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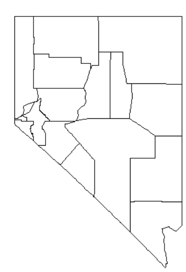
# FINANCIAL FEASIBILITY ANALYSIS OF ALTERNATIVE POTENTIAL BIOMASS BASED PRODUCTS



UNIVERSITY OF NEVADA, RENO

# FINANCIAL FEASIBILITY ANALYSIS

# OF ALTERNATIVE POTENTIAL

# BIOMASS BASED PRODUCTS

Study Conducted By

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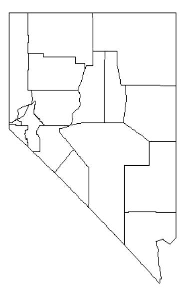

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## Table of Contents

| Chapter | Page |
| --- | --- |

## List of Tables

## Forward

The following economic analysis is incorporated into the larger study administered by the tri-county development authority which culminated in the paper, *Summary of Tri-County Pre-Commercial Analysis for Converting Wastes to Marketable Products.* It was submitted to the Western Area Power Administration, May 15, 1996.

The economic analysis provided in this paper id highly dependent on the process parameters supplied by the chemists and engineers working on process developments. Actual application parameters can be expected to vary. In terms of biomass feedstock, none of the hypothetical applications parallel exactly the situation faced in the tri-county area. This analysis effort stands to be criticized within the feedback loop of communication between all parties. Analysis involves communication between those knowledgeable in all aspects of a course of action. In the case of physical production parameters, empirical analysis of an actual facility would be preferred over the hypothetical estimates provided. Such are not available. It must be remembered however, that even empirical observations of past performance do not provide perfect information upon which to base future actions. As a scientific document, everything herein is open to question. The nature of this work is forward looking. Future market situations cannot be observed, but must be inferred from information available. The analysis provides the best possible estimates given the data and time constraint faced, and of course our skill as researchers. It is hoped that this study will prove to be helpful in furthering the economic development and bettering the quality of life in the tri-county area and beyond. We look forward to the information that comes with criticism stimulated by this analysis and apologize in advance for any omissions or errors found herein.

## Background

The analysis is based on the preliminary research conducted by Matt Frohlich and Gail Monk in their study, *Tri-County Pre-Commercial Analysis of Converting Wastes to Marketable Products*, done in conjunction with Tri-County Development Authority. A large volume of biomass waste is generated by agriculture and associated food processing industries in the tri-county area of northern Nevada comprised of Pershing, Humboldt, and Lander counties. In addition, two prolific noxious weeds, tall white top and tamarisk, were identified as potential sources of biomass material. Frohlich and Monk researched costs of harvest, collection and transportation and estimated biomass inventories by type and location. Current and potential future restrictions on burning of agricultural waste and rising costs of alternative disposal methods provided much of the impetus for the initial study. Recognition of waste biomass as a potential economic resource provided further incentive for the study.

The economic success of crops dedicated to biomass production in other geographic regions indicated to researchers that waste biomass generated in the tri-county area had the potential of being economically utilized. Tall white top growth rivals the production of dedicated biomass crops in other regions on a ton per acre dry basis. Research goals were to identify the barriers to economic use of the locally generated biomass and to examine ways to overcome them. The final objective of this study was to identify potential ways of utilizing biomass waste in the manufacture of value-added products which would generate an economic return great enough to defray disposal costs or overcome them while increasing local economic activity.

The Frolich and Monk study identifies many of the parameters used in this financial analysis. As in that study, biomass waste is viewed as a product or commodity rather than a firm level waste disposal problem. The possibilities of efficiencies resulting from operating two or more enterprises in tandem and/or simultaneously as an integrated system are also discussed. With this current economic feasibility analysis, the scope of the study is expanded to include municipal solid waste (MSW) and sewage sludge in the pool of biomass materials.

Frolich and Monk researched value-added processes utilizing waste biomass along four lines, energy generation for the local power grid, processing into chemical products, use as material for manufactured products, and space heating. Some of the proposed uses were not immediately practical options. Prices for electricity in the tri-county area are generally low due to

excess capacity. Proposed future interstate wholesaling of electrical power may have an effect on this situation in the near future. Frolich and Monk ruled out power generation for the local grid in the initial study however due to the current situation. There does not appear to be enough grain straw material generated in the tri-county area to attain the minimum economies necessary to produce paper under existing technology. Water constraints also promise to be a factor in the papermaking process. Paper manufacture from grain straw and other processes such as making wallboard with compressed grain straw and making compressed biomass pellets for mine reclamation from alfalfa straw were also temporarily put aside. Changes in factors such as market conditions for waste disposal services, energy, and potential products, and new developments in technology, will have implications for further study.
Immediate possibilities were narrowed down to:

1) Altering the available biomass through various pyrolysis processes to produce fuels and/or industrial chemicals as either commodities for market or for direct use in space heating applications,
2) utilizing the biomass as filler in polypropylene-biomass composite material.

It was speculated that using waste heat in applications such as green houses, fish production, or other space heating applications may capture further economies.

## Pyrolysis of Biomass

Pyrolysis is broadly defined as chemical decomposition of a material brought about by heat. Many pyrolysis methods were preliminarily examined. Nomenclature for the various pyrolysis systems appears to be somewhat arbitrary and can be confusing. In "selling" their technologies, the entrepreneur-scientists seem to differentiate their products via a name game. There are systems with very similar names, which may be quite different in application, and there are systems with very different names which may be quite similar to the examples in this report. Frolich grouped the various methods of pyrolysis into three categories based on feedstocks, operation and products. Each process presents specific advantages and limitations in the context of the tri-county study. Frolich postulated that the three processes might be integrated to utilize the advantages and to overcome the limitations found in the individual processes.  He identified examples of each larger process category.  The examples used are:

1) Thermochemical Conversion,

2) Rapid Thermal Pyrolysis, and

3) Thermal gasification for immediate combustion.

Analysis of biomass pyrolysis was hampered by a lack of information on the actual individual systems, variation in biomass feedstocks, the experimental nature of the processes and products, and uncertain markets for products.  In many cases, actual specifics necessary to make an in-depth and accurate analysis are guarded by system developers.  Much of the analysis is based on hypothetical plants.  All of the processes themselves however, are proven in either laboratory “bench model” sized plants, small commercial sized experimental pilot plants, or in the case of thermal gasification, a full sized plant.  Even in the case of thermal gasification, analysis is based on many hypothetical parameters.  Thermochemical conversion and rapid thermal pyrolysis systems of the capacities and exact configurations analyzed are not in existence.  It is extremely important to note that the financial feasibility analyses are dependent on theoretical scale adjustments on the part of chemists, engineers, and economic researchers.  Such preliminary assumptions must be kept in mind when examining the financial analysis.  Biomass source material also can have a profound effect on the overall viability of a given process.  The analysis is based on processes utilizing biomass similar to that available in the tri-county area, however the chemical composition of biomass in the tri-county area and process yields in terms of product mix, quality and quantity require more in-depth analysis.  All of the processes analyzed must be characterized as experimental and supplied data must be regarded as suspect and subject to change.  The actual market prices for products are subject to fluctuations and are generally uncertain.  The analysis is intended as a general framework for further study.

