Energy Fuels
From
Waste Wood

Ron Burghard

Ortana Scientific, Inc.

May 18, 2009

.Pellets

.Briquetting

.Bio-oil (fast pyrolysis)

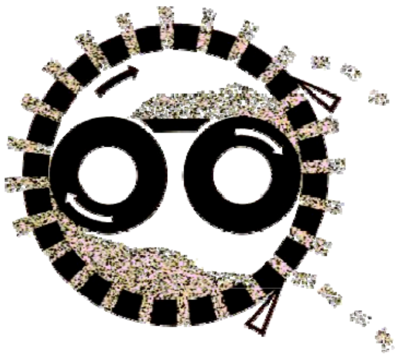
.Upgrading Bio-oil

.Methanol (syngas converstion)

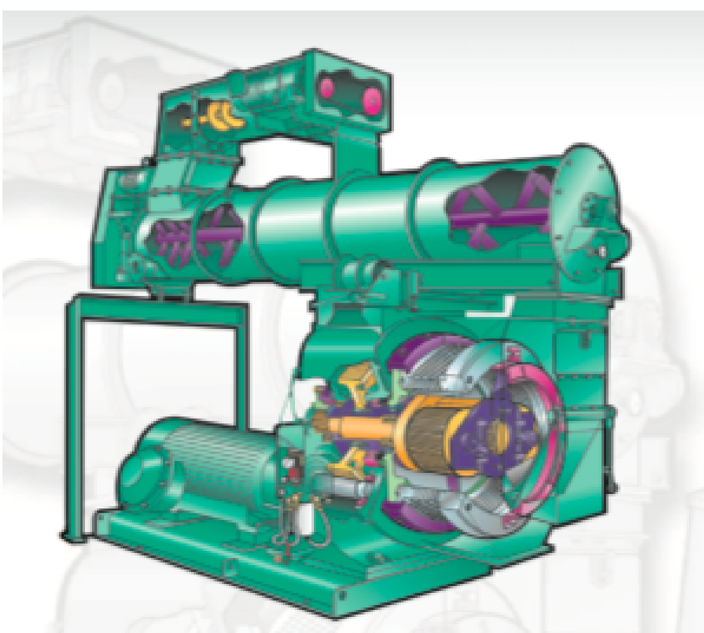
.Diesel (syngas F-T conversion)

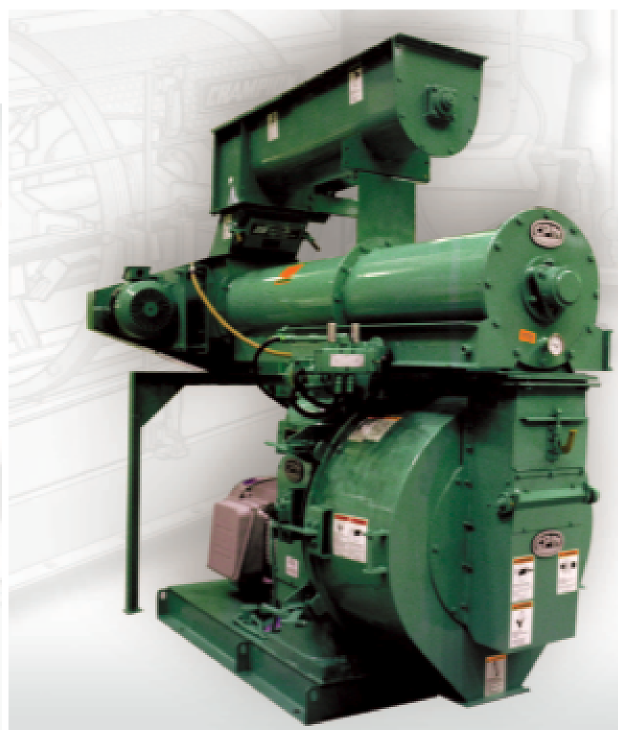
.Comparison

Pellets



A Pelletmill compresses mealy or powdery materials through a ring die into A-class granules.





