Feasibility Study of Thermal Depolymerization Process

An Interactive Qualifying Project Report

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by

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1. Energy and Resources
2. Alternative Energy Technology
3. Biodiesel

Abstract

This project explores economical, governmental and technological aspects of Changing World Technologies, Inc.'s Thermal Depolymerization Process. It concludes that although this technology works, it depends heavily on government subsidies. Additionally, the potential amount of wastes to be converted will not significantly impact the U.S. energy economy. Finally, the feedstocks used for this process would negatively impact the rendering industry. We hope that this report encourages the federal government to require independent evaluations before giving subsidies to new alternative energy processes.

Table of Contents

Table of Figures

Table of Tables

1. Introduction

Crude petroleum is used to make gas, oil, asphalt, lubricants, perfumes, insecticides and plastics. Oil touches every part of our lives on a daily basis from heating to transportation to healthcare. Petroleum is our main source of energy which fuels our cars and heats our homes. Oil is a nonrenewable resource which will eventually run out leaving many without fuel and other items, such as plastics and medical supplies, that we have come to rely on.

Current predictions of world oil production peaks vary. The world peak in production which would be followed by decline in oil has been predicted to occur anytime between 2006 and 2025.[1] Any oil shortage will negatively impact the United States' economy and stability, as we saw during the 1970s oil shortage when increased oil prices caused a stall in economic growth. The need to find alternative energy sources is extremely important to maintain stability when oil production decreases so our infrastructure and economy can continue with little disruption.

Alternative energy is described as technology that is environmentally safe and not commonly used. Solar energy or photovoltaics, wind energy, and ethanol are some well known types of alternative energy. The production of methanol, hydrocarbons, and methane from biomass are other types of alternative energy. Many of these alternative energies are subsidized and funded by the U.S. government to assist in their development and implementation. However, it is difficult to determine exactly how successful and sustainable these alternative energies will be. Some people claim that alternative energy, once accepted, will be extremely profitable. Others, however, believe alternative energy is not efficient enough to decrease our oil dependency as a result of negative energy balances occurring.

As new alternative energies appear there are several questions that continuously arise about the different alternative energy industries:

1) How much of the US oil consumption can it actually replace?
2) Can it stand on its own financially without government support?
3) Is it profitable?
4) What is the government's responsibility for the start-up of these technologies?
5) What is the energy balance?

For our project, we attempted to answer these questions specifically for thermal depolymerization process, one type of alternative energy. We focused on thermal depolymerization because it uses available biomass to produce a liquid fuel that is compatible with our current infrastructure and is being commercially produced. We will compare thermal depolymerization process to thermochemical conversion of swine manure, a similar process which has promising results but is not yet commercially available.

Thermal depolymerization (TDP or TCP), a process developed by Changing World Technologies Inc. (CWT), has a fully operational plant located in Carthage, Missouri. CWT, under their subsidiary, Renewable Environmental Solutions, LLC (RES), takes turkey offal and converts it into crude hydrocarbons which produce a biodiesel for energy uses, and other by-products that have agricultural uses.[2]

Thermochemical conversion (TCC) pilot plants, which converts swine manure to oil are being prepared for commercial use on pig farms in Illinois. This process was developed by researchers at the University of Illinois and is licensed to Worldwide BioEnergy. These plants will convert swine manure into oil and other components. TCC and TDP were chosen for analysis because of the environmental and economical benefits they appear to have. In addition, the production of a synthetic crude oil would allow us to continue to use our current technology and infrastructure for cars while reducing our petroleum dependency.

The scope of this project aimed to examine the feasibility of TDP in terms of technology and economics. We analyzed the amount of the U.S. oil consumption these processes would be able to replace. We specifically inspected TDP, operated by Changing World Technologies, Inc., since it has passed the development stage and is now in commercial production. We examined Changing World Technologies, Inc. and how government subsidies, politics, and economics are affecting their business. Furthermore, other similar alternative energy processes were examined to see if they may be more economically feasible. We examined the economic aspects of alternative energy with a focus on input – output costs, government subsidies, and the effects they have on profits.

2. Background

The U.S. consumes about 7.6 billion barrels of oil a year, one billion tons of coal a year, and 674 billion kilowatts of electricity a year. We use greater than 25% of the total world oil usage.[3] In 1999, the United States produced approximately 2.3 billion barrels of oil a year, 1.1 billion tons of coal a year, and 637.7 million kilowatts of electricity.[3] In order to meet our energy needs, we must import approximately 3.7 billion barrels of oil a year.[4] Oil, in particular, is used primarily for transportation; but also in industry, heating, and for electricity. Shown below is the breakdown of the U.S. oil consumption by economic sectors.

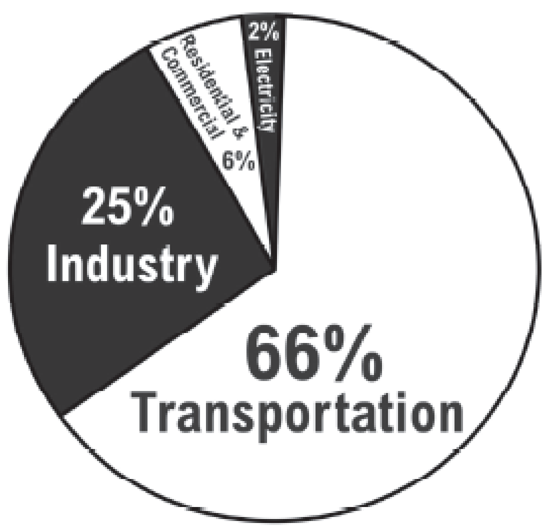

Figure 1: Breakdown of Oil Consumption by Economic Sectors in the U.S. [5]

2.1. The Oil Industry

The oil industry is one of the most profitable business sectors in the United States and the entire world. They are currently the largest business sector in the world and are valued at about $1.63 trillion.[6] The United States' gross domestic product is $12.31 trillion, and oil contributes up to 13.2% of it.[7] Because the oil industry is such a profitable part of our economy if an oil crisis were to occur it would not only affect our energy infrastructure but also our economic stability.

In the third and fourth quarters of 2006, Exxon Mobil recorded profits of $10.4 and $10.7 billion, and a total of $36.13 billion for the year, 2006.[8] In 1999, the U.S. government granted $1.7 billion worth of tax incentives to energy companies, and of that 15.8% or $263 million went to the oil industry.[9]

The price of crude petroleum sets the standard for the price of synthetic oil in order to be competitive. Oil prices are usually broken into two categories, nominal and real. The nominal value is affected by inflation and the market value, while the real value is only affected by the market value. The real price is today's standard to compare biodiesels to.[10]

2.1.1 Oil Refining

Crude oil is converted into different types of fuel and products through refining processes which consists of separation, conversion, and purification. Distillation towers are used to separate the various components of crude oil. These towers make use of the different boiling points of these components. The conversion process is mainly used to convert heavier oils into lighter oils, such as petrol. Fluidized Catalytic Crackers, Cokers, and Hydrocrackers are used to break down longer hydrocarbon chains to shorter chains. Catalytic Reformers and Alkylation are used to put together shorter chains into longer chains. Purification removes sulfur from the oil products, which is often done through a process called Hydrotreating. It is possible for bio-diesels to be refined using the current equipment used in petroleum refining.[11]

2.2 Alternative Energy Industry

2.2.1 Technologies

Thermal depolymerization is not the only technology that is available to handle biomass should there be an increase in availability. Anaerobic digestion can be used for solid wastes such as manure, waste blood, and intestinal contents. According to David Gamble of GHD, an international management and engineering consulting company, "it is a well-understood and robust technology for organic wastes generally, and can also be undertaken at a relatively small scale, which makes it technically feasible for some individual meat processing facilities to have on-site facilities, rather than have to transport wastes to centralized facilities". [12]

Anaerobic digestion is the process of natural anaerobic decomposition when the energy produced is used for power. This process can produce biogas to fuel electric generators, provide heat and produce pathogen free, soil improving material. Its feedstocks are animal manure and sewage sludge though it can process any organic material. The process includes the use of bacteria and moderate temperatures (35-70° C).[13]

Other thermochemical technologies such as gasification and pyrolysis are technically feasible, but economically challenging. Gasification and pyrolysis are in operation throughout the world for the treatment of municipal solid wastes. GHD claims that combustion, to destroy waste and produce energy, is an attractive technology if BSE, or

Mad Cow disease, concerns increase, since combustion of meat wastes have been used with coal-fired power stations and in the production of cement clinker on a large scale in Germany.