## Cost of Biomass Materials

In the following analysis, costs of biomass material are varied from a high cost scenario of $30/ton to a low cost scenario of a negative $30/ton. The high end cost assumption represents grain straw which would cost about $30/ton delivered with a small return to the grower. Frolich and Monk feel from talking with growers that this is the current economic threshold cost of straw but warn that others have estimated the economic threshold at over $40 per ton. The $30/ton price for biomass is also comparable to the estimates provided by Frolich and Monk for harvesting and delivering tall white top and tamarisk within the tri-county area. The $10/ton cost of biomass material represents the approximate delivered cost of feedlot manure. A zero cost for material was included as a baseline for analysis. Negative costs for waste biomass reflect the possibility of collecting a tipping fee for disposal. The negative $10/ton figure might be representative of some easily separated faction of municipal solid waste (MSW) such as yard and garden refuse. A tipping fee of $30/ton would be representative of MSW in the event of forced hauling to the Lockwood, Nevada refuse disposal site becomes a reality.

In all pyrolysis scenarios involving MSW some recovery of recyclable materials would be necessary and probably add to the feasibility of the process. Waste paper recovered from the MSW waste stream is included as a material for processing in the analysis of the thermochemical process. This material however, is much more valuable under current market conditions and technologies for its fiber content than for processing.

## Plant Size

There are two methods of increasing plant capacity. First, bigger reactors may be used. Second more than one reactor may be run in parallel. Most technology developers and design engineers are working towards modular designs for flexibility in size. Assuming a gain in efficiency with increased reactor size to a point and then diminishing efficiencies thereafter, plant capacities would likely depend on identifying and utilizing the most efficient sized modules for each given process. This assumption presents a “step function” scenario for plant sizes in general.

## Thermochemical Conversion of Biomass

Thermochemical conversion involves acid hydrolysis of biomass with heat in a two step process. The most attractive aspect of this process is that it utilizes wet biomass in the form of a slurry which will allow it to utilize wet biomass directly without a drying process. The process is also adaptable to a wide variety of waste biomass materials including waste paper "mud," sewage sludge, municipal solid waste (MSW), manures, agricultural byproducts and more. Another advantage of this process is that it simultaneously produces several desirable chemical products in one process. The mix of the products varies with the biomass feedstock and the operation of the system. The process produces intermediary materials with a wide range of uses, which may present a more favorable market situation than other processes producing a more limited material or product.

The thermochemical conversion system studied was developed by Biofine Inc. The technical paper *The Thermochemical Conversion of Cellulosic Waste to High Value Chemicals and Fuel Additives* by Stephen W. Fitzpatrick of Biofine Inc., is the basis for financial analysis. The paper provides pro forma financial estimates for three plant sizes of 250, 5,000 and 250,000 tons of biomass input per year dry basis. The capital costs are based on a feasibility study done for Biofine Inc. by Badger Engineering of Cambridge MA. The paper emphasizes the need to build a small-scale plant in the 250 tons per year range to prove the technology.

Dramatic economies of size are assumed by Fitzpatrick in his economic analysis of the three hypothetical facility capacities. The biomass available in the tri-county area while much less than the 250,000-ton capacity of the larger plant in the Fitzpatrick paper, is much more than the 5,000 tons of biomass per year capacity of the facility analyzed. With a larger facility there could be economies realized which would dramatically alter the estimates of the analysis.

There could be some possible economies realized by integrating a thermal-chemical conversion plant with a sewage processing facility. Sewage sludge does not appear economically feasible under the product mix and yield assumed in the analysis without a tipping fee. Cost analysis of current sewage handling processes and anticipated future costs of treatment might reveal some economic possibilities. Further integrating might include a greenhouse operation and/or a fish farm or other space heating utilization. The extensions of the analysis though logical are somewhat premature and would require further analysis.

**Product Market**

Market prices for the chemical products resulting from this process were difficult to identify. Price assumptions were necessary to proceed with the analysis. The focus of the process was on the production of levulinic acid. Levulinic acid is an intermediary chemical from which other chemical commodities are produced. An attempt was made in the analysis to associate the assumed prices for levulinic acid with prices of the other chemicals for which it is an intermediary. Price assumptions were based on information found in the Fitzpatrick paper. Fitzpatrick identifies the critical price for levulinic acid as a feedstock in the production of diphenolic acid as being $1.50/lb. Levulinic acid is also an intermediary in the production of methyl tetrahydrofuran (MTHF). Based on Fitspatrick's figures of $0.04/lb to process levulinic acid further to the fuel additive MTHF which can substitute up to 70% for gasoline a rough estimate of levulinic acid value as a fuel extender was made of $0.10/lb. Analysis at this price for all scenarios showed negative returns. The use of MTHF as an additive is based more on air pollution regulation requirements than its relative value as a fuel however, so a mid range figure of $0.75 was used for illustration purposes in the analysis.

Three other chemical products resulted from the Biofine process, formic acid, furfural, ($C_5H_4O_2$, also known as furfuraldehyde) and high lignin ash. Fitzpatrick identifies the "merchant" market price of formic acid as $0.08/lb. and a "market" price of $0.50/lb. Fitzpatrick identified the market price for furfural as $0.70/lb. No "merchant" market price was identified. Very little information could be found on this chemical product. It is probably generous to allow $0.10/lb for the furfural product. The value of this component of the product mix is vague at best. A value for high lignin ash was not included as it was considered consumed in the process.

Undoubtedly there is a large difference between what a producer can sell chemical commodities for and what end users pay for them. Chemicals have special handling and storage requirements. Regulations add to the cost of handling chemicals on the part of brokers, transporters, wholesalers, retailers and others along the market channel.

**Parameters of the Analysis**

Major parameters taken directly from or based on estimates found in *The Thermochemical Conversion of Cellulosic Biomass to High Value Chemicals and Fuel Additives*, a paper by

Stephen W. Fitzpatrick, published in Proceedings: 1st Biomass Conference of the Americas August 1993, pp. 1385-1408, are as follows:

- Capital investment of $8,000,000 required
- An expense of $30,000 annually on chemicals & miscellaneous materials
- 5,000 ton/year dry basis biomass capacity
- 8,000 hours of operation per year
- Maintenance cost of $240,000 per year
- Annual utilities cost of $553,600
- Annual labor costs of $360,000
- Taxes and insurance expense of $100,000/year
- Administrative and general expense of $240,000 annually

Table 2.1. provides detail of the estimated cost structure for a thermochemical conversion facility under the above assumptions. No cost for biomass material is included in the table. A 20-year plant life is assumed. Depreciation is straight line with a 10% salvage value assumed.

Different biomass materials have different product yields. Table 2.2. provides a comparison of product yields from different biomass feedstock materials processed while Tables 2.3 through 2.6 depict a variety of price and cost combinations for the hypothetical plant. The paper wastes appear financially more viable than the other biomass materials. Wood chips are next in indicated potential with sewage sludge estimated as least economic. “Waste paper” is paper separated from MSW while the “paper mill waste” is “mud” residue from the paper milling process. In Table 2.5., with a $1.50/lb. price for levulinic acid, the highest price used in the analysis and under the assumption of a $30/ton cost of biomass material, the highest cost assumed for biomass, all of the biomass sources are estimated to provide positive net returns over costs. Plant life is also varied between 10 and 20 years.

Sewage sludge is known to be a negative value material. Currently the value of sewage sludge is unknown but with a negative cost of $30/ton and a price of $1.50 for levulinic acid, the sewage biomass material presents positive estimated returns and financial viability.

