Biodiesel: Good, Better, Worst or why Trajectory Matters:

Biodiesel is an environmentally friendly fuel, significantly in-demand across Europe for cars. It has a substantially better energy balance than ethanol, causes a dramatic reduction in carbon emission per mile driven relative to petroleum based diesel, is 100% renewable, and it can go into existing diesel engines without modifications - so what is there not to like? Lots!

To answer this question, we feel it's worth delineating biodiesel into two categories – classic (or conventional) biodiesel and cellulosic diesel (which itself is an example of cellulosic hydrocarbons which also include cellulosic gasoline and cellulosic jet fuel). In our view, sustainable, cellulosic diesel offers a future as an oil replacement while classic biodiesel is likely to be a niche, even undesirable product. Notable flaws exist with classic biodiesel that have stopped us from investing in it. **We are skeptical about biodiesel derived from vegetable oils and animal fats for three main reasons – it doesn't scale in terms of gallons of fuels produced per acre (i.e. efficient land use), it does not have improving economics over time (it is not cost-competitive with oil without subsidies which are likely to go away at some point), and it has consistency problems. Trajectory matters – it represents the understanding that a technology's profile now does not always reflect its profile in the long run. For classic biodiesel, neither the trajectory of land efficiency nor cost is positive.** Therefore, we have come to the conclusion that the current approaches are non-economic, spot solutions for overall diesel replacement. Additionally (unlike corn ethanol) these approaches are not helping to develop new infrastructure which cellulosic diesel can leverage, limiting it's societal or business value to a short-term basis only.

We believe that there are versions of biodiesel (using conventional methods) that may make social and economic sense. Jatropha is being planted in India, China and other parts of the world. Since Jatropha grows in sub-prime non-food crop lands, it is potentially useful because land becomes less of an issue (though it is possible that biomass using energy crops is likely to be a better crop even on these marginal lands). Biodiesel made from algae is another potential source; however, large tracts of water are only available in open oceans and that creates the related issue around using genetic engineering techniques to optimize algae which would be an environmental risk. The economics of container grown algae is suspect; pond-grown algae is possible, but the economics are unclear today. Our belief is that easier solutions exist, but in our search for a diverse set of answers all avenues should be explored. We are more optimistic about the potential for designer fuels, such as cellulosic diesel, cellulosic aviation fuel, and cellulosic gasoline made directly from biomass (yes, it is possible).

Classic Biodiesel – The Current Path

The problems with classic biodiesels

	”Classic” Biodiesel	Ethanol	Cellulosic Diesel
Carbon Reduction – 2006	80%	20-30%	Not available
Carbon Reduction – 2010	80%	80%	80%
Scalability (2030-gallons per acre)	600-900	2,500 (cellulosic)	2,500 (cellulosic)
Sustainability Potential (2030)	Poor	High	High
Product Quality	Poor	Good	Good
Unsubsidized 10yr Market Competitiveness Potential	Poor (@$45 oil price)	Good (@$45 oil price)	Good (@$45 oil price)
Production Cost (2010)	High	Med-Low	Med-Low
Technology	Static	Active Development	Nascent

Trajectory: From our perspective, classic biodiesel is a dubious and risky investment. While it has lower emissions than ethanol today, it is not likely to improve its environmental profile in the future (especially the cultivation profile for feedstocks – a major potential problem) because it lacks a positive long-term trajectory. Biodiesel's competitiveness will not improve substantially over time for two main reasons: (1) its cost of production is unlikely to decline rapidly as long as it is made from vegetable oils (which are not declining in cost) and (2) technology is not a major part of its production and hence production costs are unlikely to decline. The single largest cost in biodiesel production is feedstock – and as demand increases, this cost is likely to head upwards in the long run. While biodiesel makes us feel good in the short run, it is unlikely to be competitive in the future without subsidies. On the "carbon reduction per mile driven" metric, we are likely to see all biofuels made from cellulosic biomass achieve numbers close to 80% reduction (with the possible exception of feedstocks for both biodiesel and cellulosic biofuels which are grown on land recouped by cutting down rain forests). Biodiesel feedstocks issues already exist and are discussed below. This last phenomenon must be guarded against by passing laws that measure "direct and indirect lifecycle carbon emissions" for all fuels as the various renewable fuel portfolio standards are being considered. **Later, we will discuss "cellulosic hydrocarbons" which are higher quality diesel (and gasoline) substitute products that can be used in unmodified engines and are likely to have declining cost curves with time and scale – thus having the trajectory advantage that classic biodiesel does not.**

Scalability: Biodiesel's trajectory is limited by its inability to scale to meet a substantial (30-50-80%) portion of our petroleum needs because of feedstock limitations. The keys to scalability are as follows.

