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Missouri Department of Natural Resources

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1.0 EXECUTIVE SUMMARY

A great need for increased biofuels production is expanding worldwide due to many factors such as raising petroleum prices, environmental stewardship, government mandates, incentives and the growing awareness of controlling greenhouse gases to better preserve the planet for our future generations. Ethanol and biodiesel are currently the primary biofuels competing against fossil fuels to help fill this increased energy need. Biodiesel is a nontoxic, biodegradable, renewable, alternative fuel that has many advantages over toxic fossil petroleum based fuels. However, the major obstacle standing in the way of consistent commercial production of biodiesel or any other green fuels in Missouri is the high cost of the raw materials that are presently used to produce these renewable fuels. A solution must be found to this problem before Missouri can participate fully in this new energy economy.

A viable alternative for making a renewable fuel more price-competitive with fossil fuel must encompass the use of raw materials from Missouri of a lower cost nature. Currently, most biodiesel producers compete for feed stocks which are also used in many other products ranging from pet food to ingredients for human consumption; thus the costs of these feed stocks are not conducive to stable, low cost fuel production that over the long range can remain price competitive with lower cost fossil fuel refining. Missouri can move toward a new energy economy by creating new methods that will better utilize Missouri resources by benefiting from an array of emerging clean energy technologies.

The ideal technology would be one that achieves a high rate of conversion of a lower cost Missouri feed stock into a new generation alternative biofuel, utilizing a process that will have a nominal financial impact to upgrade the current Missouri biodiesel facilities. This feasibility study reviewed and analyzed several innovative, proven technologies that will create from Missouri's abundant resources an effective method to expand its renewable energy economy, which in turn will create more jobs and retain energy dollars here in Missouri. The first of the technologies reviewed were UOP's Ecofining, which has the ability to convert fatty acids to a diesel analog[1], when paired with the Evergent pryolysis process it will allow for biomass to be converted to a bio-oil that can be used in place of the fatty acids[3]. The second technology that was considered was the Rentech Process, which utilizes a gasifier to break down the biomass to carbon monoxide and hydrogen which is then processed into electricity or liquid fuels and chemicals via Fisher-Tropsch reaction which yields fuels in the diesel and kerosene ranges as well as heavy molecular weight waxes. The final process to be reviewed was the Unitel HarvestGas process which also uses a gasification system to process the biomass into carbon monoxide and hydrogen. The HarvestGas system then uses a catalytic process to convert the gasses into dimethyl ether (DME) which has shown great promise as a diesel fuel alternative as well as a natural gas alternative.

All three processes are technologically feasible but apart from UOP have had very little long term operational proof in the market. Under ideal conditions each of the systems would offer a good payback but there hasn't been enough data collected yet to determine if the systems will be viable over the long term. There are also newer more economical technologies that are poised to hit the market.

2.0 INTRODUCTION

Increased worldwide demand for renewable fuels with widespread applications combined with significant shortages of crude oil and increased petroleum prices has generated interest in the production of synthetic diesels by various methods. Biomass is a primary source that can be converted into liquid forms through several different processes and produce renewable energy. Therefore, increasing biofuel usage in all relevant sectors can significantly reduce greenhouse gas emissions as well as diversify energy sources, enhance energy security and stimulate the rural agricultural economy.

This study evaluated the current technologies in producing improved, cleaner renewable fuels such as green diesel, synthetic diesel, or other form of bio-fuel using third generation feedstock including cellulose, municipal solid waste, industrial waste, or other forms of un-utilized or under-utilized feedstock or waste stream in Missouri. Through the identification of an ample, consistent supply of local renewable material in conjunction with the evaluation of the proven technologies, the proposed feasibility study has enabled Global Fuels to determine the best course of action to move forward in the production of green diesel, synthetic diesel, or other bio-fuel.

Unlike many traditional biofuels, green diesel and Fisher Tropsch diesel (FT diesel) have superior product properties with lower cloud point, higher cetane levels, and lower emissions[9]. Green diesel and FT diesel can generate more energy than regular biodiesel because it can be produced with a higher cetane level[8]. Green diesel and FT diesel also have many cost advantages, such as the ability to be sold into military and aviation markets. These fuels are not bound to the same limitations as biodiesel and can be used with all existing infrastructure (pipelines, storage tanks, terminals, pumps) without any issues or modifications required. Green diesel and FT diesel eliminate the intermediaries and can be directly delivered to the end user in a more cost-effective manner.

Other advantages of green diesel over biodiesel include the ability to make different blends such as a summer blend, winter blend, and Arctic blend. Additionally, it can operate better in extreme cold temperatures as compared to biodiesel so there is a wider range of applications.

Missouri possesses great natural resources and a large agricultural based economy, which provide many opportunities for the state to engage in renewable energy production. Currently, there are readily available alternative sources of bio mass feedstock and/or agricultural waste stream in Missouri that hold significant potential for renewable energy but are not being used. These materials include not only first generation and second generation sources, but also cellulose and sugars, non-food crops like jatro and switch grass, rubber tires and plastics.

One of the more commonly cited reasons for not using renewable energy is that the best resources are often available only in remote rural areas and it is expensive to transport and store from the source to the processing facilities. By using locally available resources in rural southeast Missouri areas, Global Fuels will eliminate much of these transportation/storage expenses. Specifically, Stoddard County has been identified as a biomass rich geographical area with greater availability of feedstock than most other geographical areas in Missouri.

Moreover, at this time there is no other petroleum refinery in this area of Missouri using these sources for renewable energy production. Ultimately, Global Fuels will apply the findings of the feasibility study to modify its facility accordingly and begin producing green diesel by using one or more of these alternative feedstock and waste stream sources. Ideally the feasibility study may also prove that it is possible to produce both biodiesel and green diesel simultaneously in the current facility. By using the same production line to extract multiple products, the company will be able to minimize operating expenses and energy use while it reduces overall financial impact and significantly increase the overall return on capital investment in producing the green diesel, FT diesel, or other renewable chemicals.