**Table 2.1 Cost Structure of Hypothetical Thermochemical Plant**

| | |
|---|---|
| Annual Hours of Operation | 8,000 |
| Life in Years of Plant | 20 |
| Biomass in Tons/year | 5,000 |
| | |
| Capital Investment | $8,000,000 |
| Depreciation Straight line SV = 10% | $360,000 |
| | |
| Chemicals & Miscellaneous Materials | $30,000 |
| Utilities | $553,600 |
| Labor | $360,000 |
| Maintenance | $240,000 |
| Insurance & Taxes | $100,000 |
| General Administrative | $240,000 |
| | |
| Annual Operating Costs | $1,523,600 |
| Cost of biomass material/ton dry mass | $0 |
| Total Biomass cost/year | $0 |
| Total Annual Costs | $1,883,600 |

Source: Fitzpatrick, Stephen W. “The Thermochemical Conversion of Cellulosic Biomass to High Value Chemicals and Fuel Additives”

Table 2.2 Product Mix for Various Biomass Feedstocks

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Yield in Percent of Weight | | | | |
| Levulinic Acid | 25.0% | 25.0% | 45.0% | 45.0% |
| Formic Acid | 7.5% | 10.0% | 19.5% | 17.5% |
| Fufural | 15.0% | 0.0% | 0.0% | 0.0% |
| Ash | 12.5% | 0.0% | 12.5% | 12.5% |
| Production in Pounds per ton of Biomass Feedstock | | | | |
| Levulinic Acid | 500 | 500 | 900 | 900 |
| Formic Acid | 150 | 200 | 390 | 350 |
| Fufural | 300 | 0 | 0 | 0 |
| Ash | 250 | 0 | 250 | 250 |
| Annual Production (lbs.) | | | | |
| Levulinic Acid | 2,500,000 | 2,500,000 | 4,500,000 | 4,500,000 |
| Formic Acid | 750,000 | 1,000,000 | 1,950,000 | 1,750,000 |
| Fufural | 1,500,000 | 0 | 0 | 0 |
| Ash | 1,250,000 | 0 | 1,250,000 | 1,250,000 |

Source: "The Thermochemical Conversion of Cellulosic Biomass to High Value Chemicals and Fuel Additives." by Stephen W. Fitzpatrick of Biofine, Inc. 70 Walnut St. Wellesley, MA 02181.

## Table 2.3 Financial Analysis at $30/ton Cost for Biomass Feedstock

Assuming the Following Product Prices:

| | Price Received per Pound |
|---|---|
| Levulinic Acid | $0.75 |
| Formic Acid | $0.08 |
| Furfurol | $0.10 |
| Ash | $0.00 |

20 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $360,000 | $360,000 | $360,000 | $360,000 |
| Biomass Material Cost | $150,000 | $150,000 | $150,000 | $150,000 |
| Annual Return Above Costs other than Depreciation | $411,400 | $281,400 | $1,857,400 | $1,841,400 |
| Net Annual Return | $51,400 | ($78,600) | $1,497,400 | $1,481,400 |
| | | | | |
| Payback Period Analysis | 155.64 | N/A | 5.34 | 5.40 |
| Simple Rate of Return SRR | 0.643% | -0.983% | 18.718% | 18.518% |
| Net Present Value NPV | (4,378,605) | (5,485,368) | 7,932,008 | 7,795,791 |
| IRR | 1.09% | N/A | 22.88% | 22.67% |

10 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $720,000 | $720,000 | $720,000 | $720,000 |
| Biomass Material Cost | $150,000 | $150,000 | $150,000 | $150,000 |
| Annual Return Above Costs other than Depreciation | $411,400 | $281,400 | $1,857,400 | $1,841,400 |
| Net Annual Return | ($308,600) | ($438,600) | $1,137,400 | $1,121,400 |
| | | | | |
| Payback Period Analysis | N/A | N/A | 7.03 | 7.13 |
| Simple Rate of Return SRR | -3.858% | -5.483% | 14.218% | 14.018% |
| Net Present Value NPV | (5,163,690) | (5,962,484) | 3,721,354 | 3,623,040 |
| IRR | N/A | N/A | 19.70% | 19.46% |

Source: “The Thermochemical Conversion of Cellulosic Biomass to High Value Chemicals and Fuel Additives.”

Table 2.4 Financial Analysis at $10/ton Cost for Biomass Feedstock

Assuming the Following Product Prices:

| | Price Received per Pound |
|---|---|
| Levulinic Acid | $0.75 |
| Formic Acid | $0.08 |
| Furfurol | $0.10 |
| Ash | $0.00 |

20 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $360,000 | $360,000 | $360,000 | $360,000 |
| Biomass Material Cost | $50,000 | $50,000 | $50,000 | $50,000 |
| Annual Return Above Costs other than Depreciation | $511,400 | $381,400 | $1,957,400 | $1,941,400 |
| Net Annual Return | $151,400 | $21,400 | $1,597,400 | $1,581,400 |

| | | | | |
|---|---|---|---|---|
| Payback Period Analysis | 52.84 | 373.83 | 5.01 | 5.06 |
| Simple Rate of Return SRR | 1.893% | 0.268% | 19.968% | 19.768% |
| Net Present Value NPV | (3,527,249) | (4,634,012) | 8,783,365 | 8,647,148 |
| IRR | 3.07% | 0.46% | 24.18% | 23.97% |

10 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $720,000 | $720,000 | $720,000 | $720,000 |
| Biomass Material Cost | $50,000 | $50,000 | $50,000 | $50,000 |
| Annual Return Above Costs other than Depreciation | $511,400 | $381,400 | $1,957,400 | $1,941,400 |
| Net Annual Return | ($208,600) | ($338,600) | $1,237,400 | $1,221,400 |

| | | | | |
|---|---|---|---|---|
| Payback Period Analysis | N/A | N/A | 6.47 | 6.55 |
| Simple Rate of Return SRR | -2.608% | -4.233% | 15.468% | 15.268% |
| Net Present Value NPV | (4,549,234) | (5,348,027) | 4,335,810 | 4,237,497 |
| IRR | N/A | N/A | 21.20% | 20.96% |

Source: "The Thermochemical Conversion of Cellulosic Biomass to High Value Chemicals and Fuel Additives."

Table 2.5 Financial Analysis at $30/ton Cost for Biomass Feedstock

Assuming the Following Product Prices:

| | Price Received per Pound |
|---|---|
| Levulinic Acid | $0.75 |
| Formic Acid | $0.08 |
| Furfurol | $0.10 |
| Ash | $0.00 |

20 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $360,000 | $360,000 | $360,000 | $360,000 |
| Biomass Material Cost | $150,000 | $150,000 | $150,000 | $150,000 |
| Annual Return Above Costs other than Depreciation | $2,286,400 | $2,156,400 | $5,232,400 | $5,216,400 |
| Net Annual Return | $1,926,400 | $1,796,400 | $4,872,400 | $4,856,400 |

| | | | | |
|---|---|---|---|---|
| Payback Period Analysis | 4.15 | 4.45 | 1.64 | 1.65 |
| Simple Rate of Return SRR | 24.080% | 22.455% | 60.905% | 60.705% |
| Net Present Value NPV | 11,584,327 | 10,477,564 | 36,665,286 | 36,529,069 |
| IRR | 28.41% | 26.74% | 65.40% | 65.20% |

10 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $720,000 | $720,000 | $720,000 | $720,000 |
| Biomass Material Cost | $150,000 | $150,000 | $150,000 | $150,000 |
| Annual Return Above Costs other than Depreciation | $2,286,400 | $2,156,400 | $5,232,400 | $5,216,400 |
| Net Annual Return | $1,566,400 | $1,436,400 | $4,512,400 | $4,496,400 |

| | | | | |
|---|---|---|---|---|
| Payback Period Analysis | 5.11 | 5.57 | 1.77 | 1.78 |
| Simple Rate of Return SRR | 19.580% | 17.955% | 56.405% | 56.205% |
| Net Present Value NPV | 6,357,373 | 5,558,579 | 24,459,268 | 24,360,954 |
| IRR | 26.01% | 24.13% | 65.01% | 64.81% |

Source: "The Thermochemical Conversion of Cellulosic Biomass to High Value Chemicals and Fuel Additives."