Biomass can be converted into liquid fuel by pyrolysis, an oxygen limited process. Pyrolysis works by heating up the biomass, converting much of the biomass to a gas, and then condensing this gas into a liquid fuel. The process works at temperatures of around 550°C. Currently, there are commercial pyrolysis plants in Canada (DynoMotive) and The Netherlands (BTG) but none in the United States.[14] A typical biomass liquefaction process can be seen below using pyrolysis.

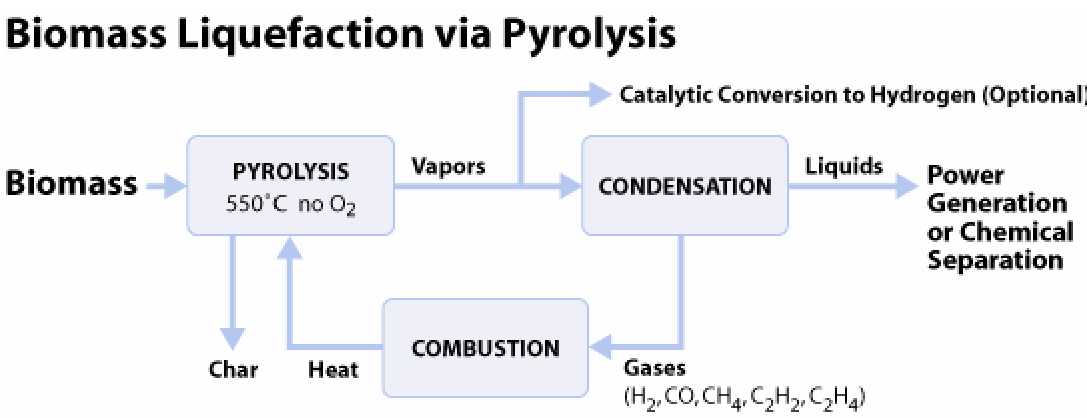

Figure 2: Pyrolysis Process[15]

Gasification is similar to pyrolysis, but oxygen is used, and the biomass is converted into a useful synthesis gas that is either burned or converted to oil in a subsequent step. This synthesis gas is made up of primarily carbon monoxide and hydrogen. Gasification is often used as a means to improve efficiency of biomass power generation, as the synthesis gas mixes well with oxygen. The simplest technique involves combining oxygen and biomass that is heated to a high temperature, 850° C. Smaller scale applications often use air instead of oxygen.[16] This process can be seen below.

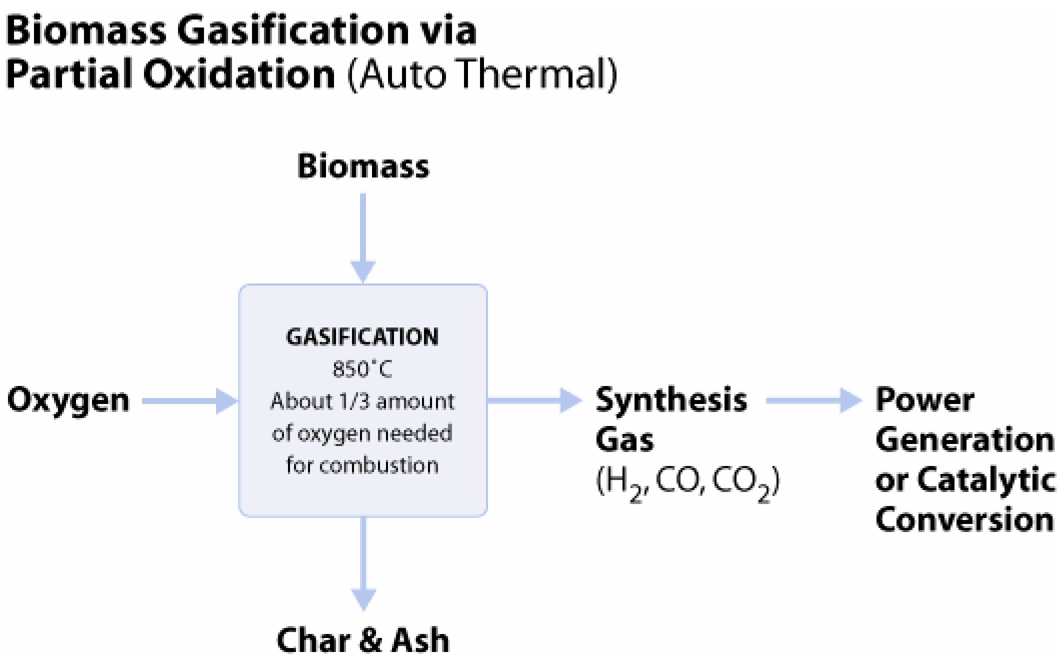

Figure 3: Gasification Process[16]

2.2.2 Economics

Alternative energy is becoming a major industry within the United States. It is estimated to be worth $70 billion in 2007, and market predictions state that the alternative energy market will grow to $93 billion by 2013. [17] The major alternative energies are photovoltaics, wind power, and biofuels. Clean Edge, a clean energy research and consulting firm predicts that the alternative energy industry will grow from "US$7 billion in 2000 to more than US$82 billion by 2010".[18] From the years 2006 – 2007, the U.S. government increased the amount of spending in renewable energies research by 33%, from $329.4 million to $494.3 million.[19] Alternative energy companies received $327 million or 20.9% of all R&D funding in 1999.[20] Congress hopes to increase the size of the global alternative energy market to $167 billion by the year 2015.[21]

There are several obstacles which the alternative energy industry faces including intangible costs, tax structures, and the expected return. For the synthetic oil companies to become profitable, they must sell their oil below the cost of comparable petroleum products and have decent profits to induce investors. For alternative energy processes to be feasible, particularly biodiesel, they must be able to compete with the oil industry. Biodiesel alternative energy companies run the risk of large oil companies dropping prices to keep synthetic oil out of the market. For this reason, alternative energies need the support of the U.S. government and consumers if they wish to become independent, profitable businesses.[22]

While there is a lot of potential for this industry, most alternative energies are not independently profitable. Most companies that are developing alternative energy are losing money due to high operating costs. Alternative energy companies must generate a profit to stay in business and improve technology. Many business analysts compare this current market to the computer market in the 1980s, when the computer industry was not profitable because there was no market for computers. Since it was such a young market no one knew what the impact would be, but people saw the potential and chose to invest.[17] Today, the computer industry is one of the strongest markets in the United States. The alternative energy market may be able to prosper like the computer industry.

However, that is dependent on the specific alternative energy technology, which we will examine in other sections.

2.2.2.1 Ethanol

Ethanol is a fuel additive that, when mixed with gasoline, decreases the pollution generated by a car. 2.8 gallons of ethanol can be produced from one bushel of corn. Investment in ethanol drastically increased in 2006.[23] As of November 2006, there are 107 grain ethanol refineries in the United States, which have the capacity to produce 5.1 billion gallons of ethanol per year.[24]

In his 2006 State of the Union Address, President Bush supported ethanol development and signed a bill into practice requiring gasoline companies to use 7.5 billion barrels of ethanol a year by 2012. Fifty-six new plants with a total capacity to produce 4 billion barrels of ethanol are being built for use in the coming years to meet this new demand.[23] Private investments in ethanol have also risen as a result of this bill. Due to supply and demand, ethanol's wholesale price has risen to about $2.75 a gallon.[25] Ethanol is currently making a $1 per gallon profit from tax credits and other government assistance. For instance, ethanol receives a $0.54 tax credit per gallon[26] so it can compete with gasoline in the transportation industry. A part of this project is to examine TDP and TCC and their economics in the same way.

