

Fields of Fire: Land Based Biomass

Biomass may be produced from crops grown especially for that purpose and converted into biogas or liquid biofuel range from 1.5 to 4 times the price per BTU of comparable fossil fuels³⁰¹; as an average say three times the cost. Biowaste as a fuel source ranges from one quarter the cost of comparable fossil fuel to 1.5 time that same cost³⁰¹. You can make natural gas or syngas from biomass, convert it into charcoal as a coal replacement, or produce various liquid products (ethanol, methanol, biodiesel) to replace petroleum products.

How much land based biofuel could we use? We currently obtain a bit over 3% (~3.3 quads) of our energy from biomass in the United States³⁰². Much of this is produced unsustainably. Some of it is not even biomass (waste plastic and such). But we discard a great deal more organic material than we use, and as already shown in the material intensity section, we know how to grow crops much more sustainably than we actually do. So it would be reasonable to assume we could continue to generate that sustainably rather than unsustainably, (without compromising the ability to use as much of it as needed for fertilizer or fiber purposes).

One example is corn. If we could use some of the stover from corn we produce anyway, either to produce additional ethanol or methanol or if we dried it and burned it directly as a coal substitute, we could obtain a small sustainable energy yield from such farms without increasing the land used or robbing it of fertility. (Removing between 40% and 50% of corn stover from a field costs it neither structure nor nutrients. In fact we have to take some of it. Too much corn stover on the soil is a nitrogen robber, and can lead to excess soil compaction.)

And corn stover is among the biomass least suited for fiber applications, so we are not competing with fiber either. (Though, stover is a good source for cellulosistic chemicals.) The enzymes required to produce ethanol from cellulose are still extremely expensive; but bio-methanol is around double the cost of fossil fuels, as is direct burning – which can be done comparatively cleanly in fluidized bed combustion plants. So we can extract 3.3 quads from existing cultivated cropland and biowaste.

Is there any way we can increase biomass from croplands? Fuel crops other than corn may be grown through rotational no-till organic methods just as crops for food, fiber and chemical may. In fact certain organic techniques (such as mixing crops) are easier if the product is harvested for fuel than for other purposes. There are a huge variety of crops suitable for energy purposes including switchgrass, hemp, elephant grass, leucana, Eucalyptus Grandis, alfalfa, hybrid poplar, coppice willow. Many of these are nitrogen fixers. Other are tree crops and can be use for soil conservation – mixed with other crops and thus NOT clear cut on harvest.

Of the 57 million acres that have been taken out of production, we already suggested using 17.7 million to produce fiber and chemical needs. Assuming that half should be left completely wild rather used for any agricultural purpose, that would still leave us with 10.8 million acres we could use for such purposes. (Again, as with kenaf and chemical crops, we don't necessarily have to dedicate land only to energy crops – though some areas may be suited to exactly that. We can increase the total crop lands by that amount and in many cases include fuel crops in rotation with other crops. The wider the variety of crops you include in a rotation the more resistance you have to disease and pests.)

Additionally, we are not utilizing most waste straw for fertilizer or fiber. In the short run we could probably generate up to 8 quads from that, giving us a 12.5 quad total. As a way of saving farms (thus making the biggest possible longer term contribution agricultural sustainability – preventing the loss of farmland) it may even be a wise choice. But energy really is not the optimum use for waste straw, given that some of it can help build soil structure, and the rest replace much of the wood used as building material. So we should not count on most of this being available for energy purposes in the long run.

What about unconventional sources? Ecologist David Tilman, at the University of Minnesota has discovered a way to get more net energy out of a hectare of mixed prairie grasses (the more variety the better) than best energy crops³⁰³, about 28.4 GJ/HA on degraded land, about 42.6 GJ/HA on fertile ground. (This means that on eroded land they get about 50% more net energy per acre than corn ethanol, 75% more on good soil.) Part of this increased energy yield is due to the process suggested to convert biomass to energy - Fischer-Tropsch hydrocarbon synthesis - which produces diesel fuel, gasoline, and electricity. The diesel or gasoline is around 2¼ times more expensive than gasoline from fossil oil³⁰⁴. (It converts biomass with around 47% efficiency. If energy needed to grow, harvest and transport grasses also comes from this process, this nets 41% of the BTU's that were in the original biomass.) For diesel, which rail and trucking depend upon, this may be the best choice. Two alternatives to Fischer Tropsch could yield the same or better results less expensively - where the products could be used.