Table 2.6 Financial Analysis at $30/ton Cost for Biomass Feedstock

Assuming the Following Product Prices:

| | Price Received per Pound |
|---|---|
| Levulinic Acid | $0.75 |
| Formic Acid | $0.08 |
| Furfurol | $0.10 |
| Ash | $0.00 |

20 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $360,000 | $360,000 | $360,000 | $360,000 |
| Biomass Material Cost | ($150,000) | ($150,000) | ($150,000) | ($150,000) |
| Annual Return Above Costs other than Depreciation | $2,586,400 | $2,456,400 | $5,532,400 | $5,516,400 |
| Net Annual Return | $2,226,400 | $2,096,400 | $5,172,400 | $5,156,400 |

| | | | | |
|---|---|---|---|---|
| Payback Period Analysis | 3.59 | 3.82 | 1.55 | 1.55 |
| Simple Rate of Return SRR | 27.830% | 26.205% | 64.655% | 64.455% |
| Net Present Value NPV | 14,138,396 | 13,031,633 | 39,219,355 | 39,083,138 |
| IRR | 32.20% | 30.57% | 69.15% | 68.95% |

10 Year Useful Facility Life

| Biomass feed stock | Wood Chips | Sewage Sludge | Waste Paper | Papermill Waste |
|---|---|---|---|---|
| Cost of Operation and Maintenance | $1,523,600 | $1,523,600 | $1,523,600 | $1,523,600 |
| Depreciation | $720,000 | $720,000 | $720,000 | $720,000 |
| Biomass Material Cost | ($150,000) | ($150,000) | ($150,000) | ($150,000) |
| Annual Return Above Costs other than Depreciation | $2,586,400 | $2,456,400 | $5,532,400 | $5,516,400 |
| Net Annual Return | $1,866,400 | $1,736,400 | $4,812,400 | $4,796,400 |

| | | | | |
|---|---|---|---|---|
| Payback Period Analysis | 4.29 | 4.61 | 1.66 | 1.67 |
| Simple Rate of Return SRR | 23.330% | 21.705% | 60.155% | 59.955% |
| Net Present Value NPV | 8,200,743 | 7,401,949 | 26,302,638 | 26,204,325 |
| IRR | 30.24% | 28.42% | 68.82% | 68.95% |

Source: "The Thermochemical Conversion of Cellulosic Biomass to High Value Chemicals and Fuel Additives."

**Comments on Thermochemical Conversion of Biomass**

The addition of MSW and/or sewage sludge to the biomass inventory identified by Frolich and Monk, would indicate a much larger facility. In the event that MSW and sewage sludge is considered for this process, economies of size would be expected.

Market prices for individual output components can have drastic impacts on the overall feasibility of establishing and operating a plant. For instance, green biomass sources containing hemicellulose yield the furfural product. These would include the tall white top and tamarisk sources postulated by Frolich and Monk. There is no hemicellulose in paper. No furfural content in output from processing sewage sludge was identified in the Fitzpatrick paper either. A favorable market price above the $0.10/lb. used in the analysis could change the feasibility outlook considerably for green biomass materials. Feasibility is highly dependent on the market prices of all chemical products.

## Rapid Thermal Processing of Biomass Materials

This is just one of many terms used to describe a rapid or fast pyrolysis system. “Ablative Fast Pyrolysis,” the nomenclature used by developers at MEETECH / NREL, is of this category. The term “ablative” means roughly “separation from source”. It appears that developers use the term “ablative” when describing systems utilizing vortex separators. Several fast pyrolysis systems were examined in the preliminary research. The analysis of this process category takes into consideration; a paper by D. Andrew Himmelblau of Biocarbons Corporation in Woburn, MA, titled *Phenol-Formaldehyde Resin Substitutes from Biomass Tars*; a report by Smith, Grahm, and Freel of Ensyn Technologies Inc. of Glouchester, Ontario, Canada titled *The Development of Commercial Scale Rapid Thermal Processing of Biomass*; and a paper titled *MSW and Biomass to Liquid Fuels by Packaged Liquefaction Plants* by H. S. Joyner et. al. of the University of Arizona, Tucson, Arizona. The Himmelblau system was chosen as representative of this process category. Financial analysis relies almost exclusively on the Himmelblau paper. The Himmelblau process does not utilize a vortex separator.

Fast pyrolysis of biomass is still in the developmental and experimental stages. Ensyn Technologies currently has a 25 ton per day plant operating in Wisconsin producing a smoke-flavoring compound. Troubles have apparently been encountered in the latest efforts to scale up at least one of the vortex systems to a commercial size pilot plant. The University of Arizona is continuing to make progress in their pyrolysis research. Biocarbons Corporation is currently operating a "bench" sized plant with a 3 inch reactor which processes up to 20 lb./hr of biomass feedstock to produce a substitute for phenol-formaldehyde (PF) resin which is used to glue exterior plywood and other building panels together. Analysis was based on the Biocarbon Corp. process due to the potential of a high value product with an expanding market and availability of information.

The president of Biocarbons Corporation, Andrew Himmelblau estimates that a commercial plant capable of processing 200 tons per day would require a reactor 8 feet in diameter, and a reactor large enough to provide necessary resin samples for testing and certification would need to be 18 inches in diameter and capable of processing up to 700 lb. of biomass/hr. In conversations, Mr. Himmelblau indicates that his system is about three years away from commercial application.

For analysis purposes the Himmelblau plant was scaled down to a production size more suitable for the tri-county area. Most capital costs were scaled down using a factor of 0.50. Exceptions were land costs, estimated at 0.20 times the Himmelblau figure of $50,000 and instrumentation costs, which were not reduced. Land prices are much lower in the rural tri-county area than in most of the U.S. and a scale-down in plant capacity does not translate into a scale-down in the amount of required instrumentation.

The hypothetical Himmelblau plant was a 200 ton/day facility (17.5% moisture content = 165 ton/day dry basis). This was adjusted to a 75ton/day (dry basis) facility. Since 0.5 * 165 = 82.5 ton/day there is some margin built into the 75 ton/day figure which would allow for inefficiencies which may occur at the smaller scale. In the Himmelblau analysis wood is received green at a 50% moisture content, dried to 17.5% moisture and then fed into the process.

**Product Market**

The market situation looks favorable with demand predicted to grow relative to supply. Large trees suitable for plywood are becoming scarce relative to demand. Oriented strand board, and/or building panels made from wood chips, require more adhesive per panel. For these reasons demand for adhesive is growing faster than demand for panels. The price of conventionally produced PF compound varies. Actual price for conventionally produced PF material used in the manufacture of adhesives is $0.35 to $0.40 per pound. Himmelblau expects the price at which adhesive manufacturers would substitute bio-oil in a 50/50 mix with PF resins made conventionally is around $0.20 /lb. According to Himmelblau conventional facilities are producing at 98% capacity.

