# Fuel and Fiber Company

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## Hemp as Biomass for Energy

### *Introduction*

Hemp advocates claim industrial hemp would be a good source of biomass to help address our energy needs. Since the oil crisis in the early seventies much work has been accomplished in the area of energy production using biomass. Biomass is any plant or tree matter in large quantity. These decades of research have lead to the discovery of several ways to convert biomass into energy and other useful products.

Questions of biomass suitability as compared to other "green" sources of energy are the subject of numerous studies and are not addressed here. Other questions concerning detailed economic and environmental impact, use of GMO's, and agronomy are also outside the scope of this analysis.

This paper does attempt to explore the options available, and outlines some of the barriers and opportunities regarding them.

### *Ways biomass can be used for energy production*

Burning:

- Co-fired with coal to reduce emissions and offset a fraction of coal use
- Burned to produce electricity
- Pelletized to heat structures
- Made or cut into logs for heating

Biomass to be burned is typically valued at $30-50 per ton, which makes whole stalk hemp as biomass to be burned impractical due to the high value of its bast fiber. One exception may be found in consideration of the latest gasification technologies used on local small scale and in remote rural applications.

- Gasification (Pyrrolysis)

Gasification uses high heat to convert biomass into "SynGas" (synthetic gas) and low grade fuel oil which has an energy content of about 40% that of petroleum diesel. By products are mostly "Char" and ash. This technology is readily available commercially in several forms and could be a viable option according to local environmental and economic conditions. Beginning in 1999, Community Power Corporation[i] joined with the US National Renewable Laboratory (NREL) and Shell Renewables, Ltd. to design and develop a new generation of small modular biopower systems. The first prototype SMB system rated at 15 kWe was deployed in the village of Alaminos in the Philippines in early 2001. The fully automated system can use a variety of biomass fuels to generate electricity, shaft power and heat.

Oils:

- Vegetable, seed and plant oil used "as-is" in diesel engines
- Biodiesel - vegetable oil converted by chemical reaction
- Converted into high-quality non-toxic lubricants

There are a number of plants high in oils, and many processes that produce vegetable oil as a waste product. These include soy, corn, coconut, palm, canola, rapeseed, and a number of other promising species. Any of these oils can be converted to biodiesel as described later, with a feedstock cost of $0 + per gallon.

## Conversion of cellulose to alcohol:

- Hydrolysis (Enzymatic & Acid)

Conversion of cellulose to fermentable glucose holds the greatest promise from both a production and feedstock supply standpoint. DOE (NREL) and a number of Universities and private enterprise have been developing this technology and achieved a number of milestones. Production estimates of 80 to 130 gallons per ton of biomass make this technology very attractive.

- Anaerobic digester (Methane)

Anaerobic digestion is used to capture methane from any waste material. It is confirmed technology under commercialization utilizing landfill gases, wastewater treatment system gases, agricultural wastes from several other sources, particularly hog and cattle manure. It is well suited for distributed power generation when co-located with electrical generation equipment. For example, Corporation for Future Resources[ii] and Minusa Coffee Company, Ltd., located near Itaipé, Minas Gerais, Brazil, have teamed to construct an anaerobic fermentation digestion facility at Minusa's coffee operation. The 600 cubic meter digester is designed to continuously produce methane rich gas, to be used for coffee drying and electric power production, as well as nitrogen-rich anaerobic organic fertilizer.

**CFR/Minusa Anaerobic digester in Brazil.**

The digester is constructed from native granite blocks quarried at the Minusa site.

This technology may be attractive in some cases when co-located with a hemp fiber processing facility or in remote locations to provide local power generation.

### *About Hemp*

Industrial hemp can be grown in most climates and on marginal soils. It requires little or no herbicide and no pesticide, and uses less water than cotton. Measurements at Ridgetown College indicate the crop needs 300-400 mm (10-13 in.) of rainfall equivalent. Yields will vary according to local conditions and will range from 1.5 to 6 dry tons of biomass per acre[iii]. California's rich croplands and growing environment are expected to increase yields by 20% over Canadian results, which will average at least 3.9 bone dry tons per acre.

### *Hemp seed oil for Bio Diesel*

#### Production of oil

Grown for oilseed, Canadian grower's yields average 1 tonne/hectare, or about 400 lbs. per acre. Cannabis seed contains about 28% oil (112 lbs.), or about 15 gallons per acre. Production costs using these figures would be about $35 per gallon. Some varieties are reported[iv] to yield as much as 38% oil, and a record 2,000 lbs. per acre was recorded in 1999. At this rate, 760 lbs.of oil per acre would result in about 100 gallons of oil, with production costs totaling about $5.20 gallon. This oil could be used as-is in modified diesel engines, or be converted to biodiesel using a relatively simple, automated process. Several systems are under development worldwide designed to produce biodiesel on a small scale, such as on farms using "homegrown" oil crops.

