Changed. Uni	Feconciled.		

Figure C.1.18. Examples of other streams in the input (input should not be done).

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CA	PE-OPEN	FOR-USE	Sep	Input Changed	▲
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	ction	Z-101A	Heater	Input Changed	
		Z-101B	Flash2	Input Changed	
🗄 📩 Streams		Z-101C	Compr	Input Changed	
	R-USE	Z-101D	Heater	Input Changed	
		Z-102	Compr	Input Changed	_
	101A	Z-103	RStoic	Input Changed	-
🛓 🔂 Z-1	L01B	Z-104	Sep	Input Changed	-
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Figure C.1.19. Block window.

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Figure C.1.20. FOR-USE Specification window for E-106.

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E Sect	GLOB4			Component ID	Specification	Basis	Value	Units	
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	Ports Stream								
<u>∧</u> 									
⊕		-	Outlet	stream ID.					
nput Changed		ļ	þ						

Figure C.1.21. FOR-USE Specification window for E-105.

Block FOR-USE	(Sep) - Data B	Browser						
📩 FOR-USE	-	ENG	- 4	■ → << Al	• >	›) 🔲 😃	🥥 N >	" / X
	NC Prc 🔺	✓Specificatio	ns 🗸 Feed	Flash 🗸 Outlet Fla	ash Utilit	y]		
	Tabpo							
	User Pi	Outlet stream						
	PE-OPEN	Outlet stream	J	-				
Flowshe		Substream:	MIXED	_				
	tion			1				
	GLOB4	· · · ·	onent ID	Specification	Basis	Value	Units	
		C6H12-0		Split fraction		0		
	R-USE	C2H5N-0	1	Split fraction		0		
	Input	C3H80-0	1	Split fraction		1		
	Block (=	C02		Split fraction				1
	Results	H20		Split fraction				1
	EO Var							
	EO Inp							
	Spec G							
	Ports							
	Stream							
	Custor							
Carlos C								
	101A -	Outlet stream ID.						
	* 410							
nput Changed		þ						

Figure C.1.22. FOR-USE Specification window for E-107.

Block FOR-USE (Sep) - Data E	
📷 FOR-USE 🛛 💌 🖻	
 NC Prc * Tabpo User Pi CAPE-OPEN Flowsheet Streams Globs Blocks FOR-USE Blocks Blocks Block = Block = EO Var EO Var EO Var EO Var Stream Custor Z-101A Z-101A Z-101A T 	✓ Specifications ✓ Feed Flash ✓ Dutlet Flash Utility Inlet flash specifications Pressure: 35 MPa

Figure C.1.23. FOR-USE feed flash window.

Block FOR-USE (Sep) - Data B	rowser
🔄 FOR-USE 💽 🖿	
NC Prc ^ Tabpo User Pi CAPE-OPEN Flowsheet Steetion GLOBA Streams Blocks GR-USE Monte Streams Monte Streams Streams Streams Monte Streams	✓ Specifications
	Estimates Temperature: F v Pressure: psia v Stream ID.

Figure C.1.24. FOR-USE outlet flash window for E-106.

TOR-USE	- 🖻	😫 ENG 💽 🗲	→ << Al	->> 🗖 🕲 🔊 🕨	
	IC Prc 🔺 🔹	✓Specifications ↓ ✓ Feed	Flash 🗸 Outlet Flash	n Utility	
	abpo	-		_	
	ser Pi	Stream: VE-105	-	Flash stream	
CAPE-	OPEN	Flash specifications			
Flowsheet		Temperature:	328 K	*	
	LOBA	Pressure:	35 MPa	•	
+ 🕅 Streams		Temperature change:	F	~	
		Vapor fraction:	· · · · ·	_	
FOR-U	ISE	Valid phases:	Vapor-Liquid	-	
🛛 🗍 📈 🚺 In	nput		Labor adma		
	lock (😑	- Estimates		- Flash options	
(Count	esults	Temperature:	F 👻	Maximum iterations: 30	3
lennet.	O Var	Pressure:	psia 🔻	Error tolerance: 0.0001	-
· · · ·	O Inp		Ibsig 💽		
	pec G				
	orts tream				
(int)	ustor				
⊕ <u>Z</u> -101					
± 2-101A	A 5	itream ID.			
🕂 🔂 Z-101B					
<	•				

Figure C.1.25. FOR-USE outlet flash window for E-105.

🖳 Block Z-101 (H	eater) - Data i	
🔁 Z-101	- 🖻	
	NC Prc 🔺	✓Specifications Flash Options Utility
	Tabpo	
	User Pi	Flash specifications
	PE-OPEN	Temperature 233.1 K -
Flowshe		Pressure 1 bar 🗸
🖃 🔂 Se	ction GLOB4	V-Ed-L
• •		Valid phases
		Vapor-Liquid 🔹
	R-USE	
	101	
T T	Input ≡	
	Hcurve	
	Dynam	
	Block (
<u>-</u>	Results	
	EO Var	
	EO Inp Spec G	
	Ports	
	Stream	Lets you type the outlet temperature. See Help.
	Custor 🚽	Lets you type the butter temperature. See help.
<		

Figure C.1.26: Z-101 Specifications window.

Block Z-101A (Heater) - D	ta Browser
🔁 Z-101A. 💌 🤅	
CAPE-OPEN CAPE-OPEN CAPE-OPEN Flowsheet GLOB2 GLOB	Valid phases Valid phases Valid phases Valid phases Valid phases Valid phases
Input Changed	J

Figure C.1.27. Z-101A Specifications window.

Block Z-101B (Flash	h2) - Data Br	owser			
🔁 Z-101B	- 🖻	ENG 💽 🗲	→ << All	• >> 🗖 🕲 🖗) n 2 X
		Specifications Flash 0	ptions Entrainmer	nt Utility	
CAPE-	-OPEN	- Flash specifications			
Section	n	Temperature	▼ 320.1	K 🔻	
	GLOB4	Pressure	▼ 0.1	bar 🔻	
		1		,	
		Valid phases			
		Vapor-Liquid	-		
🖃 📩 Z-101					
	nput 🚊				
· · · · ·	Dynam Block (
· · · · ·	Results				
Count of the second sec	O Var				
	O Inp				
· · · · · · · · · · · · · · · · · · ·	pec G				
	orts Stream				
	Custor -	ets you type the outlet tempe	rature. See Help.		
<	•				
Input Changed	,				

Figure C.1.28. Z-101B Specifications window.

Block Z-101C (Compr) - Data	Browser
Image: Section Image: Section Image: Section Image: Se	
Custor -	

Figure C.1.29. Z-101C Specifications window.

Block Z-101D (Heater) - Data Browser				
Flowsheet Section GLOB4 Sections GLOB4 Flash Specifications Understand GLOB4 Understand Understand GLOB4 </th				
Stream Custor m M				
Input Changed				

Figure C.1.30. Z-101D Specifications window.

💷 Block Z-102 (Compr) - Data	Browser
Block Z-102 (Compr) - Data C 2-102 C GLOB4 C	
Custor	

Figure C.1.31. Z-102 Specifications window.

Block Z-102 (Compr) -	
🔁 Z-102 🔄	
GLOE	🗸 🔺 Calculation Options Power Loss Convergence 🗸 Integration Parameters Utility 💽
🗄 🔂 Streams	Internation without
Blocks	Integration method
🛨 🔂 FOR-USE	Method: Direct method -
🛨 🔼 Z-101	
🗄 🔼 Z-101A	Integration steps
🕀 🔼 Z-101B	Equal pressure change
🗄 🔼 Z-101C	Number of intervals: 5
🗄 🔼 Z-101D	C Equal pressure ratio
🖻 🗟 Z-102	Pressure ratio for each step: 1.25
Setup	Pressure ratio for last sten: 1 375
Verfo	
User 🗸 User	-
J Block	
Resu	
U EO In	
Spec	
Ports	
Strea	
Custo	
< III III III	

Figure C.1.32. Z-101 Integration parameters window.

Block Z-103 (RStoic) - Data I	Browser
🔁 Z-103 🔹 🗈	
GLOBA 🔺	✓Specifications ✓Reactions Combustion Heat of Reaction Selectivity PSD ✓C →
	Operating conditions
	Temperature 318.1 K
🚊 🔂 Z-101B	Valid phases
E Z-101C E Z-101D	Vapor-Liquid 💌
⊕ Z-102	
E Z-103	
Conve	
Dynam ≡	
Results	
EO Var	
EO Inp	
Ports	
Stream	Reactor outlet pressure or pressure drop. Absolute units: value > 0 - outlet pressure; value <= 0 - pressure drop. Gauge units: outlet pressure.
< <u> </u>	
Input Changed	li.

Figure C.1.33. Z-103 Specifications window.

🗙 Z-103	!	•	٤	
		GLOBA		✓Specifications ✓Reactions Combustion Heat of Reaction Selectivity PSD ✓C ◀
	Streams	02004		Specifications Reactions Compassion Hear of Hear of Hearting Fish C
	Blocks			Reactions
		R-USE		Rxn No. Specification type Stoichiometry
1 1	🛆 Z-1			1 Frac. conversion ALGAE> .0014607 C6H12-01 + .0077286 C2H5N-01 + .001
1 1	🛆 Z-1			
1 T	A Z-1			
1 T	🛆 Z-1			
I T	🛆 Z-1			
· -	🛆 Z-1			
: T	📩 Z-1			
1	-			
	- ŏ	Conve		
		Dynam	=	
	- 0	Block		
	Ā	Results		
		EO Var		New Edit Delete Copy Paste
		EO Inp		
		Spec G		Reactions occur in series
		Ports		
		Stream	Ī	
		Custor	-	

Figure C.1.34. Z-103 Reaction parameters window.

📃 Block Z-103 (RStoic) - Data B	rowser 🗖 🖬 🗴
🔁 Z-103 🔹 🖻	
GLOBA GL	ENG
	Reaction number.

Figure C.1.35. Z-103 reaction editor window (all parameters are based on Appendix A using the molecular weights provided by ASPEN).

💷 Block Z-103 (RStoic) - Data B	rowser
🔁 Z-103 🔹 🖻	
GLOB4 ▲ ⊕ ☆ Streams	✓ Reactions Combustion Heat of Reaction Selectivity PSD ✓ Component Attr. ▲ ▲
Blocks	Substream ID: VICPSD
	Component attributes
± 101	Component ID: VALGAE Element Value
🕂 🔂 Z-101B	Attribute ID: PROXANAL MOISTURE 100 FC
	ASH
🚊 🔂 Z-103	
Conve Dynam ≡	
Block (
Results	
EO Var	
Spec G	
Ports	
Stream Custor	Substream ID.
Custor -	

Figure C.1.36. Z-103 Component attributes window

Block Z-103 (RStoic) - Data Browser
GLOB/ GLOB/ Streams GLOB/ Blocks FOR-USE Component attributes Component ID: /NEPSD / Component Attr. Utility / Substream ID: /NEPSD / Component Attributes Component ID: //NEPSD / Component Attributes FC // MM // ASH // Substream Component Attribute ID. Component Attribute ID.
Input Changed

Figure C.1.37. Z-103 Component attribute window (ultanal and sulfanal need not to be specified).

📙 Block Z-104 (Sep) -							
📩 Z-104	- 🗈	🗄 ENG 💌	4 -> << All	• >>			5 / X
· · · ·	ilob4 🔺 🖡	✓Specifications ✓Fe	ed Flash 🗸 Outlet Fla	ish Utility			
⊡		- Outlet stream condition	200				
Blocks	ISE	Outlet stream: E-10					
		Substream:					
⊞ <u>⊼</u> Z-1014	A	Substream.					
🕂 🔂 Z-101B		Component ID	Specification	Basis	Value	Units	
🕀 🔂 Z-1010		C6H12-01	Split fraction	0			
		C2H5N-01	Split fraction	0			
		C3H80-01	Split fraction	0			
⊡ 🔂 Z-104		C02	Split fraction	1			
	nput	H20	Split fraction				
· · · ·	lock (=	_					
County of County	esults						
Concerned and the second	O Var O Inp						
	pec G						
· · · ·	orts						
	tream						
(ferref)	ustor	Substream ID.					
🛨 🔂 Z-105	-						
III III III III III III III	<u> </u>						

Figure C.1.38. Z-104 Specifications window for E-104D.

🗈 Block Z-104 (Sep) - Data Browser
Slocks Specifications / Feed Flash / Dutlet Flash Utility Intel flash specifications Z-101 Z-101 Z-101 Z-101 Z-101 Z-101 Z-101 Z-102 Z-103 Z-103 Z-103 Z-103 Z-103 Z-103 Z-104 Z-103 Z-104 Z-103 Z-105 Z-1

Figure C.1.39. Z-104 feed flash window.

Block Z-104 (Sep) - Data Bro	wser
🔁 Z-104 💌 🖻	
Blocks 🔺	✓Specifications ✓Feed Flash ✓Outlet Flash Utility
FOR-USE	Stream: VE-104C V Flash stream
i	
⊞ Z-101A Z-101B	Flash specifications
	Temperature: 323.1 K
+ ⊼ Z-101D	Pressure: 870.23 psia
庄 🔂 Z-102	Temperature change:
庄 🔂 Z-103	Vapor fraction:
E 🔂 Z-104	Valid phases: Vapor-Liquid
Block (Results ≡	Estimates Flash options
EO Var	Temperature: F V Maximum iterations: 30
	Pressure: psia 💌 Error tolerance: 0.0001
Ports	
Custor	
⊡ <mark>⊘</mark> Z-105	
Hcurve -	Stream ID.
Input Changed	, ,

Figure C.1.40. Z-104 outlet window for E-104C.

Block Z-104 (Sep) - Data Brov	ser	
🔁 Z-104 💌 🛅		>> <mark>- @</mark> @ N•
Blocks ▲ □ ■ </th <th>Specifications ✓ Feed Flash ✓ Outlet Flash Util Stream: ✓ Feed Flash ✓ Outlet Flash Util Stream: ✓ Flash specifications Temperature: 323.1 K Pressure: 870.23 psia Temperature change: F Vapor fraction: Valid phases: Vapor-Liquid</th> <th>ity </th>	Specifications ✓ Feed Flash ✓ Outlet Flash Util Stream: ✓ Feed Flash ✓ Outlet Flash Util Stream: ✓ Flash specifications Temperature: 323.1 K Pressure: 870.23 psia Temperature change: F Vapor fraction: Valid phases: Vapor-Liquid	ity
→ Input → Block (→ Result: = → EO Var → EO Inp → Spec G → Ports → Stream → Custor → 2.105	Temperature: F 🚽 Maxim	n options mum iterations: 30 tolerance: 0.0001
Input Changed	Stream ID.	

Figure C.1.41. Z-104 outlet window for E-104D.

Block Z-105 (Flash2) - Data B	drowser
🔁 Z-105 🔹 🖻	
Blocks 🔺	Specifications Flash Options Entrainment Utility
FOR-USE	
🕂 🔼 Z-101	Flash specifications
	Temperature 323.1 K
	Pressure 💌 870.23 psia 💌
	V.FL.L
± Z-1010	Valid phases
	Vapor-Liquid 💽
+ 🔂 Z-104	
🖃 📩 Z-105 🚽	
🛅 Hcurve	
Results	
EO Var	
EO Inp	
Ports	
Stream	Lets you type the outlet temperature. See Help.
Custor -	Lets you type the outlet temperature. See help.
Input Changed	y In

Figure C.1.42. Z-105 Specification window.

🔁 Z-107 🔹	🗈 😰 ENG 🔻 🗢 🔶 << 🗛 🗸 🗸 🗸
Image: Constraint of the second se	Specifications Calculation Options Flash Options Utility Model Pump outlet specification Efficiencies Pump: 0.6 Driver: Pump Pump

Figure C.1.43. Z-107 Specification window.

Block Z-108 (Pump)		
📩 Z-108		
C-101 C-101 C-101 C-101A C-101B C-101B C-101C C-101C C-101D	Model C Turbine	
□ □ Z-102 □ □ Z-103 □ □ Z-104 □ □ Z-105 □ □ Z-107 □ □ □ □ □ Z-107	Pump outlet specification Discharge pressure: 45 psia Pressure increase: psi Pressure ratio: Power required: hp r Use performance curve to determine discharge conditions	
	ser Si Emolencies ser Si Pump: 0.6 Driver:	
V EC V Sp V Pa	Pump	
Cu Input Changed	ustor +	

Figure C.1.44. Z-108 Specification window.

💷 Block Z-110 (Pump) - Data B	rowser
🔁 Z-110 🔹 🖻	
2-101A □	Specifications Calculation Options Flash Options Utility Model Pump C Turbine Pump outlet specification Discharge pressure: 870.23 paia C Pressure increase: psi C Pressure radio: C Power required: hp C Use performance curve to determine discharge conditions
Input Changed	

Figure C.1.45. Z-110 Specification window.

Dynamic Configuration Dyn	namic Options - Data Browser	×
🍼 Dynamic Options 🛛 💌 🖭		
	Components Component options Is all components in dynamic simulation Remove unused components from dynamic simulation Specify components that cannot be excluded from the dynamic simulation Image: Components in dynamic simulatin dynamic simulatin dynamic simulation	
Input Complete	,	٦,

Figure C.1.46. Dynamic window.

₩ 8 5 60	N≯	
	Nex	t

Figure C.1.47. Next icon (use next after overall or section input is completed, to run the simulation click next).

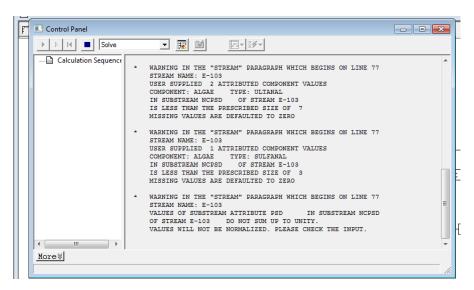


Figure C.1.48. Normal warning (ASPEN advices that some parameters were not specified. This is more at the discretion of the person doing the simulation).

▶ ▷ H 🔳 Solve		
Calculation Sequence		
Z-107	Block: Z-110 Model: FUMP	
Z-101A	Block: FOR-USE Model: SEP	
- D Z-101C	->Generating block results	
Z-101D	Block: Z-110 Model: PUMP	
Z-102	Block: Z-107 Model: PUMP	
Z-103	Block: Z-108 Model: PUMP	
Z-105 Z-110 FOR-USE	->Simulation calculations completed	
	*** No Errors or Warnings Generated ***	
	->Generating results	E
← III → More ∛]	-

Figure C.1.49. Final output (this is normal output indicating that simulations wre run with errors or warnings. Errors or warning should be corrected).

Solve	<u> </u>	Report	
Calculation Sequence	Block: Z-108	Display report for :	^
Z-107	Block: Z-11(Block	
- D Z-101A	Block: FOR-U	Streams Balance Pressure Relief	
Z-101B	->Generating b:	Pressure Heller Regression Simulation	
- 🔂 Z-101D	Block: Z-1:	Block IDs	
Z-108	Block: Z-1(→ □ □ FOR-USE ▲ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □	
Z-103	Block: Z-10		
	->Simulation ca		
Z-110		□ □ □ Z-102 □ □ □ Z-103	
	*** No Erro:		
	->Generating re		Ξ
4		Z-108	Ļ
More¥	'	OK Cancel Apply	
All blocks have been executed	а		

Figure C.1.50. Report generation window (after simulation runs, press Crlt, Alt, Delete and choose simulation).

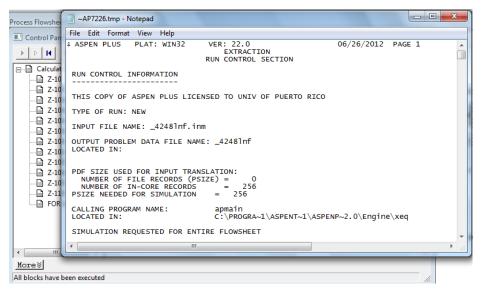


Figure C.1.51. ASPEN simulation report (where the information is used for validation purposes).

C.2 - ASPEN simulation outputs

Figures C.2.1 to C.2.5 are the summary output obtained from ASPEN ONE simulator. For illustrative purposes, the figures appear separated in different subsections C.2.1 to C.2.5.

C.2.1 - APEN Plus simulator output for Case Scenario 1

₽ ASPEN PLUS PL	AT: WIN32	VER: 22.0 EXTRACTION RUN CONTROL SECTION	06/01/2012 PAGE 1	
RUN CONTROL INFO	ORMATION			
THIS COPY OF AS	PEN PLUS LICEN	ISED TO UNIV OF PUERTO	RICO	
TYPE OF RUN: NEW	W			
INPUT FILE NAME	: _1218zrm.inm	1		
OUTPUT PROBLEM I LOCATED IN:	DATA FILE NAME	: _5138nrg		
PDF SIZE USED F(NUMBER OF FILE NUMBER OF IN-(PSIZE NEEDED FO	E RECORDS (PSI CORE RECORDS	(ZE) = 0 = 256		
CALLING PROGRAM LOCATED IN:	NAME:	apmain C:\PROGRA~1\ASPENT~	1\ASPENP~2.0\Engine\xeq	
SIMULATION REQU	ESTED FOR ENTI	RE FLOWSHEET		
DESCRIPTION				
REPREESE	NTATIVES. TOD MALIZED THESE	S SIMULATED WITH THREE AY A MASS OF ALGAE WI COMPOUN S. THIS APPLI		
₽ ASPEN PLUS PL		VER: 22.0 EXTRACTION FLOWSHEET SECTION	06/01/2012 PAGE 2	

Figure C.2.1. ASPEN print out for Case Scenario 1

	US PLAT: WI	E FLOV	22.0 EXTRACTION VSHEET SECTION	0	6/01/2012	PAGE 2
E-114 E-1110 E-116 E-115 E-106P E-106P E-106 E-108 E-110P E-105 E-108 E-110	FOR-USE IL Z-106 Z-108 EP Z-105 Z-101 P-105 Z-102	P-110 Z-106 P-105 Z-102 P-107 P-109 Z-103 Z-105	STREAM E-104 E-112 PRODUCT E-111CO2 E-115 E-105P E-107P E-109P E-104P E-107 E-109	P-110 Z-106 Z-108 Z-104 Z-101 Z-102 Z-103	FOR-USE Z-108 Z-105 P-104 P-106 P-108	
P-110 Z-106 Z-108 Z-105 Z-101 P-105 Z-101 P-102 Z-103 P-101 P-104 P-106 P-107 P-108	INLETS E PRODUCT E -11103 E-11153 E-11153 E-11153 E-11153 E-11153 E-11153 E-1019 E-1069 E-1089 E-1079 E-1089 E-1089 E-	L P 22 F E-110	E-1 PRC E-1 E-1 E-1 E-1 E-1 E-1	11SCF 06P E-105F 06 07P E-108P 09P E-110F 04P 05 07 08 09	.1CO2	

(Figure C.2.1: Continue)

COMPUTATIONAL SEQUENCE			
SEQUENCE USED WAS: P-101 Z-101 P-105 Z-102 Z-106 Z-108 P-110 FOR-US		P-108 P-104 P	-109 Z-104 Z-10
OVERALL FLOWSHEET BALANCE			
≗ ASPEN PLUS PLAT: WIN32	VER: 22.0 EXTRACTION		06/01/2012 PAGE
	FLOWSHEET SECT	ION	
OVERALL FLOWSHEET BALANCE (CONTINUED)		
××× M	ASS AND ENERGY BAI	LANCE ***	
	IN	OUT	RELATIVE DI
CONVENTIONAL COMPONENTS	(LBMOL/HR)	37.0050	1 00000
	0.00000		
C2H90_01	0.00000		-1.00000
C3H80-01 C02	20904.4		
H20	2812 54	2812 54	0 1616865
SUBTOTAL (LBMOL/HR)	23717.0	23002 0	-0.114993E-
(LB/HR)	970669.	23992.9 996003.	-0.254356E-
NON CONVENTIONAL COMPONE			
ALGAE	50668.7	25334.3	0.500000
SUBTOTAL (LB/HR)	50668.7 50668.7	25334.3	0.500000
TOTAL BALANCE			
MASS(LB/HR)	0.102134E+07	0.102134E+0	7 0.413688E-
ENTHALPY(BIU/HK)	-0.4209/0E+10	-0.411995E+1	0 -0.213328E-
	VER: 22.0	(06/01/2012 PAG
	EXTRACTION		
PH	YSICAL PROPERTIES	SECTION	

(Figure C.2.1: Continue)

COMPONENTS			
С6H12-01 С С6H12	IO2-D1 C2H5NO2-D1		REPORT NAME C6H12-01 C2H5N-01 C3H80-01 C02 ALGAE H20
ID ATTRIE ALGAE PROXA ASPEN PLUS PLAT: WI BLOCK: FOR-USE MODEL	NAL ULTANAL SULFANAL N32 VER: 22.0 EXTRACTION U-O-S BLOCK SEC		6/01/2012 PAGE 5
INLET STREAM: OUTLET STREAMS:			
CONV. COMP. (LBMC (LB/H NONCONV. COMP (LE	*** MASS AND ENERGY BA IN DL/HR) 275.901 IR) 25333.9 3/HR) 0.00000	OUT	RELATIVE DIFF. 0.00000 0.00000 0.00000
TOTAL BALANCE MASS(LB/HR)	25333.9) -0.742263E+08	25333.9	0.00000 -0.158168E-02

(Figure C.2.1: Continue)

*** INPUT DATA *	ŔŔ
INLET PRESSURE PSIA	5,076.32
FLASH SPECS FOR STREAM E-113 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	130.910 5,076.32 30 0.000100000
FLASH SPECS FOR STREAM E-112 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	130.730 5,076.32 30 0.000100000
FLASH SPECS FOR STREAM E-114 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE # ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SE	
BLOCK: FOR-USE MODEL: SEP (CONTINUED)	
C2H5N-01 C3H80-01	TION= 1.00000 0.0 0.0 TION= 0.0
C2H5N-01 C3H80-01	0.0 1.00000

(Figure C.2.1: Continue)

*** RESULTS ***	
HEAT DUTY BTU/HR	0.11740E+06
COMPONENT = C6H12-01 STREAM SUBSTREAM SPLIT FRACTION E-112 MIXED 1.00000	
COMPONENT = C2H5N-01 STREAM SUBSTREAM SPLIT FRACTION E-113 MIXED 1.00000	
COMPONENT = C3H80-01 STREAM SUBSTREAM SPLIT FRACTION E-114 MIXED 1.00000	
BLOCK: P-101 MODEL: PUMP	
INLET STREAM: E-104 OUTLET STREAM: E-104P PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE ***	
IN OUT CONV. COMP.(LBMOL/HR) 2812.54 2812.54 (LB/HR) 50668.7 50668.7 NONCONV. COMP(LB/HR) 50668.7 50668.7 TOTAL BALANCE	0.00000
MASS(LB/HR) 101337. 101337. ENTHALPY(BTU/HR) -0.673825E+09 -0.673825E+09	0.00000 9 0.00000 96/01/2012 PAGE 7

(Figure C.2.1: Continue)

BLOCK: P-101 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY FLASH SPECIFICATIONS:	90.0000 0.60000 1.00000
LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS ***	
VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	816.529 0.0 207.787 0.0 0.0 0.0 0.60000 0.0 0.0
BLOCK: P-104 MODEL: PUMP	
INLET STREAM: E-105P OUTLET STREAM: E-105 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE *** IN OUT CONV. COMP. (LBMOL/HR) 1687.52 1687.57 (LB/HR) 30401.2 30401.2 NONCONV. COMP (LB/HR) 0.00000 0.00000	RELATIVE DIFF. 2 0.00000 2 0.00000
TOTAL BALANCE MASS(LB/HR) 30401.2 30401.7 ENTHALPY(BTU/HR) -0.207267E+09 -0.207270 ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-S BLOCK SECTION	2 0.00000 0E+09 0.157463E-04 06/01/2012 PAGE 8

(Figure C.2.1: Continue)

BLOCK: P-104 MODEL: PUMP (CONTINUED) *** INPUT DATA *** OUTLET PRESSURE PSIA 30.0000 0.60000 1.00000 PUMP EFFICIENCY DRIVER EFFICIENCY FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS 30 0.000100000 TOLERANCE *** RESULTS *** *** RE VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB 489.918 -60.0000 207.787 -2.13782 -1.28269 -0.95650 0.60000 -1.28269 -139.234 BLOCK: P-105 MODEL: PUMP -----E-106P INLET STREAM: INLET STREAM: E-100P OUTLET STREAM: E-106 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS *** MASS AND ENERGY BALANCE ***
 PHADS
 AND
 ENERG

 IN
 IN

 CONV.
 COMP. (LBMOL/HR)
 1125.02

 (LB/HR)
 20267.5

 NONCONV.
 COMP(LB/HR)
 50668.7

 TOTAL
 BALANCE
 MASS(LB/HR)
 70936.2

 ENTHALPY(BTU/HR)
 -0.466558E
 €

 # ASPEN
 PLUS
 PLAT:
 WIN32
 OUT RELATIVE DIFF. 001 1125.02 20267.5 50668.7 0.00000 0.00000 70936.2 0.00000 -0.466560E+09 0.466301E-05 06/01/2012 PAGE 9 70936.2 -0.466558E+09 -0. VER: 22.0 EXTRACTION U-O-5 BLOCK SECTION

(Figure C.2.1: Continue)

BLOCK: P-105 MODEL: PUMP (CO	NTINUED)	
*** IN OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	IPUT DATA ***	30.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE		30 0.000100000
***	ESULTS ***	
VOLUMETRIC FLOW RATE CUFT/H PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB BLOCK: P-106 MODEL: PUMP	t	326.612 -60.0000 207.787 -1.42522 -0.85513 -0.63767 0.60000 -0.85513 -139.234
INLET STREAM: E-107P OUTLET STREAM: E-107 PROPERTY OPTION SET: UNIQUAC	UNIQUAC / IDEAL GAS	
*** MASS A CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR) TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR) -C \$ ASPEN PLUS PLAT: WIN32 VE	843.762 843.762 15200.6 15200.6 0.00000 0.00000 15200.6 15200.6 1010634E+09 -0.1036338	0.00000
	-5 BLOCK SECTION	

BLOCK: P-106 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	30.0000 0.60000 1.00000
	1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED	
MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
	0.000100000
*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI	244.952 15.3077
NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP	33.0315 0.27270 0.45450
ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP	0.33892 0.60000 0.45450
HEAD DEVELOPED FT-LBF/LB	35.5216
BLOCK: P-107 MODEL: PUMP	
INLET STREAM: E-108P OUTLET STREAM: E-108 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDE/	AL GAS
*** MASS AND ENERGY BALANCE	
CONV. COMP.(LBMOL/HR) 281.254 (LB/HR) 5066.87	OUT RELATIVE DIFF. 281.254 0.00000 5066.87 0.00000
	50668.7 0.00000
MASS(LB/HR) 55735.6 9 ENTHALPY(BTU/HR) -0.362926E+09 -0. ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION	55735.6 0.00000 .362926E+09 -0.106214E-05 06/01/2012 PAGE 11

(Figure C.2.1: Continue)

BLOCK: P-107 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	30.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS ***	
VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	81.6507 15.3077 33.0315 0.090901 0.15150 0.11297 0.60000 0.15150 35.5216
BLOCK: P-108 MODEL: PUMP	
INLET STREAM: E-109P OUTLET STREAM: E-109 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL G	AS
*** MASS AND ENERGY BALANCE *	××
IN 0 CONV. COMP.(LBMOL/HR) 281.251 281. (LB/HR) 5066.82 5066 NONCONV. COMP(LB/HR) 0.00000 0.00	.82 0.00000
TOTAL BALANCE MASS(LB/HR) 5066.82 5066 ENTHALPY(BTU/HR) -0.345443E+08 -0.345 ₽ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-5 BLOCK SECTION	

(Figure C.2.1: Continue)

BLOCK: P-108 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	45.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS ***	
VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	81.6505 -20.0000 149.771 -0.11876 -0.071259 -0.053138 0.60000 -0.071259 -46.4105
BLOCK: P-109 MODEL: PUMP	
INLET STREAM: E-110P OUTLET STREAM: E-110 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEA	IL GAS
NONCONV. COMP(LB/HR) 50668.7 5	OUT RELATIVE DIFF.
	0668.7 0.00000 328382E+09 0.552390E-11 06/01/2012 PAGE 13

(Figure C.2.1: Continue)

[BLOCK: P-109 MODEL: PUMP (CONTINUED)	
	*** INPUT DATA *** EQUIPMENT TYPE: TURBINE OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	45.0000 0.60000 1.00000
	FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
	*** RESULTS ***	
	VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP	0.00081651 20.0000 149.771 -0.118766-05 -0.712593-06 -0.531381-06 0.60000 -0.712593-06 46.4105
	BLOCK: P-110 MODEL: PUMP	
	INLET STREAM: E-1110IL OUTLET STREAM: PRODUCT PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
	*** MASS AND ENERGY BALANCE *** IN OUT CONV. COMP.(LBMOL/HR) 275.901 275.901 (LB/HR) 25333.9 25333.9 NONCONV. COMP(LB/HR) 0.00000 0.00000 TOTAL BALANCE	RELATIVE DIFF. 0.00000 0.00000 0.00000
	MASS(LB/HR) 25333.9 25333.9 ENTHALPY(BTU/HR) -0.742263E+08 -0.742263E+(\$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	0.00000 08 0.103601E-06 06/01/2012 PAGE 14

BLOCK: P-110 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** EQUIPMENT TYPE: PUMP OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	870.000 0.60000 0.60000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	295.307 -0.23000 1,460.72 -0.0049397 -0.0029638 -0.0013261 0.60000 -0.0017783 -0.38607
BLOCK: Z-101 MODEL: SEP INLET STREAM: E-104P OUTLET STREAMS: E-106P E-105P PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE *** IN OUT CONV. COMP. (LBMOL/HR) 2812.54 2812.55 (LB/HR) 50668.7 50668.7 NONCONV. COMP(LB/HR) 50668.7 50668.7 TOTAL BALANCE MASS(LB/HR) 101337. 101337 ENTHALPY(BTU/HR) -0.673825E+09 -0.67382	4 0.00000 7 0.00000 7 0.00000

(Figure C.2.1: Continue)

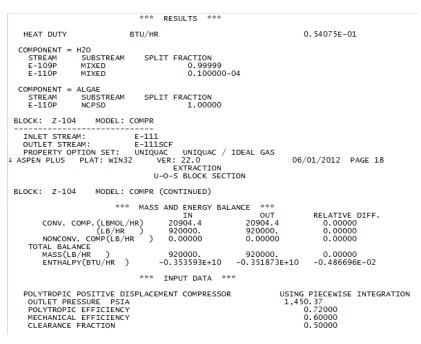
*** INPUT DATA ***	
INLET PRESSURE PSIA	90.0000 06/01/2012 PAGE 15
BLOCK: Z-101 MODEL: SEP (CONTINUED)	
FLASH SPECS FOR STREAM E-106P TWO PHASE TP FLASH PRESSURE DROP PSI MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	0.0 30 0.000100000
FLASH SPECS FOR STREAM E-105P TWO PHASE TP FLASH PRESSURE DROP PSI MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	0.0 30 0.000100000
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-105P CPT= H2O FRACTION= SUBSTREAM= NCPSD	0.60000
STREAM= E-105P CPT= ALGAE FRACTION=	0.0
*** RESULTS ***	
HEAT DUTY BTU/HR	0.28595E-03
COMPONENT = H20STREAMSUBSTREAME-106PMIXEDE-105PMIXED0.60000	
COMPONENT = ALGAE STREAM SUBSTREAM SPLIT FRACTION E-106P NCPSD 1.00000	

(Figure C.2.1: Continue)

BLOCK: Z-102 MODEL: CFUGE	
INLET STREAM: E-106 OUTLET STREAMS: E-107P E-108P PROPERTY OPTION SET: UNIQUAC UNIQUAC / J # ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-5 BLOCK SECT3	
BLOCK: Z-102 MODEL: CFUGE (CONTINUED)	
*** MASS AND ENERGY BALA IN CONV. COMP.(LBMOL/HR) 1125.02 (LB/HR) 20267.5 NONCONV. COMP(LB/HR) 50668.7 TOTAL BALANCE	OUT RELATIVE DIFF. 1125.02 0.00000 20267.5 0.00000 50668.7 0.00000
TOTAL BALANCE MASS(LB/HR) 70936.2 ENTHALPY(BTU/HR) -0.466560E+09	70936.2 0.00000 -0.466560E+09 0.292675E-09
*** INPUT DATA *** RATIO OF LIQ RADIUS TO RADIUS OF BOWL RATIO OF CAKE RADIUS TO RADIUS OF BOWL RATIO OF HEIGHT TO RADIUS OF BOWL CAKE RESISTANCE FT/LB FILTER MEDIUM RESISTANCE 1/FT MOISTURE CONTENT POROSITY OF CAKE PARTICLE SPHERICITY AVERAGE PARTICLE DIAMETER FT SURFACE TENSION DYNE/CM AVERAGE SOLID DENSITY LB/CUFT DRY SOLIDS FEED MASS FLOW RATE LB/HR	0.73800 0.79000 0.95450 0.00032174 0.38100 0.100000 0.45000
*** RESULTS *** CALCULATED PARTICLE DIAMETER FT RESULTED MOISTURE CONTENT SELECTED BOWL RADIUS FT REVOLUTION SPEED RPM BASKET HEIGHT FT	0.328084-04 0.100000 688.976 1,210.00 657.628