2.3 Waste

2.3.1 Agricultural Waste

According to the Oak Ridge National Laboratory, the United States produces 1.4 billion tons of animal manure annually. [27] Manure is typically 85%-90% water.[28] Therefore, manure would only contain 10%-15% of viable feedstock for biodiesel production. The USDA estimates that more than 500 million tons of crop residues are produced each year. [29] However, the majority of these residues must remain in the fields for decomposition and protection of new crops limiting their potential for biofuel applications.[29]

2.3.2 Rendering

Rendering is the common practice of converting non-edible or discarded slaughtering waste into useable products. According to H.W. Ockerman et al,

> The rendering industry today produces hundreds of useful products that can be broadly classified as edible and inedible oils, chemicals, meat meals, and bone meals. These valuable products are produced from animal by-products (viscera, bones, trimmings, dead stock, or feathers) that otherwise would, for the most part, be considered waste. [30]

Some of these products are described below. Tallow, a primary rendered product, is a hard fat from cattle, sheep, or horses. Tallow typically is composed of:

- Saturated fatty acids- Palmatic acid, stearic acid, myristic acid
- Monounsaturated fatty acids- oleic acid, palmitoleic acid
- Polyunsaturated fatty acids- linoleic acid, linolenic acid[31]

Stearic acid is commonly used in rubber and tires, cosmetics, soaps, lubricants, candles, hairsprays, conditioners, deodorants, creams, food flavoring, and pharmaceutical products. Oleic acid is commonly used in foods, soft soaps, bar soaps, shampoos, hair dyes, creams, nail polish, lipsticks, liquid makeups, nasal sprays, inhalers. Linolenic acid is commonly used in paints and esters.[32]

Approximately 23.5 million tons of raw materials from ruminants, porcine and poultry are sent to renderers each year in the United States.[33] The total amount of rendered products in 2004 was 8.323 million tons.[34] A study by GHD Pty Ltd claims that the majority of agricultural waste is already used in a profitable way leaving little room for alternative energies to make use of this possible feedstock.[12]

In 2002, the rendering industry employed 9,093 people in 231 establishments. The industry, as a whole, sold $2.18 billion worth of goods. About $1 billion of materials were bought, adding $1.19 billion of value.[35] Using the cost of the materials, we can estimate the cost per ton of animal waste by dividing this by the total amount of waste (23.5 million tons). This gives us an estimated cost of $42.51 per ton. This is an estimated average since the numbers for the amount of waste and cost of materials are a few years apart.

Waste from animals represents a large amount of the agricultural waste produced. Rendered meat and bone meal is primarily used as feed for others animals. According to Cooke during the BSE Inquiry in 1998, "Rendered meat by-products have clearly been used in ruminant animal production since the first few years of the 20th century".[36] In addition, Cooke notes that "levels of up to 7.5% rendered by-products have been included in the feeding of animals, with levels even higher being documented".[36] Obviously, the use of rendered products for animal consumption has gone on for a long time, on a large scale and ending it will require major action by the government and consumers. In the U.K., Cooke states, legislation in the 1970s and 1980s was passed to test salmonella in the rendered by-products intended for animal consumption. Cooke explains that, "its use was widely researched in the UK and elsewhere and in this country its safety was regulated by legislation". When it comes to the market for these rendered products, the government has a large responsibility for its regulation and safety.

When the BSE outbreak occurred in the U.K. and Europe, the U.K. took legislative steps to address the problem. According to The Transmissible Spongiform Encephalopathies (No. 2) Regulations 2006, animal protein cannot be fed to ruminants, such as cattle or sheep, or non-ruminants, such as poultry since humans consume both.[37] A ruminant is defined as any member of the order of animals which has a stomach with four chambers. This includes cattle, buffalo, sheep, deer, elk, and antelopes, among others. However, rendered parts can be used in pet food. Because of this, the U.K.'s market for meat and bone meal (MBM) has dropped considerably creating the opportunity to use MBM for waste to energy and other technologies.

On June 5, 1997, a ruminant feed ban was introduced in the United States by the FDA.[38] The ruminant feed ban consists of a few regulations. Renderers that produce products containing protein from mammalian sources that are intended for use as animal feed, are required to label the products and maintain records necessary to track the products through distribution. Renderers are exempt from these requirements if they use an FDA validated method of deactivating the transmissible spongiform encephalopathy agent (TSE). They may also be exempt if they routinely test for the TSE agent and test negative, while maintaining testing records. Lastly, they may use an FDA validated method of controlling the manufacturing process, minimizing the risk of the TSE agent from entering the final product.[38]

2.3.3 Municipal Solid Waste

Municipal Solid Waste (MSW), or trash, consists of things that we use everyday and throw out. In 2005, the United States produced 245 million tons of municipal solid waste with 79 million tons of that waste being recycled.[39] 34.2% of this waste is paper, 11.7% is food scraps, and 5.7% is wood which may be used by the alternative energy industry as feedstock.[39]

2.4 Business

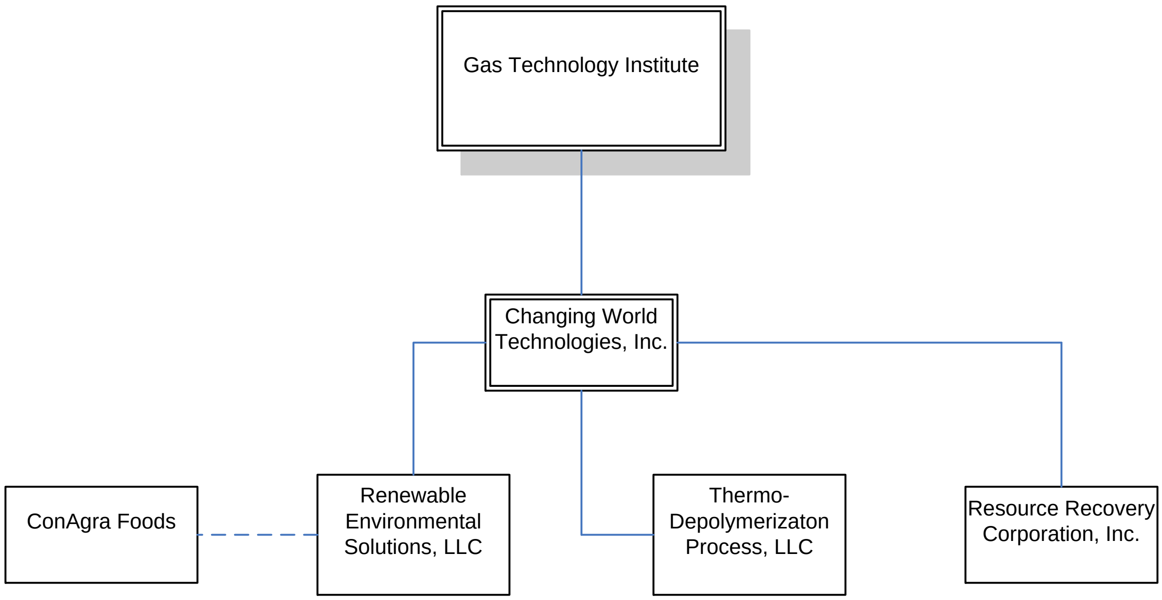

Figure 4: Flow chart of CWT business relations.