3.0 METHODS

This study applied commercially proven technologies to locally available feed stock/waste stream sources available to determine the feasibility and cost effectiveness of a new renewable energy system in Missouri. To accomplish this objective, known parameters and previous pilot studies by the owners of the technology were applied to Missouri feedstock and waste stream sources. Current proven technologies used in the proposed project included Ecofining, the Rentech Process, and Unitel's Harvest Gas process.

Data about availability of local feedstocks was compiled from data generated by the National Agriculture Statistic Service (NASS). This was then confirmed via interview of local producers. This data is presented in Table 1 in the results section and Figure 1 in the economic feasibility and market analysis section.

Information about each process was collected, including project capitalization, process feedstock capabilities, and products produced. Only a preliminary assessment of the three technologies could be included in this report because release of proprietary information would be a violation of any nondisclosure agreements and letters of intent would have been required for further data. The data collected and presented here is available in the public domain and published articles.

3.1 UOP/EVERGENT

According to UOP/Honeywell, the Ecofining process deoxygenates biomass feedstock by adding hydrogen to produce a highly-stable green diesel fuel with a lower cloud point, higher cetane value, and lower emissions as compared to biodiesel and traditional petroleum based diesel. The process is feedstock flexible so that it works with a wide range of biomass feedstock including vegetable oil, algal oils, cellulose, and stabilized pyrolysis products.

Integral to the Ecofining process is the use of Rapid Thermal Pryolysis (RTP) technology. According to Envergent Technologies, which has been developing the commercially-scale technology, RTP is a quick thermal process in which biomass, usually agricultural by-products or forest residuals, is rapidly heated to approximately 500°C in the absence of oxygen. Central to the process is a circulating transported fluidized bed reactor system similar to the one used in the UOP Fluid Catalytic Cracking (FCC) technology. Hot sand vaporizes the biomass, which is then rapidly quenched, typically yielding 65%wt to 75%wt pyrolysis oil, which can be used as fuel for industrial heat or electricity, or further upgraded using established UOP hydro processing technology to produce green transportation fuels. The process yields high-value, renewable, green gasoline, diesel and jet fuel. The fuels perform better than their petroleum counterparts and use existing refining infrastructure and fleet technologies.

In addition to pyrolysis oil, RTP also produces char and a non-condensable gas, both of which can be used to provide process energy in the re-heater to maintain the RTP process and/or in the dryer to condition the biomass. Therefore, it requires less energy for production purposes.

UOP in partnership with Boeing and other aircraft industry partners has executed demonstration flights to showcase this exciting technology. Each flight has used a 50/50 blend of green jet fuel made from second-generation, non-food feedstock with petroleum-based jet fuel. Results have

indicated that the green jet fuel met or exceeded performance specifications with higher energy density, which will allow aircraft to fly further on less fuel. [1,2,3,8]

3.2 RENTECH, INC.

Prior to the Rentech Process, the carbon based feedstocks are gasified under high temperature to produce synthesis gas (syngas), a mixture of carbon monoxide and hydrogen (CO and H2). A facility can employ almost any commercially available gasifier to produce syngas to fuel the Rentech reactor.

The Rentech Process is a proprietary technology that, together with gasification and upgrading technologies, converts synthesis gas from biomass into hydrocarbons that are subsequently processed and upgraded into ultra-clean synthetic fuels, specialty waxes, and chemicals. The Rentech Process is based on Fischer-Tropsch chemistry. Much of the original technology has been improved by Rentech, including catalyst composition, reactor design and design parameters of synthetic fuels and chemicals facilities. These enhancements have improved the quality and yields of products produced as well as the operating efficiency of the facilities.

The Rentech technology can use syngas produced from biomass feedstocks such as forestry waste, agricultural waste, green waste, algae, and energy crops. The wide variety of feedstocks listed here is a testament to the flexibility and versatility of the Rentech Process.

The Rentech Process produces ultra-clean synthetic fuels such as military and commercial jet fuels and ultra low sulfur diesel. All fuels produced by the Rentech Process can be distributed and used in existing infrastructure including pipelines and engines and are cleaner burning than traditional petroleum-derived fuels. Rentech's ultra low sulfur diesel fuel is environmentally friendly and biodegradable.

The Rentech-SilvaGas biomass gasification process can convert multiple biomass feedstocks into synthesis gas for renewable power production in addition to liquid fuels production. The syngas can be used to fuel a standard gas turbine or generator to generate green electricity. [4,10,11]

3.3 UNITEL TECHNOLOGIES

The heart of the HarvestGas system involves a pressurized oxygen-blown biomass gasifier designed for operation in an expanding bed mode. This unit converts the biomass into a mixture of hydrogen and carbon monoxide, and is optimized to minimize the formation of methane. The effluents from the gasifier are fed into an oxygen injected reformer that transforms the tars and volatiles into additional synthesis gas. The "wheel of fortune" of products that can be synthesized from the syn gas are Ammonia, Ethanol, Methanol, Butanol, Dimethyl-ether (DME), and Fischer Tropsch Diesel.

The biomass is first converted into hydrogen and carbon monoxide. After the gas stream is cleaned, the carbon monoxide is "shifted" to maximize hydrogen. The hydrogen is purified and catalytically reacted with nitrogen (from air) to make ammonia. The plant includes an air separation system to provide oxygen for the gasifier and reformer, and pure nitrogen for ammonia synthesis.