As in the other pyrolysis studies, prices for products were difficult to identify. A $0.20/lb. price for bio-oil was used as a lowest price scenario. This price floor might be higher than would actually exist depending on the quality of bio-oil produced and unforeseen market factors. The highest price used in the analysis was $0.237. Using the highest cost assumption of $30/ton for biomass feedstock the $0.237 price was found to be the minimum price necessary to yield a positive net present value (NPV) with an assumed discount rate of 10%. Each $0.01 fluctuation in price received for bio-oil represents $134,853 in annual revenue.

**Annual Costs**

Electric power and labor costs were assumed to be the same for the 75-ton/day plant as for Himmelblau's hypothetical 165-ton/day plant. It was reasoned that a similar amount of lighting and motor operation would be needed in a smaller plant and a similar number of tasks would also be performed. In these cost categories then, a higher per unit cost structure is assumed for the analysis than might actually be expected.

Cost of maintenance was figured at 0.06 times the capital cost of the plant. Insurance and taxes were estimated at 0.025 times the capital investment. Finally a general and administrative cost was added in this analysis of 40% of the operating costs consisting of the sum of power, labor, and maintenance costs. This should be a sufficient margin to cover the costs in this category under most circumstances. However, legal fees resulting from litigation over environmental and perceived environmental problems could require more spending in this area rather than less.

**Parameters of the Analysis**

A table providing details of the capital costs for a hypothetical 200 ton/day plant (165 ton/day dry basis) estimated by Himmelblau, the capital requirements estimated for the hypothetical 75 ton /day facility analyzed, and the factors used to scale down the plant size from a 165 to 75 tons per day dry basis operation is included in Appendix 2. Major parameters of the analysis are as follows:

- Capital investment of $4,350,000 required.
- 75 ton/day dry basis biomass capacity.
- 7,884 hours of operation per year.
- 20 year useful plant life.
- 547.35 lb. of bio-oil produced for each ton of biomass processed.
- Maintenance cost of 6% of estimated initial capital investment.
- Electric power costs of $30.568 per hour of operation.
- Labor costs of $103.374 per hour of operation.
- Annual taxes and insurance of 2.5% of estimated initial capital investment.
- Administrative and general expense of 40% of the cost of operation.

Price paid for biomass material and prices received for bio-oil product were varied with respect to the above assumptions. Five situations are presented in Table 3.1. which provide financial analysis of the hypothetical plant under the following conditions:

- $30 cost per ton for biomass material and a $0.237 price for bio-oil produced.
- $10 cost per ton for biomass material and a $0.20price for bio-oil produced.
- $0 cost per ton for biomass material and a $0.20 price for bio-oil produced.
- Negative $10 cost per ton for biomass material and a $0.20 price for bio-oil produced.
- Negative $30 cost per ton for biomass material and a $0.20 price for bio-oil produced.

In situation #1, a cost of $30/ton is assumed for biomass material and a market price is assumed for bio-oil of $0.237/lb. This price for bio-oil under the given assumptions is just enough to yield a positive net present value (NPV) at a 10% discount rate. The break-even price required for bio-oil for a positive net cash flow was estimated at $0.214/lb. This corresponds to a simple rate of return (SRR) of zero. The internal rate of return (IRR) of 10.03% at the $0.237 price/lb. is seen to be slightly larger than the discount rate of 10% due to rounding the bio-oil price to three digits.

In situation #2 the price received for bio-oil is assumed to be $0.20/lb. and the cost of feedstock is assumed to be $10/ton. In this situation there exists a positive net annual return on the investment.  The IRR of 9.854% is below the assumed 10% discount rate, which is reflected, in the negative NPV.

Situation #3 looks at the hypothetical plant with a zero cost of biomass inputs and $0.20/lb. price received for bio-oil product.  NPV is positive at the 10% discount rate with an IRR of 16.369%.

In the event that tri-county area municipalities are forced to truck municipal solid waste (MSW) to distant landfills, (a very real potential situation) some percentage of material in the form of yard waste could be easily separated out of the waste stream, (this is happening in large cities already) and a tipping fee could be charged for disposing of these materials locally. Situation #4 might represent this situation with a negative $10/ton cost of material.  Price received for bio-oil is held at $0.20/lb in this hypothetical scenario.   Under this set of assumptions the facility is financially viable by all indicators with a positive NPV at the 10% discount rate and an IRR of 22.42%.

Finally a negative cost of $30/ton is examined under the $0.20 price assumption for bio-oil produced in situation #5.  This is currently the highest alternative disposal cost identified.  The $30/ton cost of disposal is a rough estimate of disposal cost of waste hauled to the landfill facility in Lockwood, Nevada.  In this situation the IRR is estimated at over 34% for the tri-county area processing facility.

**Comments on Rapid Pyrolysis of Biomass**

Both the capital and operational requirements for “Feed preparation and drying” may prove much less costly than estimated.  Himmelblau’s estimates were based on wood chips with a 50% moisture content reduced by a drier to 17.5% moisture content.  Grain straw and other wastes in the tri-county area will not need as much preparation and drying.  Suitability of tri-county area biomass is yet to be determined for this process.  There is a substantial amount of margin built into the analysis but it must be remembered that these are estimates based on estimates.

The process as examined shows much promise.  Himmelblau estimates that a 165-ton/day facility (dry basis) would require an eight-foot diameter reactor.  The analysis he presents is based on a three-inch diameter scale model. This illustrates one of the many liberties that have been taken with the analysis. Assumptions and limitations of the analysis must be kept in mind.

Himmelblau stated that economics is most dependent on cost of feedstock. It can be expected however that yields and quality of bio-oil would be different for different feedstock. Product consistency is an important aspect of certification for use in adhesive applications and may be dependent on feedstock. In the case that the bio-oil is not suitable for blending with conventional PF material for adhesive manufacture, a further process can break out the phenol and aldehyde components to be marketed separately. Further analysis would be required at a later state of process development prior to actually investing in a facility of this type.

Fast pyrolysis of biomass material can be used to produce products other than the PF substitute bio-oil product portrayed in this analysis. Pyrolysis processes in this category can also produce bio-oil as fuel. This end-product probably has the lowest value of the product options identified. Bio-oil or more commonly, biodiesel is being studied both as an alternative to diesel fuel and in blends with diesel fuel due to its favorable environmental qualities relative to diesel. (See, “Life-Cycle Costs of Alternative Fuels: Is Biodiesel Cost Competitive for Urban Buses?” *Industrial Uses of Agricultural Materials Situation and Outlook Report,* USDA Economic Research Service, September, 1995) At this time it does not appear that bio-diesel will become price competitive with diesel manufactured from crude oil in the near future.

As with the other pyrolysis process categories, economies might be realized through integration with other production or waste handling functions. A materials recovery system, green house operation , and possibly a hazardous waste disposal system might add to the economic potential of this biomass conversion process.