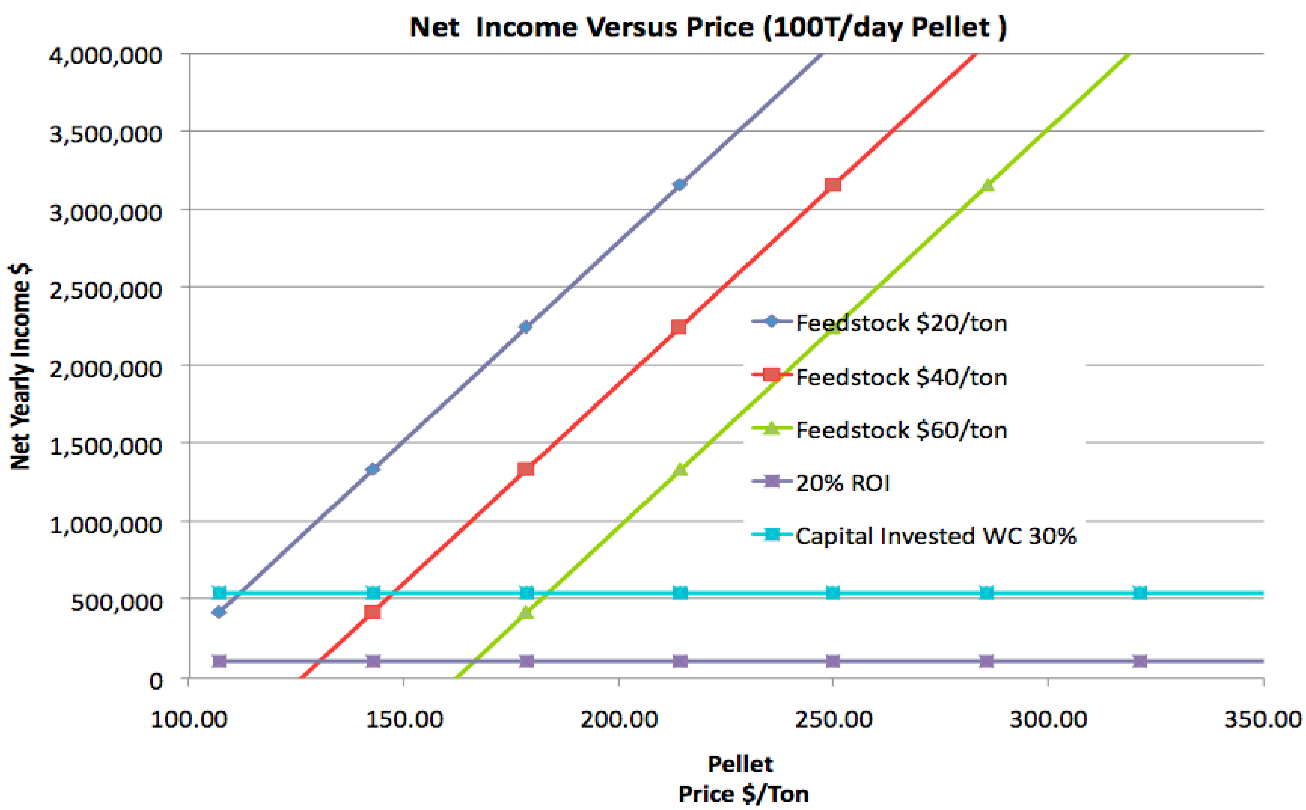
CPM Equipment

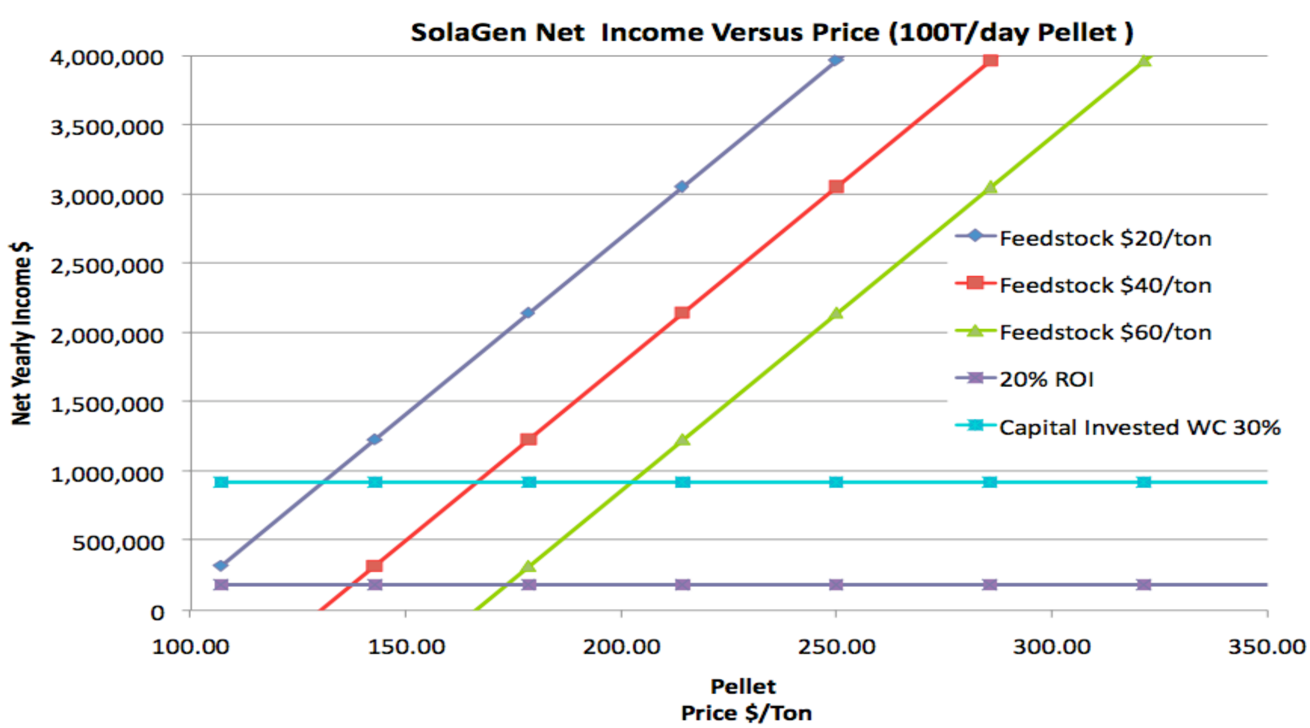
Pellet Economical Assumptions

- **100 Green Tons/day, 330 Days/year, 38% Moisture**
- **Capital Equipment (GEMCO China) $740,000*, Land & Buildings $350,000 (Total $1,090,000) Financed @7% for 15 years with 20% down ($218,000)**
- **Working Capital 30% of $1,090,000 ($327,000)**
- **Electricity 5,000,000 KWh/yr @ $0.10/KWh**
- **Labor 14 People @ $31.2K+20%, Office 1 Person @ $31.2K +20%, Manager @$62.5K + 20%**
- **Maintenance 5% of Capital Equipment, Consumables 3% of Sales**

***SolaGen Capital Equipment Costs $1.5M**

Pellets


Net Income Versus Price (100T/day Pellet)
Net Yearly Income $
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
100.00
150.00
200.00
250.00
300.00
350.00
Pellet
Price $/Ton
Feedstock $20/ton
Feedstock $40/ton
Feedstock $60/ton
20% ROI
Capital Invested WC 30%


SolaGen Net Income Versus Price (100T/day Pellet)
Net Yearly Income $
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
100.00
150.00
200.00
250.00
300.00
350.00
Pellet
Price $/Ton
Feedstock $20/ton
Feedstock $40/ton
Feedstock $60/ton
20% ROI
Capital Invested WC 30%

Briquetting

BP 6000

BP 6000 is our top model among mechanical presses. It offers a capacity range of 1200- 1800 kg/h for industrial and max. 1400 kg/h for the domestic market and satisfies customers, who have a largescale demand for briquette pressing. This machine will often operate almost around the clock and is often installed with automatic control for fully automated operation.

Ref. 1

Briquetting

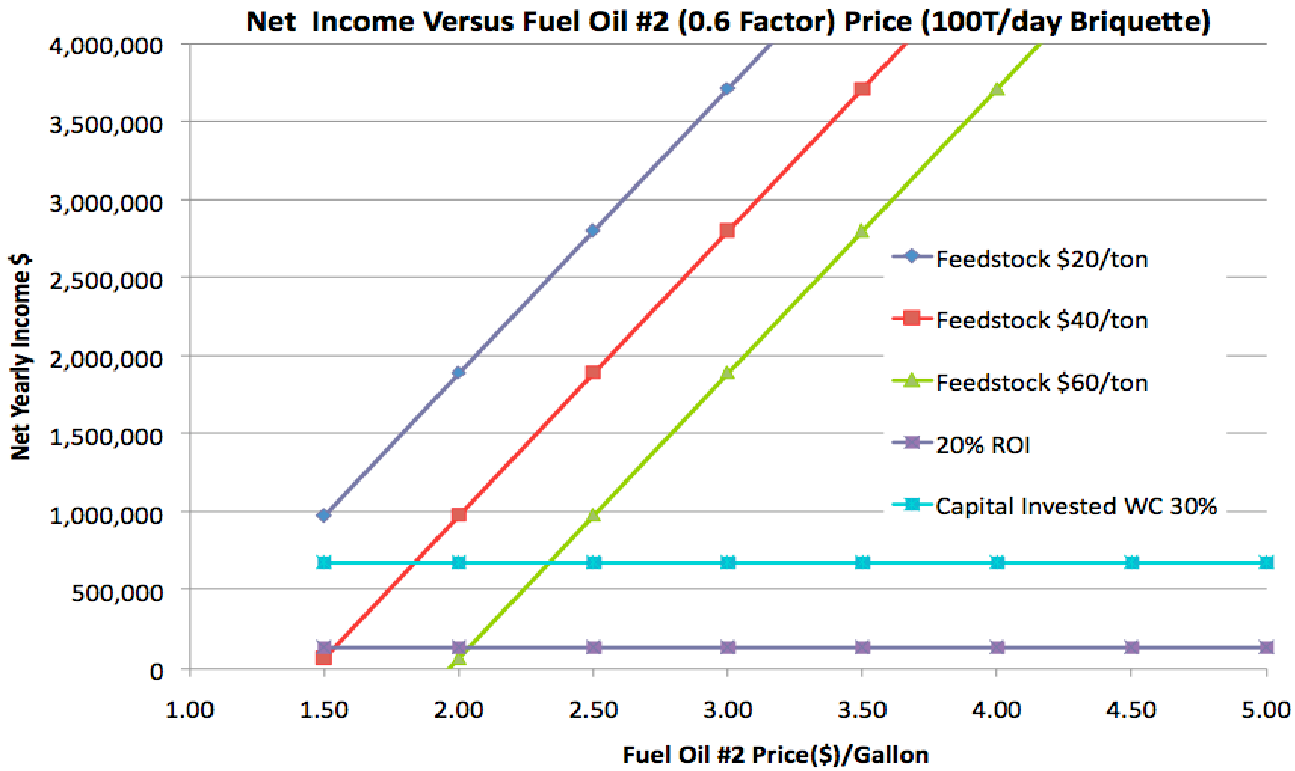
- Puck production costs less than pellets
- Capital investment may be less than pellets
- Electrical consumption ~ ½ pellets
- Bulk density and fuel values similar to pellets
- Feedstock size up to ¾", 0-15% moisture
- Pucks can be made of bark and fine dust
- Pucks can be burned in standard wood stoves