DME is an ideal one-to-one substitute and additive for liquefied petroleum gas (LPG). It is also a direct replacement for diesel, with the added advantage that DME is 100% clean in terms of sulfur, soot and particulates, and the exhaust is approximately 50% lower in terms of greenhouse gas emissions. According to General Electric, DME is an excellent fuel for stationary gas turbines. Many experts view DME as the most promising fuel option for the 21st century.

HarvestGas will make its debut as part of the SynGest bio-ammonia plant to be built in Menlo, Iowa. The facility will use 150,000 tons per year of locally supplied corn cobs to manufacture 50,000 tons of ammonia annually, enough to fertilize 500,000 acres of nearby Iowa farmland under corn. [5,12]

4.0 ECONOMIC FEASIBILITY AND MARKET ANALYSIS

There is sufficient biomass for any of the three projects at their smallest feasible size within a 90 mile radius of the Global Fuels facility in Dexter, Missouri. The amount of biomass was calculated using the USDA NASS service and allowing for residuals to be left as not depleting the soil (Table 5-1). At the time of this study the USDA BCAP program was still in existence and it would have added $40 per ton to allow for individual farms to purchase biomass handling equipment. Thru discussions with several local farmers all were very agreeable to a price of $40-$60 per ton of biomass in addition to the BCAP funds. The three process chosen were impart chose due to being feedstock agnostic, meaning that they can operate on virtually any dried biomass. This was necessitated by the variety of crops and corresponding crop residues that are grown in the Southeast Missouri region.

Storage of the dried biomass would be on farm, typically infield as is done with cotton bales after harvest. This would limit Global Fuels storage requirements to 5-10 days worth of material that could be stored in a tarp covered bunker to reduce moisture and degradation; this will also minimize costs of storage. Transport will also be minimized by targeting nonpeak times to transport the biomass to Global Fuels, avoiding harvest and planting times when both trucks and drivers are in high demand. These costs will be, on average, $250-$500 per load of 40-60 tons of biomass which would be $4.15-$12.50 per ton of biomass delivered; these costs were given to Global Fuels by “Scott Gibbs Trucking” during a personal interview.

The current Global Fuels facility would not be able to be utilized in any of these new process, there would be virtually no corresponding equipment and the size of the current facility would not meet the needs of any of the new processes. The Stoddard County Industrial Park, where Global Fuels is located, is however ideal for the location of any of the three processes, access to state highway (MO60) and interstate (I55), TEPCO pipeline access for transport of finished product and supply of any needed natural gas, and Union Pacific Rail access adjacent to the industrial park. Electrical utilities are also available from AmrenUE in the form of a substation directly adjacent to the industrial park. While the current Global Fuels building and equipment would be of little use to the new facility the location and all the advantages of that location would be ideal for an advanced fuel production facility.

The costs of production for these processes are higher than that of biodiesel, $1.00 - $2.50 per gallon for utilities, labor, and feedstock preparation (drying, shredding, etc). Typically each ton of biomass will yield 60-90 gallons of liquid fuel with a total cost of $44.15-$72.50 per ton this would give a cost of $0.49-$1.21 cost per gallon for biomass. This would give a total cost per gallon that can range from $1.49-$3.71 depending on market factors such as transport cost and feedstock cost being the biggest variables. The best way of controlling the long term costs of production would be to contract for biomass and hedge against the emerging market.

Currently there is a 1.5 billion gallon mandate from the EPA in the form of RFS2 which has <10% supply currently met, this will drive higher than market prices for Green and FT Diesel fuels. There will also be 1.7 RINs per gallon of fuel generated, currently on the open market RINs trade for $0.90-$2.00 (Low – High for 2011) per RIN. [14] This is expected to go up as the demand increases as the mandate increases each year. [13]

Return on Investment					
	UOP	UOP/Evergent	Rentech		Unitel (DME)
Capital Investment	$20,000,000	$40,000,000	$378,000,000		$140,000,000
Capacity (Gallons per Year)	10,000,000	10,000,000	36,000,000	**(Tons per Year)**	47,600
Cost per Gallon	$4.00	$3.46	$3.71	**per Ton**	$150.00
Feedstock	$3.00	$1.21	$1.21	**Feedstock**	$60.00
Fixed Costs	$1.00	$2.25	$2.50	**Fixed Costs**	$90.00
Price per Gallon Expected	$4.79	$4.79	$4.79	**Price per Ton**	$700.00
No2 Diesel Price	$3.05	$3.05	$3.05		
RIN Value	$1.53	$1.53	$1.53		
Net Profit (Per Gallon)	$0.79	$1.33	$1.08	**Net (Per Ton)**	$550.00
Net Profit	$7,900,000	$13,300,000	$38,880,000	**Net Profit**	$26,180,000
Simple Payback (Years)	2.53	3.01	9.72	**Simple Payback**	5.35
Return on Investment (10 Year)	295.0%	232.5%	2.9%	**ROI**	87.0%

Table 4-1 Summary of capital investment and a simple payback of investment.

The data in Table 4-1 shows what is possible taking an ideal market situation with a guaranteed off take of all fuel produced.

4.1 UOP ECOFINING

The Ecofining process is a two stage hydrotreating reactor system designed to use hydrogen to remove oxygen from glycerides and fatty acids. The first stage reactor completely saturates the glycerides and fatty acids, giving a straight chain hydrocarbon, in the diesel distillate range, propane and water are also generated in the reaction (Figure 4.1). The next stage is isomerisation where the saturated hydrocarbons are branched to improve the cold flow properties and a paraffinic diesel is produced. The product is then processed in a conventional distillation system to separate the propane, paraffinic diesel, and any NAPTHA that may have been generated.