**Table 3.1 Hypothetical 75 Ton/Day Facility Producing Phenol-Formaldehyde Resin Substitute (Himmelblau)**

| | Situation #1 | Situation #2 | Situation #3 | Situation #4 | Situation #5 |
|---|---|---|---|---|---|
| Capital Investment | $4,350,000 | $4,350,000 | $4,350,000 | $4,350,000 | $4,350,000 |
| Depreciation straight line SV = 10% | $195,750 | $195,750 | $195,750 | $195,750 | $195,750 |
| Hours of operation/year | 7,884 | 7,884 | 7,884 | 7,884 | 7,884 |
| Days of operation/year | 329 | 329 | 329 | 329 | 329 |
| Life in years of plant | 20 | 20 | 20 | 20 | 20 |
| Biomass ton/day dry basis | 75 | 75 | 75 | 75 | 75 |
| Biomass in tons/year | 24,638.00 | 24,638.00 | 24,638.00 | 24,638.00 | 24,638.00 |
| Oil Production/ton of dry biomass | 547.35 | 547.35 | 547.35 | 547.35 | 547.35 |
| Percent by weight | 27.4% | 27.4% | 27.4% | 27.4% | 27.4% |
| Oil produced/24 hr day in lbs | 41,051 | 41,051 | 41,051 | 41,051 | 41,051 |
| Total production/year bio oil in pounds | 13,485,336 | 13,485,336 | 13,485,336 | 13,485,336 | 13,485,336 |
| Electric power | $241,000 | $241,000 | $241,000 | $241,000 | $241,000 |
| Labor | $815,000 | $815,000 | $815,000 | $815,000 | $815,000 |
| Maintenance | $261,000 | $261,000 | $261,000 | $261,000 | $261,000 |
| Insurance & Taxes | $108,750 | $108,750 | $108,750 | $108,750 | $108,750 |
| Admin & General | $526,800 | $526,800 | $526,800 | $526,800 | $526,800 |
| Annual Cost of Operation | $1,952,550 | $1,952,550 | $1,952,550 | $1,952,550 | $1,952,550 |
| Product Price Assumptions | | | | | |
| Price/lb for bio oil as PF substitute | $0.237 | $0.20 | $0.20 | $0.20 | $0.20 |
| Value of Production | $3,196,025 | $2,697,067 | $2,697,067 | $2,697,067 | $2,697,067 |
| Biomass Cost Assumptions | | | | | |
| Cost of biomass material/dry ton | $30 | $10 | $0 | ($10) | ($30) |
| Total material cost | $740,250 | $246,750 | $0 | ($246,750) | ($740,250) |
| Cost of Operation | $1,952,550 | $1,952,550 | $1,952,550 | $1,952,550 | $1,952,550 |
| Materials cost/year | $740,250 | $246,750 | $0 | ($246,750) | ($740,250) |
| Annual costs other than depreciation | $2,692,800 | $2,199,300 | $1,952,550 | $1,705,800 | $1,212,300 |
| Depreciation | $195,750 | $195,750 | $195,750 | $195,750 | $195,750 |
| Total Annual Costs | $2,888,550 | $2,395,050 | $2,148,300 | $1,901,550 | $1,408,050 |
| Income/year | $3,196,025 | $2,697,067 | $2,697,067 | $2,697,067 | $2,697,067 |
| Revenue above costs other than depreciation | $503,225 | $497,767 | $744,517 | $991,267 | $1,484,767 |
| Revenue net of all costs including depreciation | $307,475 | $302,017 | $548,767 | $795,517 | $1,289,017 |
| Interest Rate | 10% | 10% | 10% | 10% | 10% |
| Payback period analysis | 14.1 | 14.39 | 7.93 | 5.47 | 3.38 |
| Simple rate of return (SRR) | 7.09% | 6.95% | 12.62% | 18.28% | 29.61% |
| Net present value (NPV) @10% Interest Rate | $8,472 | ($44,375) | $2,053,154 | $4,150,683 | $8,345,742 |
| Internal rate of Return (IRR) | 10.03% | 9.85% | 16.37% | 22.42% | 34.02% |

## Thermal Gasification

Thermal gasification of coal has been utilized since the 1800's or before with some biomass gasification also taking place. In this respect gasification systems are not experimental. However, technologies of the process itself, as applied to biomass, boiler technologies, and biomass harvesting technologies have changed much with time. As with the other pyrolysis processes studied, technological changes often have profound effects on the economic feasibility of this method of biomass utilization. Technologies relating to other substitute energy sources, transportation, biomass production and disposal costs, and other factors also act upon the economic feasibility of this process. Economics came into play when thermal gasification was replaced with relatively cheaper petrochemical energy sources in the first part of this century. The same forces could work to make gasification of biomass economically viable as costs for biomass feedstock fall and petrochemical prices climb.

Financial analysis is based on an actual application of this technology in Rome, Georgia. The Rome application involved retrofitting an existing boiler system for a 650-bed hospital. The unit is operated during the entire year for heating, laundry services, and air conditioning (via an absorption unit). Peak demands require the part-time use of another boiler.

The Georgia facility is operated exclusively on wood chip fuel, which is received at 45 to 50 percent moisture levels. The wood chips are dried by the circulation of pyrolysis gases through the unit. A feedstock of straight grain straw would present a different situation. Conversations with people in the field indicate that drier feedstock is a plus. A closer look needs to be taken at available biomass feedstock, grain straw, alfalfa straw, manure, MSW, and potential blends. Handling, preparation, and performance of feedstocks available in the tri-county area would present a different set of costs per BTU for operation of a gasifier system.

Differences in costs per BTU between conventional fuels and proposed biomass fuels are used to estimate the financial feasibility of such a system in the tri-county area. Analysis is made on a marginal basis. Assuming that a facility would require a boiler for a heating and cooling system and that there are no differences in costs of operation or maintenance of the system itself from those of operating a conventional oil or natural gas system, then the differences in costs of operation would be found in the costs of delivering bio-gas fuel on a BTU basis versus the delivered price of natural gas. Financial analysis is presented in Table 4.1. Table 4.2 presents the cost per million BTU for biogas for a range of biomass costs. The per ton equivalent values of biomass based on a range of prices for natural gas are also provided in Table 4.2.

The actual gasification plant must be within 100 feet of the burners to minimize condensation of the gasified tars, which would clog the system. A three-day on-site supply of biomass fuel is also considered a minimum. In the Georgia application the transfer of biomass to the gasifier is fully automated. The physical location of the plant and a fuel storage hopper would require a given square footage of space not otherwise devoted to a heating system. Construction of the Rome, Georgia facility cost under $400,000. It is not known if this includes an allowance for the additional square footage but most likely does not.

Square footage in the communities of the rural Tri-county area does not command the high prices of comparable space in more urban settings. For longer-term storage requirements, relatively low land values in outlying areas and an arid climate, would contribute to keeping storage costs of biomass feedstock supplies to a minimum.

Table 4.1 Analysis of Retrofitting an Existing Boiler System with a Biomass Gasification System

| Capital Investment Required | |
|---|---|
| Retrofit Boiler for Biogas | $400,000 |

| Annualized Cost of Retrofit | |
|---|---|
| Life in years | 20 |
| Salvage Value | 0 |
| Cost per year | $20,000 |

| Economic Comparison Natural Gas – Biogas on BTU Basis | |
|---|---|
| Natural gas cost/million BTU | $2.00 |
| Equivalent cost of biomass/ton @ 8,000,000 BTU/ton | $16.00 |
| | |
| BTU/ton of Biomass | $8,000,000 |
| Cost per ton of Biomass | $10 |
| Cost/million BTU | $1.25 |
| | |
| Price Difference per Million BTU | 0.75 |
| Million BTU Used to Cover Capital Depreciation | 26,667 |
| Annual Tons Biomass Used to Break Even | 3,333 |
| Tons Used per Day at Break Even | 9.13 |
| Use by Rome GA Hospital in tons per day | 74.4 |
| Use by Rome GA Hospital in tons per year | 27,156 |

| Potential Savings | |
|---|---|
| Per Day | $48.95 |
| Annual | $17,867.00 |
| | |
| Total Savings over Life of Investment (Nominal) | $357,340 |
| Discount Rate | 7.00% |
| NPV (Discounted Savings) | $189,283 |