(1) Sufficient feedstock to produce the fuel at a large enough scale to be material. In the case of biofuels, land efficiency in gallons of fuel produced per acre is the key factor in generating sufficient feedstock volumes. Technologies that make economic sense as investments may not be material enough to solve the global oil problem because there is not enough land to produce sufficient volumes of feedstock. Estimates suggest that conventional-vegetable oil based biodiesel can only meet a small portion of total demand (from 5-10%)[1]. Professor David Tilman's research into land usage notes that even dedicating the nation's entire soybean crop (most US biodiesel is currently soybean based) to biodiesel production would meet only about 6% of total diesel demand. Today, biodiesel yields are about 500 gallons per acre - similar to corn ethanol. However, the seed

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[1] Joshua Tickell "From the Fryer to the Fuel Tank", http://www.energyjustice.net/biodiesel/factsheet.pdf, http://www.soygold.com/news/NBBspeech.pdf

part of crops from which vegetable oil is extracted (like soy) have already been optimized and yields are not likely to rise significantly – our estimates suggest that yields will peak at 600-900 gallons per acre, providing an evolutionary dead-end. While corn ethanol yields are likely to be similar, its real advantage over biodiesel is its role as a gateway to cellulosic ethanol (and cellulosic fuels in general). We believe that cellulosic fuels can yield about 2500-3000 gallons per acre (see Appendix A) while dramatically lowering the cost per gallon (to $1.00 per gallon production cost once production technologies and feedstock yields are optimized over time). The acres of land required to replace all our oil replacement needs will also be very manageable. Some fraction of lands used for export crops could replace most of our gasoline under the right circumstances. Diesel made from cellulosic feedstock has the potential to reach the same yields as cellulosic ethanol - classic biodiesel does not. Biodiesel made from special crops like jatropha and algae may have value in certain situations despite its low yields per acre; however, we question its scalability.

(2) Lower cost per gallon than its fossil fuel competitors over time, allowing economics to drive the market. This must hold true over the long term, even when faced with potential market fluctuations/manipulations. As noted above, we assume oil can (with the widespread adoption of biofuels) decline to $45 per gallon in ten years and potentially drop to $30-35 per barrel by 2030 and an alternative fuel must be able to compete with all the price vagaries of the oil market over the next twenty-five years. The cost competitiveness is discussed in more detail later.

(3) The ability to attract capital to scale to the levels to make a practical dent in the quantity of oil we use. For this, the return on equity should make sense to keep capital flows coming into the technology deployment, and the risk of competitiveness given market parameter fluctuations and subsidies should be low. Are we likely to offer a dollar a gallon subsidy on tens or hundreds of billions of gallons of fuel? Unsubsidized market competitiveness in the long term is the key to attracting capital for scaling. And fuels that can achieve unsubsidized market competitiveness can attract the hundreds of billions of dollars of new investment that is required to compete with oil. Biodiesel is likely to fail most, if not all of the tests detailed above.

Sustainability: Sustainability pertains to the nature of the agricultural practices the feedstock is amenable to. Though any feedstock can be produced on a sustainable or unsustainable basis, biomass is much more amenable to sustainable practices because its cost of production can decline as more sustainable practices are implemented. What do we mean by that? A material increase in land use for biofuel cultivation comes with rampant increases in water, fertilizer, and pesticide demand (which would be a problem) – classic biodiesel does not show any signs of reducing its water usage or nitrogen emissions as it increases in scale (with the exception of algae or jatropha based biofuels) . Biofuels that do not utilize improved, sustainable agronomy practices are unlikely to be sustainable at a large scale, and in some cases can actually make emissions worse (see the "greenwashing" section below). We believe it is far easier to grow biomass on a sustainable basis than it is to grow seed crops from which vegetable oils for biodiesel are produced.