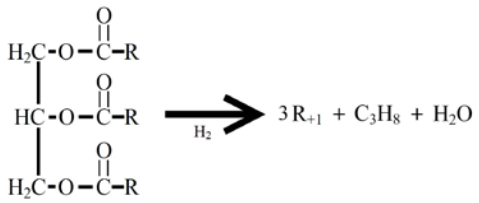


Figure 4-1

The target market for green diesel will be farmers with diesel operated equipment and fuel stations that sell primarily to heavy duty trucks. The advantages Green Diesel provides to the customer are a cleaner burning fuel, a lower cloud point than standard No.2 ULSD, lower carbon monoxide and particulate emissions, and better fuel economy due to the higher cetane value.

Green Diesel is also compatible and will improve the function of all modern pollution control devices due to its cleaner burning properties. With Global Fuels located in a large agriculture sector and located between the major transportation hubs of Memphis and St. Louis that the potential to move Green Diesel into these markets for our targeted consumers allowing Global Fuels to continue with its regional approach.

The market potential for green diesel is up to 29% of the United States diesel usage, and the annual market of No. 2 Ultra Low Sulfur Diesel (ULSD) in the United States is over 42 billion gallons per year. This leaves a total market for Green and Fisher Tropsch Diesel of 12.2 billion gallons per year, only 2% of the market share would be almost 250 million gallons per year. The demand for these fuels will outstrip the production capacity, thus allowing for a premium on the fuel. Some reports suggest up to a $35 per barrel premium over FAME Biodiesel. Green diesel will also meet the requirements for Advanced Biofuel (D code 5) under the EPA Renewable Fuels Standard (RFS2) program that will mandate the use to replace a portion of petroleum biased product in the market.

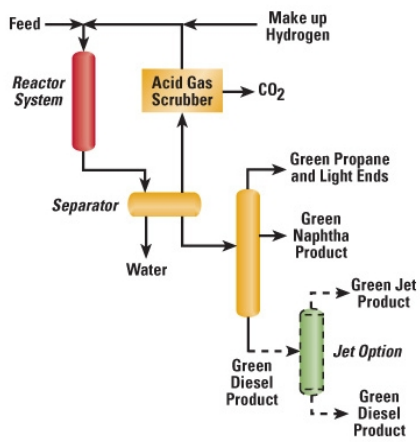


Figure 4-2

The base Ecofining process will have an approximate cost of $10 million dollars for a 3-5 million gallons capacity system, adding the capacity to process Jet A fuel will add to that cost. A Steam Methane Reformer (SMR) will also be needed for the hydrogen (H2) generation to feed the Ecofining hydrotreating reaction. Adding an Evergent Pyrolysis system would add another $20 million to the project; this would require 100 dry metric tons per day to yield enough bio-pyrolysis oil to supplement the Ecofining process. One of the major operational costs would be the hydrogen gas generation from steam and methane (natural gas). The hydrogen gas usage would depend on the amount of oxygen present in the oil to be processed, in this case higher fatty acid material would be easier and cheaper to process due to the oxygen associated with the glycerin no longer being present. The 2011 pricing of most greases was $0.39 - $0.59 per pound it would give a feedstock cost of $2.83 - $4.28 per gallon of fuel. [8] This large variance was always attributed to supply and demand issues by the feedstock suppliers.

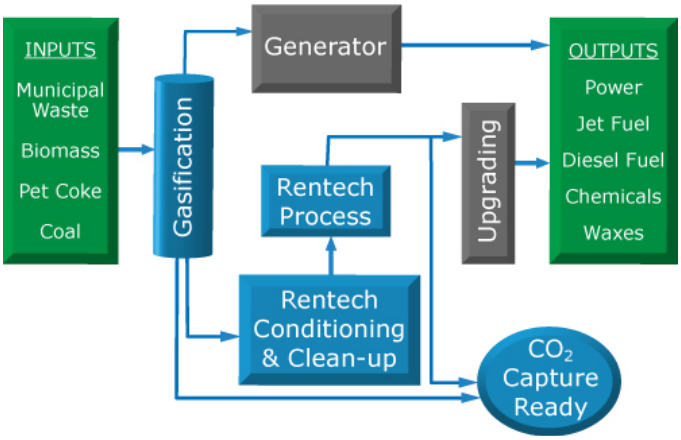
4.2 RENTECH, INC.

The Rentech process is a Fisher-Tropsch process that is designed to converts synthesis gas to synthetic diesel and kerosene rage fuels. The first step in this process is high temperature gasification where biomass is converted to Carbon Monoxide (CO) and Hydrogen Gas (H_2). The next step is to reform and clean the synthesis gas to remove unwanted contaminants that can foul the Fisher-Tropsch catalyst. The synthesis gas is then recombined into long chain alkanes (parafins).

The target market for Fisher-Tropsch Diesel (FT Diesel) will be primarily aviation and military applications. The advantages FT provides to the customer are higher sustainability, cleaner burning fuel, a lower cloud point than standard No.2 ULSD, lower carbon monoxide and particulate emissions, and better fuel economy due to the higher cetane value. Several military facilities are located within a very small radius to Global Fuels, also Global Fuels sits at the midpoint for the international airports in Memphis and St. Louis. The potential to move FT Diesel into these markets allows Global Fuels to continue with its regional approach to fuel supply.

The market potential for FT diesel is up to 29% of the United States diesel usage, the annual market of No. 2 Ultra Low Sulfur Diesel (ULSD) in the United States is over 42 billion gallons per year, similarly to Green Diesel. FT Diesel has a slight advantage in the more demanding aviation fuel portion as it can meet and exceed the Jet A1 specifications.