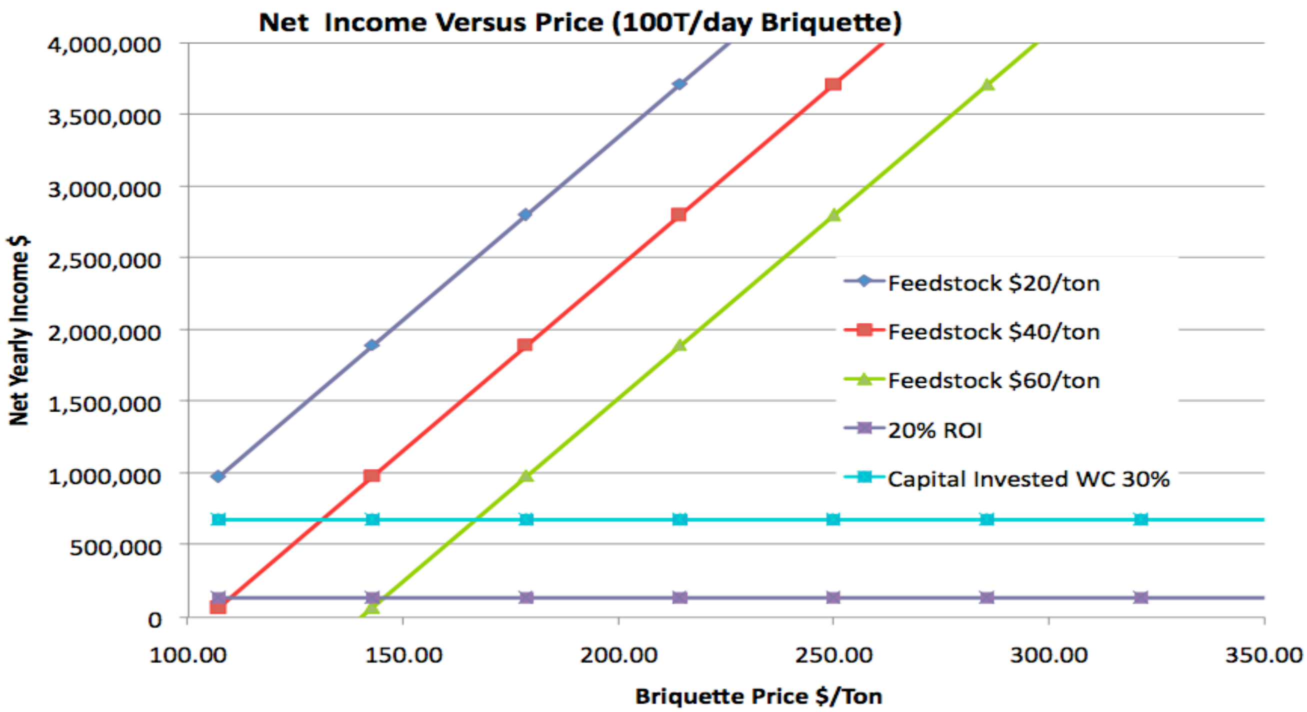
Ref. 2

Briquetting Economical Assumptions

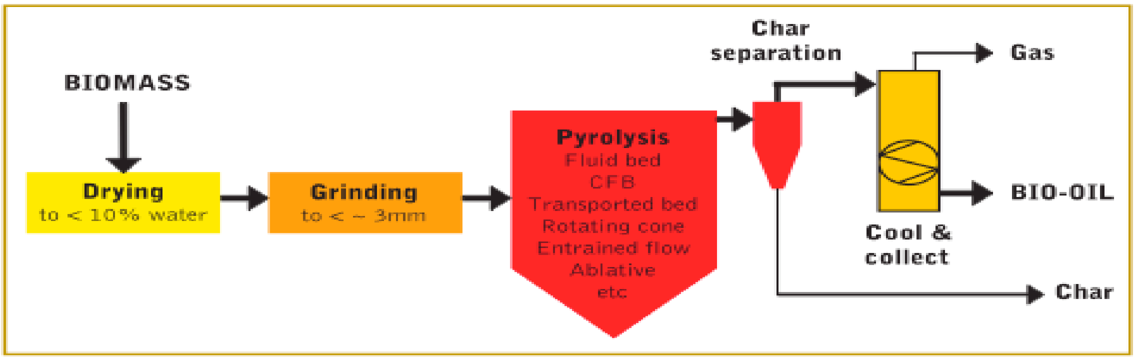
- **100 Green Tons/day, 330 Days/year, 38% Moisture**
- **Capital Equipment $1,010,000, Land & Buildings $350,000 (Total $1,360,000) Financed @7% for 15 years with 20% down ($272,000)**
- **Working Capital 30% of $1,310,000 ($408,000)**
- **Electricity 1,800,000 KWh/yr @ $0.10/KWh**
- **Labor 8 People @ $31.2K+20%, Office 1 Person @ $31.2K +20%, Manager @$62.5K + 20%**
- **Maintenance 5% of Capital Equipment, Consumables 3% of Sales**

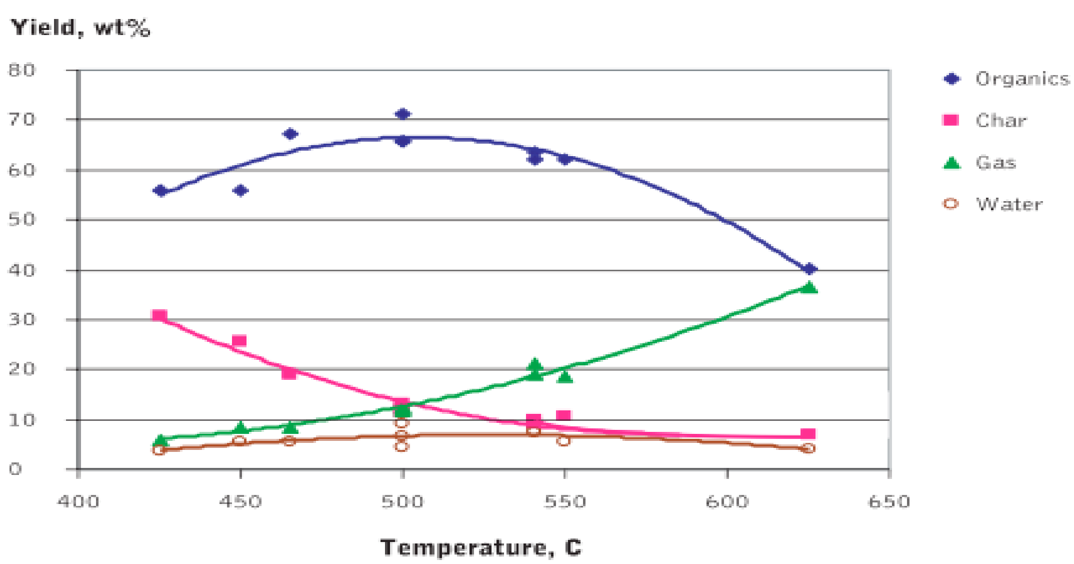
Briquetting





Wood Bio-oil





Ref. 3

Wood Bio-oil

- **Using 500C fast pyrolysis process, small wood chips (~2mm) can be converted to char (~15%), non-condensable gases (CH4, H2, etc. ~15%) and bio-oil (~70%).**

- **The bio-oil has higher oxygen/water content than petro-oil, resulting in lower energy/gallon (50%)**

- **The oil is not easily mixed with petro-oil and is more acidic and less stable**

- **Furnaces and turbo-electric generators can be converted to burn bio-oil, reducing the demand on petro-fuels**

- **One ton of "dry" wood can produce approximately 140 gallons of bio-oil. At a value of 50% of the petro-fuel oil cost (for $3.00/gallon for diesel in 2008), the value is estimated to be around $210/ton wood**