#### Production of Bio-Diesel

Basically methyl esters, or biodiesel, as it is commonly called, can be made from any oil or fat, including hemp seed oil. The reaction requires only oil, an alcohol (usually methanol) and a catalyst (usually sodium hydroxide [NaOH, or drain cleaner]). The reaction produces only biodiesel and a smaller amount of glycerol or glycerin.

The costs of materials needed for the reaction are the costs associated with production of hemp seed oil, the cost of methanol and the NaOH. In the instances where waste vegetable oil, or WVO, is used, the cost for oil is of course, free. Typically methanol costs about $2 per gallon and NaOH costs about $5 per 500g or about $0.01 per gram. For a typical 17 gallon batch of biodiesel, you'd start with 14 gallons of hemp seed oil; add to that 15% by volume of alcohol (or 2.1 gallons) and about 500g of NaOH. The process takes about 2 hours to complete and requires about 2000 watts of energy. That works out to about 2kw/hr or about $0.10 of energy (assuming $0.05 per kw/hr). So the total cost per gallon of biodiesel is $? (oil) + 2.1 x $2 (methanol) + $5 (NaOH) + $0.10 (energy) / 14 gallons = $0.66 per gallon, plus the cost of the oil.[v] Other costs may include sales, transportation, maintenance, depreciation, insurance and labor.

### *Hemp Cellulose for Ethanol*

Another approach will involve conversion of cellulose to ethanol, which can be done in several ways including gasification, acid hydrolysis and a technology utilizing engineered enzymes to convert cellulose to glucose, which is then fermented to make alcohol. Still another approach using enzymes will convert cellulose directly to alcohol, which leads to substantial process cost savings. Current costs associated with these conversion processes are about $1.37[vi] per gallon of fuel produced, plus the cost of the feedstock. Of this $1.37, enzyme costs are about $0.50 per gallon; current research efforts are directed toward reduction of this amount to $0.05 per gallon. There is a Federal tax credit of $0.54 per gallon and a number of other various incentives available. Conversion rates range from a low of 25-30 gallons per ton of biomass to 100 gallons per ton using the latest technology.

In 1998 the total California gasoline demand was 14 billion gallons. When ethanol is used to replace MTBE as an oxygenate, this will create California demand in excess of 700 million gallons per year. MTBE is to be phased out of use by 2003 according to State law.

In this case we can consider biomass production from a much broader perspective. Sources of feedstock under consideration for these processes are:

We will address these in turn and show why a dedicated energy crop holds important potential for ethanol production in California, why hemp is a good candidate as a dedicated energy crop, and how it may represent the fastest track to meeting 34% of California's upcoming ethanol market demand of at least 580-750 million gallons per year.[vii]

**725 MGY Ethanol Production**


### Forest Thinning and Slash, Mill Wastes

A 1999 California Energy Commission biomass resource assessment estimated 13.8 million bone dry tons (5.5 Mill, 4.5 Slash & 3.8 thinnings) are available in California.
If practiced within State & Federal regulations, use of this source can have significant beneficial effects. Removal of excess biomass from forests reduces the frequency & intensity of fires, helping control the spread of diseases, and contributes to overall forest health. At 59 - 66 gallons per ton, this could supply as much as 900 million gallons per year.

One proposed California project, Collins Pine's Chester Mill, which will contribute 20 MGY and be co-located with an existing biomass-powered 12 MW electric generator; yet, there is significant resistance to such uses by several prominent environmental groups, and for good reason - this could eventually lead to widespread destruction of forest habitat by overzealous energy companies willing to disregard the environment in the name of national energy security. Barriers also include harvest cost and capabilities as some slash & thinnings are extremely difficult to access, and the high lignin content of these materials.

**If 25% of the available material were used, about 200 million gallons per year could be produced.**

## Agricultural Waste

In California over 500,000 acres of rice are grown each year. Each acre produces 1-2.5 tons of rice straw which have been until now burned. Alternative methods of disposal are needed, and conversion to ethanol has been under development for several years. There are currently two projects underway proposing to use rice straw: one in California (Gridley) and one in Jennings, LA. If the Gridley project is fully implemented, it will add 25 million gallons of production to California's already-thin 9 million gallons per year. Barriers include collection costs and the high silica content (13%) of rice straw.