Based on assumption of 8,000,000 BTU/ton of biomass. This is a conservative figure and will vary.
Actual BTU's per ton dry basis for alfalfa chaff, grain straws and tall white top are from 14,000,000 to 15,000,000

Table 4.2 Cost Comparisons of Biogas and Natural Gas

Costs/million BTU of Biogas at Various Biomass Costs

| | | | |
|---|---|---|---|
| BTU/ton of Biomass | 8,000,000 | 8,000,000 | 8,000,000 |
| Cost per ton Biomass | $10 | $20 | $35 |
| Cost per Million BTU | $1.25 | $2.50 | $4.38 |

Equivalent Costs @ 8,000,000 BTU/ton yield of Biomass

| | | | |
|---|---|---|---|
| Natural Gas Cost/Million BTU | $2.00 | $3.00 | $4.00 |
| Equivalent Cost of Biomass/Ton<br>(8,000,000 BTU/ton basis) | $16.00 | $24.00 | $32.00 |

Based on assumption of 8,000,000 BTU/ton of biomass. This is a conservative figure and will vary.
Actual BTU's per ton dry basis for alfalfa chaff, grain straws and tall white top are from 14,000,000 to 15,000,000

**Biomass Fiber as Filler in Polypropylene Plastic**

The one process identified as potentially feasible in the immediate future involves a composite product developed by the USDA forest product development labs. The process combines finely ground biomass with polypropylene up to 50% by weight and possibly more. In this process a percentage of relatively expensive plastic resins are replaced by inexpensive biomass fillers and desirable properties such as increased rigidity and weight reduction are gained in the finished products.

This use of waste biomass appears to be an immediately viable economic use for at least some of the biomass generated in the tri-county area. Grain straw, mint straw, and possibly alfalfa straw would be suitable for this use at the present. Barriers to the use of alfalfa straw would include phytosanitary concerns of disease, insect pests, and the presence of noxious weed seeds as well as concerns about pesticide residues. Grain straw from this area of Nevada is generally free of contamination. At this time feedlot manure is not considered as suitable bio fiber for this use.

Financial analysis is based on the following key assumptions supplied by Integrated Resource Development:

- Capital investment of $1,250,00,
- Cost of recycled polypropylene material $0.10 per pound
- Production rate of 4,000 lb. of product per hour
- Cost of operation and maintenance of $0.05 per pound of product.
- Virgin polypropylene stock cost of $0.26 per pound.
- Cost of straw filler $.03 per pound.

Based on these figures and other assumptions of the analysis, the use of bio-fibers as filler in polypropylene product to produce a composite material appears to be economically viable. The analysis involves the manufacture of polypropylene-biofiber composite pellets suitable as feedstock for extrusion molding. Tables 5.1 and 5.2. provide details of the financial analysis of the hypothetical plant. The useful plant life was pegged at both five and ten years to accommodate obsolescence risk prevalent in the plastics industry environment. The composite pellets are expected to be utilized in a wide array of products, which would displace current plastic products as well as substitute for wood and metal applications.

**Comments on the Biofiber-Polypropylene Product**

Given the assumptions used in the analysis, the potential of producing a composite polypropylene-biomass product looks good. The use of waste bio fiber as filler in plastic products however is not without risk. The plastics industry is a very dynamic quick changing industry with many product applications and a large degree of substitutability between plastic materials made from different resin compounds. Currently, economics is acting to encourage substitution of plastics in many applications, which formerly utilized wood and metals. Competition with other producers, substitute materials, and macro-economic uncertainties all act to introduce uncertainty into the equation. Based on the potential financial savings of the composite product over a straight polypropylene resin product, and given the structural benefits of adding biofiber to make a composite material, incentive appears to be in place for further market development.

Financial estimates are based on the assumption that product will be sold at the given price and quantity. The current market situation is promising yet unknown.

**Table 5.1 Financial Analysis of Polypropylene-Biomass Process Using Post Consumer (Recycled) Polypropylene**

| | 10 Year Plant Life | 5 Year Plant Life |
|---|---|---|
| Capital Investment | $1,250,000 | $1,250,000 |
| Production per Hour (lbs) | 4,000 | 4,000 |
| Cost of Operation and Maintenance/lb | $0.05 | $0.05 |
| Cost of Polypropylene/lb | $0.10 | $0.10 |
| Cost of Straw/lb | $0.03 | $0.03 |
| Hours of Operation/year | 4,000 | 4,000 |
| Life in Years of Plant | 10 | 5 |
| Interest Rate | 10.00% | 10.00% |
| Selling Price/lb | $0.25 | $0.25 |
| Percent Polypropylene (by weight) | 50% | 50% |
| Percent Bio-filler | 50% | 50% |
| Total Production/year (lbs) | 16,000,000 | 16,000,000 |
| Total Income/year | $4,000,000 | $4,000,000 |
| Straw Used (lbs) | 8,000,000 | 8,000,000 |
| Straw Used (tons) | 4,000 | 4,000 |
| Tons of Straw per Hour | 1 | 1 |
| Annual Depreciation (SL w/10% S.V.) | $112,500 | $225,000 |
| | | |
| Materials Cost per lb. | $0.07 | $0.07 |
| Total Cost of Materials/yr | $1,040,000 | $1,040,000 |
| Cost of Operation and Maintenance | $800,000 | $800,000 |
| Total Variable Costs | $1,840,000 | $1,840,000 |
| General and Administrative Expenses | $320,000 | $320,000 |
| Annual revenue minus annual costs (not including depreciation) | $1,840,000 | $1,840,000 |
| Annual revenue minus all annual costs including depreciation | $1,727,500 | $1,615,000 |
| | | |
| Payback Period Analysis | 0.68 | 0.68 |
| Simple Rate of Return SRR | 138.20% | 129.20% |
| Net Present Value (NPV) | $10,104,196 | $5,802,663 |
| IRR @ 5 yr life 4,000 hr operation/yr | | 145.72% |
| IRR @ 10 year life 4,000 hr operation/yr | 147.18% | |

**Table 5.2 Financial Analysis of Polypropylene-Biomass Process Using Virgin Polypropylene Resin**

| | 10 Year Plant Life | 5 Year Plant Life |
|---|---|---|
| Capital Investment | $1,250,000 | $1,250,000 |
| Production per Hour (lbs) | 4,000 | 4,000 |
| Cost of Operation and Maintenance/lb | $0.05 | $0.05 |
| Cost of Polypropylene/lb | $0.26 | $0.26 |
| Cost of Straw/lb | $0.03 | $0.03 |
| Hours of Operation/year | 4,000 | 4,000 |
| Life in Years of Plant | 10 | 5 |
| Interest Rate | 10.00% | 10.00% |
| Selling Price/lb | $0.25 | $0.25 |
| Percent Polypropylene (by weight) | 50% | 50% |
| Percent Bio-filler | 50% | 50% |
| Total Production/year (lbs) | 16,000,000 | 16,000,000 |
| Total Income/year | $4,000,000 | $4,000,000 |
| Straw Used (lbs) | 8,000,000 | 8,000,000 |
| Straw Used (tons) | 4,000 | 4,000 |
| Tons of Straw per Hour | 1 | 1 |
| Annual Depreciation (SL w/10% S.V.) | $112,500 | $225,000 |
| | | |
| Materials Cost per lb. | $0.15 | $0.15 |
| Total Cost of Materials/yr | $2,320,000 | $2,320,000 |
| Cost of Operation and Maintenance | $800,000 | $800,000 |
| Total Variable Costs | $3,120,000 | $3,120,000 |
| General and Administrative Expenses | $320,000 | $320,000 |
| Annual revenue minus annual costs (not including depreciation) | $560,000 | $560,000 |
| Annual revenue minus all annual costs including depreciation | $477,500 | $335,000 |
| | | |
| Payback Period Analysis | 2.23 | 2.23 |
| Simple Rate of Return SRR | 35.80% | 26.80% |
| Net Present Value (NPV) | $2,239,150 | $950,456 |
| IRR @ 5 yr life 4,000 hr operation/yr | | 35.92% |
| IRR @ 10 year life 4,000 hr operation/yr | 43.73% | |