Quality: Another issue is the quality (or lack thereof) of biodiesel. As a blend, biodiesel works just fine, and as B5 it is a fine product. But can the same thing run at 50% or 100% biodiesel? We admire the stories we've heard of Willie Nelson's biodiesel exploits, of biodiesel made from waste oils, grease, and other such romantic notions. They do work, but will Ford warrant their trucks or cars against notoriously variable fuel specifications? Classic biodiesel has a higher cloud point (temperature at which a fuel becomes hazy or cloudy and starts to gel) than petrodiesel. This means that biodiesel starts gelling (and thus clogging up engines) at higher temperatures than petrodiesel, making it impractical in cooler climates (and thus limiting its potential market). Worse, biodiesel from different feedstocks has different properties. Will users tolerate biodiesel from different sources that is a gamble when it comes to their trucks or cars? The various forms of biodiesel are made from a range of feedstocks (soy, jatropha, animal slaughterhouse waste, and palm oil to name a few). Unfortunately utilizing multiple sources result in highly variable fuels that have significant variation in their quality, properties and consistency. This is problematic for most of the major car and truck manufacturers whose willingness to co-operate is vital. Ethanol, in comparison, is a consistent fuel with the same chemistry irrespective of the source and cellulosic diesel is likely to be similarly consistent. Beyond scalability and unsubsidized economic viability, the #1 issue facing the biodiesel industry right now is product quality and consistency. At the Alternative Energy NOW conference in February 2007, Teresa Alleman of NREL reported that 50% of the B100 samples they tested from around the country failed the ASTM D6751 standard. Their survey was not volume-weighted so this failure rate is not completely representative of the failure rate of the overall biodiesel market but it speaks volumes in terms of quality inconsistency across production facilities and vendors.

Production Cost/ Market Competitiveness: For a biofuel to be a material part of the market, it must be cheaper across a wide range of price fluctuations of the fossil fuel it is competing with.

Businesses must be able to make money in a scalable way - otherwise the infrastructure for scale will never happen despite the best of intentions. Biodiesel meets the cost competitiveness requirements currently because of a $1.00 per gallon subsidy (as all new fuels appear to need help when getting started but biodiesel needs almost twice the subsidy per gallon that ethanol gets). Because of its lack of a decreasing cost trajectory (unlike cellulosic biofuels), it seems risky to assume biodiesel can compete without the subsidies. Given our national political unwillingness to cut off subsidies if it keeps an industry on life-support, we may well be creating another government program that won't be stopped. The usage of subsidies and incentives should be limited to support technologies that are likely to achieve unsubsidized market competitiveness within 7-10 years. Today, even the National Biodiesel Board admits that biodiesel needs the government – in an April 26, 2006 press release, the CEO of the NBB cautioned that the growth trajectory of biodiesel was dependent on various federal government initiatives[2]. Our business test is to insure that technologies, once scaled, can compete unsubsidized as oil prices vary down to $45 per barrel in the next ten years and down to $30-35 by 2030. Even oil prices down to $25 per barrel (in the long run) are possible. Will biodiesel be able to compete with that? We believe cellulosic biofuels, for comparison, will achieve this level of competitiveness. Fuel alternatives to oil must have declining cost both with scale (as volumes ramp up to tens or hundreds of billions of gallons per year) and over time as technologies improve. These metrics allow these new technologies to attract vast amounts of capital. Most of the cost of biodiesel is in the feedstock which is only likely to increase in cost as the demand for this commodity increases. These feedstocks, unlike biomass feedstocks, are highly optimized crops. We anticipate yields increasing marginally (with inputs like fertilizer and water held constant) for these "already well optimized" food oils while they can increase dramatically for biomass which is a nascent crop with little work done on increasing its yields (Corn for example has seen a seven fold yield increase since the 1930's and we see no reason biomass cannot see a three fold or greater increase). As biomass yields increase and technology improves both the feedstock cost and the processing cost will decline for cellulosic fuels while improving scalability because of improved yields and hence the improved land efficiency. Classic biodiesel is unlikely to follow a similar trajectory.