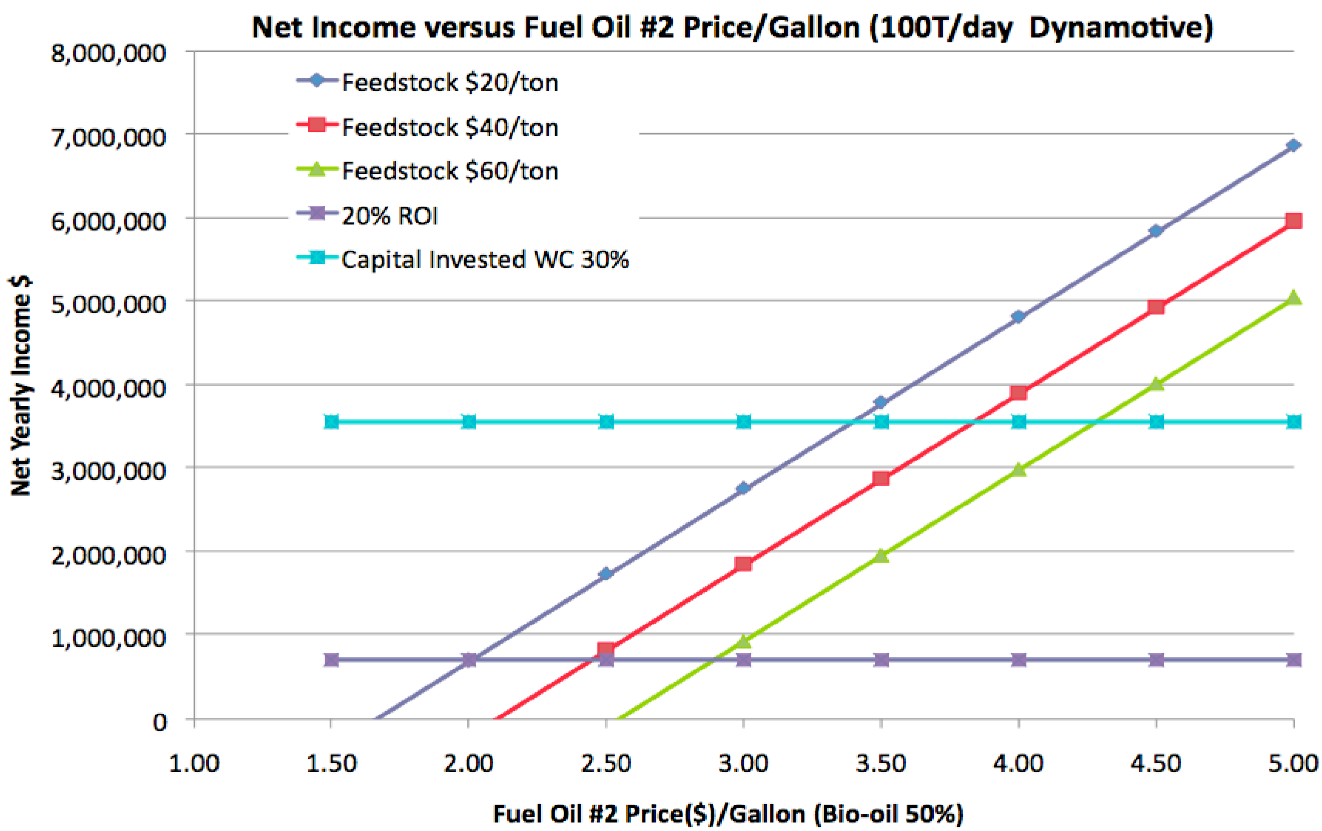
Ref. 4-5

Wood Bio-oil Economical Assumptions

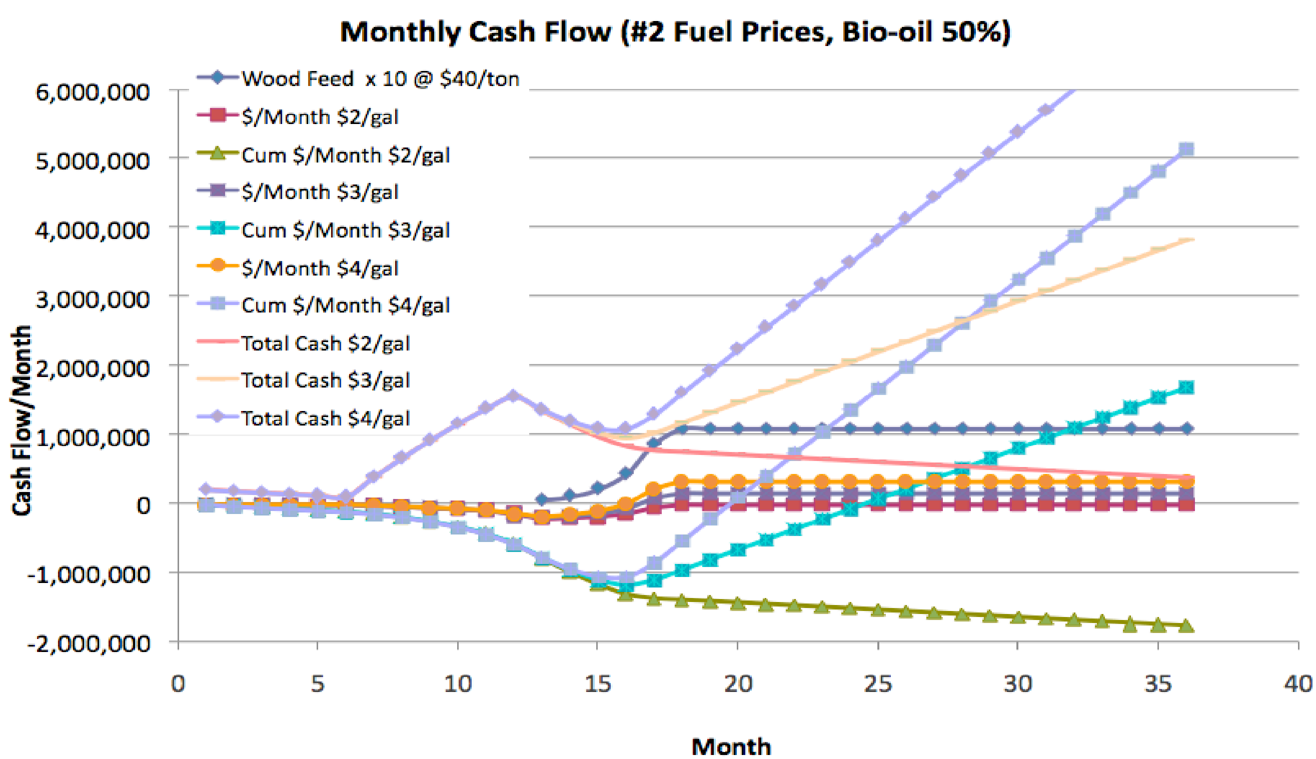
- **100 Green Tons/day, 330 Days/year, 38% Moisture**
- **Capital Equipment \$6,720K, Land & Buildings \$400K (Total \$7,120K) Financed @7% for 15 years with 20% down (\$1,424K)**
- **Working Capital 30% of \$7,120K (\$2,136K)**
- **Electricity 7,750,000 KWh/yr @ \$0.10/KWh**
- **Labor 16 People @ \$31.2K+20%, Office 1 Person @ \$31.2K +20%, Manager @\$62.5K + 20%**
- **Maintenance 5% of Capital Equipment, Consumables 5% of Sales, Royalty/License 3% of Sales**

Ref. 6

Wood Bio-oil



Net Income versus Fuel Oil #2 Price/Gallon (100T/day Dynamotive)
Feedstock $20/ton
Feedstock $40/ton
Feedstock $60/ton
20% ROI
Capital Invested WC 30%
Net Yearly Income $
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Fuel Oil #2 Price($)/Gallon (Bio-oil 50%)



Monthly Cash Flow (#2 Fuel Prices, Bio-oil 50%)
Wood Feed x 10 @ $40/ton
$/Month $2/gal
Cum $/Month $2/gal
$/Month $3/gal
Cum $/Month $3/gal
$/Month $4/gal
Cum $/Month $4/gal
Total Cash $2/gal
Total Cash $3/gal
Total Cash $4/gal
Cash Flow/Month
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
-1,000,000
-2,000,000
0
5
10
15
20
25
30
35
40
Month

Wood Bio-oil

Biggest Issue With Bio-oil!!

It can not be used directly as diesel replacement!!

Ref. 7

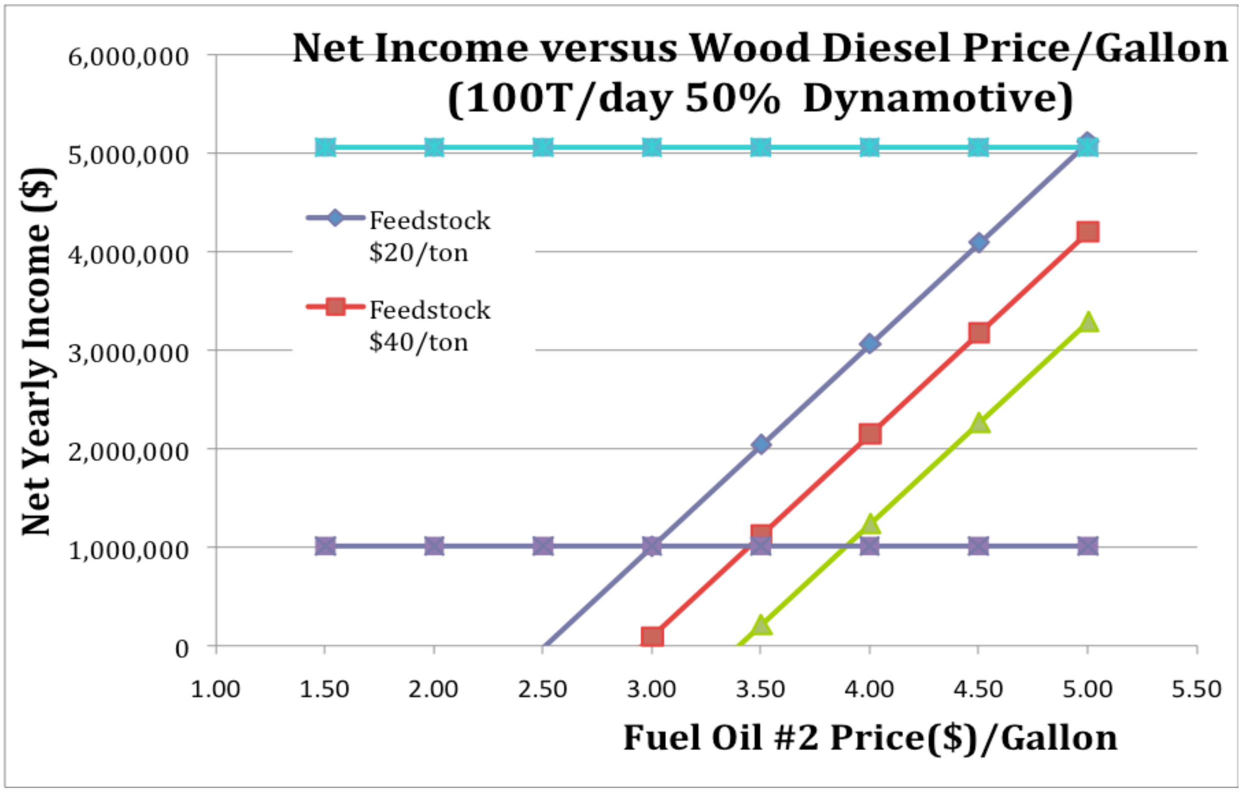
Upgrading Wood Bio-oil

- **PNNL (Doug Elliott) investigating bio-refinery using high pressure and moderate temperatures with H2 to upgrade**