Figure 4 shows the business relationships between all the companies related to CWT. Below is the description of each:

1. Gas Technology Institute (GTI) –A not-for-profit corporation which describes itself as an independent energy technology organization. GTI developed TDP and is the parent company of CWT.[40]

2. Changing World Technologies, Inc. (CWT) – The primary company for TDP is privately owned. CWT originally partnered with ConAgra Foods for the RES facility in Carthage, Missouri.[41]

3. Renewable Environmental Solutions, LLC (RES) – Company that operates the TDP plant in Carthage, Missouri. RES is a subsidiary of CWT after ConAgra Foods withdrew investments.[41]

4. ConAgra Foods, Inc. – A multinational food processing company. ConAgra Foods sells the turkey offal to RES from a Butterball factory close by.[47]

5. Thermo-Depolymerization Process, LLC– Research and development plant of CWT. It has a small scale pilot plant for TDP in Philadelphia, Pennsylvania.[41]

6. Resource Recovery Corporation, Inc. – They hold the license for TDP and is another subsidiary of CWT.[41]

2.4.1 Gas Technology Institute

The Gas Technology Institute is a non-profit organization that is the current self-proclaimed leader in research, development, and organization of energy technologies. They research new ways of producing energy using natural gas. GTI excels at finding funding for new, promising energy technologies. GTI will often invest in a new technology with others to assist in technology development. GTI's funding comes from many sources, such as licensing fees for GTI owned technology, government subsidies and grants, and membership fees companies must pay to be part of GTI. In 2007, there were about 175 members; the membership fee is $15,000 – $100,000 per year based on the net operating income of the member. Members are primarily associated with the natural gas industry. Royalties are paid to GTI for their patents. More then 1000 patents and 500 products have been developed under GTI.[42]

2.4.2 Changing World Technologies, Inc.

CWT is a subsidiary of GTI. CWT’s goal was to develop and commercially produce TDP technology. RES was made as a joint venture subsidiary between CWT and

ConAgra to run the new Carthage, MO plant in 2000. In 2004, ConAgra was bought out of its share, and CWT now owns all of the rights to RES.[43]

2.4.3 Subsidiaries

A subsidiary is a business that is controlled by a parent company. The parent company usually holds at least 51% of the shares of the subsidiary to maintain control of the smaller company. This allows the parent company to take risks with its subsidiary that it would not normally do itself. Legally, a subsidiary is responsible should it come into any trouble and the parent company is not liable. In addition, if a company wanted to work on something privately and not release the information, then they could create a private subsidiary.[44]

2.4.4 Society for Energy and Environmental Research

Another organization involved with CWT is the Society for Energy and Environmental Research (SEER). On their website, SEER is described as:

> SEER is a not-for-profit corporation (501c3) founded in 2003 to promote the exploration, development and commercial deployment of sustainable energy technologies that lessen US dependence on foreign sources, reduce the risk of climate change and other adverse environmental conditions, and promote economic growth.[45]

The chairman of SEER is James R. Woolsey. He is a former CIA director who works to support new alternative energy technologies and reduce our dependence on foreign oil.

SEER's relationship to CWT is best described below:

> SEER was initially supported by the federal government to accelerate the deployment of a thermal (CWT-TDP) process by which organic wastes are converted to alternative energy sources such as a commercial grade of diesel fuel and commodity chemicals. A company, Changing World Technologies, Ltd, and research groups at M.I.T. and Princeton University joined us in this effort. Building from this experience, we are now expanding our efforts across a range of sustainable energy technologies and seek funding support from private foundations, corporations, and state and federal agencies.[45]

SEER has been a major supporter of CWT and has helped advance their business in Congress through testimony from James R. Woolsey.

3. Technology

3.1 Liquefaction

Thermochemical conversion (TCC) is an alternative energy method that converts waste such as wood chips, manure, plastics, and animal offal into liquid fuel and other by-products. TCC appears to be a promising form of alternative energy because it creates hydrocarbons, similar to petroleum, and other chemicals which are already used in our infrastructure. In addition, TCC is beneficial to the environment by decreasing the amount of waste in landfills.[46] TCC covers a variety of chemical processes from thermal depolymerization to pyrolysis. Two of these processes are thermal depolymerization (TDP) and TCC for swine manure.

Thermochemical conversion (TCC) is defined by Appleford et al. as "a category of chemical reforming processes in which the bonds in organic matter are broken by heat in the absence of oxygen and reformed into hydrocarbon fuels and other chemicals".[46] There are multiple types of TCC, such as pyrolysis, gasification, and liquefaction. In addition, he notes additional concerns with TCC with regards to nitrogen which can cause harmful NOx emission, energy input/output, and the quality of the products.

Changing World Technologies, Inc. (CWT) has made a process that can take any carbon based material and turn it into synthetic oil.[47] Thermal depolymerization is a process which takes offal, the inedible parts of slaughtered animals, and breaks it down into oil and other useful materials. As Appleford points out, TDP appears to be a promising technology, but there is a lack of technical information which makes it difficult to independently evaluate its validity.[46]

3.2 Thermal Depolymerization

CWT's thermal conversion was developed and tested at the Thermo-Depolymerization Process, LLC facility in Philadelphia, Pennsylvania and is in operation at Renewable Environmental Solutions, LLC plant in Carthage, Missouri. The thermal conversion process occurs in four steps – preparation stage of the feedstock, two thermal stages and a separation stage between the two. Figure 4 shows the production path of TDP. A summary of this process from the patent is as follows:

> The present invention also includes a process for converting turkey offal into a least one useful material, comprising: preparing a slurry form the turkey offal; reacting the slurry in a first reaction to produce a reacted feed comprising at least one reacted solid product, and at least one reacted liquid product, and water, wherein the first reaction additionally includes use of one or more reagents that suppress hydrolysis of carbohydrates, and encourage dissociation of amines to liberate ammonia; separating at least one reacted solid product, the water, and the at least one reacted liquid product from the reacted feed; and in a second reaction, converting the at least one reacted liquid product into a mixture of hydrocarbon oils, fuel gas, and carbon.[49]

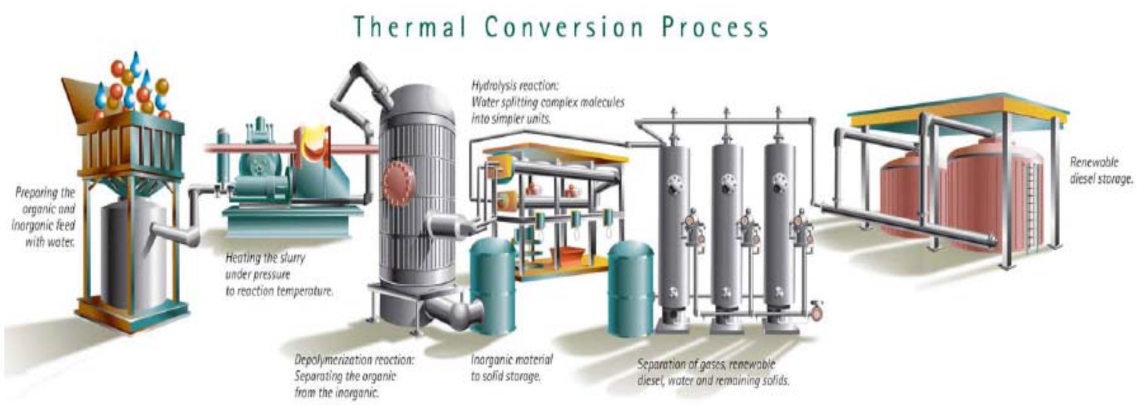

Figure 5: Path of Offal to Bio-diesel for TDP[48]

First, the feedstock is subject to a preparation stage. It is reduced in size by pulping and grinding methods. The feedstock may be any organic material. At the RES facility, the feedstock is turkey offal. However, the feedstock determines the amount of hydrocarbons and other products produced. Depending on the liquid content of the feedstock, liquid may then be added to produce a wet slurry. A wet slurry is ideal because it reduces friction and energy consumption and allows the feedstock to be easily transferred through pipes. The mix is also heated before entering the first stage reactor.[49]

The 1st stage reactor performs thermal cracking at 200 – 250°C at greater than 40 atms for approximately 5-60 minutes. Under these conditions, the first stage reaction occurs when the cell structures of the biological components are broken down and carbohydrates, proteins, fats, and nucleic acids are released. These materials will then further be broken down into their simpler parts through hydrolysis, denaturation, and other reactions. During these reactions an emulsion may form which will hinder separation and release CO_2. In order to prevent this occurrence, an oxygen scavenger such as “elemental sulfur” will be added to prevent such reactions from occurring.[49]

The pressure is then let off in 3 steps with 35% of the water flashed off. The steam is then used to heat incoming slurry. The liquid water and other solids, such as char, emulsions, and fertilizer products are then separated from the organic oil using a centrifuge and a settling tower.[50]

Then the organic liquid continues to the 2nd stage reactor where it is heated to approximately 500°C, 1-4 atms and lasts for approximately 5-120 minutes. "In the second reaction, liquor is converted to a mixture of useful materials that usually includes carbon solids, and a mixture of hydrocarbons that is typically released as hydrocarbon vapor and gases".[49] The main process that occurs during the 2nd stage is decarboxylation and some thermal cracking where gases pass through more quickly than liquids during the process. During this step, a fuel gas is produced which is used to heat the process.