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[2] http://www.biodiesel.org/resources/pressreleases/gen/20060426_Jobe_testimonyNR.pdf

In summary, current production methods of biodiesel (1) fail to be good climate change solutions because of the (likely) land inefficiency in gallons produced per acre, hence failing the scalability test. The government should not be spending our tax dollars on these technologies unless the incentives are directed towards cellulosic hydrocarbons. (2) fail the investment test because they will not achieve unsubsidized market competitiveness within 7-10 years and are uneconomic if oil prices decline to $45; (3) are based on technologies that do not have declining cost with technology improvements and hence does not have declining risk (4) The business models are unlikely to work unsubsidized. A good trajectory on technology, cost, and land efficiency is key, and classic biodiesel fails on all counts. The last two reasons suggest that investors interested in this market should direct investment to the cellulosic hydrocarbon technologies that will benefit from the lower cost of the energy crops ecosystem as it develops.

The Promise of Cellulosic Hydrocarbons:

Having detailed the flaws of classic biodiesel, we will address the potential to do cellulosic-biomass based diesel right through the path of cellulosic hydrocarbons. To reiterate, the flaws of classic biodiesel persist from its lack of trajectory, significant cost issues, inconsistent quality, and inability to scale. From Khosla Ventures perspective, we prefer investments that

(1) attack manageable but material problems
(2) use technologies that can achieve unsubsidized market competitiveness quickly
(3) use technologies that can scale
(4) use technologies that have manageable startup costs and short innovation cycles
(5) technologies that have declining costs with scale (trajectory).

Cellulosic hydrocarbons offer the potential to overcome the shortcomings of biodiesel while meeting our investment criteria. We define cellulosic hydrocarbons as designer fuels that use biomass feedstocks to produce hydrocarbons – fuels such as cellulosic diesel, cellulosic gasoline, and cellulosic aviation fuel (kerosene) that will replace their oil based counterparts in unmodified engines. Non-hydrocarbon fuels like cellulosic ethanol are covered elsewhere. Our focus here is on the diesel replacements (we do foresee potential for cellulosic gasoline, but that is not detailed here).

There are four main routes to cellulosic diesel fuels:

(1) direct fermentation of the end-use fuel from biomass based sugars and cellulose
(2) thermochemical processing and/or catalytic conversion of biomass. Thermal depolymerization, hydrotreating and other similar approaches fall into this category;
(3) gasification of the cellulosic feedstock, followed by the Fischer-Tropsch process,
(4) catalytic production of a biocrude that is cracked and/or upgraded in a refinery.

There are various attempts to produce crude oil (often called bio-oil or biocrude) from cellulosic or waste materials like municipal waste, recycled plastics, and other renewable feedstocks. This oil, though often of inconsistent quality, could be processed sufficiently to feed into traditional crackers and refineries that currently use crude. The result of this process can produce potentially economic fuels in a scalable way (especially when made from biomass feedstocks), while leveraging the existing infrastructure of oil refineries worldwide. This provides for attractive business dynamics. In addition to the paths listed here, it seems likely that the innovation ecosystem will discover additional, more efficient pathways in the future.

The commonality amongst the described pathways is their usage of cellulosic feedstocks. That is a significantly more scalable and sustainable solution (if it works) both technically and economically, because biomass can be made available in very large volumes. The development of land devoted to energy crops (potentially in a 10 x 10 year rotation with row crops like corn and soy) would help meet biomass supply needs for biofuels. This approach has the added potential benefit of improving the bio-diversity through polyculture agriculture and improving the soil as well (if energy crops are grown as grass cocktail rotations with row crops – see our BioFuels Pathways paper at www.khoslaventures.com/resources). Today, the targeted feedstock crops have little practical use, and have had far-less optimization research. As a result, they have more room for improvement than staple crops such as corn, rice, wheat, and soybeans. Furthermore, the trend of the targeted energy crops to be perennial with more established root systems and less need for water makes them more attractive that traditional row crops. For cellulosic energy crops like switchgrass, sorghum and miscanthus one can envision increasing yields per acre (our forecasts by 2030 are 24 tons/acre in a typical 40 inch per year rain region for miscanthus, high yield sorghum and similar crops which use C4 photosynthesis – see Appendix A). Even utilizing agricultural waste has significant potential – a US DOA study noted that 1.3 billion tons of such biomass is relatively easily available yearly. This is sufficient biomass to more than 100 billion gallons of ethanol using currently envisioned processes or twice as much cellulosic fuel if the carbon dioxide emissions during the production of fuels is eliminated (thus replacing most of today's oil use for both diesel and gasoline). The presence of large quantities of municipal and industrial waste is another feedstock option -–the U.S produces 7-8 million tones of municipal sewage and 245 million tons of municipal solid waste per year[3]. Winter over crops may also provide another major source of biomass crops with no additional land needs.