Conventional pyrolysis can convert biomass to methanol with around a 50% efficiency - sometimes better³⁰⁵. (You can gain another 5%-8% in the form of electricity generated from waste steam.) Methanol can substitute for gasoline, and many other liquid fuels at cost around double gasoline (per BTU). Methanol has a fuel value about half that of gasoline per gallon; many cars can't run on it; but we could put flex-fuel requirements on all new automobiles, so that we could phase in its use over the course of 13 years. Transport tankers and gas station storage tanks have to install special liners and new valves to handle it - again something that could be done over a 13 year period.

There are also environmental, health and safety concerns - all of which can be addressed. Methanol is toxic and dangerous - like gasoline. Unlike both MTBE and gasoline, it is a naturally occurring substance that many organisms have evolved to predate on. If an underground methanol tank leaks, it will seep into the water table where it will be diluted and broken down into less dangerous forms quickly³⁰⁶ - nothing like the year that is the minimum for MTBE. In the case of surface spills, the same thing will happen even faster. That does not make spills trivial; like gasoline we want to keep the stuff out of the environment and especially out of our water supplies. If really heavy concentrations occur, then (again like) gasoline it can be cleaned up, though via different methods (high temperature steam oxidation, bioremediation or both). In terms of fire safety, pure methanol is indeed more dangerous to store - due to differences in vapors, colorlessness, and tastelessness. However, in practice, the maximum concentration usually advocated is 85% methanol and 15% gasoline (which can come from FT). This takes care of all those problems; so long as transport and storage have been modified to resist corrosion by methanol, the fire safety is equivalent to gasoline³⁰⁷. Note that methanol substitutes for gasoline³⁰⁸. While diesel engines can be modified to use methanol with efficiencies approaching or exceeding the best conventional diesels³⁰⁹, maintenance and engine life to date have proven miserable compared to real diesel or biodiesel³¹⁰. There is some work being done on making gasoline engines comparable in efficiency and reliability to diesel. If that was successful then methanol could replace diesel as well.

Biomass can also be converted to charcoal with around 50% efficiency; there may be waste gas not used up by the process to make electricity, as well as waste heat to be used for the same purpose. However it may be that process waste heat either from charcoal or methanol making will be needed for drying the grasses before conversion. Charcoal is much cheaper to make than other alternatives, but it also has more limited uses. The electricity coal and natural gas make can be better replaced by wind, sun and water. 5-7% of coal in the U.S. is used in industrially, over and above electricity making. There is some use of charcoal, as charcoal. Charcoal is an extraordinarily useful soil amendment, building soil structure permanently. And we can probably find some cases where charcoal can substitute for other fuels without compromising efficiency, though mostly people switch from coal to other fuels for process efficiency sake - since coal is the cheapest fossil fuel there is.

Overall the mix would be mostly methanol for gasoline, FT for diesel and gasoline to mix with the methanol, with some percent of charcoal production.

Is there any additional land we could use for bioproduction?

There are about 4 million hectares of land degraded by mining³¹¹ we could produce fuel from by the Tilman method.

We also convert some grazing and rangeland. It is well known that Americans eat more meat that is good for us³¹². While I'm a great believer in small luxuries, could convert 15% of grazed land to energy production (concentrating on cattle land). The land currently devoted to growing grain to "finish" that beef could provide grain and legumes

to replace the protein those cattle would have provided, plus. And it would not have to be a hardship, or even require vegetarian meals. Chile and beans , red beans and rice (with sausage if you wish) , split pea (with ham or bacon if you like), much Thai, Chinese, Vietnamese or Indian food, minestrone, Italian wedding soup, and bean burritos are all examples of luxury or comfort foods that get most of their protein from vegetables, but can still include a little meat or cheese for flavor. Eating a few meals like that a week, while still having the rest be heavily meat based would be no great hardship, unless you got tired of all that meat! 15% of range land is about 50.4 million hectares, and could be confined to overgrazed, eroded land, where we should probably stop grazing cattle in any case. This will probably reduce meat production by a great deal less than 15%.

