DRAFT

Policy and Perspective: the Scoping Plan for AB 32, and how to do it Right

Executive Summary:

Science can be precise but inaccurate, resulting in wonderfully precise yet completely misguided results from a policy perspective. Similarly, econometrics modeling can paint a picture with a limited, narrow range of possibilities (aka “low standard deviation”) with a significant mistake around the mean value (“high standard error”). In the debate ranging about biofuels today, both problems persist in different manifestations – among the recent papers influencing current debate (especially around the AB32 scoping plan being considered in California) are articles by Professor Timothy Searchinger[1] arguing that biofuels harm carbon emissions more than they help, and a recent letter[2] by a group of distinguished academics (Delucchi et al) arguing for strong consideration of biofuels’ indirect land use change (iLUC) in the development of California’s Low Carbon Fuel Standard. Both are ground in solid science, well-intentioned pieces that are intended to inform the debate – unfortunately, both fall into the trap of inaccurate modeling nonetheless conducted to a high degree of precision; they provide a false sense of knowledge to the debate that can mislead policy making. My focus here is on explaining why they are wrong for the intended purpose of policy making, and to illuminate more important issues they fail to consider, besides having model input assumptions that are both likely to be wrong as currently used and that can be dramatically changed by policy signals.

AB 32 promises to be a landmark measure – putting a hard cap on GHG emissions and reducing emissions from major sources, and encouraging the development of renewable energy resources. In my view, any policy must do the following (1) attempt to measure the total lifecycle carbon emissions, not based on past data but where we are likely to be WHEN material scaling starts to happen (2) include technology trajectory considerations as the key to framing a long-term policy making approach that gives us the greatest cumulative benefit over an extended period of time (3) assigns significant priority to creating additional carbon reduction options and not shut of potential future options that may develop through successive iterations of technology and practice evolution; (4) send economic signals to the marketplace that cause innovation to happen along the right direction. Not only do Searchinger et. al. fail to include these most critical considerations (and they did not intend to either – theirs was a scientific paper with a narrow purpose) but they also fail to look at likely changes in land use patterns driven by the biofuels economic signals (a major error in their analysis resulting in precision without accuracy). Instead they use economic signals driven by other considerations (like deforestation driven by timber value) and assume without justification that it is a reasonable estimate of land use changes driven by biofuels. Much of the policy debate has failed to include any of the factors above.

We must promote technologies that are likely (in the 2025-2050 time horizon) to achieve the lowest cumulative potential carbon emissions at the lowest possible costs and which have low “adoption” risk of worldwide adoption at large scale. Cost is key – a solution that can achieve initial trajectory in California but cannot scale to China and India is destined to remain a niche solution (hybrids for e.g. appear to have high risk of adoption in the vast majority of the next billion cars shipped on this planet, based on current cost trajectories to achieve low cost or low carbon power). We believe that biofuels are

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[1] http://www.sciencemag.org/cgi/content/abstract/1151861

[2] Delucchi et al; a copy can be seen at http://www.bioenergywiki.net/images/8/89/LUC_letter.pdf

one of the few technology approaches that can achieve both low-cost and large-scale – to exceed penetration of 80% of all cars in California, and eventually the world. Furthermore, unlike many other alternatives, biofuels offer low adoption risk – engines today can run on them with small modifications. For California, the role as the incubator of startups and technology can lead to massive opportunities – a "green" boom to rival Silicon Valley. In the biofuels assessment of AB32, a few areas are key: 1) distinguishing between scalable-non-food based biofuels (cellulosic)and smaller, food-based sources (like corn ethanol and classic biodiesel), and differentiating amongst various biofuels (corn ethanol, cellulosic ethanol, biodiesel, cellulosic diesel, butanol, biocrude, and others) in general 2) Assessing non-food-based fuels on a per-facility basis, using a LEEDS-like Carbon, Land, Air and Water (CLAW) impact rating for proper life-cycle analysis, to better capture local carbon changes, productivity, etc specific to a facility, 3) understanding timelines to better understand when any impact of iLUC actually happens (realistically, 15 +years from now for cellulosic fuels, more immediate for food based fuels) – not to handicap biofuels development in advance of this impact and 4) increasing the biofuels alternatives available by 2025 or so by encouraging a multitude of experiments and investigations – and not nipping promising ideas in the bud through iLUC or other assertions at an early, uncertain stage.

