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# Forestry White Paper:
# **Multi-staged Conversion of Forest Products Waste into Synfuels**

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***Abstract***- Use of interlocking methods of converting waste wood and biomass into synthetic fuels is discussed. The use of multiple methods that interlock would increase overall efficiency.

***Index Terms***- synfuel, synthetic fuel, biomass conversion, wood, waste, esterification, Fischer-Tropsch, fermentation

The University of Pittsburgh at Bradford has initiated an “Energy Program” to address issues related to forest and energy sustainability. Among these issues is an interest in converting the abundant local forest product waste such as wood chips and sawdust, into liquid fuels. While assembling a report containing a matrix of possible conversion methods for the use of another program (2007), I noticed that the products of the different methods had different market values and that the waste of one method could be used as a component of the feedstock for another. This suggests that a linear programming problem exists for optimizing the profitability of an operation to convert waste wood into synfuel. Experience with all the processes in the local setting would be required to obtain the data to solve this linear programming problem. However, even without the actual solution, the apparent existence of such a solution is enticing. The following is excerpted from the cited report.

Conversion Technologies in Hierarchal Order:

## FUEL ALCOHOL FROM WASTE WOOD

The subject of making alcohol from waste wood, corn stalks and similar fibrous materials is vast. Methods that are purely thermochemical were developed in Germany in WWII. These and their scion processes are very much like the Fischer-Tropsch except that alcohol is produced. (see below) They begin with pyrolysis of the wood and generally leave behind an un-reacted char. This char could be gasified in a Fischer-Tropsch plant. Thermochemical methods for producing alcohols are relative simple. Both ethanol and methanol, as well as small amounts of higher alcohols, can be produced. Methanol is the alcohol produced most easily. Perhaps that is why methanol is called wood alcohol.

More efficient methods convert cellulose into ethanol through multiple fermentation processes using enzymes. Enzymatic methods for the conversion of cellulose may traceable to the turn of the 19$^{th}$ century. A specific problem with wood is that the cellulose is enclosed in lignin. Lignin is usually removed by hydrolysis. The most popular hydrolysis methods are those using acid to break through the lignin and cleave the cellulose chain. There are many different variations on this theme. I suggest reading P.C. Badger, “Ethanol from Cellulose…” in *Trends in New Crops and New Uses,* J. Janick and A. Whipkey, eds. (ASHS Press, Alexandria, VA 2002) to get a quick overview. The waste products are the lignin and the acid. Recovered lignin can be a feedstock for Fischer-Tropsch conversion. At this time recovery of the acid is possible but expensive.

## ESTERIFIED FUELS

Perhaps the most intriguing thing about the esterification process for making synthetic fuels is that it is possible, viz. that esters can be used as fuels in diesel engines. Ester fuels are normally prepared by reacting a triglyceride with ethanol. Ethanol can be produced from wood as discussed above. A source of the triglyceride is also required. These sources can be vegetable, but they are not easily obtained from wood. However simpler esters can be prepared directly form wood such as ethyl acetate by oxidation of ethanol or some more sophisticated method. Currently much attention is being given to ester fuels, and vehicles that run on the esterified grease from fried chicken and old French fry oil are in the news. This esterified food grease is in fact what people call "biodiesel" today. The esterification process involves manipulating several liquid phases at once and separation is difficult. When esterified fuels are produced from deliberately grown vegetable stocks, a great deal of cellulosic residue remains. This residue is suited to conversion in a Fischer-Tropsch process.

## FISCHER-TROPSCH FUELS

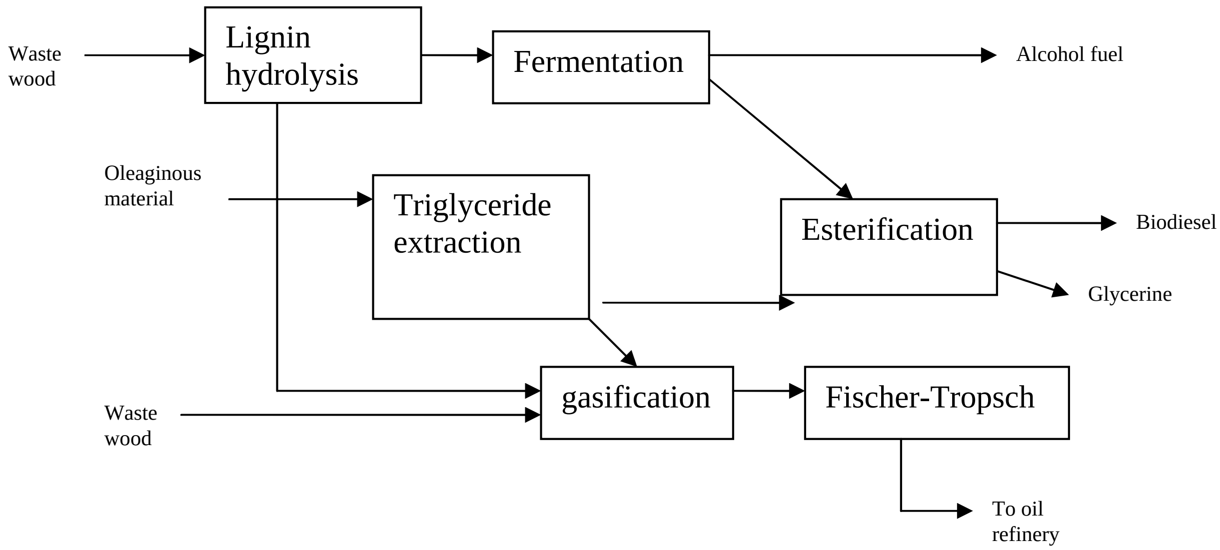
The Fischer-Tropsch process can be the garbage collector of the above processes since it only requires that its initial feedstock contain carbon that can be converted to water gas or producer gas. It converts water gas or producer gas into a petroleum-like material. Water and producer gases were the products of the illuminating gas industry. While coal was preferred as a source of carbon, at times of scarcity the illuminating gas industry was able to convert all manner of otherwise useless organic material. In making illuminating gas carbon and water were reacted to form carbon monoxide and hydrogen. Sometime around the twilight of the nineteenth century the possibility of condensing water gas into a liquid fuel was discovered. In fact, it occurred spontaneously, sometimes explosively, when illuminating gas was compressed. This was a problem that limited the storage pressure of illuminating gas. The commercial culmination of this line of thinking took place around 1920 with the development of the Fischer-Tropsch process for the condensation of water gas into oil. Fischer-Tropsch has since led a marginalized existence becoming economically viable only when petroleum was scarce. At any time, somewhere in the world, it has been commercially viable in the years since its inception -- often in the "Third World". It is a viable source of diesel fuel from low-grade coal in Africa at this time.

To oil
refinery



Discussion

One might imagine a multi-stage process for making synfuel using the locally available resources of Bradford. The flow between the various stages would be optimized using a linear programming or similar analysis. The flow chart would look something like the chart below.




Waste wood would be graded into what was suitable for conversion into ethanol and what was not. The ethanol grade would enter the ethanol process. The reject material would be gasified. The presence of a Fischer-Tropsch converter to handle the waste might make it economical to import oleaginous legumes and other triglygeride source materials. After extraction of the triglyceride, the residue would be gasified. The products would be Biodiesel ester, glycerine, ethanol and a refinery feedstock oil.

REFERENCE

Lawson, L., “Energy Program Matrix: Relating microwave techniques to potential initiatives”, Pitt-Bradford Physics Department internal communication, September, 2007.