Then, the hydrocarbon gases are condensed into a liquid to produce a synthetic oil. This hydrocarbon oil "typically comprises of hydrocarbons whose carbon chains have 20 or fewer carbon atoms"[49] resembling #2 grade diesel oil. However, it is important to note that the precise composition of the oil is dependent on the feedstock. In addition, all products produced are pathogen free which enables widespread agricultural applications without BSE or salmonella concerns.[49]

The products produced from TCP include "nitrogen fertilizer, mineral matrix, high BTU fuel-gas, TCP-40 oil and high purity fixed carbon".[50] The process also has an 85% energy efficiency using some of the products that are produced to provide energy for the process. Figure 5 show the energy input and output of TDP, and figure 6 shows the materials needed in the process and at which steps they are added.

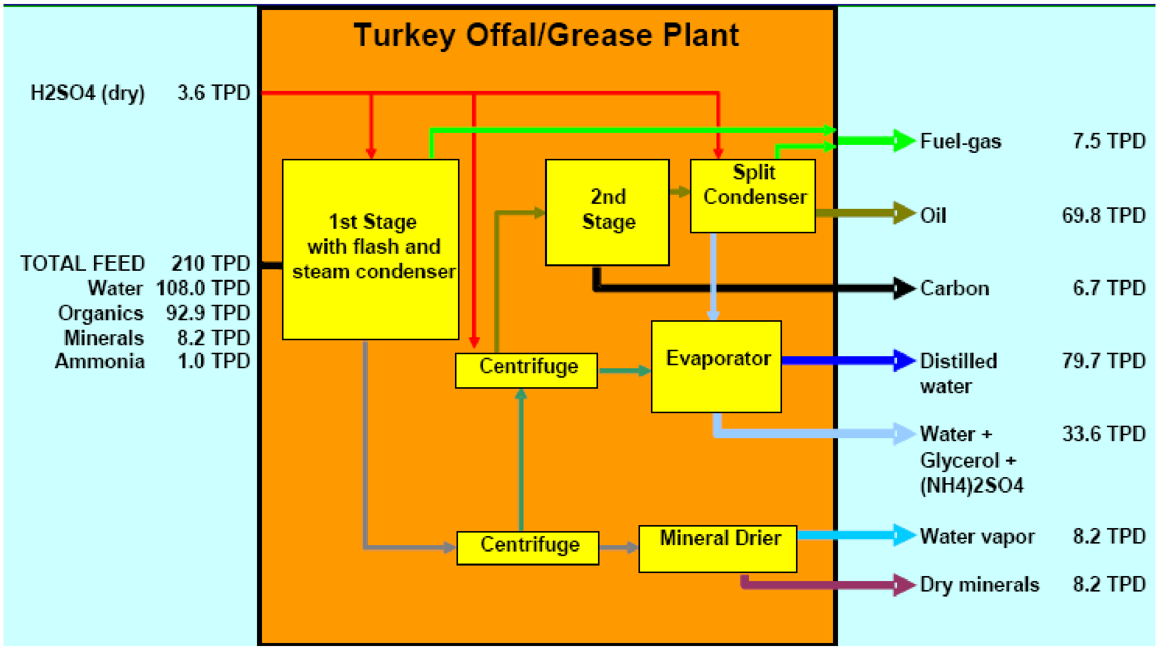

Figure 6: Beginning and End Product Values for TDP in Tons/Day.[51]

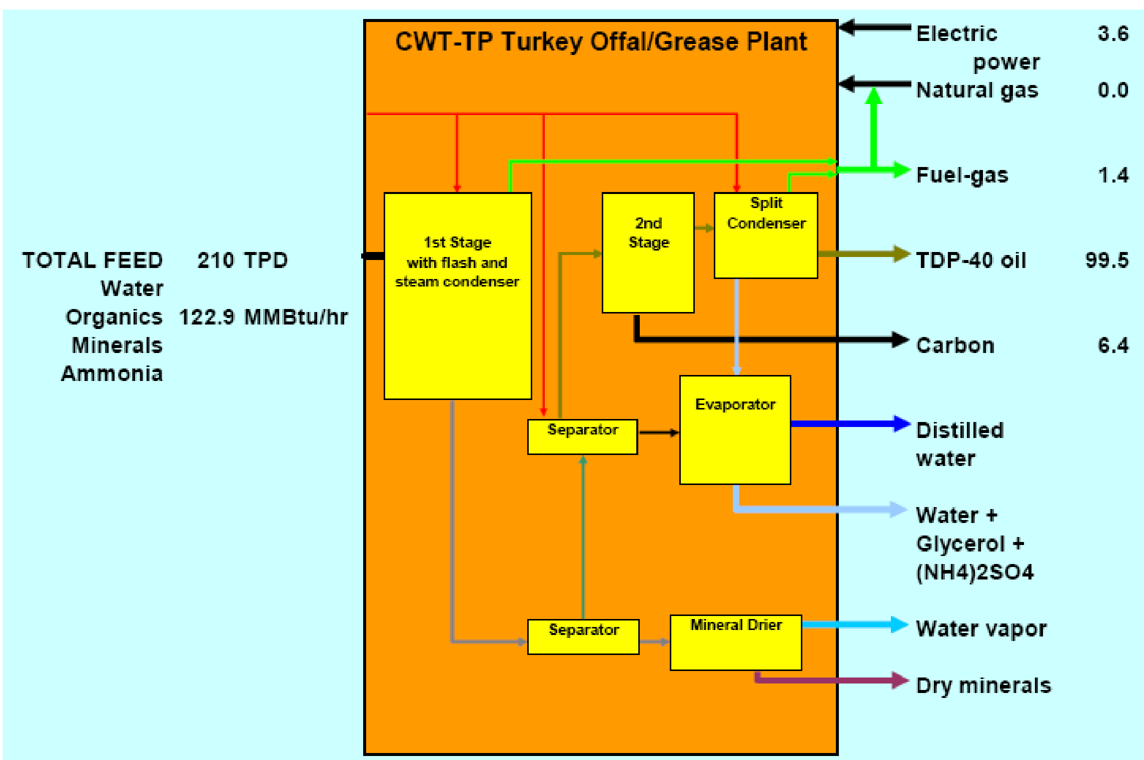

Figure 7: Energy input and output for TDP.[51]

3.3 Thermochemical Conversion of Swine Manure

CWT claims that manure can also be used in their process.[49] However, another TCC process has been used to turn manure into oil. The difference between this process and TDP was the use of one reactor instead of two and the use of carbon monoxide instead of sulfuric acid as the reducing agent. Using one reactor instead of two reactors may decrease the energy input and cost, which would increase the profitability. He et al. gave the specific breakdown of how much oil was produced and noted that every experimental group of manure is specific, with no way to standardize the amounts produced.[52] Swine manure was chosen because it is abundant in cellulose and lignin which are energy rich materials. Other manures do not contain as much of these energy rich materials, and therefore, they will produce less oil. The emphasis on the choice of manure shows that the starting product is extremely important in producing biodiesel. The conversion of the solids in swine manure to oil is between 11% and 63% for each group.[52] The variability of oil in TCC production raises questions as to whether the same variability exists for TDP.

4. Business and Government

4.1 2005 Energy Policy Act

The Energy Policy Act of 2005 gave tax credits to environment friendly energy practices. The goal of this legislation was to increase environmentally sustainable practices. Many products were given tax credits such as hybrid cars and bio-diesel fuels. Tax credits give people the incentive to use, buy, and make more energy efficient items. The $1 tax credit helped TDP biodiesel production, because it lowered the initial cost that CWT pays to produce a barrel of oil.[53] It is important for the government to assist alternative energy developers while they start up. Without the government's help, many of the companies that make these new innovations would be out of business.