Recently, the Searchinger article has gotten significant publicity. The model is inaccurate in assessing only one of many possible scenarios (though it is precise in calculating the impact of the specific assumptions it made – assumptions we believe are unlikely to represent the most probable scenarios, especially if policy sends the right economic signals today) using land-use patterns that pre-date biofuels. A policy directed future land use pattern with strong economic signals driven by a price of carbon is more likely to result in far more favorable results for biofuels than the scenario Searchinger et. al. defined. Furthermore, we find a few other key errors in Searchinger's assumptions: 1) significant land displacement is assumed: this is not true especially for non-food fuels – multitude of minimal land impact solutions exist, such as Range Fuels/Mascoma (forest waste), Iogen (wheat straw waste), Lanzatech (steel mill flue gases) Coskata (organic waste and others), as well as low-land use usage options like algae (Alegnol); land displacement may be a fairer assumption for current food crops but even there significant potential exists for amelioration of the impact by sending the right economic signals and current assumptions about their impact are extremely speculative 2) Limited, low-yielding feedstocks: miscanthus offers 2.5X the biomass yield potential of switchgrass[3] (Searchinger's feedstock assumption for cellulosic biofuels) with significant agronomic benefits and improving yields – even before the implementation of improved agronomic practices such as 10 X 10 year crop rotations as elucidated later, usage of perennial grasses and polyculture crops, and no-till irrigation ; even for food based crops, no-till agriculture and dramatic yield improvements or other sources of food crop yield increases (such as the use of GMO crops in Europe or Africa) have the potential to invalidate their carbon impact assumptions; policy should drive the adoption of these lower impact methods and practices, not shut them off; 3) limited technology and development: Searchinger et. al. seem to assume biochemical processes (60-80 gal/dry ton yields)and no agronomic improvements; thermochemical processes (Range) have significantly higher yields (90-100 gal/dry ton); hybrid-thermochemical/syngas pathways can reach 110 gal/ dry ton (Coskata, Lanzatech); diesel (Amyris, LS9) can go higher, and depolymerization pathways (Kior) can reach 150 gal / dry ton - Current miscanthus yields + the Kior process could lead to 5-7 times the energy content per acre of land imagined by Searchinger. 4) Higher food prices, higher deforestation, more released carbon: there are multiple factors competing for land use, perhaps the largest of which is livestock – should we frame the debate as an ounce of steak vs. a gallon of fuel? How do we allocate that "blame" between biofuels and steak? Biofuels and timber? Similarly on deforestation, a proper assessment of marginal impact demands investigating trends before biofuels (e.g. logging), and normalizing for those pre-biofuel impacts, not assume that

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[3] http://news.cnet.com/8301-11128_3-10002885-54.html

biofuels will follow the same land use change pattern even if the economic signals are different. Moreover, it fails to consider the possibilities – like engineering systems to store more carbon rather than release it when biomass crops replace natural grasslands.

Land use models assume an acre of land-used for biofuels is replaced elsewhere by a currently unused acre used for crops, an approach we find flawed since there are other sources of "land recovery": 1) the models assume a energy crop acre used as being the same as a crop land acre; This is true if previous use of the acre was crops but even within this narrow definition we must account for the amount of crop displaced, not the amount of land acres displaced; it must also account for increases in the productivity of that energy crop acre if, as part of a long term rotation system, it is returned to crop production at higher productivity (improving degraded lands or improving productivity of productive lands); 2) underutilized land on which yields improve and inputs increase (like better seeds) as economics of land use improve 3) use of GMO crops to improve yield where such use was disallowed or better yields through other improved technology; 4) the ability of subsistence farmers in Africa/Asia who cannot efficiently grow high input food crops to grow low input energy crops 5) smart crop rotation schemes (we have proposed a 10 x 10 year energy crop / row crop rotation in our Biomass paper[4]) and 6) most critically, a limited need for any land displacement over the next 15 years or so for non-food crops: The DOE's "billion ton report"[5] notes that "an annual biomass supply of more than 1.3 billion dry tons can be accomplished with relatively modest changes in land use and agricultural and forestry practices." We believe feedstock sources such as winter cover crops (we estimate 700M tons+ by 2030 in the US), forest waste (DOE estimate: 368M dry tons of sustainable annual production), and agricultural residue (DOE estimate: 428M tons) will be sufficient in the time period. During this period why assign deforestation caused by other factors like logging to biofuels? Though food based biofuels (like corn ethanol) may have short term negative carbon impact, they may still be justified since they have played a significant stepping stone role to encourage non-food biofuels research. This indirect impact of corn ethanol is material and may justify limited allowance of corn ethanol (but not biodiesel which has not served a material stepping stone role), for a limited period of time. This kind of nuanced approach to biofuels policy is critical, instead of applying academic models that are technically right but lead to misleading policy decisions.