BLOCK: Z-103 MODEL:	SEP		
INLET STREAM: OUTLET STREAMS: PROPERTY OPTION SET:	E-108 E-109P E UNIQUAC UNI	-110P QUAC / IDEAL GAS	5
** CONV. COMP.(LBMOL (LB/HR NONCONV. COMP(LB/ \$ ASPEN PLUS PLAT: WIN:	IN /HR) 281.25) 5066.8 HR) 50668. 32 VER: 22.0 EXTRA	RGY BALANCE *** OUT 4 281.25 7 5066.8 7 50668. 0 CTION CK SECTION	RELATIVE DIFF. 4 0.00000 57 0.00000 7 0.00000 06/01/2012 PAGE 17
BLOCK: Z-103 MODEL: TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR	•		6 0.00000 26E+09 -0.148997E-09
	*** INPUT DA	TA ***	
INLET PRESSURE PSIA			65.0000
FLASH SPECS FOR STREA TWO PHASE TP FLA PRESSURE DROP MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	SH PSI S		0.0 30 0.000100000
FLASH SPECS FOR STREA TWO PHASE TP FLA PRESSURE DROP MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	SH PSI S		0.0 30 0.000100000
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-110P SUBSTREAM= NCPSD STREAM= E-110P			0.100000-04 1.00000

(Figure C.2.1: Continue)



(Figure C.2.1: Continue)

*** RESULTS ***	
INDICATED HORSEPOWER REQUIREMENT HP 6,763.49 BRAKE HORSEPOWER REQUIREMENT HP 11,272.5 NET WORK REQUIRED HP 11,272.5 POWEL LOSSES HP 4,508.99 ISENTROPIC HORSEPOWER REQUIREMENT HP 4,763.68 CALCULATED OUTLET TEMP F 169.918 ISENTROPIC TEMPERATURE F 144.034 EFFICIENCY 0.72000 VOLUMETRIC EFFICIENCY 0.76835 DISPLACEMENT CUT/HR 181,235. OUTLET VAPOR FRACTION 1.00000 HEAD DEVELOPED, FT-LBF/LB 10,480.5 MECHANICAL EFFICIENCY USED 0.60000 INLET VOLUMETRIC FLOW RATE, CUFT/HR 139,251. OUTLET COMPRESSIBILITY FACTOR 1.00000 OUTLET COMPRESSIBILITY FACTOR 1.00000 OUTLET COMPRESSIBILITY FACTOR 1.00000 AV. ISENT. TEMP EXPONENT 1.27821 AV. ACTUAL VOL. EXPONENT 1.27821 AV. ACTUAL VOL. EXPONENT 1.42824 AV. ACTUAL TEMP EXPONENT 1.42824 AV. ACTUAL TEMP EXPONENT 1.42824 <t< th=""><th></th></t<>	
BLOCK: Z-105 MODEL: RSTOIC	
INLET STREAMS: E-111SCF E-110 OUTLET STREAM: E-111SEP PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE *** IN OUT GENERATION RELATIVE DIFF. CONV. COMP. (LBMOL/HR) 20904.4 21180.3 275.901 0.161027E-16 (LB/HR) 920000. 945334. 0.500000 -0.267989E-01 NONCONV COMP(LB/HR) 50668.7 25334.3 0.500000 TOTAL BALANCE 970669. 970668. 0.435283E-06 ENTHALPY(BTU/HR) -0.384711E+10 -0.377578E+10 -0.185415E-01	

(Figure C.2.1: Continue)

*** INPUT DATA *** STOICHIOMETRY MATRIX: REACTION # 1: SUBSTREAM MIXED : C6H12-01 0.146E-02C2H5N-01 0.773E-02C3H8O-01 0.170E-02 SUBSTREAM NCPSD : ALGAE -1.00 REACTION CONVERSION SPECS: NUMBER= 1 REACTION # 1: SUBSTREAM:NCPSD KEY COMP:ALGAE CONV FRAC: 0.5000 PHASE TP FLASH TWO TWO PHASE IP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE 116.330 5,801.51 30 0.000100000 CONVERGENCE TOLERANCE SIMULTANEOUS REACTIONS GENERATE COMBUSTION REACTIONS FOR FEED SPECIES ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION NO 06/01/2012 PAGE 20 U-O-S BLOCK SECTION BLOCK: Z-105 MODEL: RSTOIC (CONTINUED) *** RESULTS *** OUTLET TEMPERATURE OUTLET PRESSURE F 116.33 5801.5 0.71329E+08 PSIA BTU/HR HEAT DUTY VAPOR FRACTION 0.0000

(Figure C.2.1: Continue)

REACTION EXTENTS:									
REACTION	REACTION EXTENT LBMOL/HR								
1	25334.								
V-L PHASE EQUILIBRIUM :									
COMP C6H12-01 C2H5N-01 C3H80-01 C02 H2O	F(I) 0.17472E-02 0.92444E-02 0.20347E-02 0.98697 0.13279E-06	0.98697	1.0000	0.25762					
BLOCK: Z-106 MOI	DEL: SEP								
INLET STREAM: OUTLET STREAMS: PROPERTY OPTION SE			GAS						
		ENERGY BALANCE							
CONV. COMP. (LE		[N 20 2 211	OUT R .80.3	ELATIVE DIFF. 0.00000					
Ĺ	3/HR) 9453	334. 945		0.123147E-15					
NONCONV. COMP	(LB/HR) 2533	34.3 253	34.3	0.00000					
TOTAL BALANCE MASS(LB/HR ENTHALPY(BTU/H		568. 970 7578E+10 -0.37	0668 7454E+10 -	0.119933E-15 0.326944E-03					
	*** INPUT	DATA ***							
INLET PRESSURE F ‡ ASPEN PLUS PLAT:	EXT	2.0 FRACTION BLOCK SECTION		1.51 /2012 PAGE 21					

(Figure C.2.1: Continue)

U-O-S BLOCK SECTION	
BLOCK: Z-106 MODEL: SEP (CONTINUED)	
FLASH SPECS FOR STREAM E-1110IL TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	121.910 870.230 30 0.000100000
FLASH SPECS FOR STREAM E-111CO2 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	122.000 870.230 30 0.000100000
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-111CO2 CPT= C6H12-01 FRACTION= C2H5N-01 C3H80-01 C02	0.0 0.0 0.0 1.00000

(Figure C.2.1: Continue)

HEAT DUTY	BTU/HR	0.12345E+07
COMPONENT = C6H12-01 STREAM SUBSTREAM E-1110IL MIXED	SPLIT FRACTION 1.00000	
COMPONENT = C2H5N-01 STREAM SUBSTREAM E-1110IL MIXED	SPLIT FRACTION 1.00000	
COMPONENT = C3H80-01 STREAM SUBSTREAM E-1110IL MIXED	SPLIT FRACTION 1.00000	
COMPONENT = CO2 STREAM SUBSTREAM E-111CO2 MIXED	SPLIT FRACTION 1.00000	
COMPONENT = H2O STREAM SUBSTREAM E-111CO2 MIXED	SPLIT FRACTION 1.00000	
COMPONENT = ALGAE STREAM SUBSTREAM E-111CO2 NCPSD ₽ ASPEN PLUS PLAT: WIN3	1.00000	06/01/2012 PAGE 22

(Figure C.2.1: Continue)

LOCK: Z-108 MODEL: FLASH2		
INLET STREAM: E-111CO2 OUTLET VAPOR STREAM: E-116 OUTLET LIQUID STREAM: E-115 PROPERTY OPTION SET: UNIQUAC UNIQUAC /	IDEAL GAS	
*** MASS AND ENERGY BAL	ANCE ***	
IN CONV. COMP. (LBMOL/HR) 20904.4	OUT 20904.4	RELATIVE DIFF.
(LB/HR) 920000. NONCONV. COMP(LB/HR) 25334.3 TOTAL BALANCE	920000. 25334.3	0.126538E-15 0.00000
	945334. -0.370040E+10	
*** INPUT DATA ***		
TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA		L.600 0.230
MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE) 0.000100000
*** RESULTS ***		
OUTLET TEMPERATURE F OUTLET PRESSURE PSIA		121.60 870.23
HEAT DUTY BTU/HR VAPOR FRACTION		-82090. 1.0000
V-L PHASE EQUILIBRIUM :		
COMP F(I) X(I) CO2 1.0000 0.99993		
H2O 0.13454E-06 0.73099E ASPEN PLUS PLAT: WIN32 VER: 22.0		-06 0.33505E-02 01/2012 PAGE 23

(Figure C.2.1: Continue)

INTERVAL	LOWER LIMIT	UPPER LIMIT	
1	0.0 FT	6.5617-05 FT	
2	6.5617-05 FT	1.3123-04 FT	
3 4 5 6 7	1.3123-04 FT	1.9685-04 FT	
4	1.9685-04 FT	2.6247-04 FT	
5	2.6247-04 FT	3.2808-04 FT	
6	3.2808-04 FT	3.9370-04 FT	
7	3.9370-04 FT	4.5932-04 FT	
8 9	4.5932-04 FT	5.2493-04 FT	
9	5.2493-04 FT	5.9055-04 FT	
10	5.9055-04 FT	6.5617-04 FT	
ASPEN PLUS	PLAT: WIN32	VER: 22.0 EXTRACTION STREAM SECTION	06/01/2012 PAGE 2

(Figure C.2.1: Continue)

E-106P E-107 E-107P E-108 E-108P

STREAM ID	E-104	E-104P	E-105	E-105P	E-106	E-106P	E-107	E-107P	E-108	E-108P
FROM :		P-101	P-104	z-101	P-105	z-101	P-106	z-102	P-107	z-102
то	P-101	z-101		P-104	z-102	P-105		P-106	z-103	P-107
CLASS:	MIXNCPSD							MIXNCPSD		
TOTAL STREAM:	HEXACT DD	HEARCE DE	- HIXACI DD	- HEXACTOR	/ HIXACI DE	- HIXACI DD	MIXACI DD	HEXACT DD	HIXACI SD	HIMICI DD
LB/HR	1.0134+05	1.0134+05	3.0401+04	3.0401+04	7.0936+04	7.0936+04	1.5201+04	1.5201+04	5,5736+04	5.5736+04
	-6.7383+08									
SUBSTREAM: MIXED	-0.7303+00	-0.7303+00	-2.0/2/+00	-2.0/2/+00	-4.0030+00	-4.0030+08	-1.0303+00	-1.0303+00	-3.0233+00	-3.0233+00
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID
COMPONENTS: LBMOL/HR	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H20	2812.5396	2812.5396	1687.5237	1687.5237	1125.0158	1125.0158	843.7618	843.7618	281.2540	281.2540
COMPONENTS: LB/HR	2012.0000	2012.3390	100/.323/	100/.323/	1123.0130	1123.0130	045./010	045./010	201.2340	201.2340
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01 C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H20	5.0669+04	5.0669+04	3.0401+04		2.0267+04	2.0267+04	1.5201+04	1.5201+04	5066.8695	5066.8695
		5.0009+04	3.0401+04	3.0401+04	2.026/+04	2.0267+04	1.5201+04	1.5201+04	5000.8095	5000.8095
COMPONENTS: MASS FRAC C6H12-01	. 0.0	0.0			0.0	0.0		0.0	0.0	0.0
			0.0	0.0	0.0		0.0	0.0		0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H2O	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
TOTAL FLOW:	2012 5205	2012 5205	1 607 5007	1 607 5007	1125 0150	1125 0150	043 7610	843.7618	281,2540	201 2540
LBMOL/HR	2812.5396	2812.5396	1687.5237	1687.5237	1125.0158	1125.0158	843.7618			281.2540
LB/HR	5.0669+04	5.0669+04	3.0401+04	3.0401+04	2.0267+04	2.0267+04	1.5201+04	1.5201+04	5066.8695	5066.8695
CUFT/HR	816.5294	816.5294	489.8869	489.9177	326.6027	326.6118	244.9629	244.9520	81.6513	81.6507
STATE VARIABLES:	76 0100	76 0100	76 7024	76 0100	76 0507	76 0100	76.0412	76 0507	76 0700	76 0507
TEMP F	76.9100	76.9100	76.7934	76.9100	76.8587	76.9100	76.9413	76.8587	76.8723	76.8587
PRES PSIA	90.0000	90.0000	30.0000	90.0000	30.0000	90.0000	30.0000	14.6923	30.0000	14.6923
VFRAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LFRAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(Figure C.2.1: Continue)

ENTHALPY: BTU/LBMOL BTU/LB	-6817.7136	-6817.7136	-6817.8210	-6817.7136	-6817.7609	-6817.7136	-6817.6848	-6817.7609	-1.2282+05 -6817.7484	-6817.7609
BTU/HR ENTROPY:	-3.4544+08	-3.4544+08	-2.0727+08	-2.0727+08	-1.3818+08	-1.3818+08	-1.0363+08	-1.0363+08	-3.4545+07	-3.4545+07
BTU/LBMOL-R BTU/LB-R	-38.8595 -2.1570	-38.8595 -2.1570	-38.8631 -2.1572	-38.8595 -2.1570	-38.8611 -2.1571	-38.8595 -2.1570	-38.8586 -2.1570	-38.8611 -2.1571	-38.8607 -2.1571	-38.8611 -2.1571
DENSITY: LBMOL/CUFT LB/CUFT AVG MW	3.4445 62.0537 18.0153	3.4445 62.0537 18.0153	3.4447 62.0576 18.0153	3.4445 62.0537 18.0153	3.4446 62.0554 18.0153	62.0537	62.0527		62.0550	
AVG MW	10.0135	10.0135	10.0135	10.0135	10.0135	10.0135	10.0135	10.0135	10.0135	10.0155
		R: 22.0 EXTRACTION STREAM SECT		06/01/2	012 PAGE 2	5				
E-104 E-104P E-105	E-105P E-106									
E-106P E-107 E-107	P E-108 E-108F	CONTINUE)							
STREAM ID	E-104	E-104P	E-105	E-105P	E-106	E-106P	E-107	E-107P	E-108	E-108P
SUBSTREAM: NCPSD COMPONENTS: LB/HR	STRUCTUR	RE: NON CON	/ENTIONAL							
ALGAE COMPONENTS: MASS F		5.0669+04	0.0	0.0	5.0669+04	5.0669+04	0.0	0.0	5.0669+04	5.0669+04
ALGAE TOTAL FLOW:	1.0000	1.0000	0.0	0.0	1.0000	1.0000	0.0	0.0	1.0000	1.0000
LB/HR STATE VARIABLES:	5.0669+04	5.0669+04	0.0	0.0	5.0669+04	5.0669+04	0.0	0.0	5.0669+04	5.0669+04
TEMP F PRES PSIA VFRAC LFRAC SFRAC	76.9100 90.0000 0.0 0.0 1.0000	76.9100 90.0000 0.0 0.0 1.0000	MISSING 30.0000 MISSING MISSING MISSING	MISSING 90.0000 MISSING MISSING MISSING	76.8587 30.0000 0.0 0.0 1.0000	76.9100 90.0000 0.0 0.0 1.0000	MISSING 30.0000 MISSING MISSING MISSING	MISSING 14.6923 MISSING MISSING MISSING	30.0000 0.0 0.0	76.8587 14.6923 0.0 0.0 1.0000
ENTHALPY: BTU/LB BTU/HR	-6480.9341 -3.2838+08		MISSING MISSING		-6480.9581 -3.2838+08		MISSING MISSING		-6480.9518 -3.2838+08	
DENSITY: LB/CUFT AVG MW	141.9785 1.0000	141.9785 1.0000	MISSING 1.0000	MISSING 1.0000	141.9785 1.0000	141.9785 1.0000	MISSING 1.0000	MISSING 1.0000	141.9785 1.0000	141.9785 1.0000

COMPONENT ATTRIBUTES: ALGAE PROXANAL MOISTURE FC VM ASH ULTANAL	81.7000 0.0 0.0 18.4000	81.7000 0.0 0.0 18.4000	MISSING MISSING MISSING MISSING	MISSING MISSING	81.7000 0.0 0.0 18.4000	81.7000 0.0 0.0 18.4000	MISSING MISSING MISSING MISSING	MISSING MISSING MISSING MISSING	81.7000 0.0 0.0 18.4000	81.7000 0.0 0.0 18.4000
ASH	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
CARBON	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
HYDROGEN	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
NITROGEN	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
CHLORINE	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
SULFUR	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
OXYGEN SULFANAL	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
PYRITIC	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
SULFATE	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
ORGANIC	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	0.0
SUBSTREAM ATTRIBUTES:					0.0					
PSD										
FRAC1	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC2	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC3	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC4	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC5	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC6	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC7	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC8	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC9	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	0.0	0.0
FRAC10 2 ASPEN PLUS PLAT: WIN	, 0.0 vr	0.0 R: 22.0	0.0	0.0 06/01/2012	0.0 PAGE 26	0.0	MISSING	MISSING	0.0	0.0
¥ ASPEN PLUS PLAT: WIN	52 VE	EXTRACTION STREAM SECTION	DN .	06/01/2012	PAGE 20					

E-109 E-109P E-110 E-110P E-111

E-111CO2 E-1110IL E-1	11SCF E-111	SEP E-112								
STREAM ID	E-109	E-109P	E-110	E-110P	E-111	E-111C02		E-111SCF	E-111SEP	E-112
FROM :	P-108	Z-103	P-109	Z-103		Z-106	Z-106	z-104	Z-105	FOR-USE
то :		P-108	z-105	P-109	z-104	z-108	P-110	z-105	z-106	
CLASS:	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD
TOTAL STREAM:										
	5066.8188			5.0669+04		9.4533+05				
BTU/HR	-3.4544+07	-3.4544+07	-3.2838+08	-3.2838+08	-3.5359+09	-3.7003+09	-7.4226+07	-3.5187+09	-3.7758+09	-1.9832+07
SUBSTREAM: MIXED										
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID	VAPOR	VAPOR	LIQUID	VAPOR	LIQUID	LIQUID
COMPONENTS: LBMOL/HR										
		0.0	0.0	0.0	0.0	0.0	37.0059	0.0	37.0059	37.0059
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	195.7990	0.0	195.7990	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	43.0963	0.0	43.0963	0.0
C02	0.0	0.0	0.0	0.0	2.0904+04	2.0904 + 04	0.0	2.0904+04	2.0904 + 04	0.0
H20	281.2512	281.2512	2,8125-03	2.8125-03	0.0	2.8125-03	0.0	0.0	2.8125-03	0.0
COMPONENTS: LB/HR										
С6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	6666, 8937	0.0	6666, 8937	6666, 8937
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	1.4698+04	0.0	1.4698+04	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	3968,9378	0.0	3968.9378	0.0
C02	0.0	0.0	0.0	0.0	9.2000+05	9.2000+05	0.0	9.2000+05		0.0
H20	5066.8188	5066.8188	5.0669-02	5.0669-02	0.0	5.0669-02	0.0	0.0	5.0669-02	0.0
COMPONENTS: MASS FRAC										
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.2632	0.0	7.0524-03	1,0000
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.5802		1.5548-02	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.1567	0.0	4.1985-03	0.0
C02	0.0	0.0	0.0	0.0	1.0000	1.0000	0.0	1.0000	0.9732	0.0
	1,0000	1,0000	1.0000	1,0000	0.0	5.5075-08	0.0	0.0	5.3599-08	0.0
TOTAL FLOW:	1.0000	2.0000	1.0000	1.0000	0.0	5.50.5 00				0.0
LBMOL/HR	281.2512	281.2512	2.8125-03	2.8125-03	2 0904+04	2 0904+04	275 9012	2.0904+04	21180+04	37,0059
LB/HR	5066.8188	5066.8188	5.0669-02	5.0669-02		9.2000+05		9.2000+05		
CUFT/HR	81.6488	81.6505	8.1651-04	8.1651-04				9.7381+04		92,7351
STATE VARIABLES:	01.0400	01.0505	0.1051 04	0.1051 04	1.3323103	1.4555105	200.0070	5.7 501104	2.5/55/04	52.7551
TEMP F	76.8334	76.8723	76.8723	76.8723	80,5100	122,0000	121,9100	169.9179	116.3300	130,7300
PRES PSIA	45.0000	65.0000	45.0000	65.0000	870,2300	870.2300		1450.3700		
VERAC	0.0	0.0	0.0	0.0	1.0000	1.0000	0.0		0.0	0.0
LFRAC	1.0000	1.0000	1.0000	1.0000	0.0	0.0		0.0		1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0					0.0
JE NAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ENTHALPY:											
BTU/LBMOL -1	.2282+05 -1	L.2282+05	-1.2282+05	-1.2282+05	-1.6915+05	-1.6877+05	-2.6903+05	-1.6832+05	-1.7013+05	-5.3592+05	
BTU/LB -6	817.7842 -6	5817.7484	-6817.7484	-6817.7484	-3843.4072	-3834.8686	-2929,9168	-3824.7015	-3811.8442	-2974.7235	
	4544+07 -		-345,4464						-3,6035+09		
ENTROPY:			51511101	51511101	5.5555.05	515202105		515207705	510055105	110002101	
	-38.8619	-38.8607	-38,8607	-38,8607	-7.3576	-6 6875	-136,7072	-6,9628	-0 2872	-252.7076	
BTU/LB-R	-2.1572	-2.1571	-2.1571	-2.1571	-0.1672	-0.1520	-1.4888	-0.1582	-0.2103	-1.4027	
DENSITY:	-2.13/2	-2.13/1	-2.13/1	-2.13/1	-0.10/2	-0.1320	-1.4000	-0.1362	-0.2105	-1.4027	
LBMOL/CUFT	3,4446	3,4446	3,4446	3,4446	0.1501	0.1394	0.9343	0.2147	0.8223	0.3990	
LB/CUFT	62.0563	62.0550	62.0550	62.0550	6.6068	6.1355	85.7883	9.4475	36.6996	71.8918	
AVG MW	18.0153	18.0153	18.0153	18.0153	44.0098	44.0098	91.8225	44.0098	44.6326	180.1577	
						_					
ASPEN PLUS PLAT: WIN		22.0		06/01/2	012 PAGE 2	/					
		EXTRACTION									
	ST	FREAM SECT	ION								
E-109 E-109P E-110 E-11	OP E-111										
E-111CO2 E-1110IL E-111	SCF E-111SE	EP E-11 (C	ONTINUED)								
STREAM ID	E-109	E-109P	E-110	E-110P	E-111	E-111CO2	E-1110IL	E-111SCF	E-111SEP	E-112	
SUBSTREAM: NCPSD	STRUCTURE :	: NON CONV	ENTIONAL								
COMPONENTS: LB/HR											
ALGAE	0.0	0.0	5.0669+04	5.0669+04	0.0	2.5334+04	0.0	0.0	2.5334+04	0.0	
COMPONENTS: MASS FRAC											
ALGAE	0.0	0.0	1.0000	1.0000	0.0	1,0000	0.0	0.0	1.0000	0.0	
TOTAL FLOW:											
LB/HR	0.0	0.0	5.0669+04	5.0669+04	0.0	2.5334+04	0.0	0.0	2.5334+04	0.0	
STATE VARIABLES:											
TEMP F	MISSING	MISSING	76.8723	76.8723	MISSING	122,0000	MISSING	MISSING	116.3300	MISSING	
PRES PSIA	45,0000	65.0000	45.0000	65.0000	870,2300	870,2300	870,2300	1450.3700	5801.5095	5076.3208	
VFRAC	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	
LFRAC	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	
SFRAC	MISSING	MISSING	1.0000	1.0000	MISSING	1.0000	MISSING	MISSING	1.0000	MISSING	
ENTHALPY:											
BTU/LB	MISSING		-6480.9518			-6798.5139	MISSING		-6801.4464	MISSING	
BTU/HR	MISSING	MISSING	-3.2838+08	-3.2838+08	MISSING	-1.7224+08	MISSING	MISSING	-1.7231+08	MISSING	
DENSITY:											
LB/CUFT	MISSING	MISSING	141.9785	141.9785	MISSING	141.9785	MISSING	MISSING	141.9785	MISSING	
AVG MW	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	

	T ATTRIBUTES:										
ALGAE	PROXANAL										
	MOISTURE	MISSING	MISSING	81.7000	81.7000	MISSING	100.0000	MISSING	MISSING	100.0000	MISSING
	FC	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	VM	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	ASH	MISSING	MISSING	18.4000	18.4000	MISSING	18.4000	MISSING	MISSING	18.4000	MISSING
	ULTANAL										
	ASH	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	CARBON	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	HYDROGEN	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	NITROGEN	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	CHLORINE	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	SULFUR	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	OXYGEN	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	SULFANAL										
	PYRITIC	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	SULFATE	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
	ORGANIC	MISSING	MISSING	0.0	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING
SUBSTREA	M ATTRIBUTES:										
PSD											
FRAC1		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC2		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC3		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC4		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC5		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC6		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC7		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC8		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC9		0.0	0.0	0.0	0.0	MISSING	0.0	0.0	MISSING	0.0	0.0
FRAC10		0.0	0.0	0.0	0.0	MISSING	0.0	ŏ.ŏ	MISSING	0.0	0.0
ASPEN PL SPEN SPEN PL SPEN SPEN PL SPEN PL SPEN SPEN PL SPEN SP			: 22.0			12 PAGE 28					
			EXTRACTION		00,01/20						
		9	STREAM SECTI	ON							
		-									

E-113 E-114 E-115 E-1	.16 PRODUCT				
STREAM ID	E-113	E-114		E-116	PRODUCT
FROM :	FOR-USE	FOR-USE	Z-108	Z-108	P-110
то :					FOR-USE
CLASS:	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD
TOTAL STREAM:	1 1000.01	2050 0270	5.5554.64	0.000.05	5.5334.04
	1.4698+04 -4.2015+07				
BTU/HR SUBSTREAM: MIXED	-4.2015+0/	-1.2201+0/	-1./224+08	-3.5282+09	-/.4220+0/
PHASE:	LIQUID	LIQUID	MISSING	VAPOR	LIQUID
COMPONENTS: LBMOL/HR	LIQUID	LIQUID	MISSING	VAPOR	LIQUID
с6н12-01	0.0	0.0	0.0	0.0	37.0059
C2H5N-01	195,7990	0.0	0.0	0.0	195,7990
C3H80-01	0.0	43.0963	0.0	0.0	43,0963
C02	0.0	0.0	0.0	2.0904+04	0.0
H2O	0.0	0.0	0.0	2.8125-03	0.0
COMPONENTS: LB/HR					
C6H12-01	0.0	0.0	0.0	0.0	6666.8937
C2H5N-01	1.4698+04		0.0	0.0	1.4698+04
C3H80-01	0.0	3968.9378	0.0	0.0	3968.9378
CO2	0.0	0.0		9.2000+05	0.0
H2O	0.0	0.0	0.0	5.0669-02	0.0
COMPONENTS: MASS FRAC C6H12-01	0.0	0.0	MISSING	0.0	0.2632
C2H5N-01	1.0000	0.0	MISSING	0.0	0.5802
C3H80-01	0.0	1.0000	MISSING	0.0	0.1567
C02	0.0	0.0	MISSING	1.0000	0.0
H20	0.0	0.0	MISSING		0.0
TOTAL FLOW:					
	195.7990	43.0963	0.0	2.0904+04	
LB/HR	1.4698+04	3968.9378	0.0	9.2000+05	2.5334+04
CUFT/HR	163.0189	50.9022	0.0	1.4984+05	295.3072
STATE VARIABLES:					
TEMP F		130.9100		121.6000	121.9094
PRES PSIA	5076.3208	5076.3208	870.2300	870.2300	870.0000
VFRAC	0.0	0.0 1.0000	MISSING	1.0000	0.0 1.0000
LFRAC SFRAC	0.0	0.0	MISSING MISSING	0.0	0.0
3FKAL	0.0	0.0	MISSING	0.0	0.0

(Figure C.2.1: Continue)

ENTHALPY:	0.0	0.0	NITODING	0.0	0.0
BTU/LBMOL BTU/LB	-2858.5557	-2.8451+05 -3089.3440 -1.2261+07	MISSING	-1.6878+05 -3834.9522 -3.5282+09	-2929.9171
BTU/LBMOL-R BTU/LB-R DENSITY:	-114.7810 -1.5290	-141.7530 -1.5392	MISSING MISSING	-6.6938 -0.1521	-136.7073 -1.4888
LBMOL/CUFT LB/CUFT AVG MW	1.2011 90.1619 75.0672	0.8466 77.9719 92.0947	MISSING MISSING MISSING	0.1395 6.1397 44.0098	
SUBSTREAM: NCPSD COMPONENTS: LB/HR	STRUCTUR	E: NON CON	/ENTIONAL		
ALGAE \$ ASPEN PLUS PLAT: WI	0.0 N32 VE	0.0 R: 22.0 EXTRACTION STREAM SECT		0.0 06/01/2	0.0 012 PAGE 29
E-113 E-114 E-115 E-11	L6 PRODUCT	(CONTINUED))		
STREAM ID	E-113	E-114	E-115	E-116	PRODUCT
COMPONENTS: MASS FRAC ALGAE TOTAL FLOW:	0.0	0.0	1.0000	0.0	0.0
LB/HR STATE VARIABLES:	0.0	0.0	2.5334+04	0.0	0.0
TEMP F PRES PSIA VFRAC LFRAC SFRAC	MISSING 5076.3208 MISSING MISSING MISSING	MISSING 5076.3208 MISSING MISSING MISSING	121.6000 870.2300 0.0 0.0 1.0000	MISSING 870.2300 MISSING MISSING MISSING	MISSING 870.0000 MISSING MISSING MISSING
ENTHALPY: BTU/LB BTU/HR DENSITY:	MISSING MISSING		-6798.7208 -1.7224+08	MISSING MISSING	MISSING MISSING
LB/CUFT AVG MW	MISSING 1.0000	MISSING 1.0000	141.9785 1.0000	MISSING 1.0000	MI55ING 1.0000

FC MISSING MISSING 0.0 MISSING MI VM MISSING MISSING 0.0 MISSING MI ASH MISSING MISSING 18.4000 MISSING MI ULTANAL ASH MISSING MISSING 0.0 MISSING MI	SSING SSING SSING SSING SSING SSING
FC MISSING MISSING 0.0 MISSING MI VM MISSING MISSING 0.0 MISSING MI ASH MISSING MISSING 18.4000 MISSING MI ULTANAL ASH MISSING MISSING 0.0 MISSING MI	SSING SSING SSING SSING
VM MISSING MISSING 0.0 MISSING MI ASH MISSING MISSING 18.4000 MISSING MI ULTANAL ASH MISSING MISSING 0.0 MISSING MI	SSING SSING SSING
ASH MISSING MISSING 18.4000 MISSING MI ULTANAL ASH MISSING MISSING 0.0 MISSING MI	55ING 55ING
ULTANAL ASH MISSING MISSING 0.0 MISSING MI	SSING
ASH MISSING MISSING 0.0 MISSING MI	
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SULFANAL	STING
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SUBSTREAM ATTRIBUTES:	DUTES
PSD	
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FRACIO 0.0 0.0 0.0 MISSING 0	
ASPEN PLUS PLAT: WIN32 VER: 22.0 06/01/2012 P	
EXTRACTION	AGE JO
PROBLEM STATUS SECTION	
HOBELH DIATO DECIZOR	
BLOCK STATUS	
*****	*****
×	*
* Calculations were completed normally	ŵ
*	*
* All Unit Operation blocks were completed normally	*
*	ŵ
* All streams were flashed normally	ŵ
*	*

(Figure C.2.1: Continue)

Section C.2.2 - APEN Plus simulator output for Case Scenario 2

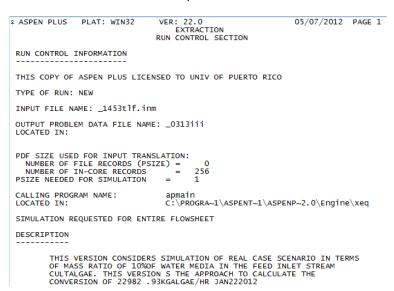


Figure C.2.2. ASPEN print out for Case Scenario 2.