- **Dynamotive developing process for upgrade :**
  "Process conditions are relatively mild (e.g. pressure < 1200 psi and temperature < 350 °C). Together with the reduced requirements for hydrogen it may be expected to enable small scale processing of BioOil to provide a renewable source of hydrocarbons from whole ligno-cellulosic biomass"

Ref. 8-9

Upgrading Wood Bio-oil

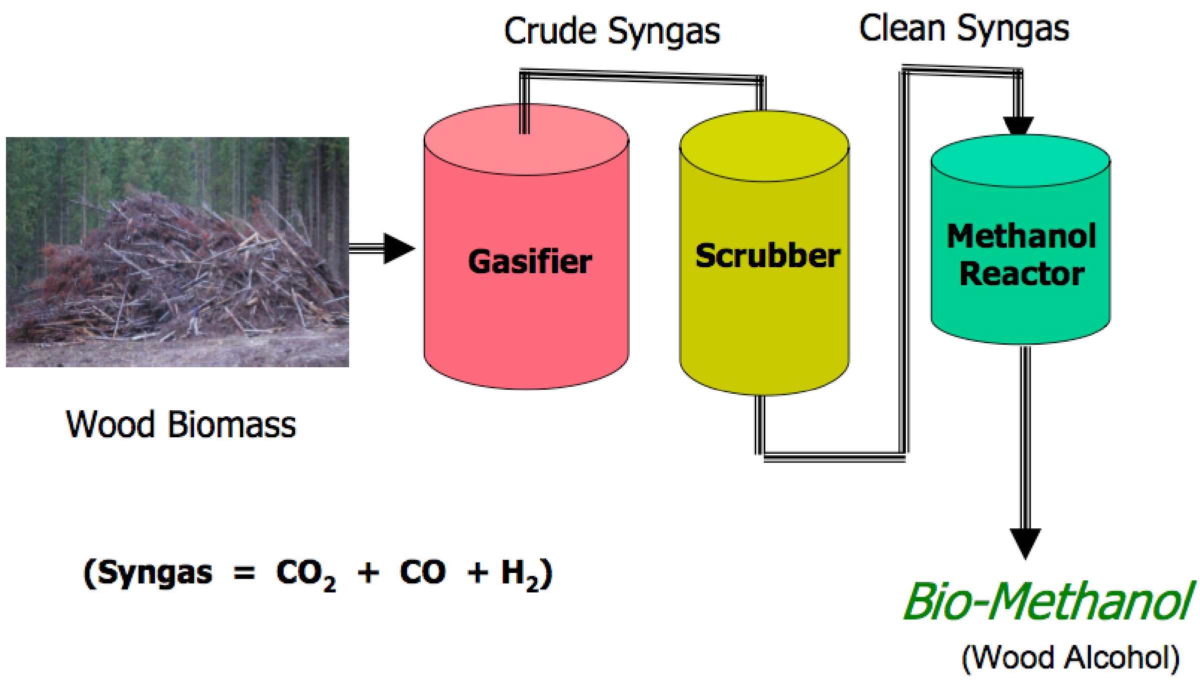


Assumptions:

- Capital Equipment Increased $3M
- 50% Reduction In Gallons of Diesel versus Gallons of Bio-oil
- $0.40/gal Consumables

Wood Methanol

Biomass to Liquid Fuel



The LPMEOH™ process represents a major departure from traditional gas-phase routes to produce methanol in the method of removing the heat of reaction. The formation of methanol from syngas is highly exothermic, as shown by the following equations.

$$CO + 2H_2 \rightarrow CH_3OH \qquad \Delta H_r = -90.8 \text{ kJ/g-mol}$$

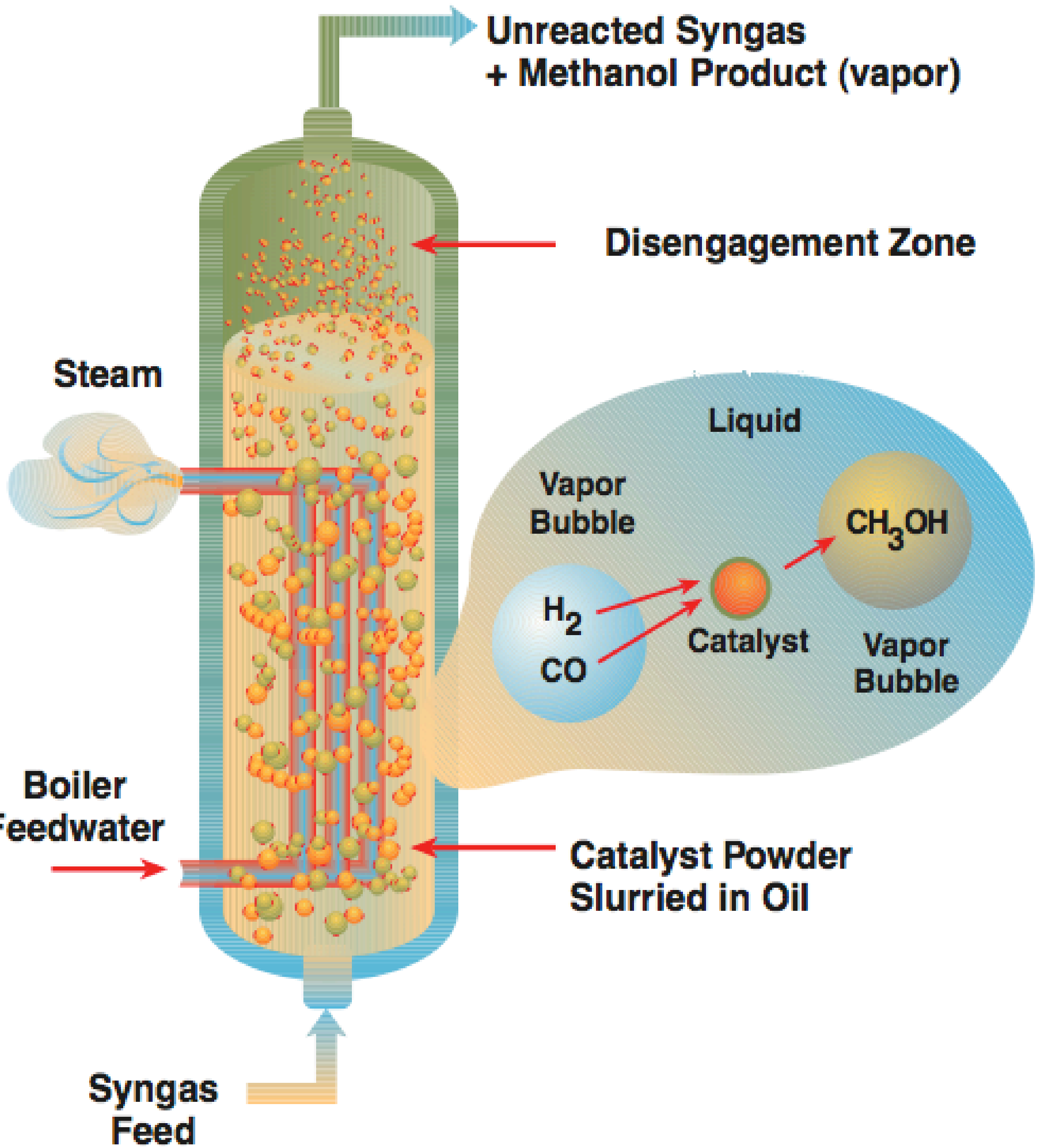
$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O \qquad \Delta H_r = -53.6 \text{ kJ/g-mol}$$

In addition to these methanol synthesis reactions, the water-gas shift reaction also occurs.

$$CO + H_2O(g) \rightarrow H_2 + CO_2 \qquad \Delta H_r = -43.1 \text{ kJ/g-mol}$$

Ref. 10-11

Wood Methanol



Ref. 12

Wood Methanol

Energy Content/Gallon 52% of Gasoline

(but higher octane 109)

- **Convert Wood to Syngas (CO, H2, CO2) with High Temperature (~900ºC)**
- **Convert Syngas to Methanol Using Catalyst at Low Temperature (~250ºC)**
- **140-185 Gallons/Ton of Dry Wood**
- **Greenhouse Gas Emissions 90-95% Less Than Gasoline**
- **Methanol Has Been Dropped From The US Gov Initiatives (Why? Is it technical or political?)**
- **There Are Major Efforts To Use Methanol For Motor Fuels In China, Brazil, and Europe**