Elsewhere, Delucchi et. al. oppose the idea of setting the iLUC impact (when assessing as part of California's Low Carbon Fuel Standard) at zero – and we disagree for a multitude of reasons, many of them noted above in response to Searchinger. Primarily, we believe enough possibilities for zero or small net carbon impact from land use impacts exist that we should be encouraging their use, not utilizing old models to discourage biofuels **– increasing optionality is key**. In particular, we disagree with their argument of scientific consensus around older land-use models and their suggestion that iLUC modeling (such as that done by Searchinger et. al.) represents "the best available science" – rather, we think it is 1) a strong misrepresentation, as the best science is being invented in labs across the country today, and is not available for models such as these 2) completely ignorant of the real range of uncertainties around policy changes and technology impact on the accuracy of these models– we believe accurate models should project conversion processes, feedstock choices and yields, agronomic practices and other technological improvements likely to be invented/developed over the next few decades 3) includes likely land use changes driven by policy that drives carbon impact of land use change signals, not use past change form unrelated economic signals like logging, and 4) reliant on the risks inherent in forecasts - their

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[4] http://www.khoslaventures.com/presentations/WhereWillBiomassComeFrom.pdf

[5] "Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion Ton Supply", Robert D. Perlack, Lynn L. Wright, Anthony F. Turhollow, Robin L. Graham, Bryce J. Stokes, Donald C. Erbach – April 2005

argument that reputable organizations like the CBO, USDA, and WTO use similar models – respectable agencies like the EIA for example, have note that their forecast of average oil prices was off by 52%; natural gas prices were of by 64%, and coal prices were of by 47%.6 Imagine the errors in immature models over the course of the next 30-40 years, especially if the economic signals are materially different! Overall, at this early stage of development, we strongly believe that intelligent qualitative analysis (for example, noting the possibility of using energy crops to restore biodiversity to degraded lands, which Delucchi et al have not modeled) is more important than overly precise yet inaccurate quantitative approaches. Encouraging and testing promising new avenues for low carbon fuels and increasing options on the number of direction for low carbon transportation solutions is more important than estimated future accounting based on past and invalid data.

Our key conclusion is that in the short run, the iLUC modeled by academics are immaterial (at best) if the biofuels trajectory leads to efficient technologies that can, (including iLUC) significantly reduce lifecycle carbon emissions**. While careful consideration should be paid to possible indirect impacts, the current fears about iLUC may well lead us to adopt standards that unnecessarily crimp our ability to innovate.** The key point of importance for California is to recognize the scope of the GHG problem as a worldwide one. As the science improves and specific studies are conducted, indirect land use for non-food biofuels should be included but only when the models have been reasonably proven to be accurate predictors, and when non-land consuming, non-food feedstocks have been reasonably depleted; in the near term, we must encourage the middle, pragmentalist ground. For food based biofuels, though the situation is more ambiguous, there are trajectory and optionality based reasons to selectively allow them on a limited quantity basis for a limited period of time to kick start attractive trajectories and condition markets (such as E85 cars and pumps). In all cases, food or non-food based fuels, we should clearly mandate the use of indirect land use impacts at a point in the future (10-15 years from the start of scaling of the technology) on a facility by facility and feedstock by feedstock basis, thus avoiding the adverse impacts Delucchi et. al. are concerned with. In this interim period research efforts to improve the science like CSiTE[7] and Biomass Assessment[8], and many other such efforts should be encouraged, accelerated and directed by policy goals. Biofuel solutions in development across California (and the world) are on the pathway to providing a variety of (relatively) low-risk, cheap, and scalable solutions towards meeting our transportation fueling needs. We must imagine the future and invent it, not extrapolate the past.

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[6] "Annual Energy Outlook: Retrospective Review", EIA, April 2007

[7] Csite.ornl.gov/presentations/CSITE_Master_Sep06_FINAL.pdf

[8] Biomass Assessment: Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy – Main Report

Policy and Perspective Discussion:

Science can be precise but inaccurate, resulting in wonderfully precise yet completely misguided results from a policy perspective. Similarly, econometrics modeling can paint a picture with a limited, narrow range of possibilities (aka “low standard deviation”) with a significant mistake around the mean value (“high standard error.”) In the debate ranging about biofuels today, both problems persist in different manifestations – among the recent papers influencing current debate (especially around the AB32 scoping plan being considered in California) are articles by Professor Timothy Searchinger[9] arguing that biofuels harm carbon emissions more than they help, and a recent letter[10] by a group of distinguished academics (Delucchi et al) arguing for strong consideration of biofuels’ indirect land use change (iLUC) in the development of California’s Low Carbon Fuel Standard. Both are grounded in solid science, well-intentioned pieces that are intended to inform the debate – unfortunately, both fall into the trap of inaccurate modeling nonetheless conducted to a high degree of precision; they providing a false sense of knowledge to the debate that can mislead policy making. My focus here is on explaining why they are wrong for the intended purpose of policy making, and to illuminate more important issues they fail to consider, as well as highlighting the model input assumptions that are (1) likely to be wrong as currently used and (2) that can be dramatically changed by policy signals.