Today, the fuel properties of biodiesel are dictated by local feedstocks. In Asia, palm oil and jatropha have a lot of traction but they also have high concentrations of saturated fatty acids (40-50% for palm oil and 20-35% for jatropha) which lead to poor cold flow properties (essentially, the usefulness of a fuel at low temperatures due to gelling). On the other hand, by controlling the genetic properties of microbes or defining precise thermochemical and catalytic chemistries, we can dictate the structure of the resulting hydrocarbons (including chain length and degrees of unsaturation) and thus control the properties of the fuel. This sort of customized chemistry approach is an advantage of cellulosic hydrocarbons; classic biodiesel cannot be customized to meet needs.

Take the example of soy based biodiesel, which is the dominant biodiesel type in the US today. Soybean oil based biodiesel products end up with cetane numbers (how easily a compressed fuel ignites – the higher the number, the more efficient the fuel) of 48.7 to 55.9 and a cloud point of -2 ^{o}C to +3 ^{o}C. What if we could create a fuel that had the same "good" qualities (the cetane number) with a lower cloud point? By controlling microbe genetics, we could produce a customized chemistry that would have a cetane value of 55 but a cloud point about 10-15^{o}C lower than the soy-based alternative. In a cold climate, this kind of methodology makes cellulosic diesel viable whereas classic biodiesel would not work. Depending on the needs (be it geography, time of year, desired end use) other customized chemistries will be desirable – all of which could be enabled through precise genetic modifications of the biocatalyst. Another advantage of the synthetic approach is that microorganisms will produce the same fuel every time, thus solving the consistency issues of classic biodiesel.

Eventually, we believe designer fuels (like butanol and cellulosic hydrocarbons) have a strong part to play in our transportation fuels matrix. There are companies all across the space utilizing a variety of techniques – an example of the innovation ecosystem at work. LS9's founders included perhaps the world's foremost plant biology authority and one of the leading DNA sequencing experts in the country; they are using synthetic biology to move pathways from other

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[3] http://www.inderscience.com/search/index.php?action=record&rec_id=13639&prevQuery=&ps=10&m=or and http://www.epa.gov/msw/facts.htm

organisms into bacterial cells from which hydrocarbons will be extracted using modified refinery technology. Initially founded to develop a bio-based drug for malaria (and which received a Gates foundation grant for that purpose), Amyris is now developing a proprietary diesel molecule made by fermentation of cellulosic feedstocks. Kior is utilizing catalytic pyrolysis process to cost effectively convert biomass into a biocrude. Another company has been founded by a chemical engineer with experience building plants across the world, and has developed an extremely efficient catalytic process to convert biomass into diesel. And these are just within Khosla Ventures' investments – there are many interesting efforts outside our portfolio.

If cellulosic hydrocarbons are produced using the approaches outlined, we are confident that they can replace conventional petroleum while combating the climate change problem. In the long run, we have a number of possibilities for meeting our transportation fuels needs: biodiesel, ethanol and other follow-on chemistries to ethanol (like butanol) or cellulosic hydrocarbons. A fundamental shift away from gasoline has already started, beginning with corn ethanol (initially) to cellulosic ethanol and eventually to other future fuels. We do not believe that classic biodiesel can do for cellulosic diesel what corn ethanol will do for cellulosic ethanol for the reasons detailed above. It will not be a viable replacement nor serve as a stepping stone to replacing petrodiesel. To supplant petrodiesel, we need cellulosic hydrocarbons.