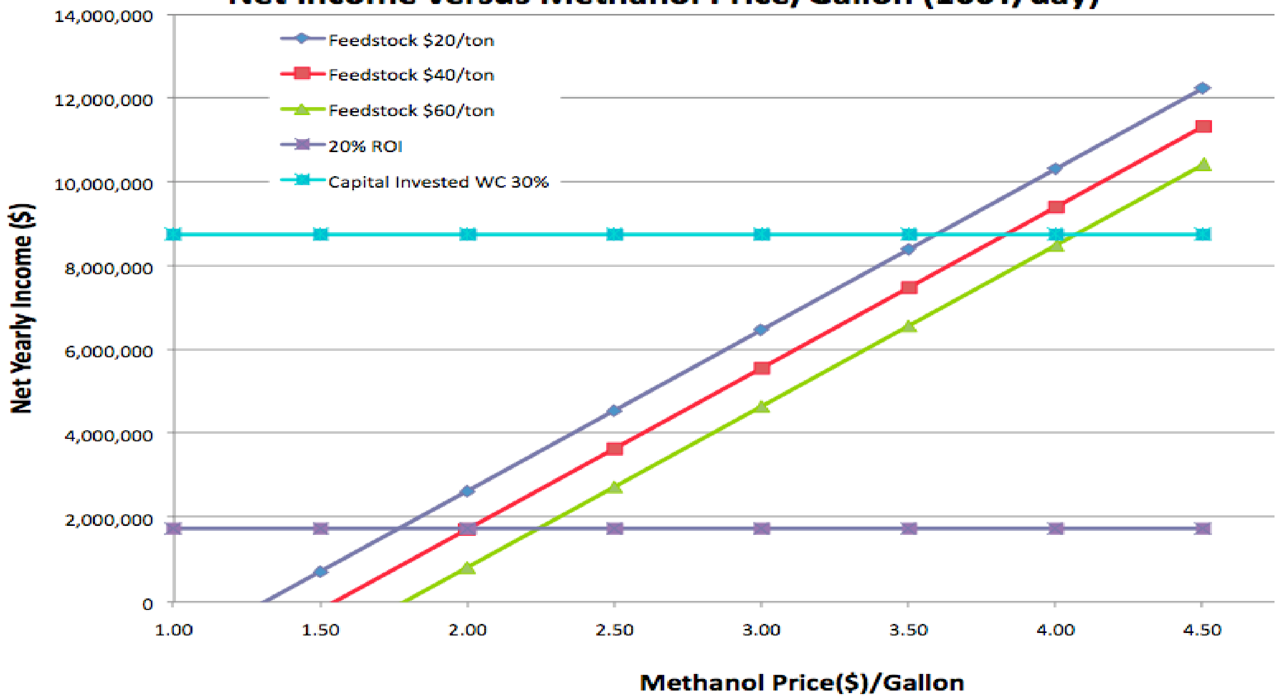
Wood Methanol Economical Assumptions

- **100 Green Tons/day, 330 Days/year, 38% Moisture**
- **Capital Equipment $17,020K, Land & Buildings $500K (Total $17,520K) Financed @7% for 15 years with 20% down ($3,504K)**
- **Working Capital 30% of $17,504K ($5,256K)**
- **Electricity 7,750,000 KWh/yr @ $0.10/KWh**
- **Labor 16 People @ $31.2K+20%, Office 1 Person @ $31.2K +20%, Manager+Staff @$62.5K each + 20%**
- **Maintenance 5% of Capital Equipment, Consumables 6% of Sales, Royalty/License 3% of Sales**

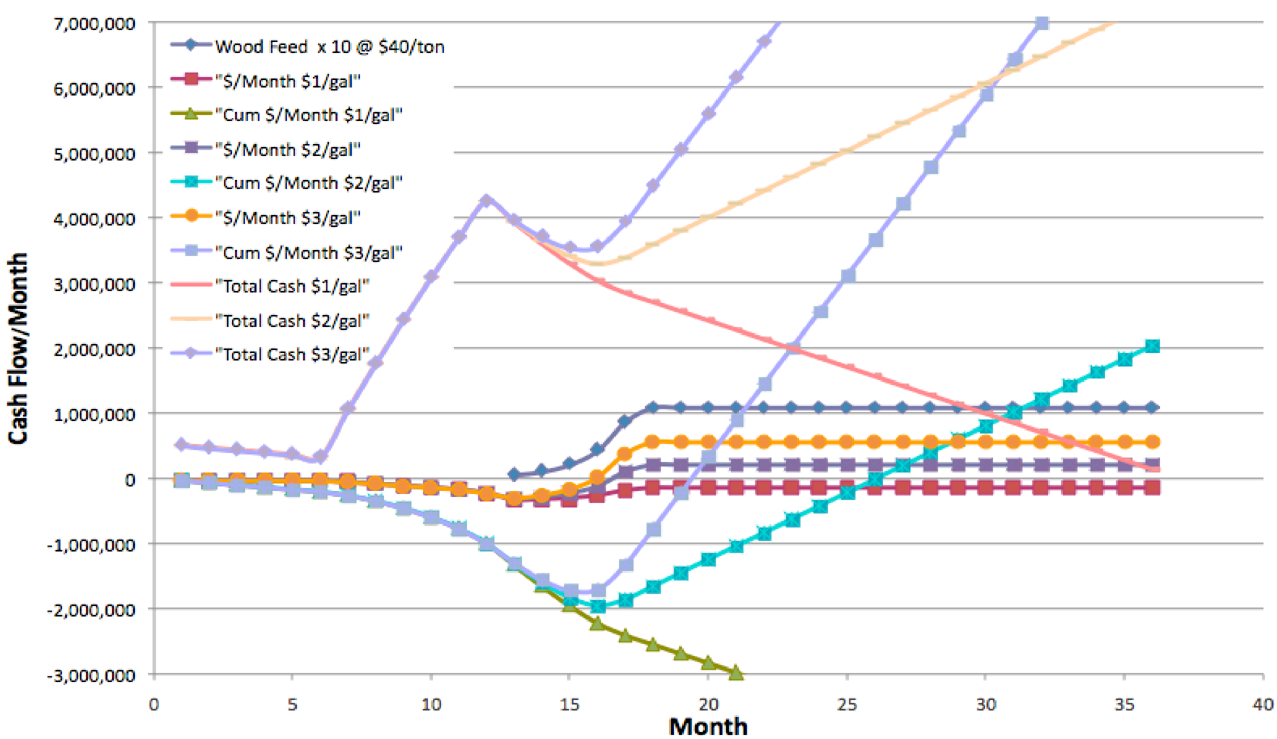
Ref. 13

Wood Methanol

Net Income versus Methanol Price/Gallon (100T/day)



Monthly Cash Flow (Methanol Prices)



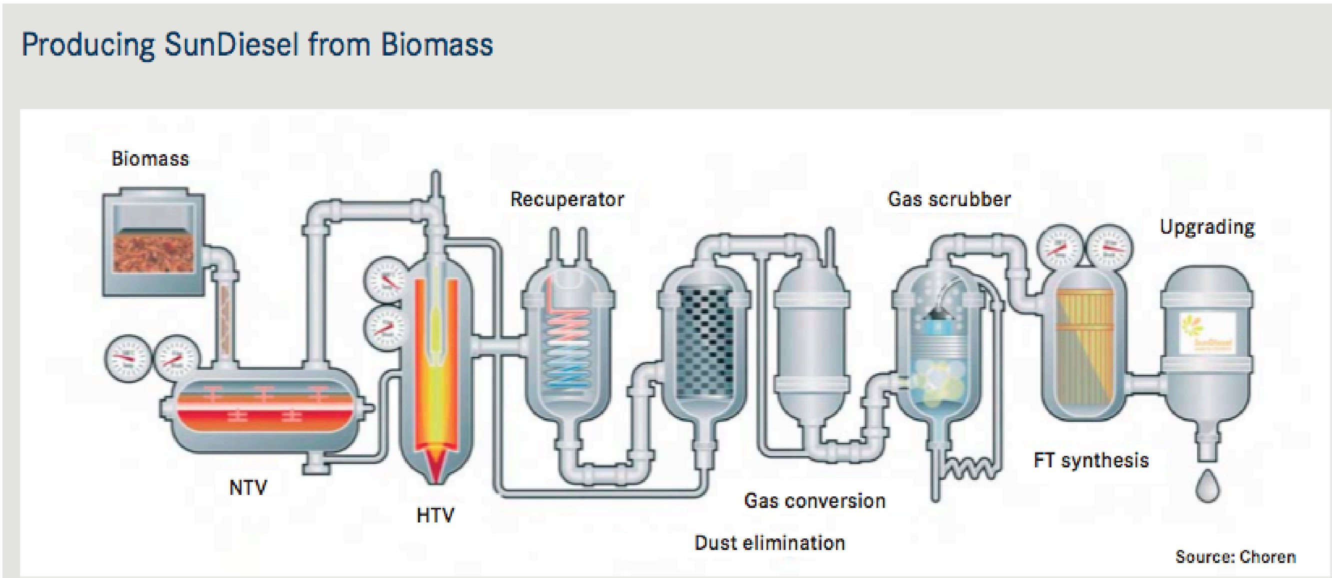
Wood Methanol

- **Wood methanol competes with methanol being produced with natural gas (prices $1.50-$2.50 the past year)**