Other agricultural wastes include orchard trimmings, walnut and almond shells, and food processing wastes, for a total of about 700 MGY potential if ALL agricultural wastes were used. This is, of course, impractical, as some must be returned to the soil somehow, plus collection and transport costs will have an effect on viability of a particular waste product. Agricultural waste has the potential to satisfy a significant share of demand, with many factors to be considered when proposing a bio-refinery based on any feedstock, which are determined by full life-cycle analysis.

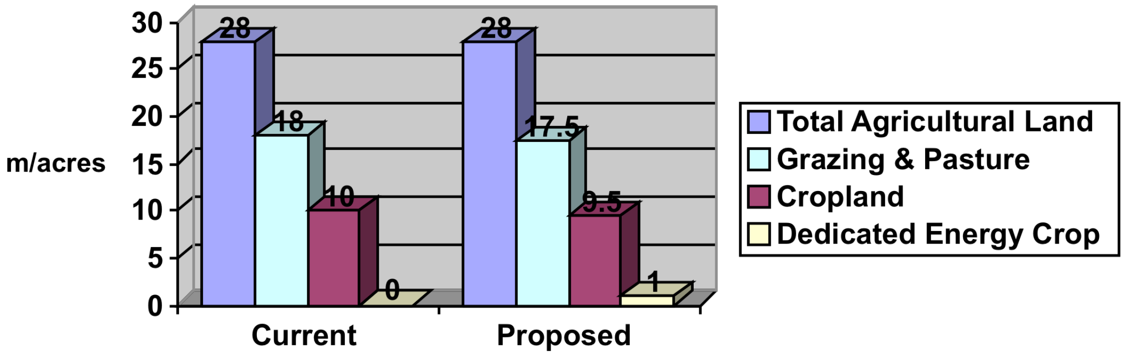
**If 25% of the available material were used, about 175 million gallons per year could be produced.**

## MSW (Municipal Solid Waste)

Though about 60% of the waste stream is cellulosic material such as yard trimmings, urban waste and paper, this source is not considered a viable option for a number of reasons; these include existing industries that recycle materials and the landfill's use of green waste as "Alternative Daily Cover" (ADC). Co-location of ethanol production is possible, but only up to about 10 MGY of production. When capital investment is considered, it is generally considered most economical to build larger capacity facilities.

**The future of MSW being used for ethanol conversion does not look good. At best, 100 MGY of capacity may eventually come online, but it will be an uphill struggle to compete with higher value uses already in place.**

California Agricultural Land




## Dedicated Energy Crops

There are 28 million acres of agricultural land in California, of which 10 million acres are established cropland. If 10% of this cropland (1 million acres) were dedicated to production of hemp as an energy and fiber crop, we could produce 150-500 million gallons of ethanol per year.

Greater estimates would result from expanding the analysis to include use of agricultural lands not currently applied to crop production as well as additional land not currently devoted to agriculture. A California Department of Food and Agriculture estimate suggests that each 1 million acres of crop production, occupying roughly 1% of the state's total land area, would supply the ethanol equivalent of about 3% of California's current gasoline demand.[viii]

## Barriers

A barrier to the development of a cellulose-to-ethanol industry is availability, consistency and make-up, and location of feedstock. Dedicated crops, such as switchgrass[ix], resolve these problems. Cannabis hemp will enhance business opportunities because we can "tailor" the cannabis plant fractions to satisfy multiple end uses such as high value composites, fine paper, nitrogen rich fertilizer, $CO_2$ , medicines, plastics, fabrics and polymers - just a portion of the many possible end uses.

## Benefits

Benefits of a dedicated energy crop include consistency of feedstock supply, enhanced co-product opportunities, and increased carbon sequestration. It is commonly held that agricultural industries must focus on multiple value-added products from the various fractions of plants. This value-adding enhances rural development by providing jobs and facilities for value-adding operations. Hemp[x] lends itself to this in a unique way due to the high value of its bast fiber. Market prices for well-cleaned, composite-grade natural fiber are about 55¢ per pound ($1,100 ton); lower value uses, such as in some paper-making, bring $400-$700 per ton, while other value-adding options, such as pulping for fine papers[xi], could increase the value of the fiber to $2,500 per ton.