However, there is one other major source for sustainable land based biomass – existing timberlands. If you remember, in the industrial section we suggested ways to reduce to one quarter the use of timberlands for paper, and also suggested ways to reduce wood demand to almost nothing, for a slightly below 93% per capita reduction in timber harvesting. Before the reduction this would have been 408 million acres¹⁰⁸ devoted to tree farming rather than wilderness. After the reduction, that would have meant a bit less than 31 million acres still in tree farms increasing to around 44 million acres by 2050 to match population growth.

That leaves 364 million acres that are either tree farms, or virgin timber scheduled for harvesting; we have made proposals to save all those acres. In the absence of technical breakthroughs in energy storage or cheap renewable electricity, we can use up to another 100 million acres of that for energy production, confining ourselves to short and medium rotation mono-cultures, and leaving 100% of old growth, and natural second growth forest and woodlands untouched.

Ok so how much energy does this add up to? The NDRC thinks we could get nearly 17 quads of energy from biomass³¹³. However this assumes greatly increased per acre crop yields, and also use of all waste fiber not needed for soil building. However we have projected saving much more energy by replacing much of wood, and even some plastic and metal with the same waste fiber. Also it assumes greatly increased crop yields per acre - which may be done sustainably or may not. So, cutting this in half to 8.5 quad would be more reasonable.

As a double check a study by the University of Tennessee Biobased Energy Analysis Group projects about 15.5 quads with both increased yield, and massive conversion of existing grazing and timberland to biofuels, about 10 quad with almost no land conversion, but with greatly increased yield³¹⁴. So a projection of 8.5 quads with significant conversion of land, but no increased yields is conservative.

Between crops, grazing land and timberland we are looking at potential of around 8.5 quads of energy from biomass. The only reason we can produce such a high amount of biomass sustainably is because we are phasing out a small portion of meat production, and because we have freed a great deal of land currently devoted to timber and paper production.

I would add that there are a wide variety of ways to process and use biofuels, and that obviously best practices should be adapted. In general corn based ethanol is a farm subsidy, not an energy program; a way of processing natural gas or coal through corn-fields into liquid fuel with either a net loss or a modest BTU boost from solar energy. The best way to convert biomass into usable fuel is FT, methanol, cellulosistic ethanol, biodiesel, and the creation of both charcoal and syngas. In all cases, electricity should be co-produced with the conversion of raw biomass to fuel. In all cases energy input should either be from the biomass itself, or from nearby renewable electricity without long distance transmission or fossil fuel backup.

While all this is technically possible in a very narrow sense there are social issue to consider. For example replacing some food crops with fuel crops may not need to increase hunger look at in the abstract; but in a globalized world market, reducing food production significantly anywhere increases food prices. Look how U.S. ethanol production from corn has increased food prices in both the U.S. and in Mexico. Fuel crops are also replacing food crops in nations in a number of poor nations, driving food prices up in areas where many people are already living on a dollar a day.

Further, in many cases fuel crops are actually increasing rather than reducing greenhouse emissions. In the U.S., extremely low to negative net energy corn ethanol is often distilled in coal powered processes. In Indonesia, palm and other fuel oil crops which do produce net energy also replace old growth rainforest, thus releasing far more emissions than the fossil fuel they replace.

To implement biofuels sustainably on a large scale would require a transformation of the entire international economy. In the absence of such change, we should probably be extremely modest in our use of them.

End Notes

³⁰¹Rober C. Brown, Colletti, Joe, and Arne Hallam, "Factors Influencing the Adoption of Biomass Energy Systems: An Evaluation for Iowa," Fifth World Congress of Chemical Engineering, San Diego, CA, July 14-18, 1996 (Ames Iowa USA: Iowa State University, 1996), Obsolete URL (<http://webbook2.ameslab.gov/Summary%20Biomass.doc>).