4.2 Odor Problems at RES Plant

The RES plant in Carthage, MO has had many odor problems due to their duct work and the nature of the materials they deal with. The processing of turkey offal releases a very strong pungent odor that can be smelled up to a mile around the plant. In 2005, the town of Carthage had no zoning laws so the RES plant was allowed to be built near a residential area. Many people living in the area complained about the odor coming from the plant. RES was sued by the state and city for the odor problems. As part of the settlement, RES installed odor scrubbers to prevent the emissions of odor outside of the plant. Since then, RES has only been fined once for the smell, because of a malfunction of their ventilation system. Additional odor violations were found to be due to duct work, which they repaired, so there were no repercussions.[54]

4.3 Investment in CWT

One of the biggest setbacks for the future development of TDP, is the high capital investment it takes to build a new plant. It costs approximately $40 million to build the RES plant which is able to produce 200,000 barrels of oil a year, at a $4 profit per barrel from government tax credits and grants.[55] To most, this is not an attractive financial investment. Many investors believe that a plant like this would need significant government backing in order to be a wise investment. TDP is still a debated technology so investments are going to be hard to obtain if the company ever decides to go public. If CWT allowed independent companies to do research on their project then potential investments might increase in the future. However, that is dependent upon CWT's business plan and future development.

The money to fund CWT came from private investors and government grants. Some of these private investors were SEER and ConAgra Foods. Overall, $17 million has been given to CWT in federal government grant money alone up to April 2006.[55] ConAgra Foods invested $27 million into RES but was later bought out. Private investments have totaled over $100 million.[55]

4.4 Current Status of CWT

CWT did have plans to open other plants in Nevada and Colorado.[43] However, these plants never materialized. Some possible explanations are because of the budget, odor and development issues of the RES plant, the other plants were postponed. Also, some of the things that they hoped would make the plant profitable never came to fruition. For instance, they thought they would receive free turkey offal from ConAgra, but since ConAgra ended their partnership, they charge CWT $30 per ton of turkey offal.

Addtionally, CWT thought that the Mad Cow disease scare would lower the prices of other offal and end meal and bone meal production. The Mad Cow scare never became as big in the United States as in other countries, so offal is still sold at competitive prices. CWT appears to be concentrating on becoming self sufficient and improving TDP before they build more plants.[56]

TDP produces a few outputs, one of which is mineral solids that can be used for fertilizers. For every 210 tons of turkey offal, TDP will produce about 8.2 tons of minerals that can be used as fertilizer.[51] The economic feasibility of making a profit from this process includes selling both turkey oil and fertilizer. The selling price of agricultural fertilizer per ton in the U.S. ranged from $232 to $521 in April of 2006.[57] This means that for every ton of turkey offal, $9-$20 could be the expected money made from fertilizer sales. Appel states that for every 210 tons of offal yields 69.8 tons of oil. 1 ton of offal, therefore, yields 0.332 tons of oil. A ton of oil is equal to approximately 8.08 barrels of oil. So for every ton of offal, 2.686 barrels of oil are produced. In 2006, the selling price of CWT's oil is $40 per barrel[58], so approximately one ton of offal turned oil sells for $107. The sale of the fertilizer contributes an additionally small but substantial profit.

5. Analysis

5.1 Estimates of Feasibility of TDP Oil Production

Below are estimates of the amount of oil produced with different feedstocks using TDP.

5.1.1 Animal Manure

About 210 million dry tons of animal manure is produced every year (0.15*1.4 billion tons). Approximating the oil output from all of the animal manure in the United States, assuming 85% water content, and 63% conversion of the solids, one could generate approximately 132 million tons of oil. Assuming that the oil output of TCC has an API of about 40 (similar to TDP and other light crude oils), we can find the volume of oil by its density. The density of API 40 crude oil is 825kg/m^3, or 0.825kg/L,[59] and the number of gallons per barrel of oil is 42 or 158kg/barrel.[60] This equates to 1 billion barrels of oil per year from manure. The United States consumes 20.66 million barrels of oil a day,[60] meaning that oil from manure could power the United States for about 47 days in a year, or contribute to about 12% of the oil that the U.S. uses per year.

By contrast, a study done at the Haubenschild Farm processed about 20,000 gallons of manure, producing 72,500 cubic feet of biogas each day. The biogas itself contained 60% methane and 35% CO_2. This gas is burned to power a 150kW generator that runs the farm, with excess energy sold to the grid.[61] Worth noting is that the startup cost of the digester in 1999 was $355,000.[61]

The Haubenshchild Farm biogas process is economically feasible, and appears to be sustainable without government grants or subsidies:

	Haubenschild Family Farm without Digester	Haubenschild Family Farm with Digester Production Subsidies	Future Farms with Grants, Loans and Subsidies	Future Farms with Loans and Production	Future Farms, No Subsidies or Grants
Average electricity price (in current dollars), $/kwh	--	$ 0.056	$ 0.036	$ 0.036	$ 0.036
Average electricity sale price (in 2005 dollars)	--	$0.056	$0.031	$0.031	$0.031
Excess Electricity Sales	--	$39,687	$26,548	$26,548	$26,548
Gross Revenue	$3,295,492	$3,335,179	$3,321,950	$3,321,950	$3,321,950
Net Farm Income	$485,423	$509,970	$496,741	$492,315	$475,698
Interest Expense	$229,127	$229,127	$229,127	$233,554	$250,170
Total Cash Expenses	$2,589,261	$2,568,901	$2,568,901	$2,573,327	$2,589,943
Rate of Return on Assets	13.5%	13.3%	12.9%	12.9%	12.9%
Rate of Return on Equity	23.3%	23.2%	21.8%	23.7%	22.9%
Asset Turnover Ratio	37.1%	35.7%	35.5%	35.5%	35.5%

Table 1: Haubenschild Farm Anaerobic Digester Economics[62]

5.1.2 Sewage Sludge

Additionally, other wastes can be feedstocks for TDP. The amount of waste produced by humans is far less than that of manure from farm animals. The 1998 estimate of dry sewage sludge in the United States is 6.9 million tons.[63] Sewage sludge would be easier to transport than animal manure because of a somewhat centralized infrastructure, but the amount of waste is significantly smaller. Assuming that human excrement and animal manure have similar efficiencies for conversion to oil, about 30 times more oil could be made from animal manure than sewage sludge, meaning that sewage sludge could replace 0.39% of U.S. oil consumption.

5.1.3 Food Waste

Another viable feedstock for energy conversion is food waste, a significant amount of the municipal solid waste. 28.67 million tons of food scraps were produced in the U.S. in 2005.[64] Like manure, food scraps contain a large amount of water. Assuming that fresh food scraps are 80% water[65] and that 70% of the solids could be converted to oil (about the amount that is converted with turkey offal); this could create approximately 26.7 million barrels of oil in a year. Therefore, food waste conversion would contribute to about 0.35% of the U.S. consumption of oil, which is an extremely small contribution.

5.1.4 Offal

TDP produces about 69.8 tons of oil for every 210 tons of turkey offal. If all the raw material currently sent to rendering plants was used as a feedstock for TDP, we can estimate the impact. Assuming that 23.5 million tons of rendering feedstock will be converted into oil with similar efficiency to that of turkey offal, it would only amount to about 3 days of oil, or 0.75% of U.S. consumption (54 million barrels/year).

It is important to know how much these technologies could affect the U.S. dependence on oil. Since, TDP and TCC, can cover a wide range of wastes large scale production should not be an issue. Manure from farm animals is possibly the most abundant source of alternative fuel.

5.2 Estimates made by proponents of TDP

Changing World Technologies Inc., its subsidiary, Renewable Environmental Solutions LLC, and the former director of the CIA and chairman of SEER, James R. Woolsey have made numerous statements about TDP and its success. Below these statements will be examined.