### *The Fuel and Fiber Company Method*

The Fuel and Fiber Company Method[xii] employs a mechanical separation step to extract the high-value bast fiber[xiii] as a first step in processing. The remaining core material is to undergo conversion to alcohol and other co-products. There is no waste stream and the system will provide a net carbon reduction due to increased biomass production. Conversion efficiency of hemp core is relative to the lignin, cellulose and hemicellulose content and method used. The following table lists some materials often cited as potential sources of biomass and their chemical make-up. A challenge is conversion of hemicellulose to glucose; yet this challenge has been met recently by Genencor, Arkenol, Iogen, and others. These technologies provide conversion of hemicellulose and cellulose fractions to glucose using cellulase enzymes or acid.

| **Hemp** | **Cellulose** | **Hemicellulose** | **Lignin** |
|---|---|---|---|
| Bast | 64.8 % | 7.7% | 4.3 % |
| Core | 34.5 % | 17.8% | 20.8 % |
| **Soft Pine** | 44% | 26% | 27.8% |
| **Spruce** | 42% | 27% | 28.6% |
| **Wheat Straw** | 34% | 27.6% | 18% |
| **Rice Straw** | 32.1% | 24.0% | 12.5% |
| **Corn Stover** | 28% | 28% | 11% |
| **Switchgrass** | 32.5% | 26.4% | 17.8% |

Chemical composition of Industrial Hemp as compared to other plant matter

Lignin has long been viewed as a problem in the processing of fiber, and detailed studies have revealed numerous methods of removal and degradation; commonly it is burned for process heat and power generation. Advances in gasification and turbine technologies enable on-site power and heat generation, and should be seriously considered in any full-scale proposal. Additionally, by full chemical assay and careful market evaluation numerous co-product and value-adding opportunities exist. Such assay should include a NIRS (Near Infrared Reflectance Spectroscopy) analysis, with as many varieties and conditions of material as can be gathered.

Reductions in lignin achieved by cultivation and harvest techniques, germplasm development and custom enzyme development will optimize processing output and efficiency. Incremental advances in system efficiencies related to these production improvements create a significant financial incentive for investors.

The Fuel and Fiber Company Renewable Resource System will process 300,000 to 600,000 tons of biomass per year, per facility; 25% to 35% of this will be high-value grades of core-free bast fiber. The remaining 65% to 75% of biomass will be used for the conversion process. Each facility will process input from 60,000 to 170,000 acres. Outputs are: Ethanol: 10-25 MGY (Million Gallons per Year), Fiber: 67,000 to 167,000 tons per year, and other co-products; fertilizer, animal feed, etc. to be determined. Hemp production will average 3.9 tons per acre with average costs of $520 per acre.

Hemp Biomass Production Model Using the Fuel and Fiber Company Method[xiv]

| | Min | Max | Average | **Improve 20%** | **Totals** | Sell 1 | Sell 2 | Total 1 | Total 2 |
|---|---|---|---|---|---|---|---|---|---|
| Tons per Acre | 1.5 | 5 | 3.25 | 0.65 | 3.9 | | | | |
| Lbs. Bast (Separated 90-94%) | 750 | 2500 | 1625 | 325 | 1950 | 0.35 | 0.55 | $682.50 | $1,072.50 |
| Lbs. Hurd | 2250 | 7500 | 4875 | 975 | 5850 | | | | |
| Gallons Per Ton | 20 | 80 | 50 | | | $2.00 | $3.00 | | |
| **Gallons Per Acre** | | | | | **146** | 292.5 | 438.8 | | |
| Ethanol costs Per Gallon | 0.92 | 1.37 | 1.145 | | | 167.46 | 167.46 | | |
| | | | | | | | Ethanol profit | $125.04 | $271.29 |
| | | | | | | | **Gross** | **$807.54** | **$1,343.79** |
| Production Costs Per Acre | 424 | 617 | 520.5 | | | | | $520.50 | $520.50 |
| Separation costs Per Ton | 41.54 | 75.68 | 58.61 | | | | | $228.58 | $228.58 |
| | | | | | | | **Costs** | **$749.08** | **$749.08** |
| | | | | | | | Profit | $58.46 | $594.71 |
| Administrative & License % | 2 | | | | | | | $16.15 | $26.88 |
| | | | | | | | **NET** | **$42.31** | **$567.84** |
| Capacity | **Acres** | **Tons Fiber** | | | | | | | |
| 10 MGY Facility | **68,376** | **66,667** | | | | | **Annual** | **$2,893,256** | **$38,826,590** |
| 25 MGY Facility | **170,940** | **166,667** | | | | | **Profits** | **$7,233,141** | **$97,066,474** |
| Total Admin & License | | | | | | | | $1,104,333 | $4,594,167 |

Capital costs not included. Estimated capital costs are $135 to $150 million per facility, plus crop payments. To add a pulping operation will require an additional $100 million and adds $117 per ton of fiber processed for pulp, which has a market value of up to $2,500 per ton. The most conservative estimates possible were used for this study. A full-scale feasibility study is needed to validate assumptions and projections. An additional $35 per ton environmental impact benefit should also be factored into future projections[xv].