<pre>\$ ASPEN PLUS</pre>	PLAT: WIN		: 22.0 EXTRACTION WSHEET SECTION	0	5/07/2012	PAGE 2
FLOWSHEET CO	NNECTIVITY	BY STREAMS	5			
E-112 E-109D E-114 E-109B E-106C E-106D E-106B	P-105 P-104	P-108 Z-105 Z-102D Z-102E Z-102C P-105 Z-102A	STREAM E-104 E-110 PRODUCT E-109C E-113 E-109A E-106A E-1066 E-106A E-106A E-106A E-107	FOR-USE P-108 Z-105 Z-107 Z-103 Z-102C Z-102E Z-102A	FOR-USE Z-107 Z-104 Z-104 P-106 Z-102B	
Z-105 Z-107 Z-104 Z-103	E-106B E-106C E-106D E-106A E-106P E-104P E-106P E-104 E-105P E-106E	-108	E-1 PRO E-1 E-1 E-1 E-1 E-1 E-1 E-1 E-1 E-1 E-1	09D E-109C 14 E-113 09B 09A 06C E-108 06D 06E 06B 06A 06P E-105F 06 04P 05	:	

(Figure C.2.2: Continue)

COMPUTATIONAL SEQUENCE			
SEQUENCE USED WAS: P-101 Z-101 P-104 P-10 Z-104 Z-105 Z-107 P-100		02C Z-102D Z-102	E P-106 Z-103
OVERALL FLOWSHEET BALANCE			
<pre>\$ ASPEN PLUS PLAT: WIN32</pre>	VER: 22.0 EXTRACTION FLOWSHEET SECT		/07/2012 PAGE 3
OVERALL FLOWSHEET BALANCE	(CONTINUED)		
*** CONVENTIONAL COMPONENT	MASS AND ENERGY BAL	ANCE *** OUT	RELATIVE DIFF.
C6H12-01 C2H5N-01 C3H80-01 C02 H20 SUBTOTAL (LBMOL/HR) (LB/HR) NON-CONVENTIONAL COMPON ALGAE SUBTOTAL (LB/HR) TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR)	0.00000 0.00000 46086.4 2812.54 48898.9 0.207892E+07 VENTS (LB/HR) 50668.7 50668.7 0.212959E+07	49174.8 0.210426E+07 25334.3 25334.3 0.212959E+07 -0.836974E+10	-0.561062E-02 -0.120394E-01 0.500000 0.500000
	PHYSICAL PROPERTIES	SECTION	

(Figure C.2.2: Continue)

COMPONENTS				
ID TYPE C6H12-01 C C2H5N-01 C C3H80-01 C C02 C ALGAE NC H20 C	C2H5NO2-D1	C6H12O6 C2H5NO2-D1	i	REPORT NAME C6H12-01 C2H5N-01 C3H8O-01 C02 ALGAE H2O
ID ALGAE ASPEN PLUS PL	AT: WIN32	ES ANAL SULFANAL VER: 22.0 EXTRACTION U-O-S BLOCK SEC		05/07/2012 PAGE 5
BLOCK: FOR-USE	MODEL: SEP			
OUTLET STREAM		UCT 1 E-110 UAC UNIQUAC /		
	*** MAS	5 AND ENERGY BA		
NONCONV.	(LB/HR) COMP(LB/HR)	IN 275.901 25333.9 0.00000		0.00000
		25333.9 -0.742263E+08		-0.143601E-15 8 -0.158158E-02

(Figure C.2.2: Continue)

*** INPUT DATA ***	
INLET PRESSURE PSIA	5,076.32
FLASH SPECS FOR STREAM E-111 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	130.910 5,076.32 30 0.000100000
FLASH SPECS FOR STREAM E-110 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	130.730 5,076.32 30 0.000100000
FLASH SPECS FOR STREAM E-112 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE ‡ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	130.910 5,076.32 30 0.000100000 05/07/2012 PAGE 6
BLOCK: FOR-USE MODEL: SEP (CONTINUED)	
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-110 CPT= C6H12-01 FRACTION= C2H5N-01 C3H80-01	1.00000 0.0 0.0
STREAM= E-112 CPT= C6H12-01 FRACTION= C2H5N-01 C3H80-01	0.0 0.0 1.00000

		*** R	ESULTS ***		
HEAT DUTY	E	TU/HR			0.11739E+06
COMPONENT = C STREAM E-110	SUBSTREAM	SPLIT	FRACTION 1.00000		
COMPONENT = C STREAM E-111	SUBSTREAM	SPLIT	FRACTION 1.00000		
COMPONENT = C STREAM E-112	SUBSTREAM	SPLIT	FRACTION 1.00000		
BLOCK: P-101	MODEL: F	UMP			
INLET STREAM OUTLET STREA PROPERTY OPT	AM:	E-104P	UNIQUAC ,	/ IDEAL GAS	
	×××	MASS A	ND ENERGY B	ALANCE ***	
	(LB/HR COMP(LB/HF)	2812.54	OUT 2812.54 50668.7 50668.7	0.00000
ASPEN PLUS	/HR) /(BTU/HR)	VE	101337. 0.673825E+09 R: 22.0 EXTRACTION 0-5 BLOCK SE(0.00000 9 0.00000 05/07/2012 PAGE 7
		0-0	-5 BLUCK SEC	LITON	

(Figure C.2.2: Continue)

BLOCK: P-101 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	90.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	816.529 0.0 207.787 0.0 0.0 0.0 0.60000 0.0 0.0
BLOCK: P-104 MODEL: PUMP	
INLET STREAM: E-105P OUTLET STREAM: E-105 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE *** IN CONV. COMP.(LBMOL/HR) 1687.52 1687.52 (LB/HR) 30401.2 30401.2 NONCONV. COMP(LB/HR) 0.00000 0.000000 TOTAL BALANCE MASS(LB/HR) 30401.2 30401.2 ENTHALPY(BTU/HR) -0.207267E+09 -0.207270E ENTHALPY(BTU/HR) -0.207267E+09 -0.207270E \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-S BLOCK SECTION	

(Figure C.2.2: Continue)

BLOCK: P-104 MODEL: PUMP (CONTINUED)	
OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	30.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB BLOCK: P-105 MODEL: PUMP	489.918 -60.0000 207.787 -2.13782 -1.28269 -0.95650 0.60000 -1.28269 -139.234
INLET STREAM: E-106P OUTLET STREAM: E-106 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GA	A5
*** MASS AND ENERGY BALANCE ** IN OL CONV. COMP.(LBMOL/HR) 1125.02 1125. (LB/HR) 20267.5 20267 NONCONV. COMP(LB/HR) 50668.7 50668 TOTAL BALANCE	JT RELATIVE DIFF. 02 0.00000 7.5 0.00000 8.7 0.00000
TOTAL BALANCE MASS(LB/HR)) 70936.2 70936 ENTHALPY(BTU/HR) -0.466558E+09 -0.4665 \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-5 BLOCK SECTION	5.2 0.00000 559E+09 0.233151E-05 05/07/2012 PAGE 9

(Figure C.2.2: Continue)

BLOCK: P-105 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	60.0000 0.60000 0.60000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS ***	
VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	326.612 -30.0000 207.787 -0.71261 -0.42756 -0.19130 0.60000 -0.25654 -69.6171
BLOCK: P-106 MODEL: PUMP	
INLET STREAM: E-106E OUTLET STREAM: E-107 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL G4	45
*** MASS AND ENERGY BALANCE **	R W
IN OI CONV. COMP. (LBMOL/HR) 1125.02 1125. (LB/HR) 20267.5 20267. NONCONV. COMP(LB/HR) 0.00000 0.0000	
MASS(LE/HR) 20267.5 20267 ENTHALPY(BTU/HR) -0.138009E+09 -0.1380 \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION	7.5 0.00000 006E+09 -0.223679E-04 05/07/2012 PAGE 10
U-O-S BLOCK SECTION	

(Figure C.2.2: Continue)

BLOCK: P-106 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	45.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	328.209 30.4962 32.3889 0.72794 1.21323 0.90470 0.60000 1.21323 71.1146
BLOCK: P-108 MODEL: PUMP	
OUTLET STREAM: E-109D OUTLET STREAM: PRODUCT PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE *** IN OUT CONV. COMP.(LBMOL/HR) 275.901 275.901 (LB/HR) 25333.9 25333.9 NONCONV. COMP(LB/HR) 0.00000 0.00000 TOTAL BALANCE MASS(LB/HR) 25333.9 25333.9 ENTHALPY(BTU/HR) -0.7422631E+08 -0.7422631 \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	0.00000 0.00000

(Figure C.2.2: Continue)

BLOCK: P-108 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** EQUIPMENT TYPE: PUMP OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	870.230 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	295.307 0.0 1,460.72 0.0 0.0 0.0 0.60000 0.0 0.0
BLOCK: Z-101 MODEL: SEP 	
TOTAL BALANCE	RELATIVE DIFF. 0.00000 0.00000 0.00000
MASS(LB/HR) 101337. 101337. ENTHALPY(BTU/HR) -0.673825E+09 -0.673825	0.00000 ie+09 -0.424771e-12

(Figure C.2.2: Continue)

	*** INPUT	DATA ***	
INLET PRESSURE PSIA ‡ ASPEN PLUS PLAT: WIN	32 VER: 2 EXT	2.0 RACTION BLOCK SECTION	90.0000 05/07/2012 PAGE 12
BLOCK: Z-101 MODEL:	SEP (CONTINU	IED)	
FLASH SPECS FOR STREA TWO PHASE TP FLA PRESSURE DROP MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	SH PSI IS		0.0 30 0.000100000
FLASH SPECS FOR STREAM E-105P TWO PHASE TP FLASH PRESSURE DROP PSI MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE			0.0 30 0.000100000
SUBSTREAM= NCPSD		FRACTION=	0.60000
STREAM= E-105P	CPT= ALGAE	FRACTION=	0.0
	*** RESUL	.TS ***	
HEAT DUTY	BTU/HR		0.28615E-03
COMPONENT = H2O STREAM SUBSTREAM E-106P MIXED E-105P MIXED		O.40000 0.60000	
COMPONENT = ALGAE STREAM SUBSTREAM E-106P NCPSD	SPLIT FRA	CTION 1.00000	

(Figure C.2.2: Continue)

BLOCK: Z-102A MODEL: HEATER			
INLET STREAM: E-106 OUTLET STREAM: E-106 PROPERTY OPTION SET: UNIQU ASPEN PLUS PLAT: WIN32			05/07/2012 PAGE 13
BLOCK: Z-102A MODEL: HEATER	(CONTINUED)		
CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR)	AND ENERGY BAL IN 1125.02 20267.5 50668.7	ANCE *** OUT 1125.02 20267.5 50668.7	RELATIVE DIFF. 0.00000 0.00000 0.00000
TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR)	70936.2 -0.466559E+09		0.00000 09 0.103637E-01
*** TWO PHASE TP FLASH SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	INPUT DATA *** F PSIA	*	-40.0900 14.5038 30 0.000100000
OUTLET TEMPERATURE F OUTLET PRESSURE PSIA HEAT DUTY BTU/HR OUTLET VAPOR FRACTION PRESSURE-DROP CORRELATION PA			-40.090 14.504 -0.48859E+07 0.0000 0.49231E+08
V-L PHASE EQUILIBRIUM :			
COMP F(I) H20 1.0000	X(I) 1.0000	Y(I) 1.000	

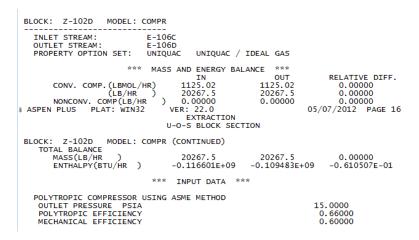
(Figure C.2.2: Continue)

BLOCK: Z-102B MODEL: HEA	TER			
INLET STREAM: E- OUTLET STREAM: E- PROPERTY OPTION SET: UN ASPEN PLUS PLAT: WIN32	IQUAC UNI VER: 22.0 EXTRA			07/2012 PAGE 14
BLOCK: Z-102B MODEL: HEA	TER (CONTIN	UED)		
*** M CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR TOTAL BALANCE	ASS AND ENE IN 1125.0 20267.) 50668.	RGY BALANCE 2 112 5 202 7 506	0UT 5.02 67.5 68.7	RELATIVE DIFF. 0.00000 0.00000 0.00000
MASS(LB/HR) ENTHALPY(BTU/HR)	70936. -0.47144	2 709 5E+09 -0.44	36.2 0210E+09	0.00000 -0.662552E-01
** TWO PHASE TP FLASH SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE		TA *** F PSIA		233.100 1.45038 30 0.000100000
OUTLET TEMPERATURE F OUTLET PRESSURE PSI	/HR	***	C	233.10 1.4504 .31236E+08 1.0000 1553.9
V-L PHASE EQUILIBRIUM :				
COMP F(I) H20 1.00	00	X(I) 1.0000	Y(I) 1.0000	к(I) 15.160

(Figure C.2.2: Continue)

BLOCK: Z-102C MODE	L: FLASH2			
INLET STREAM: OUTLET VAPOR STREAM OUTLET LIQUID STREAM PROPERTY OPTION SET ‡ ASPEN PLUS PLAT: WI	4: E-108 : UNIQUAC UI N32 VER: 22 EXTI	NIQUAC / IDEAL .0 RACTION LOCK SECTION	GAS 05/07	/2012 PAGE 15
BLOCK: Z-102C MODE	L: FLASH2 (CONT	INUED)		
CONV. COMP.(LBM (LB/I NONCONV. COMP(LI TOTAL BALANCE	TI	NERGY BALANCE N. 02 112 7.5 202 8.7 50	OUT R 25.02	ELATIVE DIFF. 0.00000 0.00000 0.00000
MASS(LB/HR) ENTHALPY(BTU/HR	7093) -0.440		936.2	0.00000 0.863023E-02
TWO PHASE TP F SPECIFIED TEMPERATU SPECIFIED PRESSURE MAXIMUM NO. ITERATU CONVERGENCE TOLERANG	RE F PSIA DNS	DATA ***	30	10 5038 00100000
OUTLET TEMPERATURE OUTLET PRESSURE HEAT DUTY VAPOR FRACTION	*** RESUL F PSIA BTU/HR	rs ***	1. -0.3	6.51 4504 8322E+07 0000
V-L PHASE EQUILIBRI	JM :			
СОМР Н2О	F(I) 1.0000	X(I) 1.0000	Y(I) 1.0000	К(I) 1.0600

(Figure C.2.2: Continue)



(Figure C.2.2: Continue)

*** RESULTS ***	
INDICATED HORSEPOWER REQUIREMENT HP BRAKE HORSEPOWER REQUIREMENT HP NET WORK REQUIRED HP POWER LOSSES HP ISENTROPIC HORSEPOWER REQUIREMENT HP CALCULATED OUTLET TEMP F EFFICIENCY (POLYTR/ISENTR) USED OUTLET VAPOR FRACTION HEAD DEVELOPED, FT-LBF/LB MECHANICAL EFFICIENCY USED INLET VOLUMETRIC FLOW RATE, CUFT/HR OUTLET VOLUMETRIC FLOW RATE, CUFT/HR INLET COMPRESSIBILITY FACTOR OUTLET COMPRESSIBILITY FACTOR AV. ISENT. TEMP EXPONENT AV. ACTUAL VOL. EXPONENT AV. ACTUAL TEMP EXPONENT	$\begin{array}{c} 2,797.71\\ 4,662.84\\ 4,662.84\\ 1,865.14\\ 1,590.71\\ 860.709\\ 0.66000\\ 1.00000\\ 180,390.\\ 0.60000\\ 1.32818\\ 4,796,150.\\ 1,062,730.\\ 1.00000\\ 1.31664\\ 1.31664\\ 1.31664\\ 1.55028\\ 1.55028\\ \end{array}$
BLOCK: Z-102E MODEL: HEATER	
INLET STREAM: E-106D OUTLET STREAM: E-106E PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-5 BLOCK SECTION	GA5 05/07/2012 PAGE 17

(Figure C.2.2: Continue)

ASPEN PLUS PLAT: WIN32			05/07/2012 PAGE 17			
BLOCK: Z-102E MODEL: HEATER	(CONTINUED)					
*** MASS CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR) TOTAL BALANCE	AND ENERGY BA IN 1125.02 20267.5 0.00000	LANCE *** OUT 1125.02 20267.5 0.00000	RELATIVE DIFF. 0.00000 0.00000 0.00000			
MASS(LB/HP)	20267.5 -0.109483E+09	20267.5 -0.138009E+0	0.00000 9 0.206701			
*** TWO PHASE TP FLASH SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	INPUT DATA ** F PSIA	*	85.9100 14.5038 30 0.000100000			
*** OUTLET TEMPERATURE F OUTLET PRESSURE PSIA HEAT DUTY BTU/HR OUTLET VAPOR FRACTION PRESSURE-DROP CORRELATION PA			85.910 14.504 -0.28527E+08 0.0000 320.45			
V-L PHASE EQUILIBRIUM :						
COMP F(I) H20 1.0000	X(I) 1.0000	Y(I) 1.000				

(Figure C.2.2: Continue)

 BLOCK: Z-103
 MODEL: COMPR

 INLET STREAM:
 E-109

 OUTLET STREAM:
 E-109A

 PROPERTY OPTION SET:
 UNIQUAC UNIQUAC / IDEAL GAS

 * ASPEN PLUS
 PLAT: WIN32
 VER: 22.0
 05/07/2012
 PAGE 18

 EXTRACTION
 U-O-5 BLOCK SECTION
 BLOCK: Z-103
 MODEL: COMPR (CONTINUED)

 MASS AND ENERGY BALANCE

 IN
 OUT
 RELATIVE DIFF.

 CONV. COMP. (LBMOL/HR)
 46086.4
 46086.4
 0.00000
 (0.00000

 NONCONV. COMP(LB/HR)
 0.202825E+07
 0.202825E+07
 0.00000

 WASS(LB/HR)
 0.202825E+07
 0.202825E+07
 0.00000

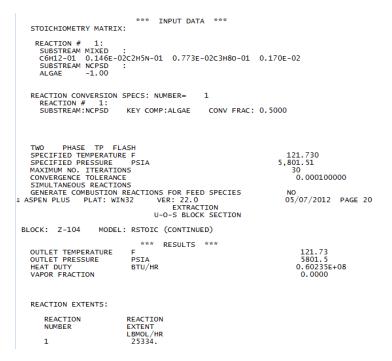
 WITHALPY(BTU/HR)
 -0.779540E+10
 -0.486696E-02

 <

(Figure C.2.2: Continue)

	*** RESULTS ***	
ф.	INDICATED HORSEPOWER REQUIREMENT HP BRAKE HORSEPOWER REQUIREMENT HP NET WORK REQUIRED HP POWER LOSSES HP ISENTROPIC HORSEPOWER REQUIREMENT HP CALCULATED OUTLET TEMP F ISENTROPIC TEMPERATURE F EFFICIENCY (POLYTR/ISENTR) USED VOLUMETRIC EFFICIENCY DISPLACEMENT CUFT/HR OUTLET VAPOR FRACTION HEAD DEVELOPED, FT-LBF/LB MECHANICAL EFFICIENCY USED INLET HEAT CAPACITY RATIO INLET VOLUMETRIC FLOW RATE , CUFT/HR OUTLET VOLUMETRIC FLOW RATE , CUFT/HR INLET COMPRESSIBILITY FACTOR OUTLET COMPRESSIBILITY FACTOR OUTLET COMPRESSIBILITY FACTOR OUTLET COMPRESSIBILITY FACTOR AV. ISENT. VOL. EXPONENT AV. ACTUAL VOL. EXPONENT AV. ACTUAL TEMP EXPONENT AV. ACTUAL TEMP EXPONENT ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	14,910.9 24,851.6 24,851.6 9,940.62 10,502.1 169.918 144.034 0.72000 0.76835 399,554. 1.00000 10,480.5 0.60000 1.28678 306,997. 214,688. 1.00000 1.27821 1.27821 1.27821 1.42824 05/07/2012 PAGE 19
	BLOCK: Z-104 MODEL: RSTOIC	
	INLET STREAMS: E-109A E-108 OUTLET STREAM: E-109B PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL	. GAS
	*** MASS AND ENERGY BALANCE IN OUT CONV. COMP.(LBMOL/HR) 46086.4 46362.3 (LB/HR) 0.202825E+07 0.205359E+07 NONCONV COMP(LB/HR) 50668.7 25334.3 TOTAL BALANCE MASS(LB/HR) 0.207892E+07 0.207892E+07 ENTHALPY(BTU/HR)-0.808490E+10 -0.802467E+10	275.901 -0.134868E-16 -0.123364E-01 0.500000

(Figure C.2.2: Continue)



(Figure C.2.2: Continue)

REACTION EXTENTS:						
REACTION NUMBER	REACTION EXTENT LBMOL/HR					
1	25334.					
V-L PHASE EQUILIBRIUM :						
COMP C6H12-01 C2H5N-01 C3H8O-01 C02	F(I) 0.79819E-03 0.42232E-02 0.92955E-03 0.99405	0.79819E-03	0.16078E-16 0.15513E-12	0.54754E-14 0.99850E-11 0.49855E-08		
BLOCK: Z-105 MO	DEL: SEP					
INLET STREAM: OUTLET STREAMS: PROPERTY OPTION S	E-109B E-109D ET: UNIQUAC U	E-109C NIQUAC / IDEAL	GAS			
(L NONCONV. COMP		359E+07 0.2	OUT REL 362.3 (05359E+07 (0.00000		
TOTAL BALANCE MASS(LB/HR ENTHALPY(BTU/		892E+07 0.20 467E+10 -0.80		0.00000 100878E-04		
*** INPUT DATA ***						
INLET PRESSURE ‡ ASPEN PLUS PLAT:	EXT	2.0 RACTION LOCK SECTION	5,801. 05/07/2	51 012 PAGE 21		

(Figure C.2.2: Continue)

BLOCK: Z-105 MODEL: SEP (CONTINUED)	
FLASH SPECS FOR STREAM E-109D TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA	121.910 870.230
MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	30 0.000100000
FLASH SPECS FOR STREAM E-109C TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	121.910 870.230 30 0.000100000
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-109C CPT= C6H12-01 FRACTION= C2H5N-01 C3H80-01 C02	0.0 0.0 0.0 1.00000

(Figure C.2.2: Continue)

	*** RESULTS ***	
HEAT DUTY	BTU/HR	80951.
COMPONENT = C6H12- STREAM SUBST E-109D MIXED	TREAM SPLIT FRACTION	
COMPONENT = C2H5N- STREAM SUBST E-109D MIXED	FREAM SPLIT FRACTION	
COMPONENT = C3H80- STREAM SUBST E-109D MIXED	TREAM SPLIT FRACTION	
COMPONENT = CO2 STREAM SUBST E-109C MIXED		
COMPONENT = ALGAE STREAM SUBST E-109C NCPSE \$ ASPEN PLUS PLAT:		05/07/2012 PAGE 22

(Figure C.2.2: Continue)

	EXTRACTION U-O-5 BLOCK SECTION								
		o b beoek beer	1014						
BLOCK: Z-107	MODEL: FLASH2								
OUTLET VAPO OUTLET LIQU	M: E-109 R STREAM: E-114 ID STREAM: E-113 TION SET: UNIQU		IDEAL GAS						
	DMP.(LBMOL/HR) (LB/HR) . COMP(LB/HR)	0.202825E+07	OUT	0.00000					
MASS(LB	/HR)		0.205359E+07 -0.795036E+10						
	***	INPUT DATA ***							
	ITERATIONS		870	L.910 D.230 D.000100000					
OUTLET TEMP OUTLET PRES HEAT DUTY VAPOR FRACT	SURE PSIA BTU/HR	RESULTS ***	-(121.91 870.23 0.11810E-05 1.0000					

(Figure C.2.2: Continue)

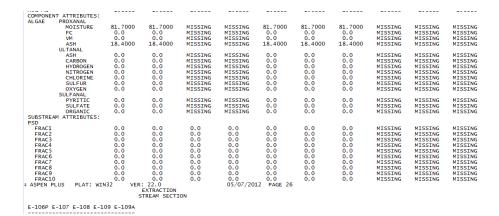
V-L PHASE	EQUILIBRIUM :			
COMP CO2 § ASPEN PLUS	F(I) 1.0000 PLAT: WIN32	X(I) D 1.0000 VER: 22.0 EXTRACTION STREAM SECTION	Y(I) 1.0000 05/07/2012	K(I) 1.8266 PAGE 23
SUBSTREAM A	TTR PSD TYPE: PSD			
1 2 3 4 5 6 7 8 9	0.0 FT 6.5617-05 FT 1.3123-04 FT 1.9685-04 FT 2.6247-04 FT 3.2808-04 FT 3.2808-04 FT 4.5932-04 FT 5.2493-04 FT	UPPER LIMIT 6.5617-05 FT 1.3123-04 FT 2.6247-04 FT 3.2808-04 FT 3.9370-04 FT 5.2493-04 FT 5.9055-04 FT 6.5617-04 FT	-	
♀ ASPEN PLUS	PLAT: WIN32	VER: 22.0 EXTRACTION STREAM SECTION	05/07/2012	PAGE 24
E-104 E-104	P E-105 E-105P E-1	106		

(Figure C.2.2: Continue)

E-106A E-106B E-106C	E-106D E-10	6E 								
STREAM ID	E-104	E-104P	E-105	E-105P	E-106	E-106A	E-106B	E-106C	E-106D	E-106E
FROM :		P-101	P-104	z-101	P-105	Z-102A	Z-102B	z-102C	Z-102D	Z-102E
то :	P-101	z-101		P-104	Z-102A	Z-102B	z-102C	Z-102D	Z-102E	P-106
TO : CLASS:	P-101 MIXNCPSD	MIXNCPSD	MIXNCPSE	MIXNCPSD	MIXNCPSD	MIXNCPSE	MIXNCPSD	MIXNCPSE	MIXNCPSE	MIXNCPSD
TOTAL STREAM;										
LB/HR	1.0134+05	1.0134+05	3.0401+04	3.0401+04	7.0936+04	7.0936+04	7.0936+04	2.0267+04	2.0267+04	2.0267+04
BTU/HR	-6.7383+08	-6.7383+08	-2.0727+08	-2.0727+08	-4.6656+08	-4.7145+08	-4.4021+08	-1.1660+08	-1.0948+08	-1.3801+08
SUBSTREAM: MIXED										
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	VAPOR	VAPOR	VAPOR	LIQUID
COMPONENTS: LBMOL/HR										
C6H12-01		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0			0 0	0 0			0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H20	2812.5396	2812 5396	1687 5237	1687 5237	1125 0158	1125 0158	1125 0158	1125 0158	1125 0158	1125 0158
COMPONENTS: LB/HR	201213330	201213330	100/1020/	100/1020/	1125.0150	1125.0150	112510150	1125.0150	112510150	112510150
C6H12-01	0.0	0.0	0.0	0.0	0.0	0 0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C02	0.0	0.0	0.0	0.0	0.0	ŏ.ŏ	0.0	0.0	0.0	0.0
H20	5 0669+04				2 0267+04	2 0267+04	2.0267+04	2.0267+04	2 0267+04	
COMPONENTS: MASS EPAC						210201101	210207101	210207101	210201101	210207101
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0 0	0.0	0.0	0 0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C6H12-01 C2H5N-01 C3H80-01 C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
H2O	1 0000	1.0000	1.0000	1,0000	1.0000	1.0000	1,0000	1.0000	1,0000	1,0000
TOTAL FLOW:	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
LBMOL/HR	2812 5206	2812 5206	1697 5227	1687.5237	1125 0158	1125 0158	1125.0158	1125 0158	1125 0158	1125 0158
LB/HR	2812.5396 5.0669+04	5 0660.04	2 0401 04	3.0401+04			2.0267+04			
CUFT/HR	816.5294	816.5294	489.8869	489.9177	326,6073		5.7666+06			
STATE VARIABLES:	010. 32.94	010.0294	409.0009	405.51//	520.0075	307.0141	3.7000+00	4.7901+00	1.002/400	520.2005
TEND E	76,9100	76,9100	76.7934	76,9100	76.8843	-40 0900	233,1000	116,5100	860,7086	85,9100
PRES PSIA	90.0000	90.0000	30,0000	90,0000	60.0000	14.5038		1.4504	15.0000	14.5038
VERAC	0.0	0.0	0.0	0.0	0.0		1.0000		1,0000	0.0
LFRAC	1 0000	1.0000								1.0000
SERAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
JE NAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(Figure C.2.2: Continue)

ENTHALPY:											
BTU/LBMOL	-1.2282+05	-1.2282+05	-1.2282+05	-1.2282+05	-1.2282+05	-1.2470+05	-1.0270+05	-1.0364+05	-9.7316+04	-1.2267+05	
									-5401.8826		
									-1.0948+08		
ENTROPY:	511511100	514544100	210/2/100	210/2/100	1.5010.00	114020100	111554100	111000100	1.0540100	1.5001.00	
BTU/LBMOL-R	-38,8595	-38,8595	-38,8631	-38.8595	-38,8603	-42,8235	-3,9332	-5,4244	-3.0710	-38,5849	
BTU/LB-R	-2.1570	-2.1570	-2.1572	-2.1570	-2.1571		-0.2183	-0.3011	-0.1705	-2.1418	
DENSITY:	-2.15/0	-2.13/0	-2.13/2	-2.13/0	-2.13/1	-2.3//1	-0.2105	-0.3011	-0.1/05	-2.1410	
	3,4445	3,4445	3,4447	3,4445	3,4446	2 6540	1.9509-04	2.3457-04	1 0505 03	3,4277	
LBMOL/CUFT											
LB/CUFT	62.0537	62.0537	62.0576	62.0537	62.0546			4.2258-03		61.7518	
AVG MW	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	
				05 (07 (0							
ASPEN PLUS PLAT: WI	LN32 VE	R: 22.0		05/07/2	012 PAGE 2	5					
		EXTRACTION									
		STREAM SECT	ION								
E-104 E-104P E-105 E-	105P E-106										
E-106A E-106B E-106C	E-106D E-10	6E (CONTINU	IED)								
STREAM ID	E-104	E-104P	E-105	E-105P	E-106	E-106A	E-106B	E-106C	E-106D	E-106E	
SUBSTREAM: NCPSD	STRUCTUR	E: NON CONV	'ENTIONAL								
COMPONENTS: LB/HR											
ALGAE	5.0669+04	5.0669+04	0.0	0.0	5.0669+04	5.0669+04	5.0669+04	0.0	0.0	0.0	
COMPONENTS: MASS FRAC											
ALGAE	1.0000	1.0000	0.0	0.0	1.0000	1.0000	1.0000	0.0	0.0	0.0	
TOTAL FLOW:											
LB/HR	5.0669+04	5.0669+04	0.0	0.0	5.0669+04	5.0669+04	5.0669+04	0.0	0.0	0.0	
STATE VARIABLES:											
TEMP F	76.9100	76.9100	MISSING	MISSING	76.8843	-40.0900	233.1000	MISSING	MISSING	MISSING	
PRES PSIA	90,0000	90,0000	30,0000	90,0000	60.0000	14,5038	1.4504	1.4504	15,0000	14.5038	
VFRAC	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING	
LFRAC	0.0	0. 0	MISSING	MISSING	0.0	0. Ŭ	0.0	MISSING	MISSING	MISSING	
SFRAC	1,0000	1,0000	MISSING	MISSING	1.0000		1,0000	MISSING	MISSING	MISSING	
ENTHALPY:	1.0000	2.0000	112002110	112002110	2.0000	1.0000	2.0000	112002110		112002110	
	-6480.9341	-6480 9341	MISSING	MISSING	-6480 9461	-6535,6624	-6407 7062	MISSING	MISSING	MISSING	
	-3.2838+08		MISSING			-3.3115+08		MISSING	MISSING	MISSING	
DENSITY:	-3.2030+00	-3.2030700	PUTODING	PITODING	-3.2030+00	-3.3113408	-3.240/408	PITOPING	PUTODING	HISSING	
LB/CUFT	141,9785	141.9785	MISSING	MISSING	141.9785	141.9785	141.9785	MISSING	MISSING	MISSING	
AVG MW	1,0000	1,0000	1.0000	1.0000	1,0000	1,0000	1,0000	1.0000	1.0000	1.0000	
AVG MW	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	



(Figure C.2.2: Continue)

E-109B E-109C E-109D E-110 E-111

STREAM ID FROM : TO : CLASS: TOTAL STREAM:	E-106P Z-101 P-105 MIXNCPSD	E-107 P-106 MIXNCPSD	E-108 Z-102C Z-104 MIXNCPSD	E-109 Z-103 MIXNCP5E	E-109A Z-103 Z-104 MIXNCP5D	E-109B Z-104 Z-105 MIXNCPSD	E-109C Z-105 Z-107 MIXNCPSD	E-109D Z-105 P-108 MIXNCPSD	E-110 FOR-USE MIXNCPSD	E-111 FOR-USE MIXNCPSD
LB/HR BTU/HR SUBSTREAM: MIXED	7.0936+04 -4.6656+08		5.0669+04 -3.2744+08	2.0283+06 -7.7954+09	2.0283+06 -7.7575+09		2.0536+06 -7.9504+09			1.4698+04 -4.2015+07
PHASE: COMPONENTS: LBMOL/HR	LIQUID	LIQUID	MISSING	VAPOR	VAPOR	LIQUID	VAPOR	LIQUID	LIQUID	LIQUID
C6H12-01 C2H5N-01 C3H80-01 C02 H20 COMPONENTS: LB/HR	0.0 0.0 0.0 1125.0158	0.0 0.0 0.0 1125.0158	0.0 0.0 0.0 0.0 0.0	0.0 0.0 4.6086+04 0.0	0.0 0.0 0.0 4.6086+04 0.0	37.0059 195.7990 43.0963 4.6086+04 0.0	0.0 0.0 4.6086+04 0.0	37.0059 195.7990 43.0963 0.0 0.0	37.0059 0.0 0.0 0.0 0.0 0.0	0.0 195.7990 0.0 0.0 0.0
C6H12-01 C2H5N-01 C3H80-01 C02 H20 C0MPONENTS: MASS ERA	0.0 0.0 0.0 2.0267+04	0.0 0.0 0.0 2.0267+04	0.0 0.0 0.0 0.0 0.0	0.0 0.0 2.0283+06 0.0	0.0 0.0 2.0283+06 0.0	6666.8928 1.4698+04 3968.9373 2.0283+06 0.0	0.0 0.0 0.0 2.0283+06 0.0	6666.8928 1.4698+04 3968.9373 0.0 0.0	6666.8928 0.0 0.0 0.0 0.0 0.0	0.0 1.4698+04 0.0 0.0 0.0
CGMPONENTS: MASS FRA C6H12-01 C2H5N-01 C3H80-01 C02 H20 T0TAL FLOW:	0.0 0.0 0.0 0.0 1.0000	0.0 0.0 0.0 0.0 1.0000	MISSING MISSING MISSING MISSING MISSING	0.0 0.0 0.0 1.0000 0.0	0.0 0.0 0.0 1.0000 0.0	3.2465-03 7.1573-03 1.9327-03 0.9877 0.0	0.0 0.0 0.0 1.0000 0.0	0.2632 0.5802 0.1567 0.0 0.0	1.0000 0.0 0.0 0.0 0.0	0.0 1.0000 0.0 0.0 0.0
LBMOL/HR LB/HR CUFT/HR	1125.0158 2.0267+04 326.6118	1125.0158 2.0267+04 328.2378	0.0 0.0 0.0	4.6086+04 2.0283+06 3.0700+05	4.6086+04 2.0283+06 2.1469+05	4.6362+04 2.0536+06 6.6645+04	4.6086+04 2.0283+06 3.3053+05	275.9011 2.5334+04 295.3073	37.0059 6666.8928 92.7350	195.7990 1.4698+04 163.0189
STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC	76.9100 90.0000 0.0 1.0000 0.0	86.0739 45.0000 0.0 1.0000 0.0	MISSING 1.4504 MISSING MISSING MISSING	80.5100 870.2300 1.0000 0.0 0.0	169.9179 1450.3700 1.0000 0.0 0.0	121.7300 5801.5095 0.0 1.0000 0.0	121.9100 870.2300 1.0000 0.0 0.0	121.9100 870.2300 0.0 1.0000 0.0	130.7300 5076.3208 0.0 1.0000 0.0	130.9100 5076.3208 0.0 1.0000 0.0

BTU/LB	-1.2282+05	-1,2267+05	MISSING							
BTU/LB		-1.2267+05	MICTNO							
								-2.6903+05		
	-6817.7136	-6809.2365	MISSING	-3843.4072	-3824.7015	-3823.7615	-3834.8873	-2929.9168	-2974.7235	-2858.5557
BTU/HR	-1.3818+08	-1.3801+08	MISSING	-7.7954+09	-7.7575+09	-7.8524+09	-7.7781+09	-7.4226+07	-1.9832+07	-4.2015+07
ENTROPY:										
BTU/LBMOL-R	-38.8595	-38.5799	MISSING	-7.3576	-6.9628	-8.5732	-6.6889	-136.7072	-252.7076	-114.7810
BTU/LB-R	-2.1570	-2.1415	MISSING	-0.1672	-0.1582	-0.1936	-0.1520	-1.4888	-1.4027	-1.5290
DENSITY:										
LBMOL/CUFT	3.4445	3.4274	MISSING	0.1501	0.2147	0.6957	0.1394	0.9343	0.3990	1.201
LB/CUFT	62.0537	61.7463	MISSING	6.6068	9.4475	30.8138	6.1365	85.7883	71.8918	90.161
AVG MW	18.0153	18.0153	MISSING	44.0098	44.0098	44.2943	44.0098	91.8225	180.1577	75.0672
ASPEN PLUS PLAT: W		R: 22.0 EXTRACTION STREAM SECT		05/07/2	012 PAGE 2	7				
E-106P E-107 E-108 E-	-109 E-109A									
E-109B E-109C E-109D	E-110 E-111	(CONTINUED))							
STREAM ID	E-106P	E-107	E-108	E-109	E-109A	E-109B	E-109C	E-109D	E-110	E-111
SUBSTREAM: NCPSD	STRUCTUR	E: NON CON	ENTIONAL							
COMPONENTS: LB/HR ALGAE	5.0669+04	0.0	5.0669+04	0.0	0.0	3 5334.04	2.5334+04	0.0	0.0	0.0
OMPONENTS: MASS FRAC		0.0	5.0009+04	0.0	0.0	2.3554+04	2.3554+04	0.0	0.0	0.0
ALGAE	1,0000	0.0	1,0000	0.0	0.0	1.0000	1,0000	0.0	0.0	0.0
TOTAL FLOW:	1.0000	0.0	1.0000	0.0	0.0	1.0000	1.0000	0.0	0.0	0.0
LB/HR	5.0669+04	0.0	5.0669+04	0.0	0.0	2.5334+04	2.5334+04	0.0	0.0	0.0
STATE VARIABLES:	3.0005+04	0.0	3.0009+04	0.0	0.0	2.3334+04	2.3554+04	0.0	0.0	0.0
TEMP F	76,9100	MISSING	116.5100	MISSING	MISSING	121.7300	121,9100	MISSING	MISSING	MISSIN
PRES PSIA	90.0000	45.0000	1.4504	870,2300	1450.3700	5801.5095	870.2300	870.2300	5076.3208	5076.320
VERAC	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSIN
LERAC	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSIN
SFRAC	1.0000	MISSING	1.0000	MISSING	MISSING	1.0000	1.0000	MISSING	MISSING	MISSIN
INTHALPY:	1.0000	MISSING	1.0000	MISSING	MIDDING	1.0000	1.0000	MISSING	MIDDING	PIISSIN
	-6480,9341	MICTNO	-6462.3863	MISSING	MICTNO	-6798.6536	6708 5605	MISSING	MISSING	MISSIN
DIU/LD	-3.2838+08		-3.2744+08	MISSING		-1.7224+08		MISSING	MISSING	MISSIN
PTII/UD					MT22TING	-1./224+00	-1./224+00	MITODING	PUTCCTING	MITCOTIM
	-3.2030+00	112002110								
BTU/HR DENSITY: LB/CUFT	141.9785	MISSING	141.9785	MISSING	MISSING	141.9785	141.9785	MISSING	MISSING	MISSIN

(Figure C.2.2: Continue)

	ATTRIBUTES: ROXANAL										
	MOISTURE	81,7000	MISSING	81,7000	MISSING	MISSING	100,0000	100.0000	MISSING	MISSING	MISSING
	FC	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	VM	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	ASH	18,4000	MISSING	18,4000	MISSING	MISSING	18.4000	18,4000	MISSING	MISSING	MISSING
U	LTANAL										
	ASH	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	CARBON	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	HYDROGEN	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	NITROGEN	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	CHLORINE	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	SULFUR	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	OXYGEN	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
S	ULFANAL										
	PYRITIC	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
	SULFATE	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
CUD CTO CAM	ORGANIC	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	MISSING
PSD	ATTRIBUTES:										
FRAC1		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC2		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC3		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC4		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC5		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC6		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC7		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC8		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC9		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC10		0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
ASPEN PLU	S PLAT: WIN3		22.0		05/07/201	2 PAGE 28					
			XTRACTION								
		ST	REAM SECTIO	N							

(Figure C.2.2: Continue)