- **Methanol is used in converting vegetable oils into diesel (~10% of diesel fuel)**

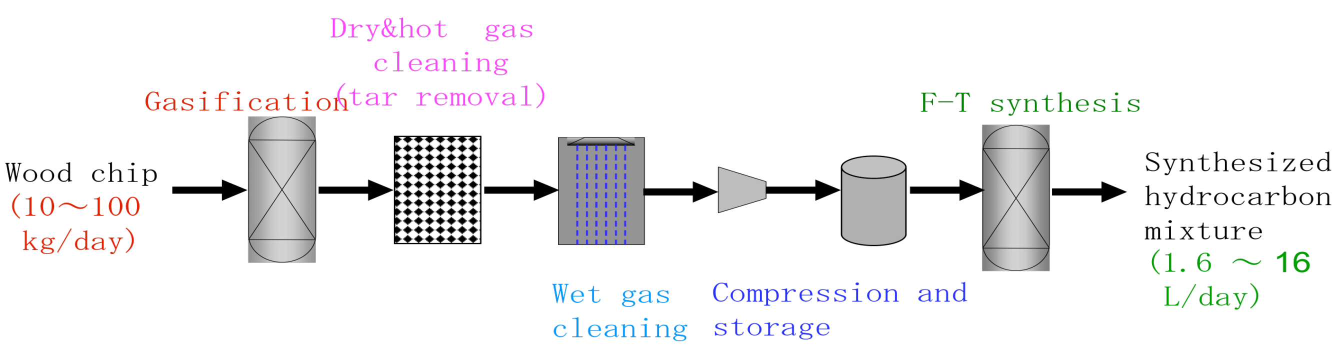
- **With Montana pushing bio-diesel production, there may be a market for the methanol locally (a few hundred miles away)**

Wood Fischer-Tropsch (FT) Diesel



BTL Bench Plant (built on March 30th, 2007)

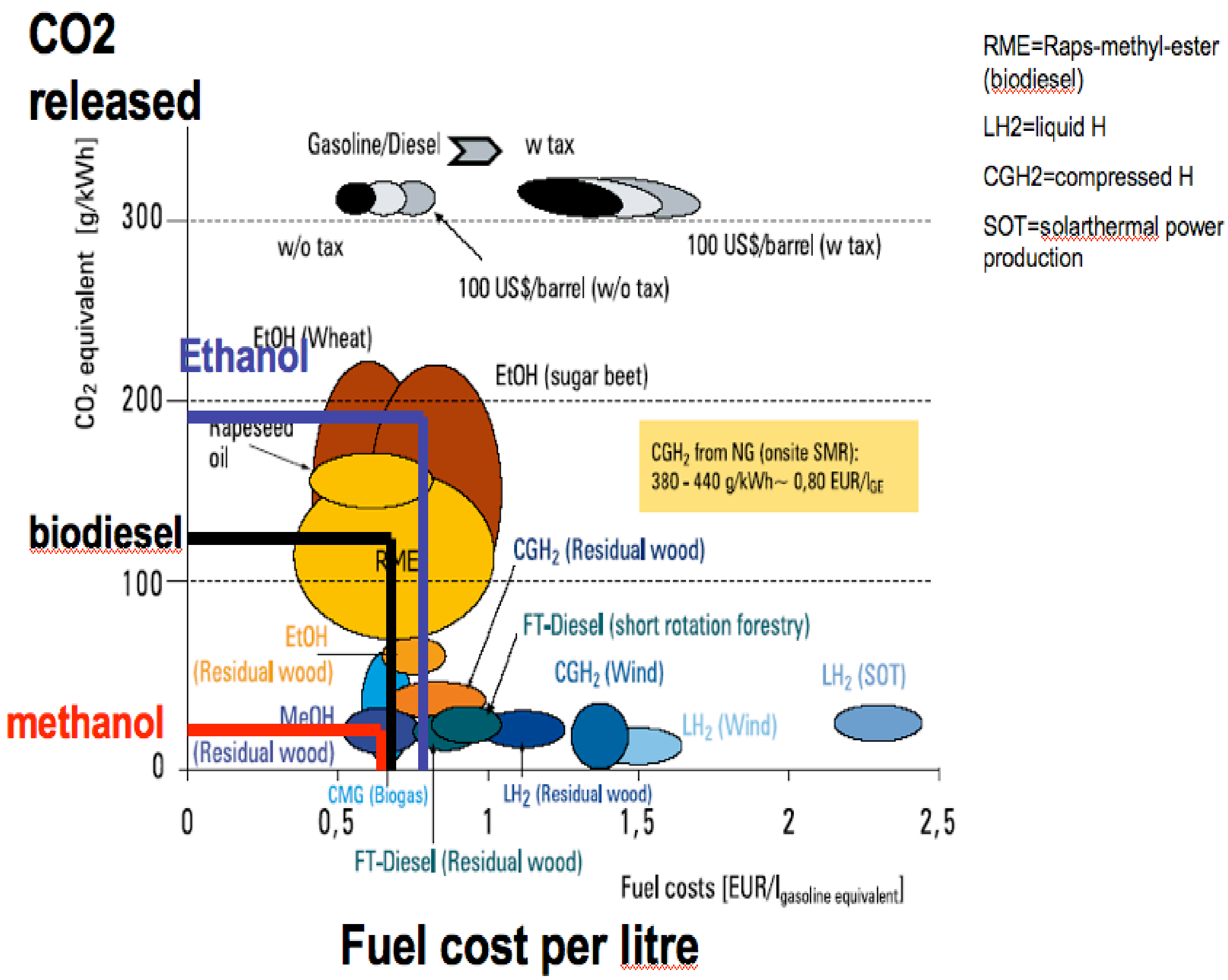
1) Atmospheric Gasification (fixed bed type)
2) Atmospheric Dry Hot &Wet Gas Cleaning
3) Compression and Storage of Synthetic Gas
4) Fischer-Tropsch(F-T) Synthesis (slurry bed type)



~38 Gallons Diesel/Ton of Wood (at larger volumes would expect >50gal/ton)

Ref. 14-15

Comparison of Options



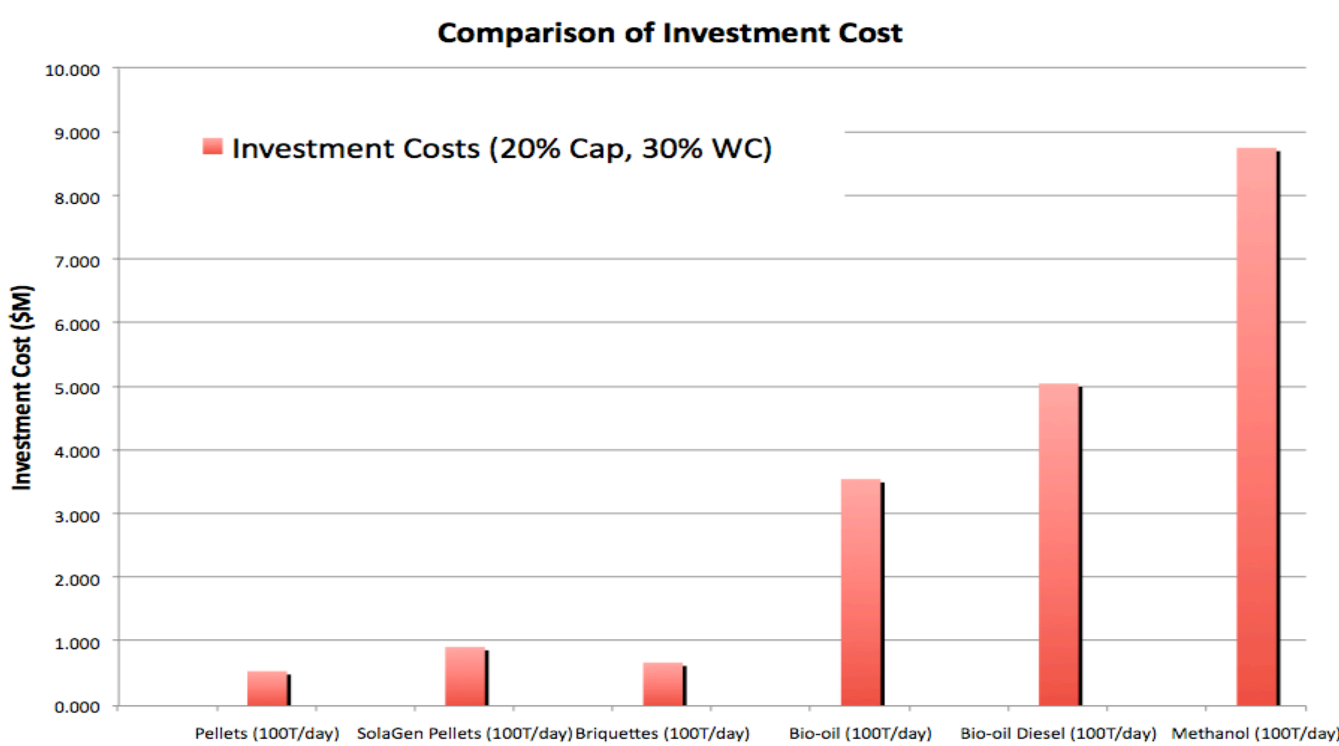
Compares fuel costs and the greenhouse gas emissions of the fuels