³⁰² Donal L. Klass, "Biomass for Renewable Energy And Fuels," *Encyclopedia of Energy*. 2004. Elsevier, Inc, Biomass Energy Research Association (BERA) Washington D.C., 28/Sep/2005 <<http://www.bera1.org/cyclopediaofEnergy.pdf>>.p196.

³⁰³ David Tilman, Jason Hill, and Clarence Lehman, "Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass," *Science* 314, no. 5805 8/Dec 2006, American Association for the Advancement of Science, 01/01/2007 <http://www.ce.cmu.edu/~gdrgr/readings/2006/12/12/Tilman_CNegativeBiofuelsFromLowInputHighDiversityGrasslandBiomass.pdf>.

³⁰⁴ Biopact [Summarizing Report from German Energy Agency], *Bioenergy Pact Between Europe and Africa: German Energy Agency: Biomass-to-Liquids Can Meet up to 35% of Germany's Fuel Needs by 2030*. 15/December 2006, Biopact, 28/Dec/2006 <<http://biopact.com/2006/12/german-energy-agency-biomass-to.html> [summary of original report in German: http://www.dena.de/fileadmin/user_upload/Download/Dokumente/Publikationen/mobilitaet/BtL_Realisierungsstudie.pdf]>.

Note that this price assumes biomass imported by ship or rail into German - so probably more than with biomass grown within 50 miles.. The price given is \$3.98/ gallon, which is for refined product. At the pump price tends to be 42% higher than refined product - so at the pump price of \$5.65 (including taxes), around 2.2 X current price of \$2.50/gallon.

³⁰⁵ Stefan Unnasch and Louis Browning, *Fuel Cycle Energy Conversion Efficiency Analysis Status Report*. 25/May 2000. California Energy Commission Transportation Technology and Fuels Office ARCADIS Geraghty & Miller, Inc, 01/03/2007 <<http://www.arb.ca.gov/msprog/zevprog/2000review/efficiency.doc>>.p7.Table 6. three specific cases:

It was considered feasible to produce Methanol with nearly 53% thermal efficiency back in 1981: L.K. Mudge et al., *Investigations on Catalyzed Steam Gasification of Biomass. Appendix B: Feasibility Study of Methanol Production Via Catalytic Gasification of 2000 Tons of Wood Per Day*, Jan-1981), On-Line Abstract. 2001. U.S. Department of Energy, 03-Jan-2007 <http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6711590>.

More recently, non-bleeding-edge technology was considered able to convert biomass into methanol which had 57% of the original BTU content. If the plant generated its own electricity that would reduce thermal efficiency to 475-49%. However, this is not the proper accounting of net energy, because even with combined heat and power, methanol combustion is not an efficient way to generate electricity. If efficiently generated electricity had been used, provided by (say) a 55% efficient combined cycle turbine that managed to place some waste heat, the range would have more like 50% - 52%, even more if the electricity was provided by wind.

Nycomb Synergetics and Ecotraffic R&D AB, *Biomass-Derived Alcohols for Automotive and Industrial Uses*, Apr 1999). May 1999, European Union Program Altener and the Swedish National Board for Industrial and Technical Development, Jan-03-2007 <<http://www.nykomb.se/pdf/methanol.pdf>>.

Lastly, Mitsubishi recently demonstrated bleeding edge technology extracted 65% of energy from biomass in the form of methanol in a pilot project. They claim that, on a large scale, 75% would be possible. Obviously this should be taken with great circulatory system threatening sacks of salt. Also, Mitsubishi

says nothing about cost. But it certainly is indicative that Methanol conversion efficiency limit is well above 50%.

Mitsubishi Power Systems, *New Product New Technology: Biomass Gasification Methanol Synthesis System*. 29/Sep 2005, Mitsubishi Power Systems, Jan-03-2007

<http://www.mhi.co.jp/power/e_power/techno/biomass/index.html>.