E-112 E-113 E-114 PRODUCT STREAM ID E-112 E-113 E-114 PRODUCT FROM : FOR-USE Z-107 Z-107 P-108 TO : FOR-USE Class: MIXNCP5D MIXNCP5D MIXNCP5D MIXNCP5D CLASS: MIXNCP5D MIXNCP5D MIXNCP5D MIXNCP5D MIXNCP5D MIXNCP5D CB/HR 3968.9373 2.5334+04 2.0283+06 2.5334+04 BTU/HR -1.2261+07 -1.7224+08 -7.7781+09 -7.4226+07 SUBSTREAM: MIXED MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 143.0963 C02 0.0 0.0 0.0 14.698+04 0.0 CAH2-01 0.0 0.0 0.0 14.698+04 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 0.0 COMPONENTS: MASS FRAC 0.0 0.0 0.0 0.0					
FROM FOR-USE Z-107 Z-107 P-108 TO FOR-USE Z-107 Z-107 P-108 TO FOR-USE Z-107 P-108 FOR-USE TO FOR-USE FOR-USE FOR-USE FOR-USE CLASS: MIXNCPSD MIXNCPSD MIXNCPSD MIXNCPSD MIXNCPSD TOTAL STREAM: 1.2261+07 1.7224+08 -7.7781+09 -7.4226+07 SUBSTREAM: MIXNCPSD MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 0.0 0.0 C02 0.0 0.0 0.0 0.0 0.0 0.0 C0412-01 0.0 0.0 0.0 0.0 0.0 0.0 C02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 C412-01 0.0 </td <td>E-112 E-113 E-114 PRO</td> <td>DUCT</td> <td></td> <td></td> <td></td>	E-112 E-113 E-114 PRO	DUCT			
FROM FOR-USE Z-107 Z-107 P-108 TO FOR-USE Z-107 Z-107 P-108 TO FOR-USE Z-107 P-108 FOR-USE TO FOR-USE FOR-USE FOR-USE FOR-USE CLASS: MIXNCPSD MIXNCPSD MIXNCPSD MIXNCPSD MIXNCPSD TOTAL STREAM: 1.2261+07 1.7224+08 -7.7781+09 -7.4226+07 SUBSTREAM: MIXNCPSD MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 0.0 0.0 C02 0.0 0.0 0.0 0.0 0.0 0.0 C0412-01 0.0 0.0 0.0 0.0 0.0 0.0 C02 0.0 0.0 0.0 0.0 0.0 0.0 0.0 C412-01 0.0 </td <td></td> <td></td> <td></td> <td></td> <td></td>					
TO FOR-USE CLASS: MIXNCPSD MIXNCPSD MIXNCPSD MIXNCPSD MIXNCPSD TOTAL STREAM: 3968.9373 2.5334+04 2.0283+06 2.5334+04 BTU/HR -1.2261+07 -1.7224+08 -7.7781+09 -7.4226+07 SUBSTREAM: MIXNCPD LIQUID MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 1.4698+04 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 CAH80-01 3968.9373 0.0 0.0 0.0 0.0 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 CO2 0.0 0.0	STREAM ID				PRODUCT
CLASS: MIXNCPSD <	FROM :	FOR-USE	z-107	z-107	P-108
TOTAL STREAM: LB/HR 3968.9373 2.5334+04 2.0283+06 2.5334+04 BTU/HR -1.2261+07 -1.7224+08 -7.7781+09 -7.4226+07 SUBSTREAM: MIXED PHASE: LIQUID MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 37.0059 C2H5N-01 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 0.0 C02 0.0 0.0 0.0 0.0 C04DPONENTS: LB/HR 0.0 0.0 0.0 0.0 C04DPONENTS: LB/HR 0.0 0.0 0.0 0.0 C0412-01 0.0 0.0 0.0 1.4698+04 0.0 C3H80-01 3968.9373 0.0 0.0 0.0 0.0 C3H80-01 3968.9373 0.0 0.0 0.0 0.0 C2415N-01 0.0 MISSING 0.0 0.0 0.0 C4H2-01 0	то :				FOR-USE
LB/HR 3968.9373 2.5334+04 2.0283+06 2.5334+04 BTU/HR -1.2261+07 -1.7224+08 -7.7781+09 -7.4226+07 SUBSTREAM: MIXED PHASE: LIQUID MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 37.0059 C2H5N-01 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 43.0963 C02 0.0 0.0 0.0 0.0 CAMPONENTS: LB/HR 0.0 0.0 0.0 0.0 CAMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 CAMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 CAMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 CAMPONENTS: MASS FRAC 0.0 0.0 0.0 0.0 C2150-01 0.0 MISSING 0.0 0.0 <t< td=""><td>CLASS:</td><td>MIXNCPSD</td><td>MIXNCPSD</td><td>MIXNCPSD</td><td>MIXNCPSD</td></t<>	CLASS:	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD
BTU/HR -1.2261+07 -1.7224+08 -7.7781+09 -7.4226+07 SUBSTREAM: MIXED PHASE: LIQUID MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 37.0059 C2H5N-01 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 43.0963 CO2 0.0 0.0 4.6086+04 0.0 H2O 0.0 0.0 0.0 0.0 0.0 CGH12-01 0.0 0.0 0.0 1.4698+04 0.0 C2H5N-01 3968.9373 0.0 0.0 3968.9373 0.0 0.0 0.0 C4H2-01 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 C4H80-01 3968.9373 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0					
SUBSTREAM: MIXED PHASE: LIQUID MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 37.0059 C2H5N-01 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 43.0963 CO2 0.0 0.0 4.6086+04 0.0 H20 0.0 0.0 0.0 0.0 0.0 CGMPONENTS: LB/HR 0.0 0.0 0.0 0.0 CGMPONENTS: LB/HR 0.0 0.0 0.0 1.4698+04 0.0 CGMPONENTS: LB/HR 0.0 0.0 0.0 3968.9373 0.0 0.0 1.4698+04 C3H80-01 3968.9373 0.0					
PHASE: LIQUID MISSING VAPOR LIQUID COMPONENTS: LBMOL/HR 0.0 0.0 0.0 37.0059 C2H5N-01 0.0 0.0 0.0 195.7990 C3H80-01 43.0963 0.0 0.0 43.0963 C02 0.0 0.0 4.6086+04 0.0 H20 0.0 0.0 0.0 0.0 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 14.6984.04 C3H80-01 3968.9373 0.0 0.0 3968.9373 0.0 0.0 3968.9373 C02 0.0 0.0 0.0 0.0 0.0 0.0 C3H80-01 3968.9373 0.0 2.0283+06 0.0 1.4698+04 2.0283+06 0.0 H20 0.0 0.0 0.0 0.0 0.0 0.0 C6H12-01 0.0 MISSING 0.0 0.0 0.0 0.0 C3H80-01 1.0000 MISSING 0.0 <td>BTU/HR</td> <td>-1.2261+07 -</td> <td>1.7224+08</td> <td>-7.7781+09</td> <td>-7.4226+07</td>	BTU/HR	-1.2261+07 -	1.7224+08	-7.7781+09	-7.4226+07
COMPONENTS: LBMOL/HR Decision Decision <thdecision< th=""> Decision <thdecision< t<="" td=""><td>SUBSTREAM: MIXED</td><td></td><td></td><td></td><td></td></thdecision<></thdecision<>	SUBSTREAM: MIXED				
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C3H80-01 43.0963 0.0 0.0 43.0963 C02 0.0 0.0 4.6086+04 0.0 H20 0.0 0.0 0.0 0.0 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 C6H12-01 0.0 0.0 0.0 0.0 1.4698+04 0.0 C3H80-01 3968.9373 0.0 0.0 0.0 3968.9373 0.0 0.0 3968.9373 C02 0.0 0.0 0.0 2.0283+06 0.0 0.0 CMPONENTS: MASS FRAC 0.0 MISSING 0.0 0.2632 C2H5N-01 0.0 MISSING 0.0 0.08802 0.0 0.0 C4H2-01 0.0 MISSING 0.0 0.0 0.0 0.0 C4H2-01 0.0 MISSING 0.0 0.0 0.0 0.0 C3H80-01 1.0000 MISSING 0.0 0.0 0.0				0.0	37.0059
C02 0.0 0.0 4.6086+04 0.0 H20 0.0 0.0 0.0 0.0 0.0 COMPONENTS: LB/HR 0.0 0.0 0.0 0.0 0.0 C2H5N-01 0.0 0.0 0.0 1.4698+04 0.0 C3H80-01 3968.9373 0.0 0.0 3968.9373 0.0 0.0 3968.9373 C02 0.0 0.0 0.0 0.0 0.0 0.0 H20 0.0 0.0 0.0 0.0 0.0 0.0 C6H12-01 0.0 MISSING 0.0 0.5802 0.3480-0 0.0 0.5802 C3H80-01 1.0000 MISSING 0.0 0.0 0.0 0.0 C02 0.0 MISSING 0.0 0.0 0.0 0.0 G3H80-01 1.0000 MISSING 0.0 0.0 0.0 0.0 H20 0.0 MISSING 0.0 0.0 0.0 0.0 0.0 <td></td> <td></td> <td></td> <td>0.0</td> <td></td>				0.0	
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C6H12-01 0.0 0.0 0.0 6666.8928 C2H5N-01 0.0 0.0 0.0 1.4698+04 C3H80-01 3968.9373 0.0 0.0 3968.9373 CO2 0.0 0.0 2.0283+06 0.0 H20 0.0 0.0 0.0 0.0 COMPONENTS: MASS <frac< td=""> 0.0 0.0 0.0 CGH12-01 0.0 MISSING 0.0 0.0 COMPONENTS: MASS FRAC 0.0 0.0 0.0 CCMFONENTS: MASS FRAC 0.0 MISSING 0.0 0.0 CCMPONENTS: MASS FRAC 0.0 MISSING 0.0 0.0 0.0 C2H5N-01 0.0 MISSING 0.0 0.05602 0.0 0.0 0.0 C3H80-01 1.0000 MISSING 1.0000 0.0 0.0 0.0 0.0 TOTAL FLOW: 43.0963 0.0 4.6086+04 275.9011 LB/HR 3968.9373 0.0<!--</td--><td></td><td>0.0</td><td>0.0</td><td>0.0</td><td>0.0</td></frac<>		0.0	0.0	0.0	0.0
C2H5N-01 0.0 0.0 0.0 1.4698-04 C3H80-01 3968.9373 0.0 0.0 3968.9373 CO2 0.0 0.0 2.0283+06 0.0 H2O 0.0 0.0 0.0283+06 0.0 COMPONENTS: MASS FRAC 0.0 MISSING 0.0 0.0283+06 C6H12-01 0.0 MISSING 0.0 0.2632 C3H80-01 0.0 MISSING 0.0 0.5802 C3H80-01 0.0 MISSING 0.0 0.0 H20 0.0 MISSING 0.0 0.0 TOTAL FLOW: 1.0000 MISSING 0.0 0.0 H20 0.0 MISSING 0.0 2.0283+06 2.534+04 LBMOL/HR 43.0963 0.0 4.6086+04 275.9011 LB/HR LB/HR 3968.9373 0.0 2.0283+06 2.5334+04 2.5334+04 CUFT/HR 50.9022 0.0 3.033+05 295.3073 295.3073 <					
C3H80-01 3968.9373 0.0 0.0 3968.9373 C02 0.0 0.0 2.0283+06 0.0 H20 0.0 0.0 0.0 0.0 CGMPONENTS: MASS FRAC 0.0 0.0 0.0 CGH12-01 0.0 MISSING 0.0 0.2632 C3H80-01 1.0000 MISSING 0.0 0.5802 C3H80-01 1.0000 MISSING 0.0 0.1567 CO2 0.0 MISSING 0.0 0.0 H20 0.0 MISSING 1.0000 0.0 H20 0.0 MISSING 1.0000 0.0 CUT/HR 3968.9373				0.0	6666.8928
CO2 0.0 0.0 2.0283+06 0.0 H2O 0.0 0.0 0.0 0.0 0.0 COMPONENTS: MASS FRAC 0.0 0.0 0.0 0.0 0.0 C6H12-01 0.0 MISSING 0.0 0.5802 0.5802 C3H80-01 1.0000 MISSING 1.0000 0.0 0.0 C02 0.0 MISSING 0.0 0.0 0.0 TOTAL FLOW: 1.0000 MISSING 0.0 0.0 0.0 LBMDL/HR 43.0963 0.0 4.6086+04 275.9011 1.8/94 LB/HR 3968.9373 0.0 2.0283+06 2.5334+04 2.5334+04 CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES: TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 1.0					
H20 0.0 0.0 0.0 0.0 COMPONENTS: MASS FRAC C6H12-01 0.0 MISSING 0.0 0.2632 C2H5N-01 0.0 MISSING 0.0 0.8802 C3H80-01 1.0000 MISSING 0.0 0.1567 C02 0.0 MISSING 0.0 0.0 H20 0.0 MISSING 0.0 0.0 TOTAL FLOW: 0.0 0.0 LBMOL/HR 43.0963 0.0 4.6086+04 275.9011 LB/HR 3968.9373 0.0 2.0283+06 2.534+04 CUFT/HR 50.9022 0.0 3.0353+05 295.3073 STATE VARIABLES: TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 0.0					
COMPONENTS: MASS FRAC MASS FRAC C6H12-01 0.0 MISSING 0.0 0.2632 C2H5N-01 0.0 MISSING 0.0 0.5802 C3H80-01 1.0000 MISSING 0.0 0.1567 C02 0.0 MISSING 1.0000 0.0 H20 0.0 MISSING 0.0 0.0 TOTAL FLOW: LBMOL/HR 43.0963 0.0 4.6086+04 275.9011 LB/HR 3968.9373 0.0 2.0283+06 2.5334+04 CUST/HR CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES: TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 L					
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C2H5N-01 0.0 MISSING 0.0 0.5802 C3H80-01 1.0000 MISSING 0.0 0.1567 CO2 0.0 MISSING 1.0000 0.0 H20 0.0 MISSING 0.0 0.0 TOTAL FLOW:					
C3H80-01 1.0000 MISSING 0.0 0.1567 CO2 0.0 MISSING 1.0000 0.0 H20 0.0 MISSING 0.00 0.0 TOTAL FLOW: 43.0963 0.0 4.6086+04 275.9011 LBMOL/HR 43.0968.9373 0.0 2.0283+06 2.5334+04 CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES: TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 870.2300 VFRAC 0.00 MISSING 1.0000 0.0 1.0000 1.0000					
CO2 0.0 MISSING 1.0000 0.0 H2O 0.0 MISSING 0.0 0.0 TOTAL FLOW:					
H20 0.0 MISSING 0.0 0.0 TOTAL FLOW: LBMOL/HR 43.0963 0.0 4.6086+04 275.9011 LB/HR 3968.9373 0.0 2.0283+06 2.5334+04 CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES: TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 1.0000					
TOTAL FLOW: 43.0963 0.0 4.6086+04 275.9011 LB/MDL/HR 43.0963 0.0 2.0283+06 2.5334+04 CUFT/HR 3968.9373 0.0 2.0283+06 2.5334+04 CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES: 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 LFRAC 1.0000					
LBMOL/HR 43.0963 0.0 4.6086+04 275.9011 LB/HR 3968.9373 0.0 2.0283+06 2.5334+04 CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES:		0.0	MISSING	0.0	0.0
LB/HR 3968.9373 0.0 2.0283+06 2.5334+04 CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES:	TOTAL FLOW:				
CUFT/HR 50.9022 0.0 3.3053+05 295.3073 STATE VARIABLES: TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 LFRAC 1.0000 MISSING 0.0 1.0000	LBMOL/HR	43.0963			
STATE VARIABLES: TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 LFRAC 1.0000 MISSING 0.0 1.0000					
TEMP F 130.9100 MISSING 121.9100 121.9100 PRES PSIA 5076.3208 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 LFRAC 1.0000 MISSING 0.0 1.0000		50.9022	0.0	3.3053+05	295.3073
PRES PSIA 5076.3208 870.2300 870.2300 870.2300 VFRAC 0.0 MISSING 1.0000 0.0 LFRAC 1.0000 MISSING 0.0 1.0000					
VFRAC 0.0 MISSING 1.0000 0.0 LFRAC 1.0000 MISSING 0.0 1.0000					
LFRAC 1.0000 MISSING 0.0 1.0000					
SFRAC 0.0 MISSING 0.0 0.0					
	SERAC	0.0	MISSING	0.0	0.0

(Figure C.2.2: Continue)

ENTHALPY:					
BTU/LBMOL BTU/LB BTU/HR	-2.8451+05	MISSING	-1.6877+05	-2.6903+05	
BTU/LB	-3089.3440	MISSING	-3834.8873	-2929.9168	
BTU/HR	-1.2261+07	MISSING	-7.7781+09	-7.4226+07	
ENTROPY					
BTU/LBMOL-R BTU/LB-R	-141.7530	MISSING	-6.6889	-136.7072	
BTU/LB-R	-1.5392	MISSING	-0.1520	-1.4888	
DENSITY: LBMOL/CUFT LB/CUFT AVG MW					
LBMOL/CUFT	0.8466	MISSING	0.1394	0.9343	
LB/CUFT	77,9719	MISSING	6.1365	85.7883	
AVG MW	92.0947	MISSING	44.0098	91.8225	
SUBSTREAM: NCPSD COMPONENTS: LB/HR	STRUCTUR	E: NON CONV	ENTIONAL		
COMPONENTS: LB/HR					
ALGAE	0.0	2.3334+04	0.0	0.0	
ASPEN PLUS PLAT:	WIN32 VE	R: 22.0		05/07/2012	PAGE
		EXTRACTION			
		STREAM SECT	ION		
c 112 c 112 c 114 o	ADDUCT (CONT				
E-112 E-113 E-114 PF	RODUCT (CONTI	NUED)			
	RODUCT (CONTI E-112	· · ·	E-114	PRODUCT	
STREAM ID	E-112	· · ·	E-114	PRODUCT	
STREAM ID COMPONENTS: MASS FRA	E-112	E-113			
STREAM ID COMPONENTS: MASS FRA ALGAE	E-112	· · ·		PRODUCT	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW:	E-112 AC 0.0	E-113 1.0000	0.0	0.0	
STREAM ID COMPONENTS: MASS FRA ALGAE TOTAL FLOW: LB/HR	E-112 AC 0.0	E-113	0.0		
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES:	E-112 AC 0.0 0.0	E-113 1.0000 2.5334+04	0.0 0.0	0.0	
STREAM ID COMPONENTS: MASS FR4 ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F	E-112 AC 0.0 0.0	E-113 1.0000 2.5334+04	0.0 0.0	0.0	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA	E-112 AC 0.0 0.0	E-113 1.0000 2.5334+04	0.0 0.0	0.0	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA	E-112 AC 0.0 0.0 MISSING 5076.3208 MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0	0.0 0.0 MISSING 870.2300 MISSING	0.0 0.0 MISSING 870.2300 MISSING	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA	E-112 AC 0.0 MISSING 5076.3208 MISSING MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0 0.0	0.0 0.0 MISSING 870.2300 MISSING MISSING	0.0 0.0 MISSING 870.2300 MISSING MISSING	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC	E-112 AC 0.0 MISSING 5076.3208 MISSING MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0	0.0 0.0 MISSING 870.2300 MISSING MISSING	0.0 0.0 MISSING 870.2300 MISSING MISSING	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY:	E-112 AC 0.0 MISSING 5076.3208 MISSING MISSING MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0 0.0 1.0000	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC SFRAC ENTHALPY: BTU/LB	E-112 AC 0.0 MISSING 5076.3208 MISSING MISSING MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0 0.0 1.0000	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC SFRAC ENTHALPY: BTU/LB BTU/HR	E-112 AC 0.0 MISSING 5076.3208 MISSING MISSING MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0 0.0	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC STRAC BTU/LB BTU/LB BTU/HR DENSTTY:	E-112 AC 0.0 MISSING 5076.3208 MISSING MISSING MISSING MISSING MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0 1.0000 -6798.5605 -1.7224+08	0.0 MISSING 870.2300 MISSING MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING MISSING	
STREAM ID COMPONENTS: MASS FR/ ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY: BTU/LB BTU/HR	E-112 AC 0.0 MISSING 5076.3208 MISSING MISSING MISSING MISSING MISSING MISSING	E-113 1.0000 2.5334+04 121.9100 870.2300 0.0 1.0000 -6798.5605 -1.7224+08	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 870.2300 MISSING MISSING MISSING MISSING MISSING MISSING	

(Figure C.2.2: Continue)

COMPONENT ATTRIBUTES:	
ALGAE PROXANAL	
	0000 MISSING MISSING
	0 MISSING MISSING
	0 MISSING MISSING
	4000 MISSING MISSING
ULTANAL	
	0 MISSING MISSING
CHLORINE MISSING 0	0 MISSING MISSING
	0 MISSING MISSING
OXYGEN MISSING 0	0 MISSING MISSING
SULFANAL	
	0 MISSING MISSING
SULFATE MISSING 0	0 MISSING MISSING
ORGANIC MISSING 0	0 MISSING MISSING
SUBSTREAM ATTRIBUTES:	
PSD	
	0 MISSING 0.0
	0 MISSING 0.0
FRAC3 0.0 0	0 MISSING 0.0
FRAC4 0.0 0	0 MISSING 0.0
FRAC5 0.0 0	0 MISSING 0.0
FRAC6 0.0 0	0 MISSING 0.0
FRAC7 0.0 0	0 MISSING 0.0
FRAC8 0.0 0	0 MISSING 0.0
FRAC9 0.0 0	0 MISSING 0.0
FRAC10 0.0 0	0 MISSING 0.0
ASPEN PLUS PLAT: WIN32 VER: 22	0 05/07/2012 PAGE 30
EXTR	ACTION
PROBLEM S	TATUS SECTION
BLOCK STATUS	

*	×
* Calculations were completed normall	/ * *
* All Unit Operation blocks were comp	leted normally
	×
* All streams were flashed normally	X
-	*

(Figure C.2.2: Continue)

Section C.2.3 - APEN Plus simulator output for Case 3

ASPEN PLUS PLAT: WIN32 05/07/2012 PAGE 1 VER: 22.0 EXTRACTION RUN CONTROL SECTION RUN CONTROL INFORMATION THIS COPY OF ASPEN PLUS LICENSED TO UNIV OF PUERTO RICO TYPE OF RUN: NEW INPUT FILE NAME: _08061bp.inm OUTPUT PROBLEM DATA FILE NAME: _08061bp LOCATED IN: PDF SIZE USED FOR INPUT TRANSLATION: NUMBER OF FILE RECORDS (PSIZE) = 0 NUMBER OF IN-CORE RECORDS = 256 PSIZE NEEDED FOR SIMULATION = 256 CALLING PROGRAM NAME: apmain C:\PROGRA~1\ASPENT~1\ASPENP~2.0\Engine\xeq LOCATED IN: SIMULATION REQUESTED FOR ENTIRE FLOWSHEET

Figure C.2.3. ASPEN print out for Case Scenario 3.

₽ ASPEN PLUS	PLAT: WIN		R: 22.0 EXTRACTION OWSHEET SECTION	0	5/07/2012	PAGE 2
FLOWSHEET CO	NNECTIVITY	BY STREAM	5 -			
E-104 E-106 E-107 E-104C E-109 E-104B E-1014 E-1010 E-101B	FOR-USE FOR-USE Z-104 Z-105 Z-103 Z-1018 Z-1018 Z-101A Z-101A Z-107	Z-102 Z-110 Z-104 Z-101C Z-101D Z-101B Z-101	STREAM E-101 E-105 PRODUCT E-104D E-104A E-104A E-103 E-101E E-101A E-102	FOR-USE Z-110 Z-104 Z-105 Z-102 Z-101B Z-101D Z-101	Z-107 FOR-USE Z-105 Z-103 Z-103 Z-108 Z-101A	
FOR-USE	INLETS PRODUCT E-104C E-104B E-104D E-104A E E-104 E-101B E-101C E-101D E-101A E-101P E-101 E-101E		 PR E- E- E- E- E- E- E- E-	TLETS 106 E-105 E ODUCT 104C E-104D 104B 104A 101C E-103 101D 101E 101B 101A 101A 101A 101P 101A		

COMPUTATIONAL SEQUENCE							
SEQUENCE USED WAS: Z-107 Z-101 Z-101A Z-101B Z-101C Z-101D Z-108 Z-102 Z-103 Z-104 Z-105 Z-110 FOR-USE							
OVERALL FLOWSHEET BALANCE							
***	MASS AND ENERGY BAL	ANCE ***					
	IN		RELATIVE DIFF.				
CONVENTIONAL COMPONENT		001	RELATIVE DITT.				
C6H12-01	0.00000	37,0059	-1.00000				
C2H5N-01	0.00000	195,799	-1.00000				
C3H80-01	0.00000						
CO2	00 0000	00 0000	0 00000				
H2O	28125.4	28125.4	0.00000				
SUBTOTAL (LBMOL/HR)	28216.3	28492.2	-0.968340E-02				
LO2 H2O SUBTOTAL(LBMOL/HR) (LB/HR) \$ ASPEN PLUS PLAT: WIN32	510687.	536021.	-0.472629E-01				
ASPEN PLUS PLAT: WIN32	VER: 22.0		05/07/2012 PAGE 3				
	EXTRACTION						
	FLOWSHEET SECTI	ION					
OVERALL FLOWSHEET BALANCE NON-CONVENTIONAL COMPO	NENTS (LB/HR)						
ALGAE	50668.7	25334.3					
SUBTOTAL (LB/HR) TOTAL BALANCE							
MASS(LB/HR)	561356.	561355.	0.752670E-06				
MASS(LB/HR) ENTHALPY(BTU/HR)	-0.379820E+10	-0.371184E+	-10 -0.227381E-01				
ASPEN PLUS PLAT: WIN32	VER: 22.0		05/07/2012 PAGE 4				
	EXTRACTION						
	PHYSICAL PROPERTIES	SECTION					

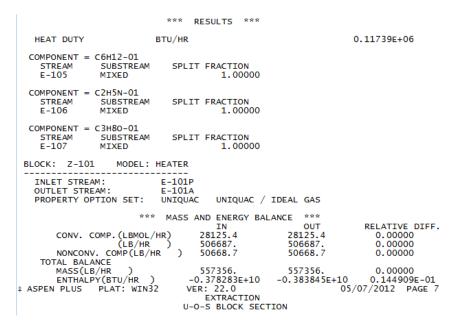
(Figure C.2.3: Continue)

COMPONENTS		
C6H12-01 C C6H12O6 C2H5N-01 C C2H5NO2-D1 C3H8O-01 C C3H8O3	C2H5NO2-D1	REPORT NAME C6H12-01 C2H5N-01 C3H80-01 C02 ALGAE H20
		05/07/2012 PAGE 5
INLET STREAM: PRODU OUTLET STREAMS: E-106 PROPERTY OPTION SET: UNIQU	E-105 E-107	
*** MASS	AND ENERGY BALANCE ***	
CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR) TOTAL BALANCE	25333.9 25333.9	0.00000 -0.287202E-15
MASS(LB/HR)	25333.9 25333.9 -0.742263E+08 -0.741089E	

(Figure C.2.3: Continue)

		***	INPUT DA	TA ***			
	INLET PRESSURE PSIA					5,076.32	
	FLASH SPECS FOR STREA TWO PHASE TP FLA SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	F PSIA	6		5	130.910 ,076.32 30 0.000100000	
	FLASH SPECS FOR STREAM TWO PHASE TP FLA SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	F PSIA	5		5	130.730 ,076.32 30 0.000100000	
Ŷ	FLASH SPECS FOR STREA TWO PHASE TP FLA SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE ASPEN PLUS PLAT: WIN	SH F PSIA S 32	VER: 22.0 EXTRA) CTION CK SECTION	5	130.910 ,076.32 30 0.000100000 05/07/2012 PAGE 6	
E	BLOCK: FOR-USE MODEL:	SEP (CONTINUED)			
	FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-105		C6H12-01 C2H5N-01 C3H80-01	FRACTION=		1.00000 0.0 0.0	
	STREAM= E-107	CPT=		FRACTION=		0.0 0.0 0.0 1.00000	

(Figure C.2.3: Continue)



(Figure C.2.3: Continue)

BLOCK: Z-101 MODEL: HEATER ((CONTINUED)		
*** IN TWO PHASE TP FLASH SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	F F PSIA		40.0900 14.5038 30 0.000100000
*** R OUTLET TEMPERATURE F OUTLET PRESSURE PSIA HEAT DUTY BTU/HR OUTLET VAPOR FRACTION PRESSURE-DROP CORRELATION PARA	RESULTS *** METER	-0.55	090 504 623E+08 000 99.
V-L PHASE EQUILIBRIUM :	×(-)		
COMP F(I) H20 1.0000	X(I) 1.0000	Y(I) 1.0000	К(I) 0.20011E-03
BLOCK: Z-101A MODEL: HEATER			
INLET STREAM: E-101A OUTLET STREAM: E-101B PROPERTY OPTION SET: UNIQUAC	UNIQUAC / ID	EAL GAS	
CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR)	ND ENERGY BALAN IN 28125.4 506687. 50668.7	OUT RE 28125.4 506687.	LATIVE DIFF. 0.00000 0.00000 0.00000
TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR) -C ‡ ASPEN PLUS PLAT: WIN32 VE U-C	557356.).383845E+10 R: 22.0 EXTRACTION D-5 BLOCK SECTIO		0.00000 0.162902 2012 PAGE 8

BLOCK: Z-101A MODEL: HEATER (CONTINUED)	
*** INPUT DATA *** TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	233.100 1.45038 30 0.000100000
*** RESULTS *** OUTLET TEMPERATURE F OUTLET PRESSURE PSIA HEAT DUTY BTU/HR OUTLET VAPOR FRACTION PRESSURE-DROP CORRELATION PARAMETER	233.10 1.4504 0.62529E+09 1.0000 2.4862
V-L PHASE EQUILIBRIUM :	
COMP F(I) X(I) Y(I) H20 1.0000 1.0000 1.0000	К(I) 15.160
BLOCK: Z-101B MODEL: FLASH2	
INLET STREAM: E-101B OUTLET VAPOR STREAM: E-101C OUTLET LIQUID STREAM: E-103 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
CONV. COMP.(LBMOL/HR) 28125.4 28125.4 (LB/HR) 506687. 506687. NONCONV. COMP(LB/HR) 50668.7 50668.7	RELATIVE DIFF. 0.00000 0.00000 0.00000
TOTAL BALANCE MASS(LB/HR) 557356. 557356. ENTHALPY(BTU/HR) -0.321316E+10 -0.324247E+10	0.00000 0.903968E-02 5/07/2012 PAGE 9

(Figure C.2.3: Continue)

BLOCK: Z-101B MODEL: F	FLASH2 (CONTINUED)	
TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE F MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE		1	16.510 1.45038 30 0.000100000
OUTLET PRESSURE F	*** RESULTS * F PSIA BTU/HR	19. 19	116.51 1.4504 -0.29311E+08 1.0000
V-L PHASE EQUILIBRIUM :	:		
) Y(I) 000 1.0000	
BLOCK: Z-101C MODEL: C	COMPR		
		C / IDEAL GAS	
NONCONV. COMP(LB/HR) 506687. R) 0.00000	OUT 28125.4 506687.	RELATIVE DIFF. 0.00000 0.00000 0.00000
MASS(LB/HR) ENTHALPY(BTU/HR)	506687. -0.291503E+		0.00000 -0.597904E-01

*** INPUT DATA ***POLYTROPIC COMPRESSOR USING ASME METHOD
OUTLET PRESSURE PSIA14.5038
0.66000POLYTROPIC EFFICIENCY
MECHANICAL EFFICIENCY
* ASPEN PLUS PLAT: WIN32 VER: 22.0
U-O-S BLOCK SECTION1.00000# ASPEN PLUS
BLOCK: Z-101CWDEL: COMPR (CONTINUED)*** RESULTS ***INDICATED HORSEPOWER REQUIREMENT HP
68,498.8
BRAKE HORSEPOWER REQUIREMENT HP
68,498.8
POWER LOSSES
EFFICIENCY (POLYTR/ISENTR) USEDISENTROPIC HORSEPOWER REQUIREMENT HP
668,498.8
POWER LOSSES668,498.8
846.263
0.66000
1.00000OUTLET VAPOR FRACTION
HEAD DEVELOPED,
FLEF/LB176,666.
1.00000INLET VOLUMETRIC FLOW RATE, CUFT/HR
0.0TLET VAPOR FRACTION
HEAD DEVELOPED,
NET-LBF/LB176,666.
1.00000INLET VOLUMETRIC FLOW RATE, CUFT/HR
0.271766+08
INLET COUPRESSIBILITY FACTOR
AV. ISENT. VOL. EXPONENT
AV. ISENT. TEMP EXPONENT1.31686
AV. ACTUAL VOL. EXPONENT
AV. ACTUAL TEMP EXPONENTAV. ACTUAL VOL. EXPONENT
AV. ACTUAL TEMP EXPONENT1.55126

BLOCK: Z-101D MODEL: HEATER	
INLET STREAM: E-101D OUTLET STREAM: E-101E PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE *** IN OUT RELATIVE DIFF. CONV. COMP. (LBMOL/HR) 28125.4 28125.4 0.00000 LB/HR) 506687. 506687. 0.00000 NONCONV. COMP(LB/HR) 0.00000 0.00000 0.00000 TOTAL BALANCE 0.00000	
TOTAL BALANCE MASS(LB/HR) 506687. 506687. 0.00000 ENTHALPY(BTU/HR) -0.274074E+10 -0.345023E+10 0.205636 \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 05/07/2012 PAGE 11 EXTRACTION 05/07/2012 PAGE 11 U-0-5 BLOCK SECTION	
BLOCK: Z-101D MODEL: HEATER (CONTINUED)	
*** INPUT DATA ***TWOPHASE TP FLASHSPECIFIED TEMPERATUREFSPECIFIED PRESSUREPSIA14.5038MAXIMUM NO. ITERATIONS30CONVERGENCE TOLERANCE0.000100000	
*** RESULTS ***OUTLET TEMPERATURE F85.910OUTLET PRESSURE PSIA14.504HEAT DUTYBTU/HR-0.70949E+09OUTLET VAPOR FRACTION0.0000PRESSURE-DROP CORRELATION PARAMETER0.0000	
V-L PHASE EQUILIBRIUM :	
COMPF(I)X(I)Y(I)K(I)H201.00001.00000.42357E-0)1

(Figure C.2.3: Continue)

BLOCK: Z-102 MODEL: COMPR JOCK: 2-102 MODEL: COMPK INLET STREAM: E-104 OUTLET STREAM: E-104A PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS *** MASS AND ENERGY BALANCE *** RELATIVE DIFF. 0.00000 0.00000 0.00000 IN 90.8888 OUT 90.8888
 IN

 CONV. COMP. (LBMOL/HR)
 90.8888

 (LB/HR)
 4000.00

 NONCONV. COMP(LB/HR)
 0.00000

 TAL BALANCE
 0.00000
 4000.00 0.00000 NONCONV. CUMP(LD/NK TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR) SPEN PLUS PLAT: WIN32 4000.00 4000.00 0.00000 -0.153736E+08 -0.153736E+08 -0.117001E-06 VER: 22.0 05/07/2012 PAGE 12 EXTRACTION U-O-S BLOCK SECTION ASPEN PLUS BLOCK: Z-102 MODEL: COMPR (CONTINUED) *** INPUT DATA *** POLYTROPIC POSITIVE DISPLACEMENT COMPRESSOR OUTLET PRESSURE PSIA POLYTROPIC EFFICIENCY MECHANICAL EFFICIENCY CLEARANCE FRACTION USING PIECEWISE INTEGRATION 870.230 0.72000 0.60000 0.50000

(Figure C.2.3: Continue)

*** RESULTS ***	
ISENTROPIC HORSEPOWER REQUIREMENT HP CALCULATED OUTLET TEMP F ISENTROPIC TEMPERATURE F EFFICIENCY (POLYTR/ISENTR) USED VOLUMETRIC EFFICIENCY DISPLACEMENT CUFT/HR OUTLET VAPOR FRACTION HEAD DEVELOPED, FT-LBF/LB MECHANICAL EFFICIENCY USED INLET HEAT CAPACITY RATIO	$\begin{array}{c} 0.\ 00070693\\ 0.\ 0011782\\ 0.\ 0011782\\ 0.\ 0001782\\ 0.\ 00015755\\ 80.\ 5122\\ 80.\ 5105\\ 0.\ 72000\\ 0.\ 99000\\ 611.\ 559\\ 1.\ 00000\\ 0.\ 25195\\ 0.\ 60000\\ 1.\ 28678\\ 605.\ 443\\ 1.\ 00000\\ 1.\ 28678\\ 1.\ 28678\\ 1.\ 28678\\ 0.\ 924932+10\\ 0.\ 184988+11\\ \end{array}$
BLOCK: Z-103 MODEL: RSTOIC	
INLET STREAMS: E-104A E-103 OUTLET STREAM: E-104B PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-5 BLOCK SECTION	05/07/2012 PAGE 13

U-O-S BLOCK SECTION BLOCK: Z-103 MODEL: RSTOIC (CONTINUED) *** MASS AND ENERGY BALANCE *** IN OUT GENERATION RELATIVE DIFF. CONV. COMP.(LBMOL/HR) 90.8888 366.790 275.901 -0.232463E-15 (LB/HR) 4000.00 29333.9 0.500000 TOTAL BALANCE MASS(LB/HR) 50668.7 25334.3 0.500000 TOTAL BALANCE MASS(LB/HR) 54668.7 54668.3 0.772865E-05 ENTHALPY(BTU/HR)-0.342814E+09 -0.262046E+09 -0.235605 *** INPUT DATA *** STOICHIOMETRY MATRIX: REACTION # 1: SUBSTREAM MIXED : C6H12-01 0.146E-02C2H5N-01 0.773E-02C3H80-01 0.170E-02 SUBSTREAM NCP5D : ALGAE -1.00 REACTION CONVERSION SPECS: NUMBER= 1 REACTION # 1: SUBSTREAM:NCP5D KEY COMP:ALGAE CONV FRAC: 0.5000 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED TEMPERATURE F SUBSTREAM:NCP5D KEY COMP:ALGAE CONV FRAC: 0.5000 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SUBSTREAM:NCP5D KEY COMP:ALGAE CONV FRAC: 0.5000 SPECIFIED TEMPERATURE F SUBSTREAM:NCP5D KEY COMP:ALGAE CONV FRAC: 0.5000