The Rentech Process will cost approximately $378 million for a complete system that will produce approximately 36 million gallons per year of high grade FT diesel fuel or Jet A1 fuel that will meet strict military requirements. A biomass gasification unit will be required to convert the solid biomass to synthesis gas, a steam reformer will be needed to convert any methane generated in the gasification process to hydrogen gas and carbon monoxide, there will be another clean up stage to remove toxic and harmful impurities from the gas stream leaving a consistent and pure stream of carbon monoxide and hydrogen flowing to the Fisher-Tropsch reactor. A light crude paraffinic oil is synthesized at the reactor and is then fed into an upgrading unit that hydrocracks and hydrotreats the oil to produce “ultra-clean synthetic fuels and specialty waxes and chemicals”. The process could also generate up to 120 megawatts of renewable electricity for sale to the surrounding community. [4]



4.3 UNITEL (HARVEST GAS)

The Unitel process is a Fisher-Tropsch process that is designed to converts synthesis gas to synthetic methanol or dimethyl-ether (DME); synthetic ammonia can also be generated. The first step in this process is high temperature gasification where biomass is converted to Carbon Monoxide (CO) and Hydrogen Gas (H_2). The next step is to reform and clean the synthesis gas to remove unwanted contaminants that can foul the Fisher-Tropsch catalyst. The synthesis gas is then combined based on the type of catalyst and reaction conditions set forth by the operator.

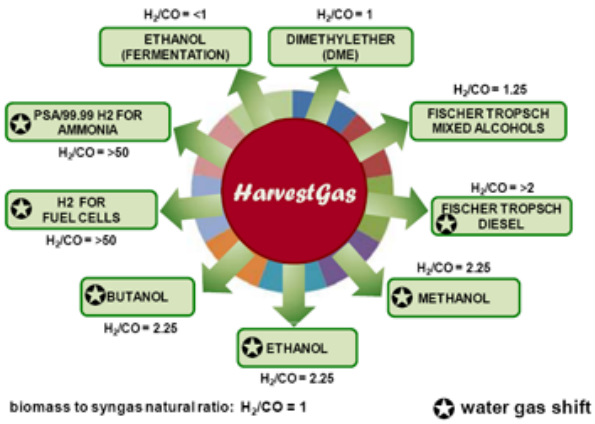


Figure 4-4

The target market for methanol would be household products and biodiesel plants, a synthetic renewable methanol would provide a significant reduction to a biodiesel plants carbon impact. Conventional methanol is primarily obtained from processing petroleum based natural gas and reacting it with oxygen to give a liquid methanol, since this methanol would be derived from a biomass source it would be sustainable and provide a direct displacement of petroleum derived methanol.

The target market for ammonia would be a component of agricultural fertilizers as with methanol this would displace the use of petroleum derived natural gas leading to a more sustainable production of ammonia.

The target market for DME would be a replacement fuel for short haul diesel engines and static diesel engines that run pumps or generators. DME is easily compressible like propane and can be direct injected into a diesel engine. Some advantages over conventional petroleum diesel are lower environmental impacts such as a reduction in all pollutants from combustion and direct replacement of petroleum based fuel, there have also been some studies that suggest a higher engine efficiency. Since this is a liquefied compressed gas there will never be any cold weather operability issues like those seen with conventional methyl-ester biodiesel or conventional petroleum diesel.

All three potential products have a good market in Global Fuels regional approach, there are currently six biodiesel producers in a 200 mile radius that could use the methanol produced. Global Fuels is located in a large agriculture region and there are several fertilizer producers in the area that are currently getting their ammonia barged in. The DME production has the best possible market being a direct replacement for diesel fuel in generators and irrigation pump motors; this would fit directly into Global Fuels agricultural and regional approach.

The Unitel Process will cost $120 to $140 million for a complete system that will produce 150 tons/day of ammonia, 193 tons/day of methanol or 136 tons/day of DME. A biomass gasification unit will be required to convert the solid biomass to synthesis gas, a steam reformer will be needed to convert any methane generated in the gasification process to hydrogen gas and carbon monoxide, there will be another clean up stage to remove toxic and harmful impurities from the gas stream leaving a consistent and pure stream of carbon monoxide and hydrogen flowing to the Fisher-Tropsch reactor. [5]

5.0 RESULTS

Data from the NASS was compiled for the Southeast Missouri Region including the counties of Butler, Cape Girardeau, Dunklin, Mississippi, New Madrid, Pemiscot, Scott, and Stoddard. This represents a 150 mile radius to the current Stoddard County Industrial site. [6]

	Acres			Tons		
	2007	**2008**	**2009**	**2007**	**2008**	**2009**
Corn	545,700	373,100	373,000	2,750,328	1,880,424	1,879,920
Cotton	379,000	303,000	260,000	355,313	284,063	243,750
Rice	171,000	192,000	191,800	1,613,385	1,811,520	1,809,633
Sorghum	25,600	24,100	9,000	96,000	90,375	33,750
Soybeans	1,748,000	2,140,000	1,119,000	3,146,400	3,852,000	2,014,200
Wheat	416,000	782,000	254,000	1,272,960	2,392,920	777,240
Totals	**3,285,300**	**3,814,200**	**2,206,800**	**9,234,386**	**10,311,302**	**6,758,493**

Table 5-1 shows that even though there was significant drop in crop acreage that there is enough biomass from crop residues to support any of the purposed projects in its entirety.

The tons of biomass were calculated using the following equation:

$$\frac{[\text{Average Units Harvested per Acre}] * [\text{Weight per Unit (Lb)}] * [\text{Acres Harvested}]}{[\text{2000 Lb/ton}] * [\text{Biomass Multiplier}]}$$

Biomass Multiplier	
Corn	1.0
Cotton	1.5
Rice	1.7
Sorghum	1.0
Soybeans	1.0
Wheat	1.7

	Chicken Litter	**Paper Fines**
Availability	10k to 15k tons/year	14.1k tons/year
Moisture %	15 to 20%	
Price/Ton	$42.00	$12.00

Table 5-2 shows the availability of waste biomass that could be used to feed any of the process and is available in the region.