³⁰⁶ Doctor L. Fishbein, *ENVIRONMENTAL HEALTH CRITERIA 196: Methanol*, 1997). *INTERNATIONAL PROGRAMME ON CHEMICAL SAFETY*. 1997. *UNITED NATIONS ENVIRONMENT PROGRAMME; INTERNATIONAL LABOUR ORGANISATION; WORLD HEALTH ORGANIZATION*, 03/Jan/2007 <<http://www.inchem.org/documents/ehc/ehc/ehc196.htm>>.

³⁰⁷ John A. Volpe National Transportation Systems Center of the U.S. Department of Transportation Research and Special Programs Administration, *CLEAN AIR PROGRAM SUMMARY OF ASSESSMENT OF THE SAFETY, HEALTH, ENVIRONMENTAL AND SYSTEM RISKS OF ALTERNATIVE FUELS - Aug 1995 Final Report*, Aug 1995), FTA-MA-90-7007-95-1 ;DOT-VNTSC-FTA-95-5. Mar 1999. *Federal Transit Administration*, 01/03/2007 <http://transit-safety.volpe.dot.gov/Publications/CleanAir/Alt_Fuel/alt_fuel.pdf>.p3-5.

³⁰⁸B.H. West et al., *Federal Methanol Fleet Project Final Report*, Mar-1993), ORNL/TM -12278. 2003. *Oak Ridge National Laboratory; U.S. Department of Energy Office of Transportation Systems*, Jan-03-2007 <<http://www.ornl.gov/info/reports/1993/3445603700029.pdf>>.

An important note on maintenance: if you look at the chapter on this subject, especially the summary tables on page 21, you will see that engine wear, and maintenance were if fact worse than with gasoline, but not a great deal worse. Given that these were retrofits rather than designed from scratch for M85, had original parts ripped out and replaced, there is little doubt that a built-from-scratch methanol car would have had reliability comparable to gasoline.

³⁰⁹ Howard ED Lentzner, "Glow-Plug-Assisted Ignition and Combustion of Methanol Studied in a Direct-Injection Diesel Engine". *Combustion Research Facility News* 23, no. No 1 Jan/Feb 2001, Sandia National Laboratories, 03-Jan-2007 <http://www.ca.sandia.gov/crf/newspubs/CRFnews/news_pdf/CRFV23N1.pdf>.

³¹⁰Biomass Energy Research Association (BERA), *Additional Commentary Submitted by D.L. Klass for the Record: Los Angeles Evaluation of Methanol- and Ethanol-Fueled Buses*. 29/May 1998, Biomass Energy Research Association (BERA), Jan-03-2007 <<http://www.bera1.org/LA-buses.html>>.

³¹¹ R. Lal, R. F. Follett, and J. M. Kimble, "ACHIEVING SOIL CARBON SEQUESTRATION IN THE UNITED STATES: A CHALLENGE TO THE POLICY MAKERS.", *Soil Science: An Interdisciplinary Approach to Soil Research* 168, no. 12 Dec 2003, Walters Kluwer | Lippincott Williams & Wilkins, 01-Jan-2007 <<http://cat.inist.fr/?aModele=afficheN&cpsidt=15361224>>.

³¹² Jim Dryden, "Does Too Much Protein in the Diet Increase Cancer Risk?" *School of Medicine News & Information*, 7/Dec 2006, Washington University in St. Louis School of Medicine, Jan-03-2007 <<http://mednews.wustl.edu/news/page/normal/8388.html>>.

³¹³Nathanael Greene et al., *Growing Energy: How Biofuels Can Help End America's Oil Dependence*, Dec-2004). Dec 2004. *Natural Resources Defense Council*, 01-Jan-2007 <<http://www.nrdc.org/air/energy/biofuels/biofuels.pdf>>.p5.

³¹⁴Burton C. English et al., *25% Renewable Energy for the United States By 2025: Agricultural and Economic Impacts*, Nov 2006). Nov 2006, 4.1 Renewable Production. *The University of Tennessee Department of Agricultural Economics Biobased Energy Economics Analysis Group*, 03/Jan/2007 <<http://www.agpolicy.org/ppap/REPORT%2025x25.pdf>>. p31.Table 11.