OUTLET TEMPERATURE OUTLET PRESSURE HEAT DUTY VAPOR FRACTION	*** RESULTS F PSIA BTU/HR	; <u>*</u> ***	112.5 5801 0.807 0.000	.5 66E+08
REACTION EXTENTS: REACTION NUMBER 1	REACTION EXTENT LBMOL/HR 25334.			
₽ ASPEN PLUS PLAT: WIN	EXTRA	0 CTION CK SECTION	05/07/20)12 PAGE 14
BLOCK: Z-103 MODEL	RSTOIC (CONTIN	IUED)		
V-L PHASE EQUILIBRIU	4 :			
C6H12-01 (C2H5N-01 (C3H80-01 (0.10089 (0.53382 (0.11750 (X(I) 0.10089 0.53382 0.11750 0.24780	Y(I) 0.14141E-13 0.80282E-10 0.11908E-07 1.0000	0.71378E-14
BLOCK: Z-104 MODEL	SEP			
INLET STREAM: OUTLET STREAMS: PROPERTY OPTION SET:			GAS	
CONV. COMP. (LBMOI (LB/HI NONCONV. COMP(LB,	IN /HR) 366.79 29333. /HR) 25334.	00 366 9 293 3 253	.790 0. 33.9 0.3 34.3 0.	ATIVE DIFF. .00000 124020E-15 .00000
MASS(LB/HR) ENTHALPY(BTU/HR	54668.) -0.26204	3 5460 6E+09 -0.263	58.3 0.0 L803E+09 -0.9	665464E-16 926038E-03

	*** INPUT DATA ***	
	INLET PRESSURE PSIA	5,801.51
	FLASH SPECS FOR STREAM E-104C TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	121.910 870.230 30 0.000100000
ę.	FLASH SPECS FOR STREAM E-104D TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	121.910 870.230 30 0.000100000 05/07/2012 PAGE 15
E	BLOCK: Z-104 MODEL: SEP (CONTINUED)	
	FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-104D CPT= C6H12-01 FRACTION= C2H5N-01 C3H80-01 C02	0.0 0.0 0.0 1.00000

(Figure C.2.3: Continue)

*** RESULTS *** 0.24266E+06 HEAT DUTY BTU/HR COMPONENT = C6H12-01 SPLIT FRACTION 1.00000 STREAM SUBSTREAM E-104C MIXED COMPONENT = C2H5N-01 STREAM SUBSTREAM SPLIT FRACTION 1.00000 E-104C MIXED COMPONENT = C3H80-01 STREAM SUBSTREAM SPLIT FRACTION E-104C MIXED 1.00000 COMPONENT = CO2 SUBSTREAM MIXED SPLIT FRACTION 1.00000 STREAM E-104D COMPONENT = ALGAE SUBSTREAM SPLIT FRACTION 1.00000 STREAM E-104D MODEL: FLASH2 BLOCK: Z-105 INLET STREAM: E-104D OUTLET VAPOR STREAM: E-109 OUTLET LIQUID STREAM: E-108 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS *** MASS AND ENERGY BALANCE *** IN 90.8888 OUT 90.8888 RELATIVE DIFF. 0.00000 0.00000 CONV. COMP. (LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR) 4000.00 25334.3 4000.00 25334.3 0.00000 TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR 29334.3 -0.187577E+09 VER: 22.0 EXTRACTION 29334.3 0.00000 ENTHALPY(BTU/HR) ASPEN PLUS PLAT: WIN32 09 0.00000 05/07/2012 PAGE 16 -0.187577E+09 U-O-S BLOCK SECTION

(Figure C.2.3: Continue)

BLOCK: Z-105 MODEL: FLASH2 (CONTINUED)		
*** INPUT DATA ' TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	87 3	1.910 0.230 0.000100000
*** RESULTS *** OUTLET TEMPERATURE F OUTLET PRESSURE PSIA HEAT DUTY BTU/HR VAPOR FRACTION V-L PHASE EQUILIBRIUM :		121.91 870.23 0.37265E-07 1.0000
COMP F(I) X(I)		K(I)
CO2 1.0000 1.000	1.0000	1.8266
BLOCK: Z-107 MODEL: PUMP		
INLET STREAM: E-101 OUTLET STREAM: E-101P PROPERTY OPTION SET: UNIQUAC UNIQUAC	/ IDEAL GAS	
*** MASS AND ENERGY B		
IN CONV. COMP.(LBMOL/HR) 28125.4	OUT 28125.4	RELATIVE DIFF. 0.00000
(LB/HR) 506687.	506687.	0.00000
NONCONV. COMP(LB/HR) 50668.7 TOTAL BALANCE	50668.7	0.00000
MASS(LB/HR) 557356.	557356.	0.00000
ENTHALPY(BTU/HR) -0.378283E+10	-0.378283E+10	0.00000

(Figure C.2.3: Continue)

*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	45.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	30 0.000100000 05/07/2012 PAGE 17
BLOCK: Z-107 MODEL: PUMP (CONTINUED) *** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP	8,165.30 0.0 103.362 0.0 0.0
ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	0.0 0.60000 0.0 0.0
BLOCK: Z-108 MODEL: PUMP	
INLET STREAM: E-101E OUTLET STREAM: E-102 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL (GAS

(Figure C.2.3: Continue)

*** MASS AND ENERGY BALANCE *** IN OUT RELATIVE DIFF. CONV. COMP.(LBMOL/HR) 28125.4 28125.4 0.00000 (LB/HR) 506687. 506687. 0.00000 NONCONV. COMP(LB/HR) 0.00000 0.00000 0.00000 TOTAL BALANCE MASS(LB/HR) 506687. 506687. 0.00000 ENTHALPY(BTU/HR) -0.345023E+10 -0.345015E+10 -0.223679E-04
*** INPUT DATA *** OUTLET PRESSURE PSIA 45.0000 PUMP EFFICIENCY 0.60000 DRIVER EFFICIENCY 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION 05/07/2012 PAGE 18
BLOCK: Z-108 MODEL: PUMP (CONTINUED) *** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR 8,205.21 PRESSURE CHANGE PSI 30.4962 NPSH AVAILABLE FT-LBF/LB 32.3889 FLUID POWER HP 18.1984 BRAKE POWER HP 30.3307 ELECTRICITY KW 22.6176 PUMP EFFICIENCY USED 0.60000 NET WORK REQUIRED HP 30.3307 HEAD DEVELOPED FT-LBF/LB 71.1146

(Figure C.2.3: Continue)

BLOCK: Z-110 MODEL: PUMP	
INLET STREAM: E-104C OUTLET STREAM: PRODUCT PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE *** IN OUT CONV. COMP. (LBMOL/HR) 275.901 275.901 (LB/HR) 25333.9 25333.9 NONCONV. COMP (LB/HR) 0.00000 0.00000	0.00000 0.00000
TOTAL BALANCE MASS(LB/HR) 25333.9 25333.9 ENTHALPY(BTU/HR) -0.742263E+08 -0.742263E	
*** INPUT DATA ***	
EQUIPMENT TYPE: PUMP OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	870.230 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	05/07/2012 PAGE 19

(Figure C.2.3: Continue)

PRESSURE NPSH AVA FLUID PO BRAKE PO ELECTRIC PUMP EFF NET WORK HEAD DEV	IC FLOW RATE CUF CHANGE PSI ILABLE FT-LBF/L WER HP WER HP	В	295.307 0.0 1,460.72 0.0 0.0 0.0 0.60000 0.0 0.0 0.0 0.0 0.0	PAGE
		STREAM SECTION		
	LOWER LIMIT	UPPER LIMIT 6.5617-05 FT		
3 4 5 6 7 8	1.9685-04 FT 2.6247-04 FT 3.2808-04 FT	1.9685-04 FT 2.6247-04 FT 3.2808-04 FT 3.9370-04 FT 4.5932-04 FT 5.2493-04 FT		

(Figure C.2.3: Continue)

E-101E E-101P E-102 E	E-103 E-104									
STREAM ID FROM : TO : CLASS:	E-101 Z-107 MIXNCP5D	E-101A Z-101 Z-101A	E-101B Z-101A Z-101B MIXNCPSD	E-101C Z-101B Z-101C MIXNCPSE	E-101D Z-101C Z-101D MIXNCP5D	E-101E Z-101D Z-108 MIXNCPSD	E-101P Z-107 Z-101 MIXNCPSD	E-102 Z-108	E-103 Z-101B Z-103	E-104 Z-102 MIXNCPSD
TOTAL STREAM:	MIXNCPSD	MIXNCPSD	MIXNCPSU	MIXNCPSL	MIXNCPSL	MIXNCP50	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD
LB/HR	5.5736+05 -3.7828+09	5.5736+05 -3.8384+09	5.5736+05 -3.2132+09	5.0669+05 -2.9150+09	5.0669+05 -2.7407+09	5.0669+05 -3.4502+09	5.5736+05 -3.7828+09	5.0669+05 -3.4502+09	5.0669+04 -3.2744+08	4000.0000 -1.5374+07
PHASE: COMPONENTS: LBMOL/HR	LIQUID	LIQUID	VAPOR	VAPOR	VAPOR	LIQUID	LIQUID	LIQUID	MISSING	VAPOR
C6H12-01 C2H5N-01	0.0	0.0	0.0 0.0 0.0 2.8125+04	0.0 0.0 0.0 2.8125+04	0.0 0.0 0.0 0.0 2.8125+04	0.0 0.0 0.0 0.0 2.8125+04	0.0 0.0 0.0 2.8125+04	0.0 0.0 0.0 2.8125+04	0.0 0.0 0.0 0.0 0.0	0.0 0.0 0.0 90.8888 0.0
C0H12-01 C2H5N-01 C3H80-01 C02 H20 C0MPONENTS: MASS FRAG	0.0 0.0 0.0 5.0669+05	0.0 0.0 0.0 5.0669+05	0.0 0.0 0.0 5.0669+05	0.0 0.0 0.0 5.0669+05	0.0 0.0 0.0 5.0669+05	0.0 0.0 0.0 5.0669+05	0.0 0.0 0.0 5.0669+05	0.0 0.0 0.0 5.0669+05		0.0 0.0 4000.0000 0.0
C6H12-01 C2H5N-01 C3H80-01 C02	0.0	0.0 0.0 0.0 0.0 1.0000	0.0 0.0 0.0 0.0 1.0000	0.0 0.0 0.0 0.0 1.0000	0.0 0.0 0.0 0.0 1.0000	0.0 0.0 0.0 0.0 1.0000	0.0 0.0 0.0 0.0 1.0000	0.0 0.0 0.0 0.0 1.0000	MISSING MISSING MISSING MISSING MISSING	0.0 0.0 0.0 1.0000 0.0
LBMOL/HR LB/HR CUFT/HR	5.0669+05	2.8125+04 5.0669+05 7695.3536	2.8125+04 5.0669+05 1.4417+08	2.8125+04 5.0669+05 1.1990+08	2.8125+04 5.0669+05 2.7177+07		2.8125+04 5.0669+05 8165.2955	5.0669+05	0.0 0.0 0.0	90.8888 4000.0000 605.4433
STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC	76.9100 45.0000 0.0 1.0000 0.0	-40.0900 14.5038 0.0 1.0000 0.0	233.1000 1.4504 1.0000 0.0 0.0	116.5100 1.4504 1.0000 0.0 0.0	846.2629 14.5038 1.0000 0.0 0.0	85.9100 14.5038 0.0 1.0000 0.0	76.9100 45.0000 0.0 1.0000 0.0	86.0739 45.0000 0.0 1.0000 0.0	MISSING 1.4504 MISSING MISSING MISSING	80.5100 870.2264 1.0000 0.0 0.0

ENTHALPY: BTU/LBMOL BTU/LB BTU/HR ENTROPY:	-1.2282+05 -6817.7136 -3.4544+09	-6922.0178	-5700.7341		-5409.1331	-6809.3888	-6817.7136	-6809.2365	MISSING	-1.6915+05 -3843.4072 -1.5374+07
BTU/LBMOL-R BTU/LB-R DENSITY:	-38.8595 -2.1570	-42.8235 -2.3771	-3.9332 -0.2183	-5.4244 -0.3011	-3.1037 -0.1723	-38.5849 -2.1418	-38.8595 -2.1570	-38.5799 -2.1415	MISSING MISSING	-7.3576 -0.1672
LBMOL/CUFT LB/CUFT AVG MW	3.4445 62.0537 18.0153	3.6549 65.8432 18.0153	1.9509-04 3.5146-03 18.0153	2.3457-04 4.2258-03 18.0153	1.0349-03 1.8644-02 18.0153	3.4277 61.7518 18.0153	3.4445 62.0537 18.0153	3.4274 61.7463 18.0153	MISSING MISSING MISSING	0.1501 6.6067 44.0098
₽ ASPEN PLUS PLAT: Ν		R: 22.0 EXTRACTION STREAM SECT		05/07/2	012 PAGE 2	2				
E-101 E-101A E-101B	E-101C E-101	LD								
E-101E E-101P E-102	E-103 E-104	(CONTINUED))							
STREAM ID	E-101	E-101A	E-101B	E-101C	E-101D	E-101E	E-101P	E-102	E-103	E-104
SUBSTREAM: NCPSD COMPONENTS: LB/HR	STRUCTUR	RE: NON CONV	/ENTIONAL							
ALGAE COMPONENTS: MASS FRA		5.0669+04	5.0669+04	0.0	0.0	0.0	5.0669+04	0.0	5.0669+04	0.0
ALGAE TOTAL FLOW:	1.0000	1.0000	1.0000	0.0	0.0	0.0	1.0000	0.0	1.0000	0.0
LB/HR STATE VARIABLES:	5.0669+04	5.0669+04	5.0669+04	0.0	0.0	0.0	5.0669+04	0.0	5.0669+04	0.0
TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY:	76.9100 45.0000 0.0 1.0000	-40.0900 14.5038 0.0 0.0 1.0000	233.1000 1.4504 0.0 0.0 1.0000	MISSING 1.4504 MISSING MISSING MISSING	MISSING 14.5038 MISSING MISSING MISSING	MISSING 14.5038 MISSING MISSING MISSING	76.9100 45.0000 0.0 1.0000	MISSING 45.0000 MISSING MISSING MISSING	116.5100 1.4504 0.0 0.0 1.0000	MISSING 870.2264 MISSING MISSING MISSING
BTU/LB BTU/HR	-6480.9341 -3.2838+08			MISSING MISSING	MISSING MISSING		-6480.9341 -3.2838+08		-6462.3863 -3.2744+08	MISSING MISSING
DENSITY: LB/CUFT AVG MW	141.9785 1.0000	141.9785 1.0000	141.9785 1.0000	MISSING 1.0000	MISSING 1.0000	MISSING 1.0000	141.9785 1.0000	MISSING 1.0000	141.9785 1.0000	MISSING 1.0000

ALGAE	PROXANAL										
	MOISTURE	81.7000	81.7000	81.7000	MISSING	MISSING	MISSING	81.7000	MISSING	81.7000	MISSIN
	FC	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	VM	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	ASH	18.4000	18.4000	18.4000	MISSING	MISSING	MISSING	18.4000	MISSING	18.4000	MISSIN
	ULTANAL										
	ASH	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	CARBON	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	HYDROGEN	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	NITROGEN	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	CHLORINE	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	SULFUR	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	OXYGEN	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	SULFANAL										
	PYRITIC	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	SULFATE	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
	ORGANIC	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
UBSTREA	M ATTRIBUTES:										
SD											
FRAC1		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC2		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC3		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC4		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC5		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC6		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC7		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC8		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC9		0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
FRAC10)	0.0	0.0	0.0	MISSING	MISSING	MISSING	0.0	MISSING	0.0	MISSIN
SPEN P			R: 22.0			12 PAGE 23					
			EXTRACTION		,,						
			STREAM SECTI	ON							

(Figure C.2.3: Continue)

STREAM ID	E-104A	E-104B	E-104C	E-104D	E-105	E-106	E-107	E-108	E-109	PRODUCT
FROM :	z-102	z-103	z-104	z-104	FOR-USE	FOR-USE	FOR-USE	z-105	z-105	z-110
то :	z-103	z-104	z-110	z-105						FOR-USE
CLASS:	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSE
TOTAL STREAM:										
	4000,0000	5.4668+04	2.5334+04	2.9334+04	6666, 8938	1.4698+04	3968,9379	2.5334+04	4000.0000	2.5334+04
	-1.5374+07									-7.4226+07
SUBSTREAM: MIXED										
PHASE:	VAPOR	LIQUID	LIQUID	VAPOR	LIQUID	LIQUID	LIQUID	MISSING	VAPOR	LIQUID
COMPONENTS: LBMOL/HR										
C6H12-01	0.0	37.0059	37,0059	0.0	37,0059	0.0	0.0	0.0	0.0	37.0059
C2H5N-01	0.0	37.0059 195.7990	195,7990	0.0	0.0	195,7990	0.0	0.0	0. Ö	195.7990
C3H80-01	0.0	43 0963	43.0963	0.0	0.0	0.0	43.0963	0.0	0.0	43.0963
CO2	90,8888	90,8888	0.0	90.8888	0.0		0.0		90.8888	0.0
H20	90.8888 0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMPONENTS: LB/HR										
С6н12-01	0.0	6666.8938	6666.8938	0.0	6666.8938	0.0	0.0	0.0	0.0	6666.8938
C2H5N-01	0.0	1.4698+04	1.4698+04		0.0	1.4698+04	0.0	0.0	0.0	1.4698+04
C3H80-01	0.0	3968.9379	3968,9379	0.0	0.0	0.0	2068 0270	0.0	0.0	3968,9379
CO2	0.0 4000.0000	4000,0000	0.0	4000.0000	0.0	0.0	0.0	0.0	4000.0000	0.0
H2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAC										
C6H12-01		0.2273	0.2632	0.0	1,0000	0.0	0.0	MISSING	0.0	0.2632
	0.0	0.5011	0.5802	0.0	0.0	1,0000	0.0	MISSING	0.0	0.5802
C3H80-01	0.0	0.1353	0.1567	0.0	0.0	0.0	1.0000	MISSING	0.0	0.1567
CO2	1,0000	0.1364	0.0	1.0000	0.0	0.0	0.0	MISSING	1.0000	0.0
H20	0.0	0.0	0.0	0.0	0.0	0.0 1.0000 0.0 0.0 0.0	0.0	MISSING	0.0	0.0
TOTAL FLOW:										
LBMOL/HR	90,8888	366, 7900	275.9012	90.8888	37,0059	195.7990	43.0963	0.0	90.8888	275,9012
LB/HR	90.8888 4000.0000	2.9334+04	2.5334+04	4000.0000		1.4698+04	3968,9379	0.0	4000.0000	
CUFT/HR	605,4433	370,9356	295.3073	651.8424		163.0189	50,9022	0.0	651.8424	295.3073
STATE VARIABLES:										
TEMP F	80,5122	112,9100	121,9100	121,9100	130,7300	130,9100	130,9100	MISSING	121,9100	121,9100
PRES PSIA		5801.5095			5076.3208			870,2300	870.2300	870.2300
VFRAC	1.0000				0.0		0.0	MISSING	1.0000	0.0
LFRAC	0.0	1.0000		0.0			1.0000	MISSING		1.0000
SERAC	0.0		0.0	0.0	0.0	0.0	0.0	MISSING	0.0	0.0

the care contract them thep										
ENTHALPY: BTU/LBMOL -1	6015+05	2 4452:05	2 6002+05	-1.6877+05	5 2502:05	2 1458-05	2 8451.05	MISSING	-1.6877+05	2 6002:05
				-3834.8873					-3834.8873	
				-1.5340+07					-1.5340+07	
ENTROPY:										
BTU/LBMOL-R	-7.3576	-104.1978	-136.7072	-6.6889	-252.7076	-114.7810	-141.7530	MISSING	-6.6889	-136.7072
BTU/LB-R	-0.1672	-1.3029	-1.4888	-0.1520	-1.4027	-1.5290	-1.5392	MISSING	-0.1520	-1.4888
DENSITY:										
LBMOL/CUFT	0.1501	0.9888	0.9343	0.1394	0.3990	1.2011	0.8466	MISSING	0.1394	0.9343
LB/CUFT AVG MW	6.6067 44.0098	79.0809 79.9747	85.7883 91.8225	6.1365 44.0098	71.8918 180.1577	90.1619 75.0672	77.9719 92.0947	MISSING	6.1365 44.0098	85.7883 91.8225
AVG MW	44.0098	/9.9/4/	91.8225	44.0098	180.13//	/5.00/2	92.0947	MISSING	44.0098	91.8225
ASPEN PLUS PLAT: WIN32 VER: 22.0 05/07/2012 PAGE 24 EXTRACTION STREAM SECTION										
E-104A E-104B E-104C E-104D E-105										
E-106 E-107 E-108 E-109 PRODUCT (CONTINUED)										
STREAM ID	E-104A	E-104B	E-104C	E-104D	E-105	E-106	E-107	E-108	E-109	PRODUCT
SUBSTREAM: NCPSD COMPONENTS: LB/HR	STRUCTUR	RE: NON CON	ENTIONAL							
ALGAE COMPONENTS: MASS FRAC	0.0	2.5334+04	0.0	2.5334+04	0.0	0.0	0.0	2.5334+04	0.0	0.0
ALGAE TOTAL FLOW:	0.0	1.0000	0.0	1.0000	0.0	0.0	0.0	1.0000	0.0	0.0
LB/HR	0.0	2.5334+04	0.0	2.5334+04	0.0	0.0	0.0	2.5334+04	0.0	0.0
STATE VARIABLES:	0.0	2.3334104	0.0	2.3334104	0.0	0.0	0.0	2.3334104	0.0	0.0
TEMP F	MISSING	112,9100	MISSING	121.9100	MISSING	MISSING	MISSING	121.9100	MISSING	MISSING
PRES PSIA	870.2300		870.2300	870.2300	5076.3208	5076.3208	5076.3208	870.2300	870.2300	870.2300
VFRAC	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
LFRAC	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	MISSING	1.0000	MISSING	1.0000	MISSING	MISSING	MISSING	1.0000	MISSING	MISSING
SFRAC								-6798.5605	MISSING	MISSING
ENTHALPY:		C003 3150								
ENTHALPY: BTU/LB		-6803.2150		-6798.5605	MISSING	MISSING				
ENTHALPY: BTU/LB BTU/HR		-6803.2150 -1.7236+08		-6798.5605 -1.7224+08	MISSING	MISSING		-1.7224+08	MISSING	MISSING
ENTHALPY: BTU/LB										

COMPO	NENT ATTRIBUTES:										
ALGAE											
ALGAE	MOISTURE	MISSING	100.0000	MISSING	100.0000	MISSING	MISSING	MISSING	100.0000	MISSING	MISSING
	FC	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	VM	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	ASH	MISSING	18.4000	MISSING	18.4000	MISSING	MISSING	MISSING	18.4000	MISSING	MISSING
	ULTANAL	MISSING	10.4000	MISSING	10.4000	MISSING	MISSING	MISSING	10.4000	MISSING	MISSING
	ASH	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	CARBON	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	HYDROGEN NITROGEN	MISSING MISSING	0.0	MISSING MISSING	0.0	MISSING MISSING	MISSING MISSING	MISSING MISSING	0.0	MISSING MISSING	MISSING MISSING
			0.0				MISSING		0.0	MISSING	MISSING
	CHLORINE	MISSING		MISSING	0.0	MISSING		MISSING			
	SULFUR	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	OXYGEN	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	SULFANAL										
	PYRITIC	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	SULFATE	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	ORGANIC	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
	REAM ATTRIBUTES:										
PSD											
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRAG		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
FRA		MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
♀ ASPEN	N PLUS PLAT: WIN	132 VER	: 22.0		05/07/20.	12 PAGE 25					
			EXTRACTION								
		PROBL	EM STATUS S	ECITON							
DL OCK	CT ATUC										
BLOCK	STATUS										
*****	***************					*********					
*						*					
	culations were cor	mlated par	mally								
* Can	culations were con	ipreced nor	marry			*					
* 411	Unit Operation b	locks word	completed n	ormally		*					
* ATT	onic operación b	TOCKS were	compreted in	ormarry		*					
× 411	streams were flag	bod pormal	1								
* AII	screams were rias	sneu norman	тy			÷					
*****	*****	*********	*******	********	********	********					

(Figure C.2.3: Continue)

Section C.2.4 - APEN Plus simulator output for Case Scenario 4

Figure C.2.4. ASPEN print out for Case Scenario 4.

WTTH	H NORMALTZED	THESE COMPO	UN S. THIS APPL	TES CASE 1	-5. (14688	3. 34
то 2	22982.93) JA	N212012			5. (14000	
♀ ASPEN PLUS	PLAT: WI	N32 VER: E	22.0 XTRACTION	0	5/07/2012	PAGE 2
		FLOW	SHEET SECTION			
FLOWSHEET C	CONNECTIVITY	BY STREAMS				
STREAM	SOURCE	DEST	STREAM	SOURCE	DEST	
E-106	FOR-USE	z-103	E-101 E-107		z-108	
E-108	FOR-USE		E-107	FOR-USE		
E-109	FOR-USE		PRODUCT	z-113	FOR-USE	
E-106C	Z-105	Z-113	E-106D	Z-105	Z-106	
E-111	Z-106		E-110	Z-106		
E-106B	z-104	Z-105	E-106A	Z-103	z-104	
E-103C	z-110c	Z-110D	PRODUCT E-106D E-110 E-106A E-105 E-103E E-1032	z-110c	z-104	
E-103D	Z-110D	Z-110E	E-103E	Z-110E	z-111	
E-103B	Z-110B	z-110c	E-103A E-102P E-101P	Z-110A	Z-110B	
E-103P	z-101	z-10	E-102P	z-101	z-109	
E-103	z-10	Z-110A	E-101P	z-108	z-101	
E-102	z-109		E-104	z-111		
FLOWSHEET		BT BLOCKS				
BL OCK	TNU 575		017			
BLOCK	INLETS PRODUCT			LETS 108 E-107 E	100	
Z-113	E-106C			DUCT	-109	
2-115	E-100C			LOGC E-106D		
7 106	E-106B E-106D			11 E-110	,	
7-104	E-106A	E-105		L06B		
7-102	E-100A	2-105		L06A		
7-1100	E-106 E-103B			LOGC E-105		
Z-110C	E-1036			L03D		
7-1100	E-103D			LOJE		
Z-110B	E-103D E-103A			L03B		
7-1104	E-103			L03A		
7-101	E-103 E-101P			03P E-102P	•	
7-10	E-103P		E-1			
Z-108	E-101			01P		
Z-109	E-101 E-102P			02		
z-111	E-103E		E-1			

COMPUTATIONAL SEQUENCE SEQUENCE USED WAS: Z-108 Z-101 Z-109 Z-10 Z-110A Z-110B Z-110C Z-110D Z-110E Z-111 Z-103 Z-104 Z-105 Z-106 Z-113 FOR-USE OVERALL FLOWSHEET BALANCE ASPEN PLUS PLAT: WIN32 05/07/2012 PAGE 3 VER: 22.0 EXTRACTION FLOWSHEET SECTION OVERALL FLOWSHEET BALANCE (CONTINUED)

 MASS AND ENERGY BALANCE

 IN
 OUT

 CONVENTIONAL COMPONENTS
 (LBMOL/HR)

 C6H12-01
 0.00000
 37.0055

 C2H5N-01
 0.00000
 195.795

 C3H80-01
 0.00000
 43.0965

 C00000
 43.0965
 00000
 OUT RELATIVE DIFF. 37.0059 -1.00000 37.0059 195.799 43.0963 90.8888 28125.4 28492.2 -1.00000 -1.00000 0.00000 0.00000 -0.968340E-02 -0.472629E-01 CO2 90.8888
 CO2
 90.8888

 H20
 28125.4

 SUBTOTAL (LBMOL/HR)
 28216.3

 (LB/HR)
 510687.

 NON-CONVENTIONAL COMPONENTS
 (LB/HR)

 ALGAE
 50668.7

 SUBTOTAL (LB/HR)
 50668.7
 536021. ALGAE SUBTOTAL (LB/HR) TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR) \$ ASPEN PLUS PLAT: WIN32 25334.3 25334.3 0.500000 561356. 561355. 0.752669E-06 -0.379820E+10 -0.371601E+10 -0.216380E-01 2 VER: 22.0 05/07/2012 PAGE 4 EXTRACTION PHYSICAL PROPERTIES SECTION

(Figure C.2.4: Continue)

COMPONENTS			
ID TYPE FORMULA C6H12-01 C C6H1206 C2H5N-01 C C2H5N02-D1 C3H80-01 C C3H803 CO2 C CO2 ALGAE NC H2O C H2O	NAME OR ALIAS C6H12O6 C2H5NO2-D1 C3H8O3 CO2 MISSING H2O		REPORT NAME C6H12-01 C2H5N-01 C3H80-01 C02 ALGAE H20
			05/07/2012 PAGE 5
BLOCK: FOR-USE MODEL: SEP			
INLET STREAM: PROD OUTLET STREAMS: E-10 PROPERTY OPTION SET: UNIQ	8 E-107		
CONV. COMP. (LBMOL/HR)	275.901 25333.9 0.00000	OUT 275.901 25333.9 0.00000	-0.143601E-15 0.00000

*** INPUT DATA ***	
INLET PRESSURE PSIA	5,076.32
FLASH SPECS FOR STREAM E-108 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	130.910 5,076.32 30 0.000100000
FLASH SPECS FOR STREAM E-107 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	130.730 5,076.32 30 0.000100000
FLASH SPECS FOR STREAM E-109 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-5 BLOCK SECTION	130.910 5,076.32 30 0.000100000 05/07/2012 PAGE 6
BLOCK: FOR-USE MODEL: SEP (CONTINUED)	
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-107 CPT= C6H12-01 FRACTION= C2H5N-01 C3H8O-01	1.00000 0.0 0.0
STREAM= E-109 CPT= C6H12-01 FRACTION= C2H5N-01 C3H80-01	0.0 0.0 1.00000

(Figure C.2.4: Continue)

*** RESULTS ***	
HEAT DUTY BTU/HR	0.11739E+06
COMPONENT = C6H12-01 STREAM SUBSTREAM SPLIT FRACTION E-107 MIXED 1.00000	
COMPONENT = C2H5N-01 STREAM SUBSTREAM SPLIT FRACTION E-108 MIXED 1.00000	
COMPONENT = C3H8O-01 STREAM SUBSTREAM SPLIT FRACTION E-109 MIXED 1.00000	
BLOCK: Z-10 MODEL: PUMP	
INLET STREAM: E-103P OUTLET STREAM: E-103 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
*** MASS AND ENERGY BALANCE ***	
CONV. COMP. (LBMOL/HR) 1125.02 1125.02 (LB/HR) 20267.5 20267.5 NONCONV. COMP(LB/HR) 50668.7 50668.7	0.00000
MASS(LB/HR) 70936.2 70936.2 ENTHALPY(BTU/HR) -0.466558E+09 -0.466560E+09	0.00000 9 0.378870E-05 95/07/2012 PAGE 7

U-O-S BLOCK SECTION	
BLOCK: Z-10 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	45.0000 0.65000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000
*** RESULTS ***	
VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NP5H AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	326.612 -45.0000 207.787 -0.6891 -0.69479 -0.51811 0.65000 -0.69479 -104.426

HEAD DEVELOPED FT-LBF/	LB	-1	.04.426
BLOCK: Z-101 MODEL: S	EP		
INLET STREAM: OUTLET STREAMS: PROPERTY OPTION SET:	E-101P E-103P E- UNIQUAC UNIC	-102P QUAC / IDEAL GAS	
CONV. COMP. (LBMOL/H (LB/HR NONCONV. COMP(LB/HR	IN (R) 28125.4) 506687. (C) 50668.7		
MASS(LB/HR) ENTHALPY(BTU/HR)	557356. -0.37828	. 557356. 3E+10 -0.378283E+1	0.00000 -0.740562E-11
	*** INPUT DAT	TA ***	
INLET PRESSURE PSIA ‡ ASPEN PLUS PLAT: WIN32	EXTRAC		90.0000 05/07/2012 PAGE 8
BLOCK: Z-101 MODEL: S	EP (CONTINUED))	
FLASH SPECS FOR STREAM TWO PHASE TP FLASH PRESSURE DROP P MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE			0.0 30 0.000100000
FLASH SPECS FOR STREAM TWO PHASE TP FLASH PRESSURE DROP P MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE			0.0 30 0.000100000
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-102P C SUBSTREAM= NCPSD	PT= H20	FRACTION=	0.96000
	PT= ALGAE	FRACTION=	0.0

	*** RESULTS ***	
HEAT DUTY B	TU/HR	0.28014E-01
COMPONENT = H2O STREAM SUBSTREAM E-103P MIXED E-102P MIXED	SPLIT FRACTION 0.040000 0.96000	
COMPONENT = ALGAE STREAM SUBSTREAM E-103P NCPSD	SPLIT FRACTION 1.00000	
BLOCK: Z-103 MODEL: C	DMPR	
INLET STREAM: OUTLET STREAM: PROPERTY OPTION SET: ASPEN PLUS PLAT: WIN32	E-106A UNIQUAC UNIQUAC / IDEAL GAS	05/07/2012 PAGE 9
BLOCK: Z-103 MODEL: C	OMPR (CONTINUED)	
*** CONV. COMP.(LBMOL/H LB/HR NONCONV. COMP(LB/HR TOTAL BALANCE	MASS AND ENERGY BALANCE *** IN OUT R) 90.8888 90.8888) 4000.00 4000.00) 0.00000 0.00000	RELATIVE DIFF. 0.00000 0.00000 0.00000
MASS(LB/HR) ENTHALPY(BTU/HR)	4000.00 4000.00 -0.153736E+08 -0.152988E+0	0.00000 8 -0.486795E-02

(Figure C.2.4: Continue)

*** INPUT DATA ***	
POLYTROPIC POSITIVE DISPLACEMENT COMPRESSOR OUTLET PRESSURE PSIA POLYTROPIC EFFICIENCY MECHANICAL EFFICIENCY CLEARANCE FRACTION	USING PIECEWISE INTEGRATION 1,450.51 0.72000 0.60000 0.50000
*** RESULTS ***	
INDICATED HORSEPOWER REQUIREMENT HP BRAKE HORSEPOWER REQUIREMENT HP NET WORK REQUIRED HP POWER LOSSES HP ISENTROPIC HORSEPOWER REQUIREMENT HP CALCULATED OUTLET TEMP F ISENTROPIC TEMPERATURE F EFFICIENCY (POLYTR/ISENTR) USED VOLUMETRIC EFFICIENCY DISPLACEMENT CUFT/HR OUTLET VAPOR FRACTION HEAD DEVELOPED, FT-LBF/LB MECHANICAL EFFICIENCY USED INLET HEAT CAPACITY RATIO INLET VOLUMETRIC FLOW RATE, CUFT/HR OUTLET VOLUMETRIC FLOW RATE, CUFT/HR INLET COMPRESSIBILITY FACTOR OUTLET COMPRESSIBILITY FACTOR AV. ISENT. TEMP EXPONENT AV. ACTUAL VOL. EXPONENT AV. ACTUAL VOL. EXPONENT AV. ACTUAL TEMP EXPON	29.4125 49.0208 49.0208 19.6083 20.7158 169.936 144.046 0.72000 0.76830 788.028 1.00000 10,482.6 0.60000 1.28678 605.441 423.365 1.00000 1.27821 1.27821 1.27821 1.42824 1.42824 05/07/2012 PAGE 10
U-O-S BLOCK SECTION	

BLOCK: Z-104 MODEL: RSTOIC
INLET STREAMS: E-106A E-105 OUTLET STREAM: E-106B PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS
*** MASS AND ENERGY BALANCE *** RELATIVE DIFF. CONV. COMP. (LBMOL/HR) 90.8888 366.790 275.901 -0.774877E-16 (LB/HR) 4000.00 29333.9 -0.863639 -0.863639 NONCONV COMP(LB/HR) 50668.7 25334.3 0.500000 TOTAL BALANCE 54668.7 54668.3 0.772865E-05 ENTHALPY(BTU/HR) -0.342739E+09 -0.262046E+09 -0.235438
*** INPUT DATA *** STOICHIOMETRY MATRIX:
REACTION # 1: SUBSTREAM MIXED : C6H12-01 0.146E-02C2H5N-01 0.773E-02C3H80-01 0.170E-02 SUBSTREAM NCPSD : ALGAE -1.00
REACTION CONVERSION SPECS: NUMBER= 1 REACTION # 1: SUBSTREAM:NCPSD KEY COMP:ALGAE CONV FRAC: 0.5000
TWO PHASE TP FLASH SPECIFIED TEMPERATURE F 112.910 SPECIFIED PRESSURE PSIA 5,801.51 MAXIMUM NO. ITERATIONS 30 CONVERGENCE TOLERANCE 0.000100000 SIMULTANEOUS REACTIONS FOR FEED SPECIES NO GENERATE COMBUSTION REACTIONS FOR FEED SPECIES NO \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 05/07/2012 PAGE 11 EXTRACTION U-O-S BLOCK SECTION