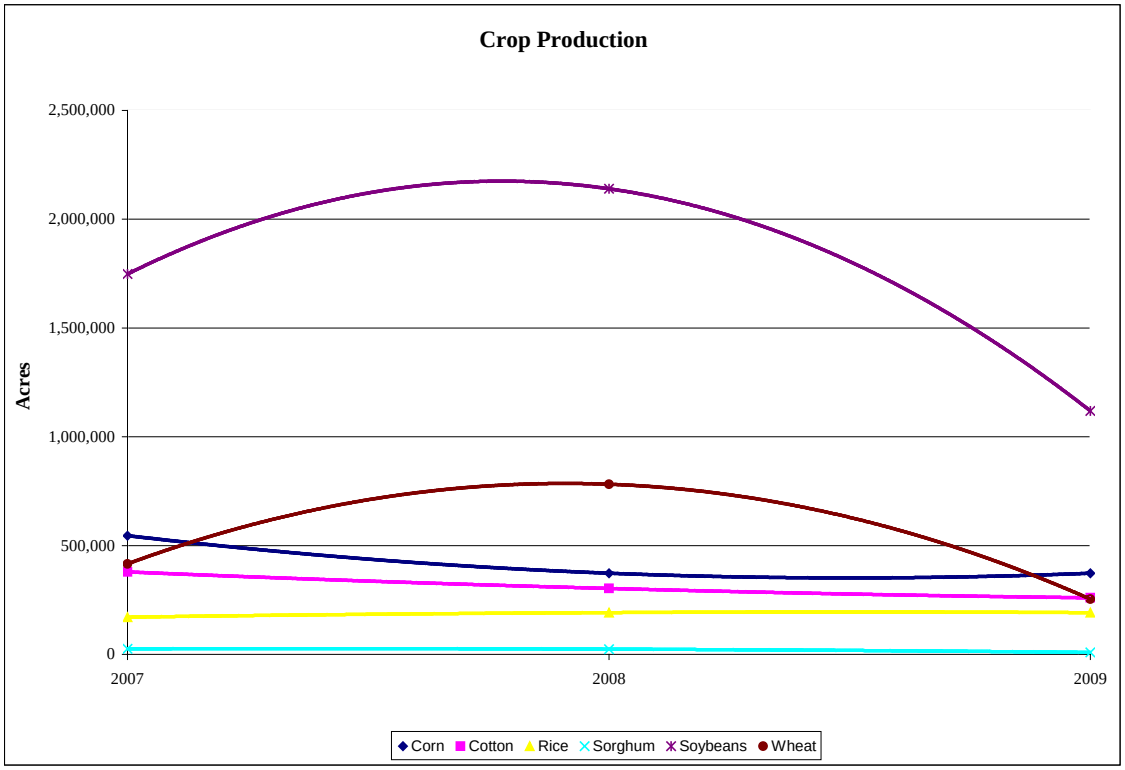


Figure 5-1

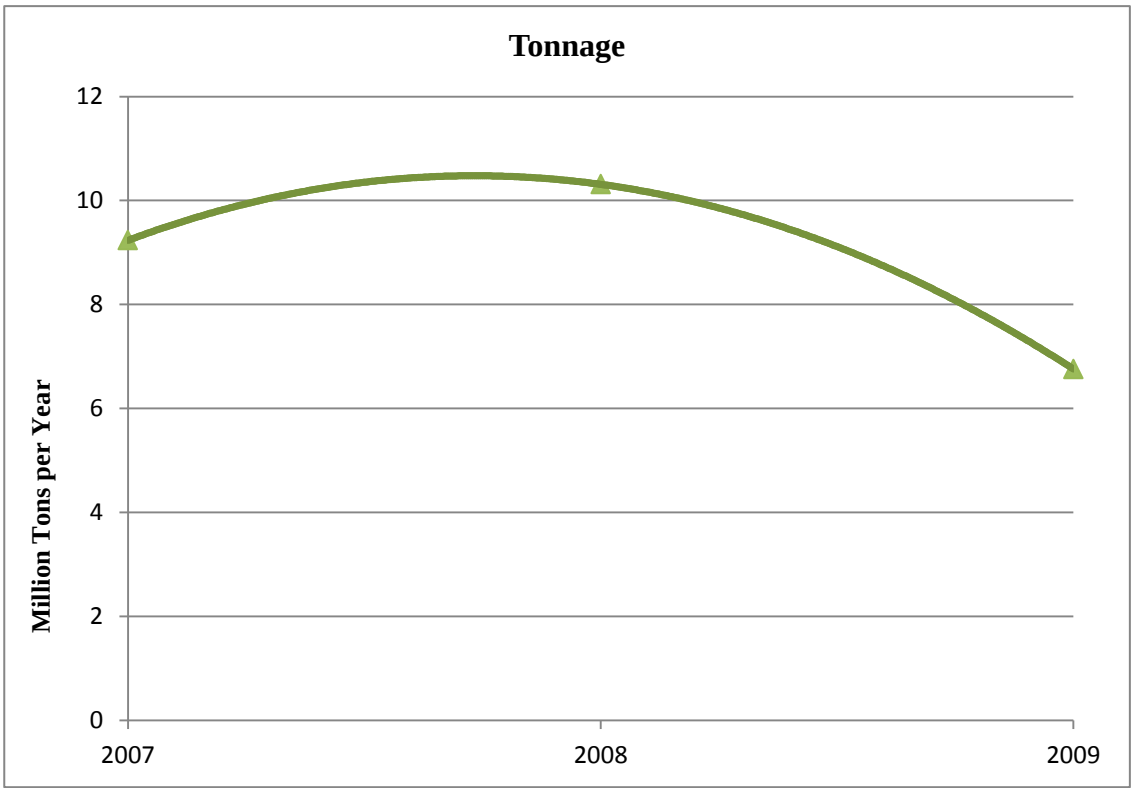


Figure 5-2

Even as overall biomass tonnage in the region fell over the three year period examined there would still be more than forty times the biomass required by even the largest of the three projects, Rentech.