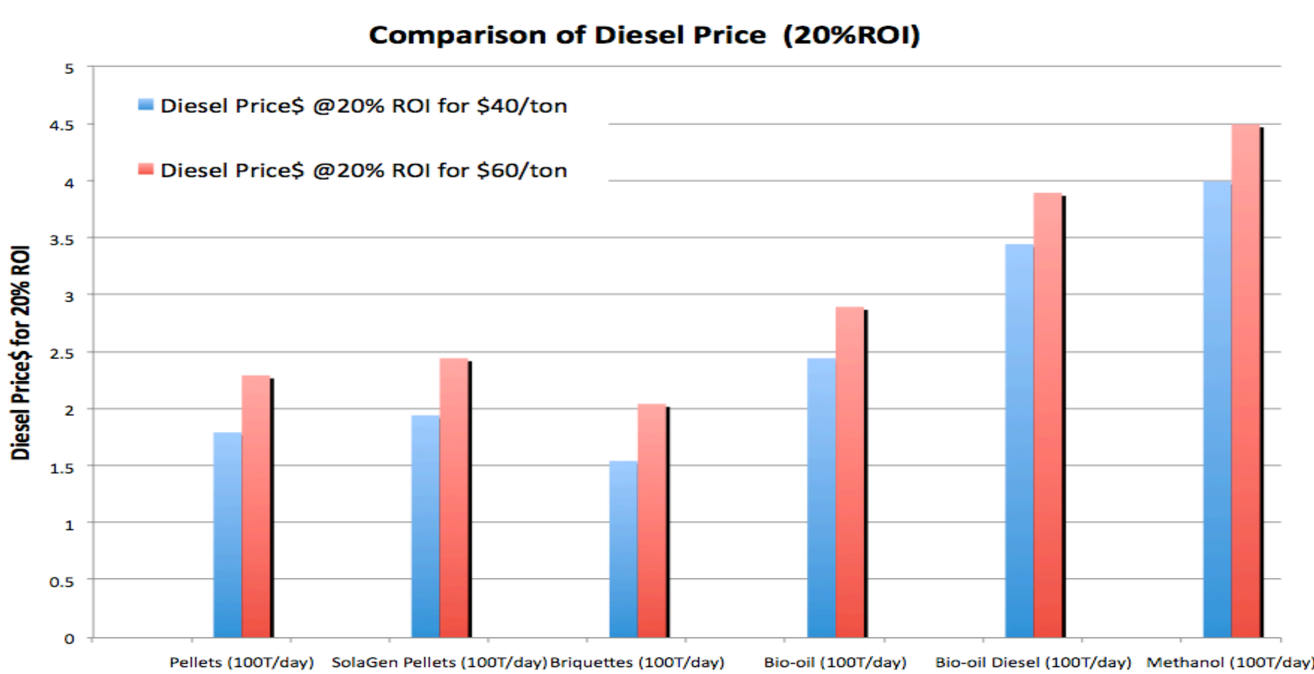
Schindler J, R Wurster, M Zerta, V Blandow and W Zittel. 2006. Where will the energy for hydrogen production come from? – Status and alternatives. European Hydrogen Association, Ludwig-Bolkow-Systemtechnik GmbH (LBST), Ottobrunn, Germany

Methanol and F-T Diesel From Residual Wood are Both Low In CO2 Released and Reasonable In Cost (diesel cost ~2.6X higher/gallon than methanol)

Ref. 16-17

Comparison of Options (cont)





Assumes: pellet and briquette price is 0.6 of diesel heat equivalent (0.3 of diesel/lb), bio-oil and methanol are 0.5 diesel price/gal

Conclusions and Recommendations

- **When high prices of gasoline and diesel return, the options of using waste wood to make biofuels will become economically competitive**
- **The technology is becoming available to convert waste wood into liquid energy products on a smaller scale (<100 dry tons/day)**
- **It is critical to know the available wood resources and the cost of feedstock before proceeding on any option**
- **While promising options appear to exist, more study and more accurate evaluations need to be done before any major commitments are made, and the price of oil will need to get to greater than $125/barrel before some become economical**
- **Currently, the simpler technologies (pellets and briquettes, which are also much cheaper in capital) appear to be better economically**
- **Other technologies that need to be evaluated include 1) wood-to-ethanol conversion (new technologies becoming available), 2) torrefaction, 3) biochar and 4) gasifaction**

References:

1. C. F. Nielsen Briquetting Plant, http://www.briquettingsystems.com/brochures/BP6000-brochure.png

2. Wayne Winkler, http://www.briquettingsystems.com

3. IEA Bioenergy, Annual Report 2006

4. A. V. Bridgwater, G.V.C. Peacocke, "Fast Pyrolysis Processes For Biomass", Renewable and Sustainable Energy Reviews, Vol. 4, 2000, pp 1-73 www.elsevier.com/locate/rser

5. Dinesh Hohan, Charles U. Pttman, Jr., and Philip H. Steele, "Pyrolysis of Wood/Biomass fo Bio-oil: A Critical Review", Energy & Fuels, Vol. 20, 2006, pp 848-889

6. "Bio-Oil Commercialization Plan", Prepared for the NH Office of Energy and Planning by Cole Hill Associates, July 2004

7. Stefan Czernik (NREL), "Review of Fast Pyrolysis of Biomass", Mississippi BioenergyThermochemicalConversion Technologies Roundtable, Jackson, MS, January 28, 2004

8. Personal Communication with Douglas C. Elliott (PNNL)

9. http://www.dynamotive.com/en/news/releases/2008/april/080403.html

10. Kristiina Vogt, "Portable Methanol Production Using Woody Waste", KVogt_Pablo_NCAT_10-31-07.pdf

11. "Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process", US DOE Report, 1999

12. A DOE Assessment, "Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process", DOE/NETL-2004/1199

13. Carlo N. Hamelinck, Andre P.C. Faaij, "Future Prospects for Production of Methanol and Hydrogen from Biomass", Report NWS-E-2001-49, Utrecht University, September 2001

14. http://www.choren.com/en/biomass_to_energy/carbo-v_technology/

15. Kinya Sakanishi, "Specification and Production Technologies of Bio-Fuels in Japan", BTRC, 2007 http://www.nist.gov/oiaa/KinyaSakanishi.pdf

16. J. Schindler, R. Wurster, M. Zerta, V. Blandow and W. Zittel of the Ludwig-Bölkow-Systemtechnik GmbH, "Where will the Energy for Hydrogen Production come from? -Status and Alternatives-" EHA (European Hydrogen Association), 2006 http://translate.google.com/translate?hl=en&sl=de&u=http://www.hyweb.de/Wissen/artikel.html&sa=X&oi=translate&resnum=3&ct=result&prev=/search%3Fq%3DSchindler%2BJ,%2BR%2BWurster,%2BM%2BZerta,%2BV%2BBlandow%2Band%2BW%2BZittel%26hl%3Den%26client%3Dfirefox-a%26rls%3Dorg.mozilla:en-US:official%26hs%3DZGm

17. Kristiina Vogt, "Overall Survey and Definition of Bioenergy: Biomass and Biofuels" www.coic.org/base/Day1/Kristiina%20Vogt%201.pdf