(Figure C.2.4: Continue)

U-U-S BLUCK SECITON				
BLOCK: Z-104 MODEL:	RSTOIC (CON	TINUED)		
OUTLET TEMPERATURE OUTLET PRESSURE HEAT DUTY VAPOR FRACTION	*** RESUL F PSIA BTU/HR	.TS ***	5 0.	12.91 801.5 80691E+08 .0000
REACTION EXTENTS:				
NUMBER	REACTION EXTENT LBMOL/HR 25334.			
V-L PHASE EQUILIBRIUM	:			
C6H12-01 0 C2H5N-01 0 C3H80-01 0	F(I) .10089 .53382 .11750 .24780	X(I) 0.10089 0.53382 0.11750 0.24780	Y(I) 0.14141E-1 0.80282E-1 0.11908E-0 1.0000	0 0.76591E-11
BLOCK: Z-105 MODEL:	SEP			
INLET STREAM: OUTLET STREAMS: PROPERTY OPTION SET:		E-106D JNIQUAC / IDEA	L GAS	
** CONV. COMP.(LBMOL LB/HR NONCONV. COMP(LB/ TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR	/HR) 366.) 2933 HR) 2533	33.9 2 34.3 2	OUT 66.790 9333.9 5334.3	RELATIVE DIFF. 0.00000 0.248039E-15 0.00000 0.133093E-15 -0.926038E-03

(Figure C.2.4: Continue)

*** INPUT DATA	教教教
INLET PRESSURE PSIA ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTI U-O-S BLOCK	
BLOCK: Z-105 MODEL: SEP (CONTINUED)	
FLASH SPECS FOR STREAM E-106C TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	121.910 870.230 30 0.000100000
FLASH SPECS FOR STREAM E-106D TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	121.910 870.230 30 0.000100000
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-106D CPT= C6H12-01 FR C2H5N-01 C3H8O-01 C02	ACTION= 0.0 0.0 0.0 1.00000

(Figure C.2.4: Continue)

	*** RESULTS ***	
HEAT DUTY	BTU/HR	0.24266E+06
COMPONENT = C6H12-01 STREAM SUBSTREAM E-106C MIXED	SPLIT FRACTION 1.00000	
COMPONENT = C2H5N-01 STREAM SUBSTREAM E-106C MIXED	SPLIT FRACTION 1.00000	
COMPONENT = C3H8O-01 STREAM SUBSTREAM E-106C MIXED	SPLIT FRACTION 1.00000	
COMPONENT = CO2 STREAM SUBSTREAM E-106D MIXED	SPLIT FRACTION 1.00000	
COMPONENT = ALGAE STREAM SUBSTREAM E-106D NCPSD ₽ ASPEN PLUS PLAT: WIN3	1.00000	05/07/2012 PAGE 13
BLOCK: Z-106 MODEL:	FLASH2	
INLET STREAM: OUTLET VAPOR STREAM: OUTLET LIQUID STREAM: PROPERTY OPTION SET:		

(Figure C.2.4: Continue)

***	MASS AND ENERGY E	BALANCE *** OUT	RELATIVE DIFF.
CONV. COMP. (LBMOL/H			0.00000
(LB/HR) 4000.00	4000.00	0.00000
NONCONV. COMP(LB/HR) 25334.3	25334.3	0.00000
TOTAL BALANCE	20224 2	20224 2	
MASS(LB/HR) ENTHALPY(BTU/HR)	29334.3	29334.3 -0.187579E+09	0.00000 0.133751E-04
ENTHALPY (BTU/ HK)	-0.18/3//E+0	-0.18/3/9E+09	0.155/5IE-04
	INFOT DATA	***	
TWO PHASE TP FLASH			
SPECIFIED TEMPERATURE F			.730
SPECIFIED PRESSURE P MAXIMUM NO. ITERATIONS	SIA	30	. 230
CONVERGENCE TOLERANCE			.000100000
	*** RESULTS ***		
OUTLET TEMPERATURE F			121.73
	SIA TU/HR		870.23 2508.9
VAPOR FRACTION	TU/ HK		1.0000
VALOR TRACTION			1.0000
V-L PHASE EQUILIBRIUM :			
V E THASE EQUILIBRIUM .			
	I) X(I)		K(I)
CO2 1.	0000 1.000	1.0000	1.8230
BLOCK: Z-108 MODEL: P			
INLET STREAM:	E-101		
	E-101P		
PROPERTY OPTION SET:		/ IDEAL GAS	
ASPEN PLUS PLAT: WIN32	VER: 22.0 EXTRACTION		07/2012 PAGE 14
	U-O-S BLOCK SE		
	J-U-J BLOCK SI		

(Figure C.2.4: Continue)

U-O-S BLOCK SECT	ION	
BLOCK: Z-108 MODEL: PUMP (CONTINUED)		
*** MASS AND ENERGY BAL IN CONV. COMP.(LBMOL/HR) 28125.4 (LB/HR) 506687. NONCONV. COMP(LB/HR) 50668.7 TOTAL BALANCE	OUT 28125.4 506687. 50668.7	RELATIVE DIFF. 0.00000 0.00000 0.00000
MASS(LB/HR) 557356. ENTHALPY(BTU/HR) -0.378283E+10	557356. -0.378283E+10	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	0.	0000 60000 00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.) 000100000
*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NP5H AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	8,165. 0. 00 0. 0. 0. 0. 0. 0. 0.	0 787 0 0 0 60000 0

ę

HEAD DEVELOPED FT-LBF/LB

0.0

BLOCK: Z-109 MODEL: PUMP	
INLET STREAM: E-102P OUTLET STREAM: E-102 PROPERTY OPTION SET: UNIQUAC UNIQUAC ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-S BLOCK SE	05/07/2012 PAGE 15 N
BLOCK: Z-109 MODEL: PUMP (CONTINUED)	
*** MASS AND ENERGY B IN CONV. COMP. (LBMOL/HR) 27000.4 (LB/HR) 486419. NONCONV. COMP(LB/HR) 0.00000 TOTAL BALANCE MASS(LB/HR) 486419. ENTHALPY(BTU/HR) -0.331627E+10	OUT RELATIVE DIFF. 27000.4 0.00000 486419. 0.00000 0.00000 0.00000
*** INPUT DATA OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	*** 30.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000

(Figure C.2.4: Continue)

***	RESULTS ***		
VOLUMETRIC FLOW RATE CUFT	/HR	7,83	8.68
PRESSURE CHANGE PSI			0.0000
NPSH AVAILABLE FT-LBF/LB			7.787
FLUID POWER HP			4.2052
BRAKE POWER HP ELECTRICITY KW			0.5231 5.3041
PUMP EFFICIENCY USED			0.60000
NET WORK REQUIRED HP		-2	
HEAD DEVELOPED FT-LBF/LB			9.234
BLOCK: Z-110A MODEL: HEATE	R -		
INLET STREAM: E-10	3		
OUTLET STREAM: E-10			
PROPERTY OPTION SET: UNIQU			
♀ ASPEN PLUS PLAT: WIN32			5/07/2012 PAGE 16
	EXTRACTION		
	0-0-3 BLOCK SEC	TION	
BLOCK: Z-110A MODEL: HEATER	R (CONTINUED)		
*** MAS	5 AND ENERGY BA	LANCE ***	
	IN	OUT	RELATIVE DIFF.
CONV. COMP. (LBMOL/HR) (LB/HR)	1125.02	1125.02	0.00000
(LB/HR)	20267.5	20267.5	
NONCONV. COMP(LB/HR) TOTAL BALANCE	50668.7	50668.7	0.00000
MASS(LB/HR)	70936 2	70936 2	0,00000
ENTHALPY(BTU/HR)	-0.466560E+09	-0.471445E+09	0.00000 0.103622E-01
*** TWO PHASE TP FLASH	INPUT DATA **	*	
SPECIFIED TEMPERATURE	F		-40.0900
SPECIFIED PRESSURE	PSIA		14.5038
MAXIMUM NO. ITERATIONS			30
CONVERGENCE TOLERANCE			0.000100000

HEAT DUTY B OUTLET VAPOR FRACTION PRESSURE-DROP CORRELATI	SIA TU/HR	-1	-40.090 14.504 0.48852E+07 0.0000 0.33000E+08						
V-L PHASE EQUILIBRIUM :	I) X(I)	Y(I)	к(I)						
	0000 1.000		0.20011E-03						
BLOCK: Z-110B MODEL: H	EATER								
INLET STREAM: E-103A OUTLET STREAM: E-103B PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS ASPEN PLUS PLAT: WIN32 VER: 22.0 05/07/2012 PAGE 17 EXTRACTION U-0-5 BLOCK SECTION									
BLOCK: Z-110B MODEL: H	EATER (CONTINUED)								
*** CONV. COMP.(LBMOL/H (LB/HR NONCONV. COMP(LB/HR TOTAL BALANCE) 20267.5	ALANCE *** OUT 1125.02 20267.5 50668.7	RELATIVE DIFF. 0.00000 0.00000 0.00000						
MASS(LB/HR) ENTHALPY(BTU/HR)	70936.2 -0.471445E+09	70936.2 -0.440210E+09	0.00000 -0.662552E-01						
	INFOT DATA	× ×							
TWO PHASE TP FLASH SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	F PSIA		233.100 1.45038 30 0.000100000						

(Figure C.2.4: Continue)

OUTLET TEMPERATURE OUTLET PRESSURE HEAT DUTY OUTLET VAPOR FRACTION PRESSURE-DROP CORRELA				233.10 1.4504 0.31236E+08 1.0000 1553.9
V-L PHASE EQUILIBRIUN	4 :			
	F(I) 1.0000	X(I) 1.0000		
BLOCK: Z-110C MODEL:	FLASH2			
INLET STREAM: OUTLET VAPOR STREAM: OUTLET LIQUID STREAM: PROPERTY OPTION SET: ASPEN PLUS PLAT: WIN	: E-105 UNIQUAC 132 VER: EX U-O-S	22.0 (TRACTION BLOCK SECT)	05/	'07/2012 PAGE 18
BLOCK: Z-110C MODEL:	: FLASH2 (CON	ITINUED)		
** CONV. COMP. (LBMOL (LB/HF NONCONV. COMP(LB/ TOTAL BALANCE	L/HR) 112 R) 202	ENERGY BALA IN 25.02 267.5 568.7	ANCE *** OUT 1125.02 20267.5 50668.7	RELATIVE DIFF. 0.00000 0.00000 0.00000
MASS(LB/HR) ENTHALPY(BTU/HR		936.2 9210E+09	70936.2 -0.444042E+09	0.00000 0.863023E-02
TWO PHASE TP FLA SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	ASH E F PSIA NS	DATA ***	3	5.510 1.45038 0.000100000

ENTHALPY(BTU/HR) -0.	440210E+09	-0.444042E+09	0.863023E-02							
TWO PHASE TP FI SPECIFIED TEMPERATU SPECIFIED PRESSURE MAXIMUM NO. ITERATU CONVERGENCE TOLERANG	LASH RE F PSIA DNS	PUT DATA ***	1 30	5.510 45038 9.000100000							
OUTLET TEMPERATURE OUTLET PRESSURE HEAT DUTY VAPOR FRACTION V-L PHASE EQUILIBRI	F PSIA BTU/HR	SULTS ***	-0	116.51 1.4504 0.38322E+07 1.0000							
COMP H2O	F(I) 1.0000	X(I) 1.0000	Y(I) 1.0000	К(I) 1.0600							
BLOCK: Z-110D MODEL: COMPR INLET STREAM: E-103C OUTLET STREAM: E-103D PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS											

(Figure C.2.4: Continue)

BLOCK: Z-110D MODEL: COMPR TOTAL BALANCE	(CONTIN	UED)			
MASS(LB/HR) ENTHALPY(BTU/HR)	20267 -0.1166	.5 01E+09	2026 -0.109	57.5 9629E+09	0.00000 -0.597904E-01
***	INPUT	DATA	***		
POLYTROPIC COMPRESSOR USING OUTLET PRESSURE PSIA POLYTROPIC EFFICIENCY MECHANICAL EFFICIENCY	ASME ME	THOD		0	.5038 .66000 .00000
***	RESULT	S ***			
INDICATED HORSEPOWER REQUI BRAKE HORSEPOWER REQUI NET WORK REQUIRED POWER LOSSES ISENTROPIC HORSEPOWER REQUI CALCULATED OUTLET TEMP F EFFICIENCY (POLYTR/ISENTR) OUTLET VAPOR FRACTION HEAD DEVELOPED, FT-LL MECHANICAL EFFICIENCY USED INLET HEAT CAPACITY RATIO INLET VOLUMETRIC FLOW RATE OUTLET VOLUMETRIC FLOW RATE INLET COMPRESSIBILITY FAC OUTLET COMPRESSIBILITY FAC OUTLET COMPRESSIBILITY FAC AV. ISENT. TEMP EXPONENT AV. ACTUAL VOL. EXPONENT AV. ACTUAL TEMP EXPONENT	IREMENT IREMENT USED BF/LB , CUFT/ E, CUFT/ TOR	HP HP HP HP		1,560 846 0 1 176,666 1 4,796,150 1,087,060 1,087,060 1 1 1 1 1	.95 .95 .0 .98 .263 .00000 .00000 .32818

BLOCK: Z-110E MODEL: HEATE	R		
	3E	05/	/07/2012 PAGE 20
BLOCK: Z-110E MODEL: HEATE	R (CONTINUED)		
*** MAS CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR) TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR)	S AND ENERGY BAL IN 1125.02 20267.5 0.00000 20267.5	OUT 1125.02 20267.5 0.00000	
ENTHALPY(BTU/HR)	-0.109629E+09	-0.138009E+09	0.205636
*** TWO PHASE TP FLASH SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	INPUT DATA *** F PSIA		85.9100 14.5038 30 0.000100000
**** OUTLET TEMPERATURE F OUTLET PRESSURE PSIA HEAT DUTY BTU/H OUTLET VAPOR FRACTION PRESSURE-DROP CORRELATION P	R		85.910 14.504 0.28380E+08 0.0000 0.0000

(Figure C.2.4: Continue)

PRESSURE-DROP	CORRELATION PARA	0.0000				
V-L PHASE EQUI	LIBRIUM :					
COMP	F(I)	X(I)	Y(I)	K(I)		
н2о	1.0000	1.0000	1.0000	0.42357E-01		
BLOCK: Z-111	MODEL: PUMP					
INLET STREAM:	E-103E					
OUTLET STREAM:						
	N SET: UNIQUAC AT: WIN32 VE	R: 22.0		07/2012 PAGE 21		
		EXTRACTION	,			
	U-0)-S BLOCK SECT	ION			
BLOCK: Z-111	MODEL: PUMP (CO	NTINUED)				
	*** MASS A	AND ENERGY BAL	ANCE ***			
CON14 CON15	(1.5000) (115)	IN	OUT	RELATIVE DIFF.		
CONV. COMP		1125.02 20267.5	1125.02 20267.5	0.00000		
NONCONV. C			0.00000	0.00000		
TOTAL BALANCE		20267.5	20267.5	0.00000		
MASS(LB/HR ENTHALPY(B	ти/нв) – С	20207.5).138009E+09	-0.138006E+09	-0.223679E-04		
OUTLET PRESSU		NPUT DATA ***	45	. 0000		
PUMP EFFICIEN				60000		
DRIVER EFFICI	ENCY		1.	. 00000		
FLASH SPECIFI	CATTONS:					
LIQUID PHASE	CALCULATION					
NO FLASH PERF			3(
TOLERANCE	R OF ITERATIONS			000100000		

*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP BRAKE POWER HP ELECTRICITY KW PUMP EFFICIENCY USED NET WORK REQUIRED HP HEAD DEVELOPED FT-LBF/LB	328.209 30.4962 32.3889 0.72794 1.21323 0.90470 0.60000 1.21323 71.1146
BLOCK: Z-113 MODEL: PUMP	
INLET STREAM: E-106C OUTLET STREAM: PRODUCT PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	05/07/2012 PAGE 22
BLOCK: Z-113 MODEL: PUMP (CONTINUED)	
*** MASS AND ENERGY BALANCE *** IN OUT OUT CONV. COMP. (LBMOL/HR) 275.901 275.901 (LB/HR) 25333.9 25333.9 NONCONV. COMP (LB/HR) 0.00000 0.00000	RELATIVE DIFF. 0.00000 0.00000 0.00000
TOTAL BALANCE MASS(LB/HR) 25333.9 25333.9 ENTHALPY(BTU/HR) -0.742263E+08 -0.742263E+	0.00000 -08 -0.401506E-15
*** INPUT DATA ***	
EQUIPMENT TYPE: PUMP OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	870.230 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000

(Figure C.2.4: Continue)

PRESSURE NPSH AVA: FLUID PO BRAKE PO ELECTRIC PUMP EFF NET WORK HEAD DEVI	WER HP ITY KW ICIENCY USE REQUIRED ELOPED FT-L	I -LBF/LB D HP BF/LB	/HR		295.307 0.0 1,460.72 0.0 0.0 0.0 0.60000 0.0 0.0 0.0 0.0 0.0	PAGE 23
1 2 3 4 5 6 7 8	LOWER LIM 0.0 6.5617-05 1.3123-04 1.9685-04 2 6247-04	IT FT FT FT FT FT FT FT FT FT FT	UPPER LIN 6.5617-05 1.3123-04 1.9685-04 2.6247-04 3.2808-04 3.9370-04 4.5932-04 5.2493-04 5.9055-04 6.5617-04	FT FT FT FT FT FT FT FT		
≗ ASPEN PLUS	PLAT: WIN	N32	VER: 22.0 EXTRACTION STREAM SECTI		05/07/2012	PAGE 24
E-101 E-101	P E-102 E-1	02P E-1	03			

E-103A E-103B E-103C E-103D E-103E

STREAM ID	E-101	E-101P	E-102	E-102P	E-103	E-103A	E-103B	E-103C	E-103D	E-103E
FROM :		z-108	z-109	z-101	z-10	Z-110A	Z-110B	z-110c	Z-110D	Z-110E
то :	Z-108	z-101		z-109	Z-110A	Z-110B	z-110c	Z-110D	Z-110E	z-111
CLASS:	MIXNCPSD	MIXNCPSE	MIXNCPSD	MIXNCPSD						
TOTAL STREAM:										
	5.5736+05									
	-3.7828+09	-3.7828+09	-3.3163+09	-3.3163+09	-4.6656+08	-4.7145+08	-4.4021+08	-1.1660+08	-1.0963+08	-1.3801+08
SUBSTREAM: MIXED										
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	VAPOR	VAPOR	VAPOR	LIQUID
COMPONENTS: LBMOL/HR										
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H2O	2.8125+04	2.8125+04	2.7000+04	2.7000+04	1125.0160	1125.0160	1125.0160	1125.0160	1125.0160	1125.0160
COMPONENTS: LB/HR										
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H2O	5.0669+05	5.0669+05	4.8642+05	4.8642+05	2.0267+04	2.0267+04	2.0267+04	2.0267+04	2.0267+04	2.0267+04
COMPONENTS: MASS FRAC										
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H8O-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H2O	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
TOTAL FLOW:										
LBMOL/HR	2.8125+04	2.8125+04	2.7000+04	2.7000+04	1125.0160	1125.0160	1125.0160	1125.0160	1125.0160	1125.0160
LB/HR	5.0669+05	5.0669+05	4.8642+05	4.8642+05	2.0267+04	2.0267+04	2.0267+04	2.0267+04	2.0267+04	2.0267+04
CUFT/HR	8165,2955	8165.2955	7838.1911	7838.6837	326,6045	307,8141	5.7666+06	4,7961+06	1.0871+06	328,2086
STATE VARIABLES:										
TEMP F	76.9100	76.9100	76.7934	76.9100	76.8683	-40.0900	233.1000	116.5100	846.2629	85.9100
PRES PSIA	90.0000	90.0000	30,0000	90.0000	45,0000	14.5038	1.4504	1.4504	14.5038	14.5038
VFRAC	0.0	0.0	0.0	0.0	0.0	0.0	1.0000	1.0000	1.0000	0.0
LFRAC	1.0000	1.0000	1.0000	1.0000	1,0000	1.0000	0.0	0.0	0.0	1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

ENTHALPY: BTU/LBMOL BTU/LB	-6817.7136	-6817.7136	-6817.8210		-6817.7520	-6922.0178	-5700.7341	-5753.1142	-5409.1331	-6809.3888	
BTU/HR	-3.4544+09	-3.4544+09	-3.3163+09	-3.3163+09	-1.3818+08	-1.4029+08	-1.1554+08	-1.1660+08	-1.0963+08	-1.3801+08	
ENTROPY: BTU/LBMOL-R	-38.8595	-38.8595	-38.8631	-38.8595	-38.8608	-42.8235	-3.9332	-5.4244	-3.1037	-38,5849	
BTU/LB-R	-2.1570	-2.1570	-2.1572	-2.1570	-2.1571	-2.3771	-0.2183	-0.3011	-0.1723	-2.1418	
DENSITY:	2	2 4445		2 4445	2 4446	2 6540	1 0500 04	2 2457 04	1 0340 03	2 4277	
LBMOL/CUFT LB/CUFT	3.4445 62.0537	3.4445 62.0537	3.4447	3.4445 62.0537	3.4446 62.0551	65.8432	1.9509-04	2.3457-04 4.2258-03		3.4277 61.7518	
AVG MW	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153		18.0153	18.0153	
	AT. 147122 VE	D. 33 0		05 (07 /2	012 0465 2	F					
ASPEN PLUS PL	LAT: WIN32 VE	R: 22.0 EXTRACTION	u	05/07/2	012 PAGE 2	2					
		STREAM SECT									
5 101 5 1010 5	102 E-102P E-103										
E-IOI E-IOIP E-	102 E-102P E-105										
E-103A E-103B E	-103C E-103D E-10	3E (CONTINU	JED)								
STREAM ID	E-101	E-101P	E-102	E-102P	E-103	E-103A	E-103B	E-103C	E-103D	E-103E	
SUBSTREAM: NCPS		RE: NON CON	/ENTIONAL								
COMPONENTS: LB/ ALGAE		5.0669+04	0.0	0.0	5.0669+04	5.0669+04	5.0669+04	0.0	0.0	0.0	
COMPONENTS: MAS	S FRAC										
ALGAE	1.0000	1.0000	0.0	0.0	1.0000	1.0000	1.0000	0.0	0.0	0.0	
TOTAL FLOW: LB/HR	5,0669+04	5.0669+04	0.0	0.0	5.0669+04	5.0669+04	5.0669+04	0.0	0.0	0.0	
STATE VARIABLES	:										
TEMP F	76.9100	76.9100	MISSING	MISSING	76.8683	-40.0900	233.1000	MISSING	MISSING	MISSING	
PRES PSIA VFRAC	90.0000 0.0	90.0000 0.0	30.0000 MISSING	90.0000 MISSING	45.0000	14.5038 0.0	1.4504	1.4504 MISSING	14.5038 MISSING	14.5038 MISSING	
LERAC	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING	
SFRAC	1.0000	1.0000	MISSING	MISSING	1.0000	1.0000	1.0000	MISSING	MISSING	MISSING	
ENTHALPY:	1.0000	1.0000	MISSING	MITOPING	1.0000	1.0000	1.0000	MIT22TNG	MIT22TNC	MISSING	
BTU/LB	-6480,9341	-6480 9341	MISSING	MISSING	-6480 9536	-6535.6624	-6407 7062	MISSING	MISSING	MISSING	
BTU/HR	-3, 2838+08		MISSING			-3.3115+08		MISSING	MISSING	MISSING	
DENSITY:	-3.2030+00	-3.2030+00	HISSING	HI33ING	-5.2030+00	-3.3113+00	-3.240/400	MI222ING	HI33ING	HISSING	
LB/CUFT	141,9785	141.9785	MISSING	MISSING	141.9785	141.9785	141,9785	MISSING	MISSING	MISSING	
AVG MW	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	

COMPONEN	NT ATTRIBUTES:										
ALGAE	PROXANAL										
	MOISTURE	81,7000	81,7000	MISSING	MISSING	81,7000	81,7000	81,7000	MISSING	MISSING	MISSING
	FC	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	VM	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	ASH	18,4000	18,4000	MISSING	MISSING	18,4000	18,4000	18,4000	MISSING	MISSING	MISSING
	ULTANAL	2011000	2011000			201.1000	2011000	2011000			
	ASH	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	CARBON	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	HYDROGEN	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	NITROGEN	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	CHLORINE	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	SULFUR	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	OXYGEN	ŏ.ŏ	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	SULFANAL										
	PYRITIC	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	SULFATE	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
	ORGANIC	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	MISSING	MISSING	MISSING
SUBSTRE	AM ATTRIBUTES:										
PSD											
FRAC1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC2		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC3		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC 5		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC6		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC7		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC8		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC9		0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
FRAC1	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	MISSING	MISSING
ASPEN P ASPEN ASP	PLUS PLAT: WI	N32 VE	R: 22.0		05/07/2012	PAGE 26					
			EXTRACTION								
			STREAM SECTI	ION							

E-103P E-104 E-105 E-106 E-106A

(Figure C.2.4: Continue)

E-106B E-106C E-106D E-107 E-108	3
	-

STREAM ID	E-103P	E-104	E-105	E-106	E-106A	E-106B	E-106C	E-106D	E-107	E-108
FROM :	z-101	z-111	z-110C		Z-103	z-104	z-105	Z-105	FOR-USE	FOR-USE
то :	Z-10		z-104	Z-103	z-104	Z-105	Z-113	Z-106		
CLASS:	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSE	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD
TOTAL STREAM:										
LB/HR	7.0936+04		5.0669+04	4000.0000	4000.0000	5.4668+04	2.5334+04	2.9334+04	6666.8928	1.4698+04
BTU/HR	-4.6656+08	-1.3801+08	-3.2744+08	-1.5374+07	-1.5299+07	-2.6205+08	-7.4226+07	-1.8758+08	-1.9832+07	-4.2015+07
SUBSTREAM: MIXED										
PHASE:	LIQUID	LIQUID	MISSING	VAPOR	VAPOR	LIQUID	LIQUID	VAPOR	LIQUID	LIQUID
COMPONENTS: LBMOL/HR										
C6H12-01	0.0	0.0	0.0	0.0	0.0	37.0059	37.0059	0.0	37.0059	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	195.7990	195.7990	0.0	0.0	195.7990
C3H80-01	0.0	0.0	0.0	0.0	0.0	43.0963	43.0963	0.0	0.0	0.0
C02	0.0	0.0	0.0	90.8888	90.8888	90.8888	0.0	90.8888	0.0	0.0
H2O	1125.0160	1125.0160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMPONENTS: LB/HR										
C6H12-01	0.0	0.0	0.0	0.0	0.0	6666.8928	6666.8928	0.0	6666.8928	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	1.4698+04	1.4698+04	0.0	0.0	1.4698+04
C3H80-01	0.0	0.0	0.0	0.0	0.0	3968, 9373	3968, 9373	0.0	0.0	0.0
CO2	0. Ŭ	0. Ŭ	0.0	4000.0000	4000.0000	4000.0000	0.0	4000.0000	0.0	0.0
H20	2.0267+04	2.0267+04	0.0	0.0	0.0	0.0	0. 0	0.0	0. Ŭ	0.0
COMPONENTS: MASS FRAC										
С6H12-01	0.0	0.0	MISSING	0.0	0.0	0.2273	0.2632	0.0	1,0000	0.0
C2H5N-01	0.0	ŏ.ŏ	MISSING	0.0	ŏ.ŏ	0.5011	0.5802	0.0	0.0	1.0000
C3H80-01	0.0	0.0	MISSING	0.0	0.0	0.1353	0.1567	0.0	0.0	0.0
C02	0.0	ŏ.ŏ	MISSING	1.0000	1.0000	0.1364	0.0	1.0000	ŏ.ŏ	0.0
H20	1.0000	1.0000	MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FLOW:	1.0000	1.0000	HISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LBMOL/HR	1125.0160	1125.0160	0.0	90.8888	90.8888	366.7900	275,9011	90.8888	37,0059	195,7990
LB/HR	2.0267+04	2.0267+04	0.0	4000.0000	4000.0000	2.9334+04	2,5334+04	4000.0000	6666.8928	1,4698+04
CUFT/HR	326.6118	328.2379	0.0	605.4408	423.3652	370.9355	295.3073	651.8424	92.7350	163.0189
STATE VARIABLES:	520.0110	520.25/5	0.0	005.4400	423.3032	5/0.5555	295.5075	031.0424	52.7550	103.0105
TEMP F	76,9100	86.0739	MISSING	80.5100	169,9357	112,9100	121,9100	121,9100	130,7300	130,9100
PRES PSIA	90.0000	45.0000	1.4504	870.2300	1450.5100	5801.5095	870.2300	870.2300	5076.3208	5076.3208
VERAC	0.0	0.0	MISSING	1.0000	1.0000	0.0	0.0	1.0000	0.0	0.0
LFRAC	1.0000	1.0000	MISSING	0.0	0.0	1.0000	1.0000	0.0	1.0000	1.0000
SFRAC	0.0	0.0	MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JF NAL	0.0	0.0	MISSING	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Contraction of the second	~	···		~				··· ·		~	
ENTHALPY:											
BTU/LBMOL	-1.2282+05 -	1.2267+05	MISSING	-1.6915+05	-1.6832+05	-2.4453+05	-2.6903+05	-1.6877+05	-5.3592+05	-2.1458+05	
BTU/LB	-6817.7136 -	6809.2365				-3057.5720					
BTU/HR	-1.3818+08 -	1.3801+08	MISSING	-1.5374+07	-1.5299+07	-8.9691+07	-7.4226+07	-1.5340+07	-1.9832+07	-4.2015+07	
ENTROPY:											
BTU/LBMOL-R	-38.8595	-38.5799	MISSING	-7.3576	-6.9627	-104.1978	-136,7072	-6,6889	-252,7076	-114.7810	
BTU/LB-R	-2.1570	-2.1415	MISSING	-0.1672	-0.1582	-1.3029	-1.4888	-0.1520	-1,4027	-1.5290	
DENSITY:						210020					
LBMOL/CUFT	3.4445	3,4274	MISSING	0.1501	0.2147	0.9888	0.9343	0.1394	0.3990	1,2011	
LB/CUFT	62.0537	61.7463	MISSING	6,6068	9,4481	79.0809	85,7883	6,1365	71.8918	90,1619	
AVG MW	18.0153	18.0153	MISSING	44.0098	44.0098	79.9747	91.8225	44.0098	180,1577	75.0672	
	10.0100	10.0100	112002110	1110050	1110050	1515141	51.0225		10011011	13100/2	
2 ASPEN PLUS PLAT: WIN32 VER: 22.0 05/07/2012 PAGE 27											
÷ //b/ E// / E// /		EXTRACTION		03/01/2	012 17/02 L						
		TREAM SECT									
		TREAM DECT.	1014								
E-103P E-104 E-105 E-	106 E-1064										
2 1051 2 104 2 105 2	100 1 1004										
E-106B E-106C E-106D	E-107 E-108)								
2 1000 2 1000 2 1000	- 107 - 100	(CONTINUED)									
STREAM ID	E-103P	E-104	E-105	E-106	E-106A	E-106B	E-106C	E-106D	E-107	E-108	
BIREAU 10	2 200	2 204	2 205	2 200	2 2004	2 1000	2 2000	2 1000	2 207	2 100	
SUBSTREAM: NCPSD STRUCTURE: NON CONVENTIONAL											
COMPONENTS: LB/HR	Diffoctone		Entriconne								
ALGAE	5.0669+04	0.0	5.0669+04	0.0	0.0	2.5334+04	0.0	2.5334+04	0.0	0.0	
COMPONENTS: MASS ERAC		0.0	5.0005104	0.0	0.0	2.3334104	0.0	2.3334104	0.0	0.0	
ALGAE	1.0000	0.0	1.0000	0.0	0.0	1,0000	0.0	1,0000	0.0	0.0	
TOTAL FLOW:	2.0000	0.0	1.0000		0.0	2.0000	0.0	2.0000	0.0		
LB/HR	5.0669+04	0.0	5.0669+04	0.0	0.0	2.5334+04	0.0	2.5334+04	0.0	0.0	
STATE VARIABLES:	5.0005104	0.0	5.0005104	0.0	0.0	2.3334104	0.0	2.3334104	0.0	0.0	
TEMP F	76,9100	MISSING	116.5100	MISSING	MISSING	112,9100	MISSING	121,9100	MISSING	MISSING	
PRES PSIA	90,0000	45,0000	1.4504	870.2300		5801.5095	870,2300		5076.3208	5076.3208	
VFRAC	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING	
LFRAC	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING	
SFRAC	1.0000	MISSING	1.0000	MISSING	MISSING	1.0000	MISSING	1.0000	MISSING	MISSING	
ENTHALPY:	1.0000	MISSING	1.0000	MISSING	MISSING	1.0000	MISSING	1.0000	MISSING	MISSING	
	-6480.9341	MICCINC	-6462.3863	MISSING	MICTNO	-6803.2150	MICCINC	-6798.5605	MISSING	MISSING	
	-3.2838+08		-3.2744+08	MISSING		-1.7235+08		-1.7224+08	MISSING	MISSING	
DENSITY:	-3.2030+08	MISSING	-5.2/44+08	MISSING	MISSING	-1./230+08	MISSING	-1./224+08	MISSING	MISSING	
LB/CUFT	141.9785	MICCINC	141.9785	NTCOTHO	NTCOTHO	141.9785	NTCOTHO	141.9785	NTCOTHO	NTCOTHO	
AVG MW	1.0000	MISSING 1.0000	1.0000	MISSING 1.0000	MISSING 1.0000	1.0000	MISSING 1.0000	1.0000	MISSING 1.0000	MISSING 1.0000	
AVG MW	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	

(Figure C.2.4: Continue)

COMPONENT ATTRIBUTES: ALGAE PROXANAL										
MOISTURE	81.7000	MISSING	81.7000	MISSING	MISSING	100.0000	MISSING	100.0000	MISSING	MISSING
FC	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
VM	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
ASH	18.4000	MISSING	18.4000	MISSING	MISSING	18.4000	MISSING	18.4000	MISSING	MISSING
ULTANAL	0.0		0.0			0.0		0.0		
ASH	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
CARBON	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
HYDROGEN NITROGEN	0.0	MISSING MISSING	0.0	MISSING MISSING	MISSING MISSING	0.0	MISSING	0.0	MISSING MISSING	MISSING MISSING
CHLORINE	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
SULFUR	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
OXYGEN	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
SULFANAL	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	HISSING	MISSING
PYRITIC	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
SULFATE	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
ORGANIC	0.0	MISSING	0.0	MISSING	MISSING	0.0	MISSING	0.0	MISSING	MISSING
SUBSTREAM ATTRIBUTES:										
PSD										
FRAC1	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC2	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC3	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC4	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC5	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC6	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC7	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC8	0.0	MISSING	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0
FRAC9 FRAC10	0.0	MISSING MISSING	0.0	MISSING MISSING	MISSING MISSING	0.0	0.0	0.0	0.0	0.0
ASPEN PLUS PLAT: WIN		: 22.0	0.0		12 PAGE 28		0.0	0.0	0.0	0.0
+ ASPEN FLOS FLAT, WIN		EXTRACTION		03/07/20.	LE FAGE 20					
		TREAM SECTI	ON							
		Inclusion DECT1								

(Figure C.2.4: Continue)

	STREAM SECTION			
E-109 E-110 E-111 PRO				
STREAM ID	E-109		E-111	PRODUCT
FROM :	FOR-USE	z-106	Z-106	Z-113
то :				FOR-USE
CLASS:	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD
TOTAL STREAM:				
	3968.9373	2.5334+04	4000.0000	2.5334+04
BTU/HR	-1.2261+07 -	1.7224+08	-1.5340+07	-7.4226+07
SUBSTREAM: MIXED				
PHASE:	LIQUID	MISSING	VAPOR	LIQUID
COMPONENTS: LBMOL/HR				
C6H12-01	0.0	0.0		37.0059
C2H5N-01	0.0	0.0		195.7990
C3H8O-01	43.0963	0.0	0.0	43.0963
CO2	0.0	0.0	90.8888	0.0
H2O	0.0	0.0	0.0	0.0
COMPONENTS: LB/HR				
С6н12-01	0.0	0.0	0.0	6666.8928
C2H5N-01	0.0	0.0	0.0	1.4698+04 3968.9373
C3H80-01	3968.9373	0.0	0.0	3968.9373
C02	0.0	0.0	4000.0000	0.0
н20	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAG	2			
C6H12-01	0.0	MISSING	0.0	0.2632
C2H5N-01	0.0	MISSING	0.0	0.5802
C3H80-01	1.0000	MISSING	0.0	0.1567
C02	0.0	MISSING	1.0000	0.0
H2O	0.0	MISSING	0.0	0.0
TOTAL FLOW:				
LBMOL/HR	43.0963	0.0	90.8888	275,9011
LB/HR	3968.9373	0.0	90.8888 4000.0000	2.5334+04
CUFT/HR	50,9022	0.0	651,6407	
STATE VARIABLES:	5015022			20000000
TEMP F	130.9100	MISSING	121.7300	121,9100
PRES PSIA	5076.3208	870.2300	870.2300	870,2300
VERAC	0.0	MISSING		
VFRAC LFRAC	0.0	MISSING MISSING	1.0000	0.0

(Figure C.2.4: Continue)

ENTHALPY:					
BTU/LBMOL ·	-2.8451+05	MISSING		-2.6903+05	
BIU/LB -	-3089.3440	MISSING	-3834.9249		
	-1.2261+07	MISSING	-1.5340+07	-7.4226+07	
ENTROPY:					
	-141.7530			-136.7072	
BTU/LB-R	-1.5392	MISSING	-0.1521	-1.4888	
DENSITY					
LBMOL/CUFT	0.8466			0.9343 85.7883	
LB/CUFT	77.9719		6.1384	85.7883	
AVG MW	92.0947	MISSING	44.0098	91.8225	
SUBSTREAM: NCPSD	STRUCTUR	RE: NON CON	ENTIONAL		
COMPONENTS: LB/HR ALGAE	0.0	2.5334+04	0.0	0.0	
ALGAE ASPEN PLUS PLAT: WI		R: 22.0	0.0	05/07/2012	DACE 20
¥ ASPEN PLUS PLAT. WI	NDZ VE	EXTRACTION		03/07/2012	PAGE 29
		STREAM SECT			
		STREAM SEC	101		
E-109 E-110 E-111 PROD					
2 105 2 110 2 111 180					
STREAM ID	E-109	E-110	E-111	PRODUCT	
COMPONENTS: MASS FRAC					
ALGAE	0.0	1.0000	0.0	0.0	
TOTAL FLOW:					
LB/HR	0.0	2.5334+04	0.0	0.0	
STATE VARIABLES:					
TEMP F		121.7300		MISSING	
PRES PSIA		870.2300			
VFRAC	MISSING			MISSING	
LFRAC	MISSING		MISSING		
SFRAC	MISSING	1.0000	MISSING	MISSING	
ENTHALPY:		6700 6536			
BTU/LB		-6798.6536			
BTU/HR	MISSING	-1.7224+08	MISSING	MISSING	
DENSITY:	NTCOTHO	141 0705	NTCOTHO	NTCOTHO	
LB/CUFT	MISSING				
AVG MW	1.0000	1.0000	1.0000	1.0000	

(Figure C.2.4: Continue)

COMPONENT AT							
	XANAL IOISTURE	MISSING	100.0000	MISSING	MISSING		
	C	MISSING	0.0	MISSING	MISSING		
	M	MISSING	0.0	MISSING	MISSING		
	SH	MISSING	18,4000	MISSING	MISSING		
	ANAL		101.000				
	SH	MISSING	0.0	MISSING	MISSING		
Ċ	ARBON	MISSING	0.0	MISSING	MISSING		
H	YDROGEN	MISSING	0.0	MISSING	MISSING		
N	ITROGEN	MISSING	0.0	MISSING	MISSING		
C	HLORINE	MISSING	0.0	MISSING	MISSING		
5	SULFUR	MISSING	0.0	MISSING	MISSING		
C	XYGEN	MISSING	0.0	MISSING	MISSING		
SUL	FANAL						
F	YRITIC	MISSING	0.0	MISSING	MISSING		
5	JULFATE	MISSING	0.0	MISSING	MISSING		
C	RGANIC	MISSING	0.0	MISSING	MISSING		
SUBSTREAM AT	TRIBUTES:						
PSD							
FRAC1		0.0	0.0	MISSING	0.0		
FRAC2		0.0	0.0	MISSING	0.0		
FRAC3		0.0	0.0	MISSING	0.0		
FRAC4		0.0	0.0	MISSING	0.0		
FRAC5		0.0	0.0	MISSING	0.0		
FRAC6		0.0	0.0	MISSING	0.0		
FRAC7		0.0	0.0	MISSING	0.0		
FRAC8		0.0	0.0	MISSING	0.0		
FRAC9		0.0	0.0	MISSING	0.0		
FRAC10		0.0	0.0	MISSING	0.0 05/07/2012		~~
ASPEN PLUS	PLAT: WI	N3Z VER	: 22.0 EXTRACTION		05/07/2012	PAGE :	50
		DROBI	EXTRACTION EM STATUS S	CTTON			
		PROBL	EM STATUS 5	ECTION			
BLOCK STATUS							
BEOCK STATUS							
******	********	*****	******	*****	*****	******	ŵ
*							×
* Calculation	ons were co	mpleted nor	mally				¥
¥.							ŵ
* All Unit C	peration b	locks were	completed n	ormally			×
*				-			¥
	ıs were fla	shed normal	1y				ŵ
			-				*
*					************		

(Figure C.2.4: Continue)

Section C.2.5 - APEN Plus simulator output for Case 5

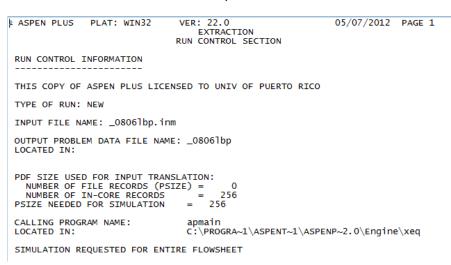


Figure C.2.5. ASPEN print out for Case Scenario 5.