5.1.1 Amount of Waste and Oil produced

Changing World Technologies, Inc., and one of their chief proponents, James R. Woolsey, estimated that TDP can convert 6 billion tons of agricultural waste to 4 billion tons of oil. This is displayed on CWT's website as follows:

> Agricultural wastes alone make up approximately 50% of the total yearly waste generation (6 billion tons) in the U.S. With the TCP, the 6 billion tons of agricultural waste could be effectively converted into 4 billion barrels of oil.[66]

In testimony before the House of Representatives, James R. Woolsey explains how these numbers were calculated:

> According to those who manage the process at the ConAgra facility, EPA estimates that there are approximately 6 billion tons of agricultural (i.e., plant and animal) waste created every year. Of course major shares of this do not need to be removed from the field as must be done with rice straw and may be left there to decompose. But the overall volume of fuel that could theoretically be produced from such waste is interesting because the amount is so large that even a small share would be significant. Discounting for 50 per cent moisture content and assuming a conservative yield of 20 per cent diesel from the rest of agricultural waste, using thermal conversion our total agricultural waste would yield nearly 11 million barrels/day.[67]

Assuming 50% moisture content, the CWT/Woolsey estimate would be 3 billion dry tons of waste. According to the EPA though, there are no current estimates for the **total** amount of agricultural waste in the United States.[68] However, the EPA and USDA jointly have estimates for **useable** agricultural, municipal, and various wood waste for use as biomass feedstock.[69] The actual yield of oil that TDP may create by taking all of the useable agricultural waste in the United States is likely to be significantly less than CWT's and Woolsey's estimates. Using the EPA and USDA estimates for individual agricultural wastes, using current practices, only about 501 million dry tons of waste is useable as a biomass feedstock.[69] The table below shows the breakdown of these wastes.

Type of Waste	*Amount (Millions of Dry Tons)*	*Reference*
Agricultural Waste		
Animal Manures and Residues[1]	60.00	69
Crop Residues	113.00	69
Animal Carcass/Meat Waste	12.08	70
Urban Wood Waste	47.00	69
Primary Mill Waste	145.00	69
Logging and Site Clearing Residues	64.00	69
Fuel Treatment to Reduce Fire Risk	60.00	69
Total Available Waste	**501.08**	

Table 2: Prediction of Available Biomass

There are three main reasons for the discrepancy between the two estimates. First, much of the current agricultural waste, such as manure and crop residues, is left on the land as a fertilizer and soil builder. This is not only convenient, but necessary for sustainable agricultural practices. Secondly, it is worth noting the limited nature of estimating agricultural waste, and the uncertainties involved. According to the California Integrated Waste Management Board,

> Quantifying the amounts and types of agricultural residues generated in each of the crop categories is extremely difficult, as it would require conducting comprehensive research throughout the state with continuous updates to the compiled data. Without ongoing data collection, any quantification estimates would only be valid for the time frame that the study was done and would be susceptible to ongoing market changes. Therefore, the quantification of agricultural residue tonnages should be viewed with these inherent limitations in mind and the tonnages quoted should not be considered absolute values.[71]

Both estimates have an uncertainty, so it is hard to determine just how much waste actually exists. Thirdly, agricultural waste is costly to collect and transport. The following table shows how much available biomass (including crop residues and forest residues) is accessible including the costs of collection and transportation.

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[1] Includes animal manures, MSW (i.e. food waste and sewage sludge), and animal fats

	< $20/dry ton	< $30/dry ton	< $40/dry ton	< $50/dry ton
Alabama	840566	6962610	10712357	17681689
Arizona	219736	575227	863091	1100491
Arkansas	402364	4092273	7085549	13604348
California	1587813	6158022	8224305	11298705
Colorado	180661	651769	3356589	3581889
Connecticut	246938	560563	610563	906309
Delaware	38959	94931	194008	461521
Florida	2761950	6753122	6778408	9533398
Georgia	934094	6390823	8540684	16111675
Idaho	204265	2572162	4117282	7165782
Illinois	435047	1038411	26838517	33359162
Indiana	347610	993684	13409571	18606863
Iowa	173802	404337	24582843	32786037
Kansas	737289	1283148	12733412	21343522
Kentucky	454699	1472165	5757811	10809048
Louisiana	516322	3568870	7976754	11834427
Maine	151358	1195597	1571597	2213697
Maryland	204643	543071	899539	1959222
Massachusetts	419272	938787	1026787	1435895
Michigan	505734	2468224	4627235	12163103
Minnesota	990517	2916529	15493892	21247327
Mississippi	598831	4908719	10673390	17930978
Missouri	477547	1345911	8029706	19522892
Montana	69060	1421766	2159358	6761444
Nebraska	114073	210121	18467094	21773296
Nevada	184112	314853	333203	336603
New Hampshire	133579	922298	1061298	2016455
New Jersey	389089	726481	791204	975806
New Mexico	167896	424160	960689	1081589
New York	1168080	3328133	3884648	8438083
North Carolina	669035	4188056	5789513	10855777
North Dakota	326510	558184	2506662	21043177
Ohio	744518	1472864	13018429	18962520
Oklahoma	111173	3873692	7816207	12699956
Oregon	192532	3341220	4126075	9809975
Pennsylvania	571963	2205605	2832294	7427043
Rhode Island	29803	80671	87671	115514
South Carolina	1293900	4468833	6332258	9368065
South Dakota	131982	285637	9601746	16005411
Tennessee	878029	3381715	10720281	15232952
Texas	1227449	4221749	13526432	20747118
Utah	158765	388275	647821	722821
Vermont	40802	392004	513004	1022669
Virginia	599454	3058757	5055411	8714941
Washington	297432	3979387	5938641	9920241

West Virginia	241236	1361393	1971651	3736487
Wisconsin	425466	2450110	11502364	14963398
Wyoming	224383	551638	787223	1465684
U.S. Total	**23820338**	**1.05E+08**	**3.15E+08**	**5.11E+08**

Table 3: Biomass Collection and Transportation Costs[72]

Most of the available crop waste/feedstock is more expensive than $30/ton. There is likely more waste than this available, but it may be too costly to obtain.

An estimate for the average cost of manure can be made by adding the value of the manure to the transportation costs. The average nutrient value of hog manure as a fertilizer is about $4.30 in Canadian dollars per ton.[73] This is equal to about $3.68 in American dollars per ton.[2] In the Broadkill Watershed in Delaware, the average transportation cost for manure within a 15-mile radius is $13.38 per ton.[74] This may be more or less than the national average, but transportation is still dependent on petroleum prices.

The CWT/Woolsey conversion appears to be oversimplified as well. A better estimated conversion can be done by separating the different types of waste, and evaluating them separately. TDP is much more efficient ton for ton with animal waste than plant waste since there is a greater fat content. The patent application for TDP contains conversion factors for turkey waste and pure cellulose.[49] According to CWT, "It is worth noting that the yields from cattle and pork processing wastes are similar to those from poultry processing waste."[49] In our results, we used the turkey waste conversion factor for all

[2] Conversion from Canadian to American dollars from:
Yahoo! Finance (2007). U.S. Dollar to Canadian Dollar Exchange Rate. Retrived January 28, 2007 from Yahoo! Web site:
http://finance.yahoo.com/currency/convert?amt=1&from=USD&to=CAD&submit=Convert.

animal wastes. Our estimate for plant wastes used only the information available from CWT for cellulosic conversion. Plant wastes typically are composed of mostly cellulose, hemicellulose, and lignin. Since there have been no published results converting hemicellulose and lignin, it is hard to determine what the actual yields will be with crop residues or wood as feedstock. In our estimates, we multiplied the published yield for the conversion of pure cellulose by the percent of cellulose contained in the type of waste. These are averages, of course.

A study of conversion of swine manure to oil was used to estimate a conversion factor for manure and animal residues. The following table shows an estimate of how much oil can be produced from available agricultural and wood wastes.