Currently several individuals are known to be looking into production of a biofiber-polypropylene composite material. Being first to actually set up an operation could have the advantage of economic inertia in terms of covering establishment costs and developing markets for output. Capital requirements of establishing a production plant can generally be counted on to rise rather than decline. In the face of increased entries to the industry, product prices can be counted on to fall at some point in time at least in relative terms. Established market channels, market penetration and shelf space etc. are an important part of the capitalized value of a business. On the other side of the issue there could be risk of competitive pressure and process obsolescence to those first on-line.

## Integrated Systems

The hypothesis by Matt Frolich that more than one system might be combined into an integrated process might yet prove economically beneficial. In the analysis of pyrolysis systems, it became evident that both the thermochemical conversion and rapid pyrolysis systems were already integrated processes. In the case of thermochemical conversion of biomass to commodity chemical products it is assumed that either there is steam available from an existing paper mill or that the high lignin char produced is used to provide energy to run the system. In the case of rapid pyrolysis, the system is fueled by char produced and by partial combustion of the biomass itself. In addition, there is a low BTU gasifier, which fires a boiler for the process. The overlapping functions/requirements of the three types of pyrolysis systems studied lead to the conclusion that integrated systems might be able to overcome some of the barriers faced by individual process systems.

Waste heat from the biomass-plastic composite product process might also be usable in some further application. Heat from a pyrolysis system might be utilized in the plastic manufacturing system. Such possibilities demand further study.

# Appendix 1

## Appendix 1

The formulas used in this financial analysis can be found in many financial management texts. The book *Financial Management in Agriculture* (Barry et al. 1983) was the source of formulas with several other books used for general reference.

Payback period is a rough indicator of the risk of an investment. This method estimates the length of time it will take the investment to pay for itself. Faults of this methodology are that time value money or interest rate factors are not considered, it is computed using the estimated cost of the investment and cash flows in nominal dollars. The Payback period (P) is estimated as follows:

$$P = I/E$$

where: P = Payback period in years

I = Initial investment required

E = Estimated annual cash flows.

For this analysis, estimated cash flows are net of cost of materials, cost of operation and maintenance, and cost of general and administrative expenses. Depreciation was not included as an expense. Payback period analysis is a simple crude method of comparing different investments. The quicker the potential payback period is the less risk exposure there is over time. There may be however many sources of risk involved with any prospective financial decision.

Simple rate of return (SRR) is another crude method applied in this analysis. Like payback period analysis it is simple and crude but can be illuminating. SRR is often called return on investment (ROI) analysis and is estimated as follows:

$$SRR = Y/I$$

where, SRR = Simple rate of return

Y = Average annual profits *(revenues less all expenses including depreciation)*

I = Initial investment required.

Depreciation is expensed in this method. In this method of analyzing potential financial investments the higher the rate of return the better. Potential investors using this methodology will most likely have a minimum required rate of return (RRR) in mind when examining the investment in question.

Assumptions of both these methodologies as applied to this analysis were that the initial investment is to be made at once, and that cash flows would be in even amounts.   No potential variance of cash flows is incorporated into the analysis. Neither the SRR nor the payback  method make allowances for the time value of money.  There is no discounting of future cash flows involved.   As simple as these two methods are they provide some important information for examining the potential of a capital investment.  More complex financial analysis, which takes into account the timing of returns, has also been applied.

Net present value (NPV) discounts the estimated annual cash flows utilizing a discount (interest) rate specified by the analyst.  The interest rate used to discount the estimated cash flows represents the opportunity cost of capital invested.  As in the SRR it is known as the potential investor's required rate of return (RRR) on the investment.   NPV is applied using a 10% required rate of return.  This analysis indicates that the plastics plant investment has a positive NPV, which means that the estimated returns on the initial investment are greater than the required rate of return.   The rate of return calculated in this more dynamic method of analysis is not directly comparable to that generated by SRR analysis.    A positive NPV indicates that the cash flows generated by the investment pay back the investment plus the required interest on capital and still have a positive margin on top of that.

The actual rate of return earned by the investment is estimated using  internal rate of return analysis (IRR).  IRR finds the rate of interest on the investment, which equates to zero net revenue.  In the analysis of the hypothetical plastics plant, the net revenue has had a margin for general and administrative expenses deducted prior to the IRR analysis.   Part of this administrative margin might actually accrue to the proprietors in the form of "normal" profits.  The IRR is the amount of interest earned by the capital invested.  In the analysis it is assumed that the total amount of capital is invested at the beginning of the first period.  However, some of the capital may be borrowed.  In this case the difference between the amount of interest paid on capital and the amount it is earning can be captured by the proprietor(s).  As in other analysis methods employed, the IRR is based on the assumption of equal net annual cash flows for the designated life of the plant.  IRR gives an estimate of the

Cash flows generated by the initial investment were estimated as equal annual positive cash flows net of all expenses other than depreciation, throughout the projected life of the plant.  This most likely would not be the case for an actual plant. There could be variation in cash flows, which would significantly alter the actual returns to capital invested.

# Appendix 2

Table A2.1 Original Himmelblau Figures and Adjustments Made for Analysis

| | Himmelblau Estimate 200 ton/day | Adjustment Factor Used | Hypothetical 75/ton day Facility |
|---|---|---|---|
| Material Preparation and Drying | $2,402,000 | 0.5 | $1,201,000 |
| Gasifier Area | $812,000 | 0.5 | $406,000 |
| Scrubber | $941,000 | 0.5 | $470,500 |
| Miscellaneous Plant Equipment | $555,000 | 0.5 | $277,500 |
| Total Equipment Installed | $4,710,000 | | $2,355,000 |
| Land | $50,000 | 0.2 | $10,000 |
| Buildings including Excavation and Site Preparation | $312,000 | 0.5 | $156,000 |
| Fire Protection and Sewer | $183,000 | 0.5 | $91,500 |
| Instrumentation | $350,000 | 1.0 | $350,000 |
| Piping and Insulation | $327,000 | 0.5 | $163,500 |
| Electrical Distribution | $377,000 | 0.5 | $188,500 |
| Sub-Total | $1,599,000 | | $959,500 |
| Construction Management | $442,000 | 0.5 | $221,000 |
| Design and Engineering | $536,000 | 0.5 | $268,000 |
| Sub-Total | $978,000 | | $489,000 |
| Escalation and Contingency | $1,093,000 | 0.5 | $546,500 |
| | $8,380,000 | | $4,350,000 |

Source: “Phenol-formaldehyde Resin Substitutes from Biomass Tars.”

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