FLOWSHEET CON	NECTIVITY BY E	BLOCKS		
Z-105 Z-106 Z-104 Z-103 Z-101 Z-102 P-101 P-104	PRODUCT E-109C E-109D E-109D E-109A E-108 E-109 E-104 E-106 E-104	3	OUTLETS E-111 E-110 PRODUCT E-109C E-10 E-109A E-109A E-105P E-10 E-104P E-104P E-105 E-104P E-105 E-106)9D 3
P-106	E-107		E-107P	
SEQUENCE USEE P-101 Z-10 FOR-USE OVERALL FLOWS	DI P-104 P-105	Z-102 P-106 Z-103		Z-106 P-108
	*** N	IASS AND ENERGY BAL TN	ANCE *** OUT	RELATIVE DIFF.
C6H12-C C2H5N-C C3H80-C C02 H2O SUBTOTAL (L (L	.BMOL/HR) .B/HR)		37.0059 195.799 43.0963 90.8888 2812.54 3179.33 80002.6	-1.00000 -1.00000 -1.00000 0.00000

(Figure C.2.5: Continue)

OVERALL FLOWSHEET BALANCE (CO NON-CONVENTIONAL COMPONENT ALGAE SUBTOTAL (LB/HR) TOTAL BALANCE	S (LB/HR) 50668.7	25334.3 25334.3	0.500000 0.500000
MASS(LB/HR) ENTHALPY(BTU/HR) ‡ ASPEN PLUS PLAT: WIN32	-0.689199E+09	-0.607125E+09 05/	0.401107E-05 -0.119086 07/2012 PAGE 4
COMPONENTS			
ID TYPE FORMULA C6H12-01 C C6H1206 C2H5N-01 C C2H5N02-D1 C3H80-01 C C3H803 C02 C C02 ALGAE NC H20 C H20	NAME OR ALIAS C6H12O6 C2H5NO2-D1 C3H8O3 CO2 MISSING H2O		REPORT NAME C6H12-01 C2H5N-01 C3H80-01 C02 ALGAE H20
			07/2012 PAGE 5
BLOCK: FOR-USE MODEL: SEP			
INLET STREAM: PROD OUTLET STREAMS: E-11 PROPERTY OPTION SET: UNIQ	1 E-110		
*** MAS CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR) TOTAL BALANCE	5 AND ENERGY BAL IN 275.901 25333.9 0.00000	ANCE *** OUT 275.901 25333.9 0.00000	RELATIVE DIFF. 0.00000 -0.287202E-15 0.00000
MASS(LB/HR) ENTHALPY(BTU/HR)	25333.9 -0.742263E+08	25333.9 -0.741089E+08	-0.287202E-15 -0.158164E-02

(Figure C.2.5: Continue)

	*** INPUT DATA	资资资	
INLET PRESSURE PSIA		5,076.32	
FLASH SPECS FOR STREA TWO PHASE TP FLA SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	SH F PSIA S	130.910 5,076.32 30 0.000100000	
FLASH SPECS FOR STREA TWO PHASE TP FLA SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	SH F PSIA S	130.730 5,076.32 30 0.000100000	
FLASH SPECS FOR STREA TWO PHASE TP FLA SPECIFIED TEMPERATURE SPECIFIED PRESSURE MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE ASPEN PLUS PLAT: WIN	SH F PSIA S		6
BLOCK: FOR-USE MODEL:	SEP (CONTINUED)		
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-110	CPT= C6H12-01 FRAG C2H5N-01 C3H80-01	CTION= 1.00000 0.0 0.0	
STREAM= E-112		CTION= 0.0 0.0 0.0 1.00000	

(Figure C.2.5: Continue)

*** RESULTS *** HEAT DUTY BTU/HR 0.11740E+06 COMPONENT = C6H12-01 STREAM SUBSTREAM E-110 MIXED SPLIT FRACTION 1.00000 COMPONENT = C2H5N-01 STREAM SUBSTREAM E-111 MIXED SPLIT FRACTION 1.00000 COMPONENT = C3H80-01 STREAM SUBSTREAM SPLIT FRACTION 1.00000 E-112 MIXED BLOCK: P-101 MODEL: PUMP INLET STREAM: E-104 OUTLET STREAM: E-104P PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS *** MASS AND ENERGY BALANCE *** IN OUT CONV. COMP.(LBMOL/HR) 2812.54 2812.54 (LB/HR) 50668.7 50668.7 NONCONV. COMP(LB/HR) 50668.7 50668.7 TAI BALANCE RELATIVE DIFF. 0.00000 0.00000 0.00000 NONCONV. COMP(LB/HK TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR) \$ ASPEN PLUS PLAT: WIN32 101337. 101337. 0.00000 -0.673825E+09 -0.673825E+09 0.00000 VER: 22.0 05/07/2012 PAGE 7 EXTRACTION U-O-5 BLOCK SECTION BLOCK: P-101 MODEL: PUMP (CONTINUED) *** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY 90.0000 0.60000 1.00000 FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE 30 0.000100000

(Figure C.2.5: Continue)

*** RESULTS ***	01.6 530
VOLUMETRIC FLOW RATE CUFT/HR PRESSURE CHANGE PSI	816.529 0.0
NPSH AVAILABLE FT-LBF/LB	207.787
FLUID POWER HP	0.0
BRAKE POWER HP	0.0
ELECTRICITY KW PUMP EFFICIENCY USED	0.0
NET WORK REQUIRED HP	0.0
HEAD DEVELOPED FT-LBF/LB	0.0
BLOCK: P-104 MODEL: PUMP	
INLET STREAM: E-105P	
OUTLET STREAM: E-105	
PROPERTY OPTION SET: UNIQUAC UNIQUAC / I	DEAL GAS
*** MASS AND ENERGY BALA	NCF ***
IN IN	OUT RELATIVE DIFF.
IN CONV. COMP.(LBMOL/HR) 2534.38 (LB/HR) 45657.5	2534.38 0.00000
(LB/HR) 45657.5 NONCONV. COMP(LB/HR) 0.00000	45657.5 0.00000 0.00000 0.00000
TOTAL BALANCE	
MASS(LB/HR) 45657.5 ENTHALPY(BTU/HR) -0.311280E+09	45657.5 0.00000
≤ ASPEN PLUS PLAT: WIN32 VER: 22.0	-0.3112/5E+09 -0.145801E-04 05/07/2012 PAGE 8
EXTRACTION	03/07/2012 PAGE 0
U-O-S BLOCK SECTION	ON
BLOCK: P-104 MODEL: PUMP (CONTINUED)	
*** INPUT DATA ***	
OUTLET PRESSURE PSIA	100.000
PUMP EFFICIENCY DRIVER EFFICIENCY	0.60000 1.00000
DRIVER EFFICIENCY	1.00000
FLASH SPECIFICATIONS:	
LIQUID PHASE CALCULATION NO FLASH PERFORMED	
MAXIMUM NUMBER OF ITERATIONS	30
TOLERANCE	0.000100000

(Figure C.2.5: Continue)

VOLUMETRIC FLOW RATE CUFT/HR	735.774
PRESSURE CHANGE PSI NPSH AVAILABLE FT-LBF/LB FLUID POWER HP	184.582 1.07022
BRAKE POWER HP ELECTRICITY KW	1.78369
PUMP EFFCIENCY USED NET WORK REQUIRED HP	0.60000
HEAD DEVELOPED FT-LBF/LB	46.4114
BLOCK: P-105 MODEL: PUMP	
INLET STREAM: E-106P OUTLET STREAM: E-106 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDE	AL GAS
*** MASS AND ENERGY BALANC IN	E *** OUT RELATIVE DIFF.
CONV. COMP. (LBMOL/HR) 278.163 (LB/HR) 5011.19 NONCONV. COMP(LB/HR) 50668.7	278.163 0.00000 5011.19 0.00000 50668.7 0.00000
TOTAL BALANCE MASS(LB/HR) 55679.9 ENTHALPY(BTU/HR) -0.362545E+09 -0 ‡ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-0-5 BLOCK SECTION	05/07/2012 PAGE 9
BLOCK: P-105 MODEL: PUMP (CONTINUED)	
*** INPUT DATA *** OUTLET PRESSURE PSIA PUMP EFFICIENCY DRIVER EFFICIENCY	45.0000 0.60000 1.00000
FLASH SPECIFICATIONS: LIQUID PHASE CALCULATION NO FLASH PERFORMED MAXIMUM NUMBER OF ITERATIONS TOLERANCE	30 0.000100000

(Figure C.2.5: Continue)

*** RESULTS ***	
VOLUMETRIC FLOW RATE CUFT/HR	80.7557
PRESSURE CHANGE PSI	-35.0000
NPSH AVAILABLE FT-LBF/LB	184.582
FLUID POWER HP	-0.20556
BRAKE POWER HP	-0.12334
ELECTRICITY KW	-0.091972
PUMP EFFICIENCY USED	0.60000
NET WORK REQUIRED HP	-0.12334
HEAD DEVELOPED FT-LBF/LB	-81.2199
BLOCK: P-106 MODEL: PUMP	
INLET STREAM: E-107	
OUTLET STREAM: E-107P	-
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GA	5
*** MASS AND ENERGY BALANCE **	
IN OU	T RELATIVE DIFF.
CONV. COMP. (LBMOL/HR) 278.163 278.1	
(LB/HR) 5011.19 5011.	
	00 0.00000
TOTAL BALANCE MASS(LB/HR) 5011.19 5011.1	19 0.00000
ENTHALPY(BTU/HR) -0.341649E+08 -0.3416	
	05/07/2012 PAGE 10
+ ASPEN PLOS PLAT. WINSZ VER. 22.0 EXTRACTION	03/07/2012 PAGE 10
U-O-S BLOCK SECTION	
0-0-5 BEOCK SECTION	
BLOCK: P-106 MODEL: PUMP (CONTINUED)	
*** INPUT DATA ***	
OUTLET PRESSURE PSIA	90.0000
PUMP EFFICIENCY	0.60000
DRIVER EFFICIENCY	1.00000
FLASH SPECIFICATIONS:	
LIQUID PHASE CALCULATION	
NO FLASH PERFORMED	
MAXIMUM NUMBER OF ITERATIONS	30
TOLERANCE	0.000100000

(Figure C.2.5: Continue)

***	RESULTS ***
VOLUMETRIC FLOW RATE CUFT/H	IR 80.7552
PRESSURE CHANGE PSI	45.0000
NPSH AVAILABLE FT-LBF/LB	103.361
FLUID POWER HP	0.26429
BRAKE POWER HP	0.44048
ELECTRICITY KW	0.32847
PUMP EFFICIENCY USED	0.60000
NET WORK REQUIRED HP	0.44048
HEAD DEVELOPED FT-LBF/LB	104.425
BLOCK: P-108 MODEL: PUMP	
INLET STREAM: E-1090	
OUTLET STREAM: PRODUC	т
PROPERTY OPTION SET: UNIQUA	C UNIQUAC / IDEAL GAS
*** MASS	AND ENERGY BALANCE ***
	IN OUT RELATIVE DIFF.
CONV. COMP. (LBMOL/HR)	
(LB/HR)	25333.9 25333.9 0.00000
NONCONV. COMP(LB/HR)	0.00000 0.00000 0.00000
TOTAL BALANCE	25222 0 0.0000
MASS(LB/HR)	25333.9 25333.9 0.00000 0.742263E+08 -0.742263E+08 0.585573E-07
ENTHALPY(BIU/HR) -	0./42203E+08 -0./42203E+08 0.3855/3E-0/
♀ ASPEN PLUS PLAT: WIN32 V	
	EXTRACTION 0-5 BLOCK SECTION
0-	O-S BLOCK SECTION
BLOCK: P-108 MODEL: PUMP (C	ONTINUED)
××× T	NPUT DATA ***
EQUIPMENT TYPE: PUMP	
OUTLET PRESSURE PSIA	870.100
PUMP EFFICIENCY	0.60000
DRIVER EFFICIENCY	1.00000
FLASH SPECIFICATIONS:	
LIQUID PHASE CALCULATION	
NO FLASH PERFORMED	
MAXIMUM NUMBER OF ITERATIONS	
TOLERANCE	0.000100000

(Figure C.2.5: Continue)

*** RESULTS *** VOLUMETRIC FLOW RATE CUFT/HR 295.307 PRESSURE CHANGE PSI -0.13000 NPSH AVAILABLE FT-LBF/LB 1,460.72 FLUID POWER HP -0.0016752 BRAKE POWER HP -0.0012492 PUMP EFFICIENCY 0.60000 NET WORK REQUIRED 0.0016752 HEAD DEVELOPED FT-LBF/LB -0.21821
BLOCK: Z-101 MODEL: FILTER
INLET STREAM: E-104P OUTLET STREAMS: E-105P E-106P PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS
*** MASS AND ENERGY BALANCE *** IN OUT RELATIVE DIFF. CONV. COMP.(LBMOL/HR) 2812.54 2812.54 0.00000 (LB/HR) 50668.7 50668.7 0.143599E-15 NONCONV. COMP(LB/HR) 50668.7 50668.7 0.00000 TOTAL BALANCE
TOTAL BALANCE MASS(LB/HR) 101337. 101337. 0.143599E-15 ENTHALPY(BTU/HR) -0.673825E+09 -0.673825E+09 0.569701E-09
BLOCK: Z-101 MODEL: FILTER (CONTINUED)
*** INPUT DATA ***
MAXIMUM PRESSURE DROP PSI10.0000FILTER WIDTH TO DIAMETER RATIO2.00000ANGULAR VELOCITY RPM12.0000CAKE FORMATION ANGLE DEG120.006MASS FRACTION OF SOLIDS IN CAKE0.91000AVERAGE POROSITY0.0100000FILTRATION RESISTANCE FT/LB2,976,330.CAKE COMPRESSIBILITY0.0AVERAGE PARTICLE DIAMETER FT0.328084-04PARTICLE SPHERICITY0.75000FILTER-MEDIUM RESISTANCE 1/FTMISSING

(Figure C.2.5: Continue)

FILTER-MEDIUM RESISTANCE 1/FT		MISSING
*** RES	ULTS ***	
FILTER DIAMETER FT FILTER WIDTH FT AVERAGE PARTICLE DIAMETER FT AVERAGE SOLID DENSITY LB/CUFT TOTAL SOLIDS MASS FLOW RATE LB/ SURFACE TENSION DYNE/CM VOLUME FLOW RATE OF FILTRATE CU MASS FRACTION OF SOLIDS IN CAKE CAKE THICKNESS FT FILTRATION RESISTANCE FT/LB AVERAGE POROSITY CAKE COMPRESSIBILITY BLOCK: Z-102 MODEL: SEP	0.7 MTS 141.9 HR 50,668.7 72.8 FT/HR 735.7 0.9 0.5 2,976,330.	4281 100000
INLET STREAM: E-106 OUTLET STREAMS: E-107 PROPERTY OPTION SET: UNIQUAC	E-108 UNTOUAC / TDEAL GAS	
*** MASS AND CONV. COMP.(LBMOL/HR) 27: (LB/HR) 50: NONCONV. COMP(LB/HR) 50:	ENERGY BALANCE *** IN OUT 8.163 278.163 11.19 5011.19	0.00000 0.00000
TOTAL BALANCE MASS(LB/HR) 55 ENTHALPY(BTU/HR) -0.3	679.9 55679.9 62546E+09 -0.362546E+09	0.00000 -0.478158E-10
*** INPU	T DATA ***	
	22.0 05/0 XTRACTION BLOCK SECTION	45.0000 07/2012 PAGE 13

(Figure C.2.5: Continue)

BLOCK: Z-102 MODEL:	SEP (CONTINUE	D)								
FLASH SPECS FOR STREAM E-107 TWO PHASE PRESSURE DROP PSI 0.0 MAXIMUM NO. ITERATIONS 30 CONVERGENCE CONVERGENCE 0.000100000										
FLASH SPECS FOR STREA TWO PHASE TP FLA PRESSURE DROP MAXIMUM NO. ITERATION CONVERGENCE TOLERANCE	SH PSI IS		0.0 30 0.000100000							
FRACTION OF FEED SUBSTREAM= MIXED STREAM= E-107 SUBSTREAM= NCPSD STREAM= E-107			1.00000 0.0							
	*** RESULT	5 ***								
HEAT DUTY	BTU/HR		0.17335E-01							
COMPONENT = H20 STREAM SUBSTREAM E-107 MIXED	SPLIT FRAC	TION .00000								
COMPONENT = ALGAE STREAM SUBSTREAM E-108 NCPSD	SPLIT FRAC	TION .00000								
BLOCK: Z-103 MODEL:	COMPR									
INLET STREAM: OUTLET STREAM: PROPERTY OPTION SET: \$ ASPEN PLUS PLAT: WIN	32 VER: 22. EXTR	IQUAC / IDEAL GAS 0 ACTION DCK SECTION	05/07/2012 PAGE 14							

(Figure C.2.5: Continue)

BLOCK: Z-103 MODEL: COMPR	R (CONTINUED) 55 AND ENERGY BAL		
CONV. COMP.(LBMOL/HR) (LB/HR) NONCONV. COMP(LB/HR)	IN 90.8888 4000.00) 0.00000	OUT 90.8888 4000.00 0.00000	RELATIVE DIFF. 0.00000 0.00000 0.00000
TOTAL BALANCE MASS(LB/HR) ENTHALPY(BTU/HR)			
* * Y	* INPUT DATA **	**	
POLYTROPIC POSITIVE DISPLAG OUTLET PRESSURE PSIA POLYTROPIC EFFICIENCY MECHANICAL EFFICIENCY CLEARANCE FRACTION	CEMENT COMPRESSOR	R USING 1,4	5 PIECEWISE INTEGRATI(50.37 0.72000 0.60000 0.50000
19 PC	* RESULTS ***		
INDICATED HORSEPOWER REQU REX WORK REQUIRED POWER LOSSES ISENTROPIC HORSEPOWER REQU CALCULATED OUTLET TEMP F ISENTROPIC TEMPERATURE F EFFICIENCY (POLYTR/ISENTR; VOLUMETRIC EFFICIENCY DISPLACEMENT COUTLET VAPOR FRACTION HEAD DEVELOPED, FT-1- MECHANICAL EFFICIENCY USEI INLET HEAT CAPACITY RATIO INLET VOLUMETRIC FLOW RATI OUTLET VOLUMETRIC FLOW RATI INLET COMPRESSIBILITY FAX OUTLET COMPRESSIBILITY FAX OUTLET COMPRESSIBILITY FAX AV. ISENT, VOL. EXPONENT AV. ACTUAL TEMP EXPONENT	HP UIREMENT HP) USED UFT/HR LBF/LB D E , CUFT/HR TE, CUFT/HR CTOR CTOR	11 14 74 10,44 6(42	19.4067 19.0112 19.0112 19.0112 19.0112 19.0112 19.0112 19.0112 19.0112 10.0111 10.01000 0.76835 37.982 1.00000 0.6 0.60000 1.28678 1.28678 1.00000 1.27821 1.42824 1.42824 1.42824 1.077/2012 PAGE 15

(Figure C.2.5: Continue)

BLOCK: Z-104 MODEL: RSTOIC	
INLET STREAMS: E-109A E-108 OUTLET STREAM: E-109B	
PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS	
CONV. COMP. (LBMOL/HR) 90.8888 366.790 23 (LB/HR) 4000.00 29333.9 NONCONV COMP(LB/HR) 50668.7 25334.3	ERATION RELATIVE DIFF. 75.901 -0.154975E-15 -0.863639 0.500000
MASS(LB/HR) 54668.7 54668.3 ENTHALPY(BTU/HR)-0.343679E+09 -0.262046E+09	0.772865E-05 -0.237529
*** ΤΝΡΙΙΤ ΠΔΤΔ ***	
STOICHIOMETRY MATRIX:	
REACTION # 1: SUBSTREAM MIXED : CGH12-01 0.146E-02C2H5N-01 0.773E-02C3H80-01 0.: SUBSTREAM NCP5D : ALGAE -1.00	L70E-02
REACTION CONVERSION SPECS: NUMBER= 1 REACTION # 1: SUBSTREAM:NCPSD KEY COMP:ALGAE CONV FRAC: 0.	5000
TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE SIMULTANEOUS REACTIONS GENERATE COMBUSTION REACTIONS FOR FEED SPECIES \$ ASPEN PLUS PLAT: WIN32 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	112.910 40.0000 30 0.000100000 NO 05/07/2012 PAGE 16
	OUTLET STREAM: E-1098 PROPERTY OPTION SET: UNIQUAC UNIQUAC / IDEAL GAS *** MASS AND ENERGY BALANCE *** IN OUT GENI CONV. COMP.(LBMOL/HR) 90.8888 366.790 27 (LB/HR) 4000.00 29333.9 NONCONV COMP(LB/HR) 50668.7 25334.3 TOTAL BALANCE MASS (LB/HR) 54668.7 54668.3 ENTHALPY(BTU/HR)-0.343679E+09 -0.262046E+09 *** INPUT DATA *** STOICHIOMETRY MATRIX: REACTION # 1: SUBSTREAM MIXED : CGH12-01 0.146E-02C2H5N-01 0.773E-02C3H80-01 0.3 SUBSTREAM MIXED : ALGAE -1.00 REACTION CONVERSION SPECS: NUMBER= 1 REACTION # 1: SUBSTREAM:NCPSD KEY COMP:ALGAE CONV FRAC: 0.3 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED TEMPERATURE F SPECI

(Figure C.2.5: Continue)

BLOCK: Z-104 MODEL:	RSTOIC (C	ONTINUED)		
OUTLET TEMPERATURE OUTLET PRESSURE HEAT DUTY VAPOR FRACTION	*** RE F PSIA BTU/HR	SULTS ***	0	112.91 40.000 .81631E+08 .21976
REACTION EXTENTS:				
NUMBER	REACTION EXTENT LBMOL/HR 25334.			
V-L PHASE EQUILIBRIUN	. :			
C6H12-01 C C2H5N-01 C C3H8O-01 C	F(I) .10089 .53382 .11750 .24780	X(I) 0.12931 0.68417 0.15059 0.35929E-0	0.75421E- 0.11542E-	12 0.11452E-11 09 0.11024E-08 06 0.76645E-06
BLOCK: Z-105 MODEL:	SEP			
INLET STREAM: OUTLET STREAMS: PROPERTY OPTION SET:	E-109B E-109C UNIQUAC		EAL GAS	
** CONV. COMP.(LBMOL (LB/HF NONCONV. COMP(LB/ TOTAL BALANCE	./HR) 3	ND ENERGY BALAN IN 266.790 29333.9 25334.3	CE *** OUT 366.790 29333.9 25334.3	RELATIVE DIFF. 0.00000 0.248039E-15 0.00000
MASS(LB/HR) ENTHALPY(BTU/HR) -0.	54668.3 262046E+09 -	54668.3 0.261805E+09	0.266186E-15 -0.916463E-03

(Figure C.2.5: Continue)

***	INPUT DATA ***	
	VER: 22.0 EXTRACTION J-O-5 BLOCK SECTION	5,801.51 05/07/2012 PAGE 17
BLOCK: Z-105 MODEL: SEP (C	CONTINUED)	
FLASH SPECS FOR STREAM E-109 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	90	121.910 870.230 30 0.000100000
FLASH SPECS FOR STREAM E-109 TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED PRESSURE PSIA MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	Ð	121.730 870.230 30 0.000100000
	26H12-01 FRACTION= 22H5N-01 23H80-01 202	0.0 0.0 0.0 1.00000

(Figure C.2.5: Continue)

	*** RESULTS ***	
HEAT DUTY BT	ru/hr	0.24016E+06
COMPONENT = C6H12-01 STREAM SUBSTREAM E-109C MIXED	SPLIT FRACTION 1.00000	
COMPONENT = C2H5N-01 STREAM SUBSTREAM E-109C MIXED	SPLIT FRACTION 1.00000	
COMPONENT = C3H80-01 STREAM SUBSTREAM E-109C MIXED	SPLIT FRACTION 1.00000	
COMPONENT = CO2 STREAM SUBSTREAM E-109D MIXED	SPLIT FRACTION 1.00000	
COMPONENT = ALGAE STREAM SUBSTREAM E-109D NCPSD ‡ ASPEN PLUS PLAT: WIN32	SPLIT FRACTION 1.00000 VER: 22.0 EXTRACTION U-O-S BLOCK SECTION	05/07/2012 PAGE 18
BLOCK: Z-106 MODEL: FL	ASH2	
INLET STREAM: E OUTLET VAPOR STREAM: E OUTLET LIQUID STREAM: E PROPERTY OPTION SET: U	-113	5
CONV. COMP. (LBMOL/HF	IN OUT IN 0UT IN 0UT	T RELATIVE DIFF. 88 0.00000 00 0.00000 .3 0.00000
ENTHALPY(BTU/HR)	29334.3 29334 -0.187579E+09 -0.1875	77E+09 -0.133751E-04

(Figure C.2.5: Continue)

ENTHALPY(BTU/HR) -0.1875	79E+09 -0.187577E+09 -0.133751E-04
*** INPUT D	
TWO PHASE TP FLASH SPECIFIED TEMPERATURE F SPECIFIED TEMPERATURE F MAXIMUM NO. ITERATIONS CONVERGENCE TOLERANCE	121.910 870.000 30 0.000100000
*** RESULT	
OUTLET TEMPERATURE F OUTLET PRESSURE PSIA HEAT DUTY BTU/HR VAPOR FRACTION	121.91 870.00 2508.9 1.0000
V-L PHASE EQUILIBRIUM :	
ASPEN PLUS PLAT: WIN32 VER: 22.	X(I) Y(I) K(I) 1.0000 1.0000 1.8271 0 05/07/2012 PAGE 19 ACTION 4 SECTION
SUBSTREAM ATTR PSD TYPE: PSD	
INTERVAL LOWER LIMIT UP 1 0.0 FT 6.5 2 6.5617-05 FT 1.3 3 1.3123-04 FT 1.9 4 1.9685-04 FT 2.6 5 2.6247-04 FT 3.2 6 3.2808-04 FT 3.9 7 3.970-04 FT 4.5 8 4.5932-04 FT 5.2 9 5.2493-04 FT 5.2 9 5.2493-04 FT 5.2 9 5.29055-04 FT 5.2	PER LIMIT 517-05 FT 123-04 FT 585-04 FT 247-04 FT 370-04 FT 370-04 FT 193-04 FT 193-04 FT 55-04 FT 517-04 FT
	0 05/07/2012 PAGE 20 ACTION 4 SECTION
E-104 E-104P E-105 E-105P E-106	

(Figure C.2.5: Continue)

STREAM ID	E-104	E-104P	E-105	E-105P	E-106	E-106P	E-107	E-107P	E-108	E-109
FROM : TO : CLASS:		P-101	P-104	Z-101	P-105	z-101	z-102	P-106	z-102	
то :	P-101	z-101		P-104	Z-102	P-105	P-106		z-104	Z-103
CLASS:	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD	MIXNCPSD
TOTAL STREAM:										
						5.5680+04				
BTU/HR -	6.7383+08 -	-6.7383+08	-3.1128+08	-3.1128+08	-3.6255+08	-3.6255+08	-3.4165+07	-3.4164+07	-3.2838+08	-1.5374+07
SUBSTREAM: MIXED										
PHASE:	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	LIQUID	MISSING	VAPOR
COMPONENTS: L PMOL /HP	-									
C6H12-01 C2H5N-01 C3H80-01 C02 H20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90,8888
H20	2812.5396	2812.5396	2534.3763	2534.3763	278, 1633	278, 1633	278, 1633	278.1633		0.0
COMPONENTS: LB/HR					27012033	2.012035	2.012000	2.0.2000		0.0
C6H12-01 C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C2H5N-01	0 0	0.0	0.0	ŏ. ŏ	0.0	0.0	0.0	0.0	0.0	0.0
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0. 0	ŏ.ŏ
C02	0.0	0.0	0.0	0.0						4000.0000
						5011.1889			0.0	0.0
COMPONENTS: MASS FRAC		5.0005+04	4.303/404	4.303/404	5011.1005	5011.1005	5011.1005	5011.1005	0.0	0.0
C6H12-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
C2H5N-01	0.0	0.0	0.0	0.0	0.0	0.0			MISSING	ŏ.ŏ
C3H80-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	1.0000
H20	0.0 1.0000	1 0000	1.0000		1.0000		1.0000	1.0000	MISSING	0.0
TOTAL FLOW:	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	MISSING	0.0
	2812.5396	2812.5396	2534.3763	2534.3763	278.1633	278.1633	278.1633	278.1633	0.0	90.8888
LB/HR						5011.1889			0.0	4000.0000
CUFT/HR	816.5294	816.5294	735.8166	735.7738	80.7552	80.7557	80.7552	80.7657	0.0	605.4433
STATE VARIABLES:	010. 52.54	010. 52.54	/ 33.0100	/ 55.// 50	00.7552	00.7557	00.7552	00.7037	0.0	005.4455
	76,9100	76,9100	77.0179	76,9100	76,8989	76,9100	76,8989	77.1417	MISSING	80, 5100
PRES PSIA		90,0000	100.0000	80.0000	45.0000	80,0000	45.0000	90.0000	45,0000	870.2264
VERAC	0.0	0.0	0.0	0.0	43.0000	0.0	43.0000	0.0	MISSING	1.0000
LERAC		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	MISSING	0.0
SFRAC	0.0	0.0	0.0	0.0	0.0				MISSING	0.0

(Figure C.2.5: Continue)