Comparison of Diesel Fuel Attributes				
	Diesel (ULSD)	**Biodiesel (FAME)**	**Ecofining (Green Diesel)**	**Rentech (FT Diesel)**
Oxygen (%)	0	11	0	0
Specific Gravity	0.84	0.88	0.78	0.77
Sulphur (ppm)	<10	<1	<1	<1
Heating Value (MJ/kg)	43	38	44	44
Cloud Point (^oC)	-5	-5 to +15	-20 to +20	-16 to +10
Cetane Number	40	50-65	70-90	>75
Oxidation Stability	Good	Marginal	Good	Good

Table 5-3 Comparison of fuel attributes of the current market diesel and biodiesel to the properties of Green Diesel and Synthetic FT Diesel.

The fuel quality of both Green Diesel and FT diesel easily surpass that of conventional petroleum diesel and methyl-ester biodiesel. This quality is intrinsic to the processes and the products that are produced. Green Diesel from Ecofining can be tailored to meet demands of differing applications thru the isomerization process. This expands the traditional markets for Green Diesel into military and government applications. The FT diesel of the Rentech process can also be customized by changing the reaction conditions of the FT reaction, opening up the same specialty markets. [9]

Comparison of Gas and Diesel Fuel Attributes					
	DME	**Methane LNG**	**Propane**	**Methanol**	**Diesel ULSD**
Formula	CH_3OCH_3	CH_4	C_3H_8	CH_3OH	-
Boiling Point(°C)	-25.1	-161.5	-42	64.8	180~360
Liquid Density(g/cm3(@20°C))	0.67	-	0.49	0.79	0.84
Gas Specific Gravity	1.59	0.55	1.52	-	-
Auto Ignition (°C)	350	632	504	470	254-285
Explosion Limit(%)	3.4~17	5~15	2.1~9.4	5.5~36	0.6~7.5
Cetane Rating	55~60	0	5	5	40~55
Heat Value (kcal/kg)	6,900	12,000	11,100	5,040	10,200

Table 5-4 Comparison of DME and various gas fuels and conventional diesel.

Dimethyl Ether has a good potential application in the diesel market, however there will be several hurdles to overcome to gain market acceptance, as with biodiesel. Some of the hurdles is that there is no current quality specifications for DME as a fuel, there is no real distribution network that can deliver a gas and it would need to be compressed to be stored as a liquid. There is also the issue that extensive mechanical vehicle modification would need to be performed to use DME as a diesel substitute. [12]

	UOP/Evergent	Rentech	Unitel/Harvest Gas
Type of Fuel Produced	Green Diesel	Fisher Trospch Diesel	Dimethyl Ether
Co-Products Produced	Propane/Methane	Naptha and Waxes	Amonia
Amount of Product Produced	10 Million Gallons of Green Diesel per Year	30 Million Gallons of FT Diesel per Year	136 tons per day DME 150 tons per day Amonia
Capital Cost	$25 - 45 million	$378 million	$120 - 140 million
Type of Feedstock Used	Cellulose and Fatty Acids	Any Organic Biomass	Any Organic Biomass

Table 5-5. Summary of information from the three technologies.

6.0 CONCLUSION

The evaluation of the three proven technologies selected for this feasibility study indicates that the technologies are feasible however there are more efficient and more economical scaled systems that will be available to the market soon, but due to the constraints of the study were not eligible for consideration.

As stated, the UOP/Evergent system would require an initial capital expenditure of $15-20 million. The natural progression to the production of jet fuel would require an additional investment of $5 million. Installation of a pyrolysis unit would add an additional $10-20 million. During the course of this study it was determined that while it is possible to use an Ecofining system to upgrade pyrolysis oil to a useable fuel, it has not been accomplished to date and at best estimate UOP is two to three years away from attempting that process. The Ecofining system would still require fats and oils to produce liquid fuels.

The Rentech system scaled from the Natchez project indicates a construction cost of approximately $10.50 per gallon, which would equate to approximately $378 million for the size plant desired. Apart from the capital investment the amount of biomass that this project would consume would be prohibitive. Global Fuels believes that smaller to medium sized projects would be a better fit for this region as it would lessen the radius needed for transporting low energy density biomass. There would also need to be a significant upgrade in infrastructure to the surrounding area including roads and rail lines before a project of this magnitude could be undertaken.

Unitel Technologies can provide the Harvest Gas System, which at an input tonnage of 450 tons per day would require an initial investment of $120-140 million. The outputs of this system are less desirable in the current market focusing on liquid fuels. DME would make an excellent diesel substitute however with the resistance that the over-the-road trucking industry has shown for alternative fuels that require special handling and vehicle modification there will only be a small to niche market in the transportation sector.

The above costs do not include the preparation or demolition of the existing equipment and facilities. This would increase the costs by approximately $250,000. The increase in infrastructure is also not included and has the potential to cost approximately $2 million to $10 million for the Ecofining project and Rentech project, respectively.

As the technology is improved and simplified, it is expected that costs will decrease and the investment climate will improve. At that time, we will revisit the feasibility of this type of industry for this area. Currently there are research institutes that are conducting pilot work for a completely scalable system that would produce a green diesel/gasoline blend from biomass. Global Fuels is continuing contact with this organization throughout the pilot study and development of this technology. Global Fuels is also actively seeking new and innovative technologies that are being brought to the market place, once such system in the IH^2 system being developed with the Gas Technology Institute. IH^2 is a novel hydropyrolysis and hydroconversion process.