Green Niches and "feel good" Actions

One of the reasons that biodiesel has received significant attention is the belief and desire of many people to "do something", irrespective of its actual impact. Unfortunately, this has often lead environmental idealism to dwarf pragmatism, which achieves little. For example, the city of San Francisco collects grease from restaurants and turns it into a million gallons of biodiesel a year to run its buses. Is this really an economical solution or simply a show of "being green"? Even if the economics work in San Francisco (because the grease has to be collected anyway) will it ever scale to have a material impact? Will it be good enough quality for manufacturers to warranty their engines for it, and to control particulate and other emissions in a predictable way? We think the answer to these questions is "No." We have no problems with the usage of these fuels on a private level, but should the limited federal, state or city dollars be spent providing incentives to marginal solutions? What solutions should we focus our attention on and promote? Using solar cells in a foggy city like San Francisco is a similarly poor "feel good" idea that is often pushed. The cost of this solar power in San Francisco with its low solar radiation is very high and the use of funds for this purpose is very cost inefficient. Elsewhere, our article on Dr. Herman Scheer[4] notes the effects of "feel good" or "romantic local" solutions on nuclear technology in the past, and its role in promoting non-scalable solutions today. It is important to note that products that may meet a niche, green market are not necessarily practical as climate change solutions or energy security solutions till they achieve massive scale. At the policy level our focus should be on larger, material solutions.

Bad to Worse

One particularly problematic example of misguided "feel good" actions is the use of Indonesian and Malaysian palm oil-based biodiesel. Perceived as an environmentally friendly fuel, the palm-oil in question is produced from palm-trees planted on cleared rainforest land. The cost is high: the increase in carbon emissions from the removal of the carbon capturing rainforest ecosystem is not offset by the decrease in emissions from regular diesel to classic biodiesel , meaning that the biodiesel is significantly worse than (from a climate change perspective) regular petrodiesel[5]. To add insult to injury, the biodiesel produced from palm oil is actually subsidized at a $1.00 per gallon – serving only to provide more incentives for the destruction of the rainforest. Furthermore, this is done without providing any value-addition in the US that might justify the subsidies on economic grounds (if not on environmental). This is a textbook example of "Greenwash." From any perspective, actively importing oils (such as palm) that are environmentally disastrous to utilize for an "environmentally friendly" fuel makes no sense – we propose a ban on biodiesel produced from imported oils to fix the problem. Unfortunately greenwashing is a real problem in the whole "going green" phenomenon, and many other examples abound.

The Media's Role

An important aspect of the adoption of biofuels at large is the role of the media – fighting and winning the PR battle is a vital step to success while losing it can lead to the spread of

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[4] http://news.com.com/Keeping+clean+tech+down-to-earth/2010-11392_3-6176105.html
[5] http://www.deseretnews.com/dn/view/0,1249,660207597,00.html

misinformation. For example, a common media refrain on corn ethanol is that its environmental benefits are “limited”, and that its adoption has more to with politics than science. Meanwhile, hybrids-vehicles have captured the media imagination as an environmentally friendly technology – even though corn-based ethanol offers the same “carbon emission per mile driven” benefits as the usage of hybrids, at 1/100th the cost per car. How often do we see “hybrid carbon emission reductions” criticized? Similar battles are likely to be fought in the long-run with biofuels – getting the correct information disseminated to the public is a vital step.

What Else Can We Do?

Despite our skepticism about some avenues, there are still plenty of possibilities for innovation to meet our biofuels needs in economic and environmentally pragmatic ways. While our focus here has been on broadening the supply of diesel-replacement fuels, there are approaches at work to reduce our need for gasoline and to dramatically reduce demand as well. The two largest factors in reducing transportation fuel demand are increased efficiency standards (i.e. – CAFE) and the development of newer, more efficient engines.

- Efficiency: Better engines & lighter cars, hybrids, plug-in electric cars can all reduce our need for liquid fuels. The best way to achieve higher mileage and promote these technologies is to increase CAFE mileage efficiency requirements dramatically by law.

- New engines – At Khosla Ventures, we have investments in new engine technology, such as Transonic Combustion whose goal is to increase engine efficiencies dramatically. HCCI and other engine technologies will allow substantially increased mileage for the same performance on all fuels be they ethanol, diesel or gasoline. The SAAB 9-5 Biopower Turbo is another example of a turbo compression engine in the marketplace that achieves mileage on ethanol disproportionate to ethanol’s lower energy content .Today, most engines are optimized for gasoline usage; as biofuels penetrate the market, new engines with better optimization /higher compression are likely to be developed for ethanol, butanol, and other biofuels. It is likely that ethanol can achieve equal mileage per gallon to gasoline with optimized engines, despite its lower energy content per gallon. Cellulosic hydrocarbons may develop with little need for engine and infrastructure changes but would benefit from general improvement in engine efficiencies.