ENTHALPY:										
				-1.2282+05						-1.6915+05
				-6817.7136						-3843.4072
	-3.4544+08	-3.4544+08	-3.1128+08	-3.1128+08	-3.4165+07	-3.4165+07	-3.4165+07	-3.4164+07	MISSING -	-1.5374+07
ENTROPY:										
BTU/LBMOL-R	-38.8595	-38.8595	-38.8562	-38.8595	-38.8599	-38.8595	-38.8599	-38.8524	MISSING	-7.3576
BTU/LB-R	-2.1570	-2.1570	-2.1568	-2.1570	-2.1571	-2.1570	-2.1571	-2.1566	MISSING	-0.1672
DENSITY: LBMOL/CUFT	3,4445	3,4445	3,4443	3.4445	3.4445	3,4445	3,4445	3,4441	MISSING	0.1501
LB/CUFT	62.0537	62.0537	62.0501	62.0537	62.0541	62.0537	62.0541	62.0460	MISSING	6,6067
AVG MW	18,0153	18.0153	18.0153	18.0153	18,0153	18.0153	18.0153	18.0153	MISSING	44.0098
AVG MW	10.0135	10.0135	10.0135	10.0135	10.0135	10.0135	10.0135	10.0135	MISSING	44.0090
ASPEN PLUS PLAT: WI	N32 VE	R: 22.0		05/07/2	012 PAGE 2	1				
ASIEN TEOS		EXTRACTION	1	03/07/2	VIE TAGE E	-				
		STREAM SECT								
E-104 E-104P E-105 E-1	105P E-106									
E-106P E-107 E-107P E-	-108 E-109	(CONTINUED)								
	E 101	5 1045	- 105	F 1055	F 100	E 100E	- 107	F 1075	= 100	= 100
STREAM ID	E-104	E-104P	E-105	E-105P	E-106	E-106P	E-107	E-107P	E-108	E-109
SUBSTREAM: NCPSD	STRUCTUR	E: NON CONV								
COMPONENTS: LB/HR	STRUCTUR	E. NON CONV	ENTIONAL							
AI GAE	5.0669+04	5.0550.04								
				0.0	5 0669+04	5 0669+04	0.0	0.0	5 0669±04	0.0
COMPONENTS: MASS ERAC		5.0669+04	0.0	0.0	5.0669+04	5.0669+04	0.0	0.0	5.0669+04	0.0
COMPONENTS: MASS FRAC										
COMPONENTS: MASS FRAC ALGAE TOTAL FLOW:		1.0000	0.0	0.0	5.0669+04 1.0000	5.0669+04 1.0000	0.0 0.0	0.0 0.0	5.0669+04 1.0000	0.0 0.0
ALGAE		1.0000				1.0000				
ALGAE TOTAL FLOW:	1.0000	1.0000	0.0	0.0	1.0000	1.0000	0.0	0.0	1.0000	0.0
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F	1.0000 5.0669+04 76.9100	1.0000 5.0669+04 76.9100	0.0 0.0 MISSING	0.0 0.0 MI5SING	1.0000 5.0669+04 76.8989	1.0000 5.0669+04 76.9100	0.0 0.0 MISSING	0.0 0.0 MI5SING	1.0000 5.0669+04 76.8989	0.0 0.0 MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA	1.0000 5.0669+04 76.9100 90.0000	1.0000 5.0669+04 76.9100 90.0000	0.0 0.0 MISSING 100.0000	0.0 0.0 MISSING 80.0000	1.0000 5.0669+04 76.8989 45.0000	1.0000 5.0669+04 76.9100 80.0000	0.0 0.0 MISSING 45.0000	0.0 0.0 MISSING 90.0000	1.0000 5.0669+04 76.8989 45.0000	0.0 0.0 MISSING 870.2264
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC	1.0000 5.0669+04 76.9100 90.0000 0.0	1.0000 5.0669+04 76.9100 90.0000 0.0	0.0 0.0 MISSING 100.0000 MISSING	0.0 0.0 MISSING 80.0000 MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0	1.0000 5.0669+04 76.9100 80.0000 0.0	0.0 0.0 MISSING 45.0000 MISSING	0.0 0.0 MI55ING 90.0000 MI55ING	1.0000 5.0669+04 76.8989 45.0000 0.0	0.0 0.0 MISSING 870.2264 MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC	1.0000 5.0669+04 76.9100 90.0000 0.0 0.0	1.0000 5.0669+04 76.9100 90.0000 0.0 0.0	0.0 0.0 MISSING 100.0000 MISSING MISSING	0.0 0.0 MISSING 80.0000 MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0	1.0000 5.0669+04 76.9100 80.0000 0.0 0.0	0.0 0.0 MISSING 45.0000 MISSING MISSING	0.0 0.0 MISSING 90.0000 MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0	0.0 0.0 MISSING 870.2264 MISSING MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC	1.0000 5.0669+04 76.9100 90.0000 0.0	1.0000 5.0669+04 76.9100 90.0000 0.0	0.0 0.0 MISSING 100.0000 MISSING	0.0 0.0 MISSING 80.0000 MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0	1.0000 5.0669+04 76.9100 80.0000 0.0	0.0 0.0 MISSING 45.0000 MISSING	0.0 0.0 MI55ING 90.0000 MI55ING	1.0000 5.0669+04 76.8989 45.0000 0.0	0.0 0.0 MISSING 870.2264 MISSING MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY:	1.0000 5.0669+04 76.9100 90.0000 0.0 0.0 1.0000	1.0000 5.0669+04 76.9100 90.0000 0.0 0.0 1.0000	0.0 0.0 MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 80.0000 MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0 1.0000	1.0000 5.0669+04 76.9100 80.0000 0.0 0.0 1.0000	0.0 0.0 MISSING 45.0000 MISSING MISSING MISSING	0.0 0.0 MISSING 90.0000 MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0 1.0000	0.0 0.0 MISSING 870.2264 MISSING MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY: BTU/LB	1.0000 5.0669+04 76.9100 90.0000 0.0 1.0000 -6480.9341	1.0000 5.0669+04 76.9100 90.0000 0.0 1.0000 -6480.9341	0.0 0.0 MISSING MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 80.0000 MISSING MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0 1.0000 -6480.9393	1.0000 5.0669+04 76.9100 80.0000 0.0 1.0000 -6480.9341	0.0 0.0 MISSING 45.0000 MISSING MISSING MISSING	0.0 0.0 MISSING 90.0000 MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 1.0000 -6480.9393	0.0 0.0 MISSING 870.2264 MISSING MISSING MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY: BTU//LB - BTU//HR -	1.0000 5.0669+04 76.9100 90.0000 0.0 0.0 1.0000	1.0000 5.0669+04 76.9100 90.0000 0.0 1.0000 -6480.9341	0.0 0.0 MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 80.0000 MISSING MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0 1.0000	1.0000 5.0669+04 76.9100 80.0000 0.0 1.0000 -6480.9341	0.0 0.0 MISSING 45.0000 MISSING MISSING MISSING	0.0 0.0 MISSING 90.0000 MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0 1.0000	0.0 0.0 MISSING 870.2264 MISSING MISSING MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY: BTU//LB - BTU//LB - BTU//HR - DENSITY:	1.0000 5.0669+04 76.9100 90.0000 0.0 1.0000 -6480.9341 -3.2838+08	1.0000 5.0669+04 76.9100 90.0000 0.0 1.0000 -6480.9341 -3.2838+08	0.0 0.0 MISSING 100.0000 MISSING MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 80.0000 MISSING MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 1.0000 -6480.9393 -3.2838+08	1.0000 5.0669+04 76.9100 80.0000 0.0 1.0000 -6480.9341 -3.2838+08	0.0 0.0 MISSING 45.0000 MISSING MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 90.0000 MISSING MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 1.0000 -6480.9393 -3.2838+08	0.0 0.0 MISSING 870.2264 MISSING MISSING MISSING MISSING
ALGAE TOTAL FLOW: LB/HR STATE VARIABLES: TEMP F PRES PSIA VFRAC LFRAC SFRAC ENTHALPY: BTU//LB - BTU//HR -	1.0000 5.0669+04 76.9100 90.0000 0.0 1.0000 -6480.9341	1.0000 5.0669+04 76.9100 90.0000 0.0 1.0000 -6480.9341	0.0 0.0 MISSING MISSING MISSING MISSING MISSING	0.0 0.0 MISSING 80.0000 MISSING MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 0.0 1.0000 -6480.9393	1.0000 5.0669+04 76.9100 80.0000 0.0 1.0000 -6480.9341	0.0 0.0 MISSING 45.0000 MISSING MISSING MISSING	0.0 0.0 MISSING 90.0000 MISSING MISSING MISSING	1.0000 5.0669+04 76.8989 45.0000 0.0 1.0000 -6480.9393	0.0

(Figure C.2.5: Continue)

LB/CUFT	141.9785	141.9785	MISSING		141.9785	141.9785	MISSING	MISSING	141.9785	MISSING
AVG MW	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
COMPONENT ATTRIBUTES:										
ALGAE PROXANAL										
MOISTURE	81.7000	81.7000	MISSING	MISSING	81.7000	81.7000	MISSING	MISSING	81.7000	MISSING
FC	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
VM	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
ASH	18.4000	18.4000	MISSING	MISSING	18.4000	18.4000	MISSING	MISSING	18.4000	MISSING
ULTANAL										
ASH	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
CARBON	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
HYDROGEN	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
NITROGEN	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
CHLORINE	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
SULFUR	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
OXYGEN	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
SULFANAL										
PYRITIC	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
SULFATE	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
ORGANIC	0.0	0.0	MISSING	MISSING	0.0	0.0	MISSING	MISSING	0.0	MISSING
SUBSTREAM ATTRIBUTES:										
PSD										
FRAC1	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC2	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC3	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC4	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC5	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC6	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC7	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC8	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC9	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
FRAC10	0.0	0.0	MISSING	MISSING	0.0	0.0	0.0	0.0	0.0	MISSING
ASPEN PLUS PLAT: WI	IN32 VEI	R: 22.0		05/07/201	2 PAGE 22					
		EXTRACTION								
		STREAM SECTI	ON							
E-109A E-109B E-109C	E-109D E-11	.0								
		-								

(Figure C.2.5: Continue)

E-111 E-112 E-113 E-1	114 PRODUCT									
				- 400-						
STREAM ID	E-109A	E-109B	E-109C	E-109D	E-110	E-111	E-112	E-113	E-114	PRODUCT
FROM :	z-103	z-104	z-105	z-105	FOR-USE	FOR-USE	FOR-USE	z-106	z-106	P-108
то :	z-104	Z-105	P-108	z-106						FOR-USE
CLASS:	MIXNCPSE	MIXNCPSD	MIXNCPS	MIXNCPSD						
TOTAL STREAM:										
	4000.0000						3968.9373	2.5334+04	4000.0000	
	-1.5299+07	-2.6205+08	-7.4226+07	-1.8758+08	-1.9832+07	-4.2015+07	-1.2261+07	-1.7224+08	-1.5340+07	-7.4226+07
SUBSTREAM: MIXED										
PHASE:	VAPOR	MIXED	LIQUID	VAPOR	LIQUID	LIQUID	LIQUID	MISSING	VAPOR	LIQUID
COMPONENTS: LBMOL/HR										
С6H12-01	0.0	37.0059	37.0059	0.0	37.0059	0.0	0.0	0.0	0.0	37.0059
C2H5N-01	0.0	195.7990	195.7990	0.0	0.0	195.7990	0.0	0.0	0.0	195.7990
C3H80-01	0.0	43.0963	43.0963	0.0	0.0	0.0	43.0963	0.0	0.0	43.0963
CO2	90.8888	90.8888	0.0	90.8888	0.0	0.0	0.0	0.0	90.8888	0.0
H2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMPONENTS: LB/HR										
C6H12-01	0.0	6666.8928	6666.8928	0.0	6666.8928	0.0	0.0	0.0	0.0	6666.8928
C2H5N-01	0.0	1.4698+04	1.4698+04	0.0	0.0	1.4698+04	0.0	0.0	0.0	1.4698+04
C3H80-01	0.0	3968.9373	3968.9373	0.0	0.0	0.0	3968.9373	0.0	0.0	3968.9373
CO2	4000.0000	4000.0000	0.0	4000.0000	0.0	0.0	0.0	0.0	4000.0000	0.0
H2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMPONENTS: MASS FRAG	2									
C6H12-01	0.0	0.2273	0.2632	0.0	1.0000	0.0	0.0	MISSING	0.0	0.2632
C2H5N-01	0.0	0.5011	0.5802	0.0	0.0	1.0000	0.0	MISSING	0.0	0.5802
C3H80-01	0.0	0.1353	0.1567	0.0	0.0	0.0	1.0000	MISSING	0.0	0.1567
C02	1.0000	0.1364	0.0	1.0000	0.0	0.0	0.0	MISSING	1.0000	0.0
H2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0	0.0
TOTAL FLOW:										
LBMOL/HR	90.8888 4000.0000	366.7900	275,9011	90.8888	37,0059	195.7990	43.0963	0.0	90.8888	275.9011
LB/HR	4000.0000	2.9334+04	2.5334+04	4000.0000	6666.8928	1.4698+04	3968.9373	0.0	4000,0000	2.5334+04
CUFT/HR	423.3946	1.2686+04	295.3073	651.6407	92,7350	163.0189	50,9022	0.0	652.0148	295.3072
STATE VARIABLES:										
TEMP F	169.9187	112,9100	121,9100	121.7300	130,7300	130,9100	130,9100	MISSING	121,9100	121,9097
PRES PSIA	1450.3700	40,0000	870,2300	870.2300	5076.3208	5076.3208	5076.3208	870,0000	870,0000	870,1000
VERAC	1.0000	0,2198	0.0	1.0000	0.0	0.0	0.0	MISSING	1.0000	0.0
LFRAC	0.0	0.7802	1.0000	0.0	1.0000	1.0000	1.0000	MISSING	0.0	1.0000
SFRAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	MISSING	0.0	0.0

(Figure C.2.5: Continue)

ENTHALPY: BTU/LBMOL	1 6822105	2 4452:05	2 6002:05	1 6977:05	5 2502:05	-2.1458+05	2 8451-05	MICTNO	-1.6877+05	2 6002:05
						-2858.5557			-3834.8873	
						-4.2015+07			-1.5340+07	
ENTROPY:				210010101	210002.00				2.000.000	
BTU/LBMOL-R	-6.9628	-103.6020	-136.7072	-6.6917	-252.7076	-114.7810	-141.7530	MISSING	-6.6884	-136.7073
BTU/LB-R	-0.1582	-1.2954	-1.4888	-0.1521	-1.4027	-1.5290	-1.5392	MISSING	-0.1520	-1.4888
DENSITY:										
LBMOL/CUFT	0.2147		0.9343	0.1395	0.3990	1.2011	0.8466	MISSING	0.1394	0.9343
LB/CUFT	9.4475	2.3123	85.7883	6.1384	71.8918	90.1619	77.9719	MISSING	6.1348	85.7884
AVG MW	44.0098	79.9747	91.8225	44.0098	180.1577	75.0672	92.0947	MISSING	44.0098	91.8225
ASPEN PLUS PLAT: WI	N22 VE	R: 22.0		05/07/2	012 PAGE 2	2				
# ASPEN PLOS PLAT. WI	ND2 VE	EXTRACTION	u	03/07/2	UIZ FAGE Z					
		STREAM SECT								
E-109A E-109B E-109C	E-109D E-11	LO								
E-111 E-112 E-113 E-11	L4 PRODUCT	(CONTINUED))							
STREAM ID	E-109A	E-109B	E-109C	E-109D	E-110	E-111	E-112	E-113	E-114	PRODUCT
SUBSTREAM: NCPSD	STRUCTUR	RE: NON CONV	/ENTIONAL							
COMPONENTS: LB/HR ALGAE	0.0	2.5334+04	0.0	2,5334+04	0.0	0.0	0.0	2.5334+04	0.0	0.0
COMPONENTS: MASS FRAC	0.0	2.3334+04	0.0	2.3334+04	0.0	0.0	0.0	2.0334+04	0.0	0.0
ALGAE	0.0	1.0000	0.0	1,0000	0.0	0.0	0.0	1.0000	0.0	0.0
TOTAL FLOW:	0.0	1.0000	0.0	1.0000	0.0	0.0	0.0	1.0000	0.0	0.0
LB/HR	0.0	2.5334+04	0.0	2.5334+04	0.0	0.0	0.0	2.5334+04	0.0	0.0
STATE VARIABLES:										
TEMP F	MISSING	112.9100	MISSING	121.7300	MISSING	MISSING	MISSING	121.9100	MISSING	MISSING
PRES PSIA	1450.3700	40.0000	870.2300	870.2300	5076.3208		5076.3208	870.0000	870.0000	870.1000
VFRAC	MISSING	0.0	MISSING	0.0	MISSING	MISSING	MISSING	0.0	MISSING	MISSING
LFRAC	MISSING	0.0	MISSING		MISSING	MISSING	MISSING	0.0	MISSING	MISSING
SFRAC	MISSING	1.0000	MISSING	1.0000	MISSING	MISSING	MISSING	1.0000	MISSING	MISSING
ENTHALPY: BTU/LB	MISTING	-6803.2150	MISTING	-6798.6536	MISSING	MISSING	MICTNO	-6798.5605	MISSING	MISSING
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APPPENDIX D: CAPCOST ANALYSIS

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D.1 - Cost information for Case Scenario 1 in 5-year project

Table D.1.1. Econom	nic Options for Case S	cenario 1 in 5-year project.
---------------------	------------------------	------------------------------

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 23,584,680.93
FCIL	\$ 101,762,637.8
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.1.2. Economic Information for Case Scenario 1 in 5-year project.

Revenue From Sales	\$ 198,762,429
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 57,369,864
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 14,014,880

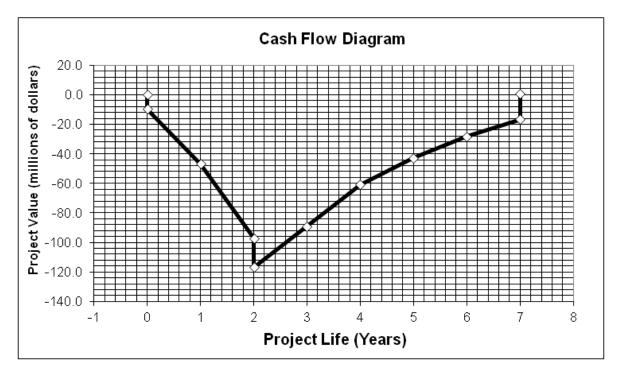


Figure D.1.1. Cash flow diagram for Case Scenario 1 in 5-year project.

Net Present Value (millions)	0.46
------------------------------	------

- Discounted Cash Flow Rate of Return 10.13%
 - Discounted Payback Period (years) 3.9

Figure D.1.2. Discounted profitability criterion for Case Scenario 1 in 5-year project.

D.2 - Cost information for Case Scenario 1 in 10-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 23,584,681
FCI∟	\$ 101,762,638
Total Module Factor	1.18
Grass Roots Factor	0.50

Table D.2.2. Economic Information for Case Scenario 1 in 10-year project.

Revenue From Sales	\$ 186,548,001
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 57,369,864
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 14,014,880

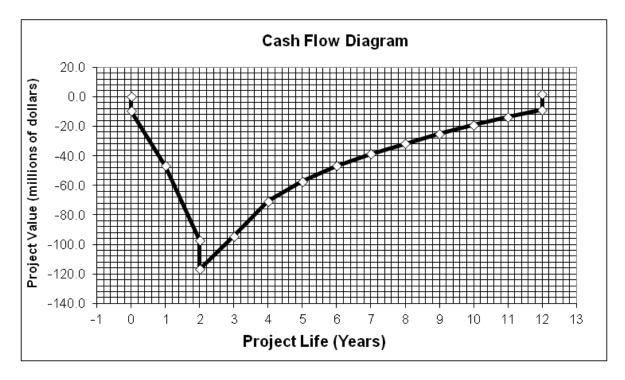


Figure D.2.1. Cash flow diagram for Case Scenario 1 in 10-year project.

- Net Present Value (millions)1.87Discounted Cash Flow Rate of Return10.35%
 - Discounted Payback Period (years) 6.4

Figure D.2.2. Discounted profitability criterion for Case Scenario 1 in 10-year project.

D.3 - Cost information for Case Scenario 1 in 20-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 23,584,681
FCIL	\$ 101,762,638
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.3.2. Economic Information for Case Scenario 1 in 20-year project.

Revenue From Sales	\$ 167,671,112
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 57,369,864
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 14,014,880

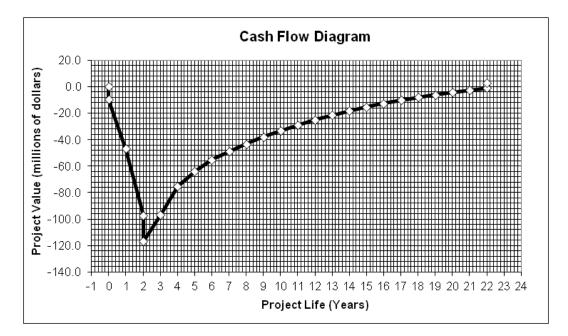


Figure D.3.1. Cash flow diagram for Case Scenario 1 in 20-year project.

Net Present Value (millions) 2.98

Discounted Cash Flow Rate of Return 10.40%

Discounted Payback Period (years) 8.9

Figure D.3.2. Discounted profitability criterion for Case Scenario 1 in 20-year project.

D.4 - Cost information for Case Scenario 2 in 5-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 23,010,318
FCIL	\$ 80,694,001
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.4.1. Economic Options for Case Scenario 2 in 5-year project.

 Table D.4.2.
 Economic Information for Case Scenario 2 in 5-year project.

Revenue From Sales	\$ 181,218,052
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 54,159,306
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,936,723

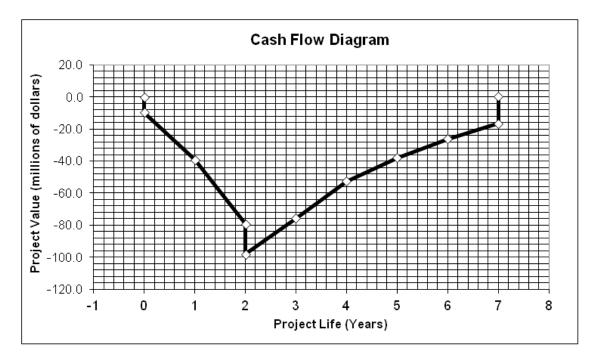


Figure D.4.1. Cash flow diagram for Case Scenario 2 in 5-year project.

Net Present Value (millions)	0.19
Discounted Cash Flow Rate of Return	10.06%
Discounted Payback Period (years)	3.8

Figure D.4.2. Discounted profitability criterion for Case Scenario 2 in 5-year project.

D.5 - Cost information for Case Scenario 2 in 10-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 23,010,318
FCIL	\$ 80,694,001
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.5.1. Economic Options for Case Scenario 2 in 10-year project.

 Table D.5.2. Economic Information for Case Scenario 2 in 10-year project.

Revenue From Sales	\$ 171,668,548
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 54,159,306
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,936,723

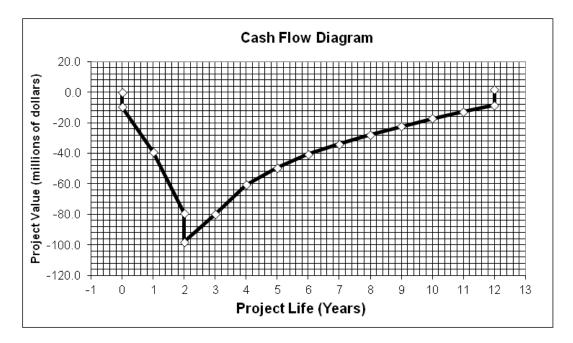


Figure D.5.1. Cash flow diagram for Case Scenario 2 in 10-year project.

Net Present Value (millions)	1.83
Discounted Cash Flow Rate of Return	10.40%
Discounted Payback Period (years)	5.9

Figure D.5.2. Discounted profitability criterion for Case Scenario 2 in 10-year project.

D.6 - Cost information for Case Scenario 2 in 20-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 23,010,318
FCI∟	\$ 80,694,001
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.6.1. Economic Options for Case Scenario 2 in 20-year project.

 Table D.6.2. Economic Information for Case Scenario 2 in 20-year project.

Revenue From Sales	\$ 166,560,718
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 54,159,306
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,936,723

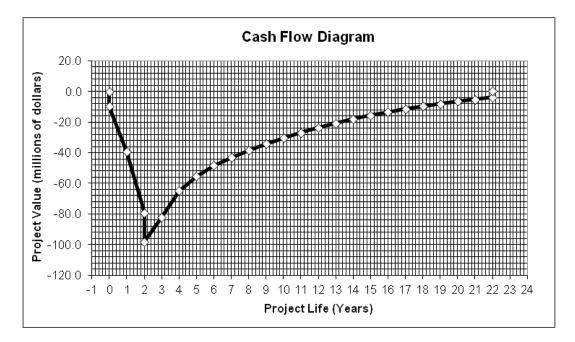


Figure D.6.1. Cash flow diagram for Case Scenario 2 in 20-year project.

Net Present Value (millions)	0.10
Discounted Cash Flow Rate of Return	10.02%
Discounted Payback Period (years)	8.5

Figure D.6.2. Discounted profitability criterion for Case Scenario 2 in 20-year project.

D.7 - Cost information for Case Scenario 3 in 5-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 28,348,543
FCIL	\$ 88,499,339
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.7.1. Economic Options for Case Scenario 3 in 5-year project.

 Table D.7.2. Economic Information for Case Scenario 3 in 5-year project.

Revenue From Sales	\$ 250,285,265
C _{RM} (Raw Materials Costs)	\$ 19,332,032
C _{UT} (Cost of Utilities)	\$ 112,562,498
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 10,980,068

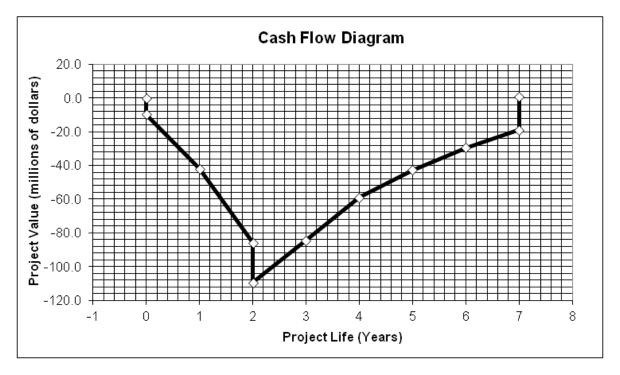


Figure D.7.1. Cash flow diagram for Case Scenario 3 in 5-year project.

Net Present Value (millions)	0.61
Discounted Cash Flow Rate of Return	10.18%
Discounted Payback Period (years)	3.7

Figure D.7.2. Discounted profitability criterion for Case Scenario 3 in 5-year project.

D.8 - Cost information for Case Scenario 3 in 10-year project

Table D.8.1. Ecol	nomic Options for Case Scenario 3	in 10-year project.
	Cost of Land \$	9 758 808

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 28,348,543
FCI∟	\$ 88,499,339
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.8.2.
 Economic Information for Case Scenario 3 in 10-year project.

Revenue From Sales	\$ 239,847,386
C _{RM} (Raw Materials Costs)	\$ 19,332,032
C _{UT} (Cost of Utilities)	\$ 112,562,498
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 10,980,068

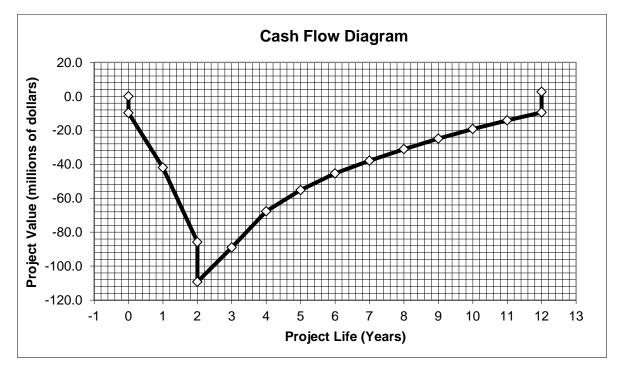


Figure D.8.1. Cash flow diagram for Case Scenario 3 in 10-year project.

Net Present Value (millions)	2.66	
Discounted Cash Flow Rate of Return	10.52%	
Discounted Payback Period (years)	5.7	

Figure D.8.1. Discounted profitability criterion for Case Scenario 3 in 10-year project.

D.9 - Cost information for Case Scenario 3 in 20-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 28,348,543
FCI∟	\$ 88,499,339
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.9.1. Economic Options for Case Scenario 3 in 20-year project.

 Table D.18: Economic Information for Case Scenario 3 in 20-year project.

Revenue From Sales	\$ 234,295,419
C _{RM} (Raw Materials Costs)	\$ 19,332,032
C _{UT} (Cost of Utilities)	\$ 112,562,498
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 10,980,068

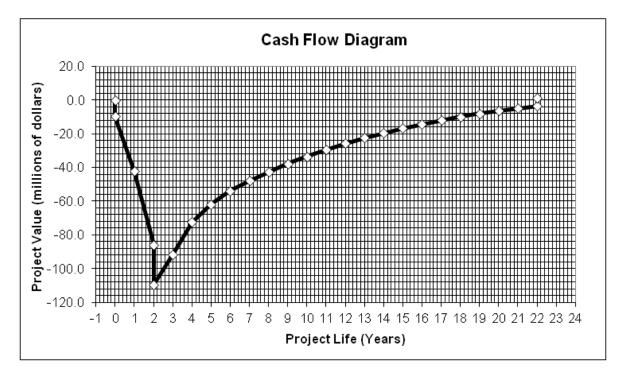


Figure D.9.1. Cash flow diagram for Case Scenario 3 in 20-year project.

Net Present Value (millions)	1.15
Discounted Cash Flow Rate of Return	10.16%
Discounted Payback Period (years)	8.1

Figure D.9.2. Discounted profitability criterion for Case Scenario 3 in 20-year project.

D.10 - Cost information for Case Scenario 4 in 5-year project

Table D.10.1. Economic Options for Case Scenario 4 i	n 5-year project.
--	-------------------

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 22,686,646
FCI∟	\$ 80,758,497
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.10.2.
 Economic Information for Case Scenario 4 in 5-year project.

Revenue From Sales	\$ 177,664,753
C _{RM} (Raw Materials Costs)	\$ 19,332,032
C _{UT} (Cost of Utilities)	\$ 54,931,497
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,058,225

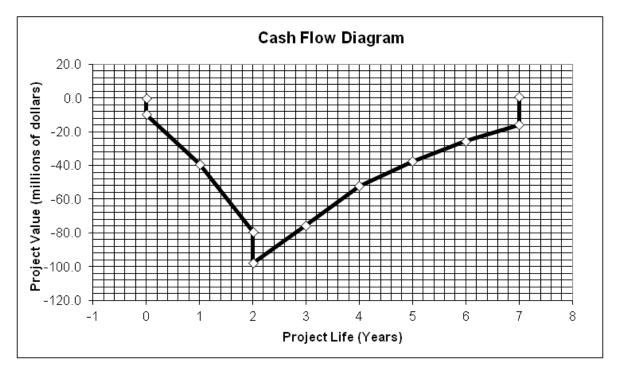


Figure D.10.1. Cash flow diagram for Case Scenario 4 in 5-year project.

Net Present Value (millions)	0.84
Discounted Cash Flow Rate of Return	10.27%
Discounted Payback Period (years)	3.7

Figure D.10.2. Discounted profitability criterion for Case Scenario 4 in 5-year project.

D.11 - Cost information for Case Scenario 4 in 10-year project

Table D.11.1. Economic Options for Case Scenario 4 in 10-year project.

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 22,686,646
FCIL	\$ 80,758,497
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.11.2.
 Economic Information for Case Scenario 4 in 10-year project.

Revenue From Sales	\$ 167,448,993
C _{RM} (Raw Materials Costs)	\$ 19,332,032
C _{UT} (Cost of Utilities)	\$ 5,4931,497
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,058,225

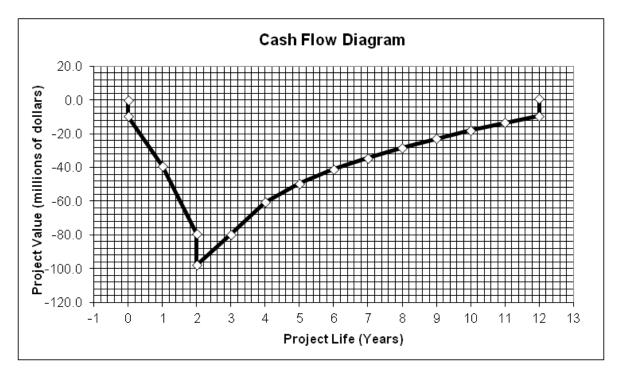


Figure D.11.1. Cash flow diagram for Case Scenario 4 in 10-year project.

Net Present Value (millions)	0.94
Discounted Cash Flow Rate of Return	10.21%
Discounted Payback Period (years)	6.0

Figure D.11.2. Discounted profitability criterion for Case Scenario 4 in 10-year project.

D.12 - Cost information for Case Scenario 4 in 20-year project

 Table D.12.1. Economic Options for Case Scenario 4 in 20-year project.

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 22,686,646
FCIL	\$ 80,758,497
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.12.2.
 Economic Information for Case Scenario 4 in 20-year project.

Revenue From Sales	\$ 163,007,419
C _{RM} (Raw Materials Costs)	\$ 19,332,032
C _{UT} (Cost of Utilities)	\$ 54,931,497
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,058,225

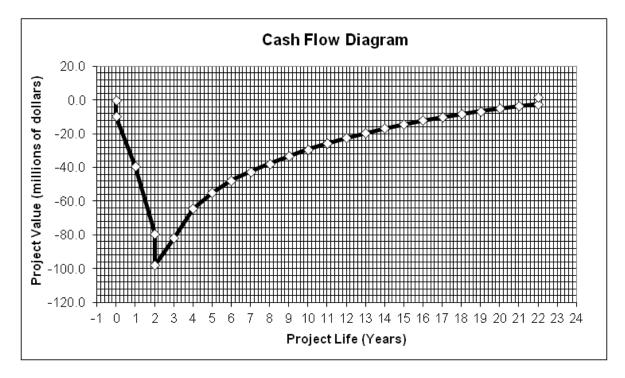


Figure D.12.1. Cash flow diagram for Case Scenario 4 in 20-year project.

Net Present Value (millions)	1.59
Discounted Cash Flow Rate of Return	1 0.25%
Discounted Payback Period (years)	8.2

Figure D.12.2. Discounted profitability criterion for Case Scenario 4 in 20-year project.

D.13 - Cost information for Case Scenario 5 in 5-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 22,923,617
FCI∟	\$ 96,760,710
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.13.2.
 Economic Information for Case Scenario 5 in 5-year project.

Revenue From Sales	\$ 188,768,787
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 53,313,443
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,936,723

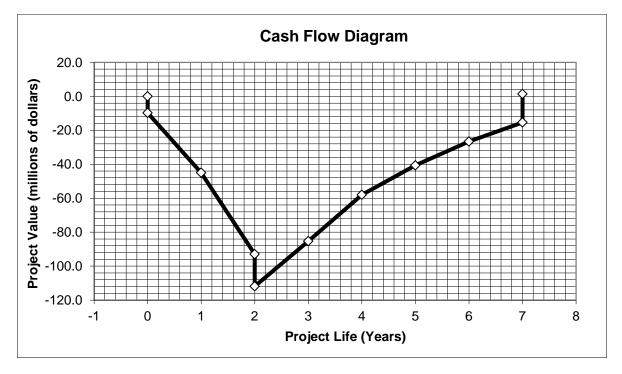


Figure D.13.1. Cash flow diagram for Case Scenario 5 in 5-year project.

Net Present Value (millions)	1.39
Discounted Cash Flow Rate of Return	10.40%
Discounted Payback Period (years)	3.9

Figure D.13.2. Discounted profitability criterion for Case Scenario 5 in 5-year project.

D.14 - Cost information for Case Scenario 5 in 10-year project

Cost of Land	\$ 9,758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 22,923,617
FCIL	\$ 96,760,710
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.14.2.
 Economic Information for Case Scenario 5 in10-year project.

Revenue From Sales	\$ 176,332,241
C _{RM} (Raw Materials Costs)	\$ 21,312,162
C _{UT} (Cost of Utilities)	\$ 53,313,443
C _{WT} (Waste Treatment	
Costs)	\$ 5,298,060
C _{OL} (Cost of Operating	
Labor)	\$ 12,936,723

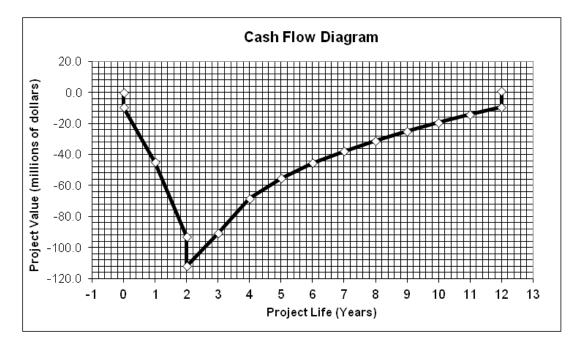


Figure D.14.1. Cash flow diagram for Case Scenario 5 in 10-year project.

Net Present Value (millions)	0.96
Discounted Cash Flow Rate of Return	10.19%
Discounted Payback Period (years)	6.4

Figure D.14.2. Discounted profitability criterion for Case Scenario 5 in 10-year project.

D.15 - Cost information for Case Scenario 5 in 20-year project

Cost of Land	\$ 9758,808
Taxation Rate	42%
Annual Interest Rate	10%
Salvage Value	0
Working Capital	\$ 22,923,617
FCI∟	\$ 96760,710
Total Module Factor	1.18
Grass Roots Factor	0.50

 Table D.15.1 Economic Options for Case Scenario 5 in 20-year project.

 Table D.15.2.
 Economic Information for Case Scenario 5 in 20-year project.

	\$
Revenue From Sales	171,002,292
	\$
C _{RM} (Raw Materials Costs)	21312,162
, , , , , , , , , , , , , , , , , , ,	\$
C _{UT} (Cost of Utilities)	53313,443
C _{WT} (Waste Treatment	\$
Costs)	5298,060
C _{OL} (Cost of Operating	\$
	12,936,723

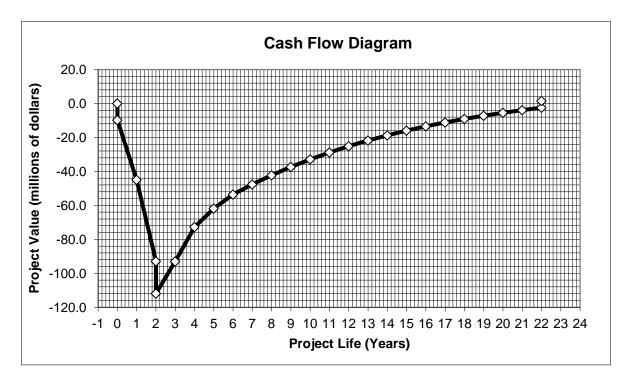


Figure D.15.1 Cash flow diagram for Case Scenario 5 in 20-year project.

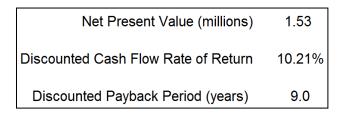


Figure D.15.2. Discounted profitability criterion for Case Scenario 5 in 20-year project.