Global Fuels is also broadening the scope of initial study for future research to include biomass to electricity and heat. There are several innovative and smaller scale projects such as Innovative Energy Inc. (IEI) that can generate electricity on a community scale from biomass. There are other areas of interest as well that include biomass pelletization for use as a fuel source for coal fired power plants and residential and commercial boilers.

7.0 ACKNOWLEDGMENTS

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Appendix A: ROI Calculations

UOP							
	Discount Rate	2.10%					
Year	**Outlay**	**Inlay**	**Profit**	**Total Profit**	**NPV**	**ROI**	**dROI**
0	$20,000,000	$0	($20,000,000)	($20,000,000)	N/A	N/A	N/A
1		$7,900,000	$7,900,000	($12,100,000)	($12,262,488)	-60.5%	-61.3%
2		$7,900,000	$7,900,000	($4,200,000)	($4,684,121)	-21.0%	-23.4%
3		$7,900,000	$7,900,000	$3,700,000	$2,738,373	18.5%	13.7%
4		$7,900,000	$7,900,000	$11,600,000	$10,008,201	58.0%	50.0%
5		$7,900,000	$7,900,000	$19,500,000	$17,128,502	97.5%	85.6%
6		$7,900,000	$7,900,000	$27,400,000	$24,102,353	137.0%	120.5%
7		$7,900,000	$7,900,000	$35,300,000	$30,932,765	176.5%	154.7%
8		$7,900,000	$7,900,000	$43,200,000	$37,622,688	216.0%	188.1%
9		$7,900,000	$7,900,000	$51,100,000	$44,175,013	255.5%	220.9%
10		$7,900,000	$7,900,000	$59,000,000	$50,592,569	295.0%	253.0%

UOP/Evergent							
	Discount Rate	2.80%					
Year	**Outlay**	**Inlay**	**Profit**	**Total Profit**	**NPV**	**ROI**	**dROI**
0	$40,000,000	$0	($40,000,000)	($40,000,000)	N/A	N/A	N/A
1		$13,300,000	$13,300,000	($26,700,000)	($27,062,257)	-66.8%	-67.7%
2		$13,300,000	$13,300,000	($13,400,000)	($14,476,904)	-33.5%	-36.2%
3		$13,300,000	$13,300,000	($100,000)	($2,234,342)	-0.3%	-5.6%
4		$13,300,000	$13,300,000	$13,200,000	$9,674,765	33.0%	24.2%
5		$13,300,000	$13,300,000	$26,500,000	$21,259,499	66.3%	53.1%
6		$13,300,000	$13,300,000	$39,800,000	$32,528,695	99.5%	81.3%
7		$13,300,000	$13,300,000	$53,100,000	$43,490,949	132.8%	108.7%
8		$13,300,000	$13,300,000	$66,400,000	$54,154,619	166.0%	135.4%
9		$13,300,000	$13,300,000	$79,700,000	$64,527,840	199.3%	161.3%
10		$13,300,000	$13,300,000	$93,000,000	$74,618,521	232.5%	186.5%

Rentech							
	Discount Rate	2.80%					
Year	Outlay	Inlay	Profit	Total Profit	NPV	ROI	dROI
0	$378,000,000	$0	($378,000,000)	($378,000,000)	N/A	N/A	N/A
1		$38,880,000	$38,880,000	($339,120,000)	($340,178,988)	-89.7%	-90.0%
2		$38,880,000	$38,880,000	($300,240,000)	($303,388,121)	-79.4%	-80.3%
3		$38,880,000	$38,880,000	($261,360,000)	($267,599,339)	-69.1%	-70.8%
4		$38,880,000	$38,880,000	($222,480,000)	($232,785,350)	-58.9%	-61.6%
5		$38,880,000	$38,880,000	($183,600,000)	($198,919,601)	-48.6%	-52.6%
6		$38,880,000	$38,880,000	($144,720,000)	($165,976,265)	-38.3%	-43.9%
7		$38,880,000	$38,880,000	($105,840,000)	($133,930,219)	-28.0%	-35.4%
8		$38,880,000	$38,880,000	($66,960,000)	($102,757,023)	-17.7%	-27.2%
9		$38,880,000	$38,880,000	($28,080,000)	($72,432,901)	-7.4%	-19.2%
10		$38,880,000	$38,880,000	$10,800,000	($42,934,729)	2.9%	-11.4%

Unitel							
	Discount Rate	2.80%					
Year	Outlay	Inlay	Profit	Total Profit	NPV	ROI	dROI
0	$140,000,000	$0	($140,000,000)	($140,000,000)	N/A	N/A	N/A
1		$26,180,000	$26,180,000	($113,820,000)	($114,533,074)	-81.3%	-81.8%
2		$26,180,000	$26,180,000	($87,640,000)	($89,759,800)	-62.6%	-64.1%
3		$26,180,000	$26,180,000	($61,460,000)	($65,661,284)	-43.9%	-46.9%
4		$26,180,000	$26,180,000	($35,280,000)	($42,219,147)	-25.2%	-30.2%
5		$26,180,000	$26,180,000	($9,100,000)	($19,415,513)	-6.5%	-13.9%
6		$26,180,000	$26,180,000	$17,080,000	$2,767,011	12.2%	2.0%
7		$26,180,000	$26,180,000	$43,260,000	$24,345,341	30.9%	17.4%
8		$26,180,000	$26,180,000	$69,440,000	$45,335,935	49.6%	32.4%
9		$26,180,000	$26,180,000	$95,620,000	$65,754,800	68.3%	47.0%
10		$26,180,000	$26,180,000	$121,800,000	$85,617,510	87.0%	61.2%

A Discount Rate of 2.8% was selected for a ten year time period based on OMB Circular A-94.
NPV = Net Present Value
ROI = Return on Investment, includes calculations from total profits.
dROI = discounted Return on Investment, includes calculations from NPV to account for discount rate.