Type of Waste	*Amount (Millions of Dry Tons)*	*Amount (Millions of Wet Tons)*	*Estimated Solids Content*	*Percentage of Solids Converted to Oil*	*Tons of Oil Produced (millions)*	*Barrels of Oil produced (millions)[6]*	*Percent of National Oil Consumption[9]*	*Percent of US Oil Imports[9]*
Agricultural Waste								
Animal Manures and Residues[3]	60.00 [1]	600.00	10.00% [5]	53.80% [5]	32.28	232.42	3.08%	5.15%
Crop Residues	113.00 [1]	161.43	70.00% [6]	3.89% [7]	4.39	31.64	0.42%	0.70%
Animal Carcass/Meat Waste	12.08 [2]	23.50	51.40% [4]	64.63% [4]	7.81	56.21	0.75%	1.25%
Total Agricultural Waste	*185.08*	*784.93*	*NA*	*NA*	*44.48*	*320.26*	*4.25%*	*7.10%*
Wood/Forest Waste								
Urban Wood Waste	47.00 [1]	67.14	70.00% [6]	4.44%	2.09	15.04	0.20%	0.33%
Primary Mill Waste	145.00 [1]	207.14	70.00% [6]	4.44%	6.44	46.40	0.62%	1.03%
Logging and Site Clearing Residues	64.00 [1]	91.43	70.00% [6]	4.44%	2.84	20.48	0.27%	0.45%
Fuel Treatment to Reduce Fire Risk	60.00 [1]	85.71	70.00% [6]	4.44%	2.67	19.20	0.25%	0.43%
Total Wood/Forest Waste	*316.00*	*451.43*	*NA*	*NA*	14.04	101.11	1.34%	2.24%
Total Available Waste from this work	**501.08**	**1236.36**	**NA**	**NA**	**58.52**	**421.37**	**5.59%**	**9.35%**
Woolsey's Esitmate for Agricultural Waste[8]	**3000.00**	**6000.00**	**50.00%**	**20.00%**	**600.00**	**4149.833**	**55.04%**	**92.04%**

Table 4: Predicted Oil Conversion for TDP Feedstocks

Notes:

1. Amount of Manure, Crop Residues, and Wood/Forest Waste obtained from the Billion Ton Vision Paper from the Oak Ridge National Laboratories.[69]
2. Amount of Animal Carcass/Meat Waste was estimated by the amount of animal carcass/meat waste sent to rendering plants.[34]
3. Includes animal manures, MSW (i.e. food waste and sewage sludge), and animal fats[69]
4. Estimated Solids and Estimated Conversion for Animal carcass obtained from Adams et al.[51]
5. Estimated Manure Solids and Conversion obtained from Zhang et al.[52]
6. Estimated Wood, Paper, and Agricultural Residues Solids, along with the conversion from tons of oil to barrels of oil obtained from Oak Ridge National Laboratories.[72]
7. The estimations for the conversion of Wood, Paper, and Agricultural Residues were made by using the output from CWT's Philadelphia Plant when using pure cellulose as an input.[49]
8. Woolsey's Estimation is obtained from his testimony to the Committee on Agriculture, Nutrition and Forestry of the United States Senate, May 6, 2004.[67]
9. U.S. oil consumption and amount imported obtained from the Energy Information Administration.[4]

The conversion of animal manures and organic municipal solid waste residues will yield about 3% of our national consumption of oil. The conversion of normally rendered animal parts will yield less than 1% of our national consumption. However, this is still more than what will be produced with plant waste as a feedstock, due to its low conversion rate.

5.1.2 Bans on Meat and Bone Meal Rendering

In Europe, where the concern for preventing the spread of Mad Cow disease is much greater than the United States, there is a large profit to be made in the disposal of meat and carcass wastes. In the same testimony before the House, Woolsey stated that:

> For example, in Europe, because of concern about BSE, a negative cost ("tipping fee") of well over $100/ton is recognized for some animal carcasses, since the type of disposal now required there means that such waste cannot be used to produce feed for chickens or for other such purposes. At tipping fees of that magnitude, the thermal conversion process now used at the ConAgra's turkey processing plant and applied to cattle carcasses would produce diesel fuel that could be given away free, and the plant operators would still make a substantial profit.[67]

Using CWT's current process, one ton of turkey offal produces 2.39 barrels of oil. It costs them about $80 per barrel to produce their oil. In 2006, they were paying $30 per ton of turkey offal[55], or $12.54 per barrel of oil produced. This means that their production, maintenance, and overhead costs must be about $67.46 per barrel. However, if BSE concerns increased then a tipping fee could be established. Assuming a $100 per ton tipping fee, CWT would receive $41.79 per barrel of oil. Without government subsidies, this would still result in a $25.67 loss per barrel. Therefore, estimates in this study project a net loss compared to Woolsey's "substantial profit". The assumption was made by Woolsey that they would receive both the government subsidies for being an alternative energy as well as tipping fees from slaughterhouses.

Changing World Technologies, Inc. has stated interest in building plants in Europe because of the less competitive market for animal offal.[55] If the U.S. adapts regulations similar to those in the U.K. resulting in tipping fees, then TDP could be more feasible as well as profitable in the U.S. The $100 tipping fee would not be the case necessarily though, especially in the United States where tipping fees are already used in certain instances. In 2006, landfill tipping fees for animal carcasses are between $10 and $30 per ton in the United States which is much less than the predicted $100 per ton tipping fee.[75]

6. Conclusions

Changing World Technologies, Inc. have estimated that their thermal depolymerization process could produce 4 billion barrels of oil a year[66] for which there is no independent research to validate this statement. However, our independent study has shown that with the current technology and available raw materials only 421 million barrels of oil could be produced a year. That amount would supply approximately 5.59% of the U.S. oil consumption using our predicted conversion factors and feedstock amounts. Additionally, we were unable to determine whether the energy balance was positive for TDP which would greatly impact its future development. However, although this technology is plausible, the economics does not appear to be competitive enough with other technologies.

Other technologies appear to have a better economic outlook and results. For instance, anaerobic digestion is a well known and well tested alternative energy technology which utilizes many of the same feedstocks as TDP. It appears to be extremely promising and has been extensively researched, developed and commercially produced.

Changing World Technologies, Inc.'s business practices have had some issues. First there are concerns about the actual number of grants that CWT has received for the Carthage plant. We believe that grants amount to approximately $17 million, but we have no way to be certain. In addition, RES is generating only a slim profit as a result of tax credits from the federal government. Using our profit projections, the return on investment, or break even point, would occur in approximately 100 years because of the tax credits they are receiving. Part of the issue of CWT had, was the assumption that due to Mad Cow disease, a tipping fee would be paid to them to remove the offal. This assumption has not yet become a reality, and it has contributed to CWT's slim profit margins.

In addition, if all available animal waste and offal was processed using TDP then the economy would be affected by the closure of rendering plants. Rendering is a profitable and useful business. Renders are not paid tipping fees but are still able to generate a substantial profit. Alternatively, CWT would have to compete at market prices for offal.

7. Recommendations

Our recommendations after focusing on TDP are as follows. First, the U.S. government should force alternative energies to be independently evaluated prior to receiving government grants or tax credits. Also, these industries need to develop with the goal of self-sufficiency without government aid. In addition, the government needs to become more active in dispersing and monitoring grants to such alternative energy companies to make certain that the estimates of the technology given are indeed realistic.

TDP is one alternative energy process that needs to be independently assessed. There is a difference between a working technology and a profitable, self-sufficient technology. The primary issue that TDP faces is whether the technology is worth the price when the feedstock utilized is so limited and the amount of oil produced is so variable.

8. Appendix

-Ron Graber – 417-358-2191
-Reporter for the Carthage Press

January 13, 2007

Anthony Distefano - Hello, my name is Anthony Distefano, and I was hoping that I could ask you a few questions about the RES facility located in Carthage?
Ron Graber - Sure.

AD - Can you give me an idea on what the current public opinion is of the RES facility?
RG - There currently is a very mixed public opinion, but usually it is just the people living close to the plant that have the biggest complaints.

AD - Why do people living near it dislike it so much?
RG - The odors coming from the plant are not very pleasant.

AD - Why the plant was built so close to the homes?
RG - There are currently no county zoning areas in Carthage.

AD - Did anything happen to RES for the smells?
RG - They got fined $25000 for first offense, because it could not be justified. 2nd emission was justified, because they found cracks in a pipe that carried oxide vapors. They were required to add reinforcements to the duct work.

AD - Currently, how many people work there and how many are local residents of Carthage?
RG - 20-30 people work there, maybe about 10 local people work there.

AD - Alright, I would like to thank you for your time and help.
RG - It was my pleasure, Good Luck.

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