Summary

In conclusion, we are optimistic that viable petroleum-replacement solutions exist that will be more economic than their fossil competitors (gasoline and diesel), unsubsidized. While classic biodiesel suffers from a lack of trajectory, scalability, and sustainability, cellulosic hydrocarbons are on track to overcome these hurdles. The presence of obstacles is not cause enough to retain the old tired petroleum-based approach, despite what many naysayers would have us believe. The key question to ask with any new approach is “What is” versus “what can be”. Otherwise we get the “same old, same old” and the vision of the “nothing can change” crowd. We must not let the perfect be the enemy of the good. We need to imagine the future and make it happen through the right policies in Washington and the empowerment of our scientists, technologists, entrepreneurs and venture capitalists. If we don't “imagine the future” and don’t attempt to make the “new and possible” happen because we believe it won’t, it results in a self-fulfilling prophecy. Alan Kay, a premier computer scientist, put it best – “The best way to predict the future is to invent it.”

Appendix A:

How Much Fuel Can We Produce?

Below are Khosla Ventures projections of the expected yields of cellulosic ethanol from 2005 to 2030, accounting for improvements in yield of biomass crops, efficiency of ethanol production per ton of biomass, and increases in land usage. Over the period, crop yields are likely to increase four-fold! Additionally, it's worth noting that the gasoline demand does not take into account increased engine efficiencies (such as that proposed by Transonic Combustion, one of our investments) or increased CAFE (Demand in the table below is projected to grow 1% per year along historical lines though we hope technology improvements and policy both reduce our per mile driven consumption of liquid fuels - a single technology like Transonic is developing can cut our gasoline and diesel needs in half). While our tables are projections for cellulosic ethanol, they are also reasonable approximations of the trends for all cellulosic fuels, including cellulosic diesel. Regarding demand for the new fuels, we feel its worth noting that as good cellulosic hydrocarbon technologies emerge (for diesel, gasoline, and aviation fuels), the "consumption constraints" (the limited numbers of vehicles that can use the new fuels today) will fade, and we won't need to change our cars and trucks to use the new fuels.

Year	Biomass Yield (tons/ac)	Ethanol Yield (Gals/ton) (best technology)	Biomass Acres Million Acres	Production Cellu.Ethanol (Billions Gals)	Production Corn Ethanol (Billions Gals)	Production Total Ethanol (Billions Gals)	Ethaol Prod. Gas. Equival. (Billions Gals)	Gasoline Demand(1%) (Billions Gal)
2008	7.0	90.0	0	0.0	6.9	6.9	5.5	144.2
2009	7.3	93.6	0.1	0.1	8.3	8.4	6.7	145.7
2010	7.8	97.3	1	0.8	10.0	10.7	8.6	147.1
2011	8.3	98.3	3	2.5	10.9	13.4	10.7	148.6
2012	8.9	99.3	5	4.4	12.0	16.5	13.2	150.1
2013	9.6	100.3	7.5	7.2	13.2	20.4	16.4	151.6
2014	10.2	101.3	10	10.4	14.6	24.9	19.9	153.1
2015	10.9	102.3	13	14.6	14.6	29.1	23.3	154.6
2016	11.7	103.3	16	19.4	14.6	33.9	27.1	156.2
2017	12.5	104.4	19	24.8	14.6	39.4	31.5	157.8
2018	13.4	105.4	22	31.1	14.6	45.7	36.5	159.3
2019	14.3	106.5	25	38.2	14.6	52.8	42.2	160.9
2020	15.4	107.5	28	46.2	14.6	60.8	48.6	162.5
2021	16.3	108.6	31	54.8	14.6	69.3	55.5	164.2
2022	17.2	109.7	34	64.3	14.6	78.9	63.1	165.8
2023	18.3	110.0	37	74.4	14.6	89.0	71.2	167.5
2024	19.4	110.0	40	85.3	14.6	99.8	79.9	169.1
2025	20.5	110.0	43	97.2	14.6	111.7	89.4	170.8
2026	21.8	110.0	46	110.2	14.6	124.8	99.8	172.5
2027	23.1	110.0	49	124.4	14.6	139.0	111.2	174.3
2028	24.5	110.0	52	140.0	14.6	154.5	123.6	176.0
2029	24.5	110.0	56	150.9	14.6	165.5	132.4	177.8
2030	24.5	110.0	60	161.7	14.6	176.3	141.0	179.5