We will be addressing a few key points: (a) The ideal goals for biofuels policy, and its role in the scoping plan of the AB 32 bill; (b) the problems with early-stage modeling, and their relevance in the biofuels debate; (c) the Searchinger et. al. paper, and the analytical flaws in their assessment of biofuels; (d)Delucchi et al, and their support for an indirect land use standard in AB 32 which we believe would be disadvantageous for California; and (e) proposals to address the legitimate issues and pitfalls with biofuels raised by the critics. When assessing options, the key is not to view issues in a vacuum – rather, it is an assessment of which set of risks (among all the pragmatic choices, including the default choices of “no action”), that we should be taking. It is unlikely that we will find an ideal replacement for fossil fuels without any risks or downsides – the goal is to not allow the perfect to be enemy of the good, but to make the best long term risk adjusted cumulative positive impact choice, aided by preserving as much optionality as possible at reasonable cost.

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[9] http://www.sciencemag.org/cgi/content/abstract/1151861

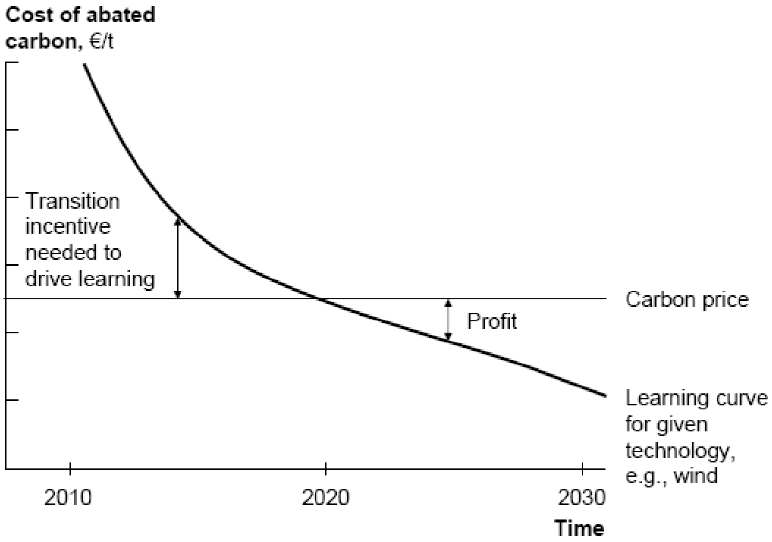
[10] Delucchi et al; a copy can be seen at http://www.bioenergywiki.net/images/8/89/LUC_letter.pdf

The Framing of the AB 32 Bill

AB 32 promises to be a landmark measure – putting a hard cap on GHG emissions; reducing emissions from major sources, and encouraging the development of renewable energy resources. We believe policy should be concentrated on a few key points:

- Think long-term: a long-term approach that sets the stage / platform for long term emissions reductions worldwide, rather than a short-term approach that reduces California emissions at high cost and with little marginal benefit beyond that. Solutions should be scalable to other parts of the world. California should attempt to measure the total lifecycle carbon emissions of biofuels, not based on past data but where we are likely to be WHEN material scaling starts to happen. Can the effective emissions of biofuels be impacted materially over time by the right policy signals when scaling starts to happen? Can we use the time between now and then to invent the processes and methods rather than accept the past calculations?
- Capacity building for carbon reduction: Increase our ability to respond to future needs for carbon reductions. Thus, technology and capacity building for future large reductions may be more critical than actual, immediate reductions. In short, optimization should be for total cumulative reduction by a date like 2025 or 2050, and most importantly on increased carbon response capability. We do not currently know if 550ppm, 450ppm or 350ppm carbon dioxide levels in the atmosphere are the right targets, and the ability to respond quickly in the future as climate change models and impacts become more accurately assessable is critical. Allowing new options for improvement to proliferate is critical and optionality must be assigned significant weight if the future trajectory of the option appears promising.
- Trajectory matters: AB 32 should focus on starting a technology trajectory – with the aim of significant emissions reduction, but also on achieving unsubsidized market competitiveness for scalable low carbon technologies such that they can scale towards broad acceptance in California, beyond legal mandates, and in the developing world. We must promote technologies that are likely in the 2025-2050 time horizon achieve the lowest potential carbon emissions at the lowest possible costs and which have low "adoption" risk of worldwide adoption at large scale. The adoption risk of new

technologies, often driven by startup cost, upfront capital costs, critical mass of infrastructure, or consumer behavior change, is often ignored and must be assessed. Assessing adoption risk beyond California is also critical to assess worldwide impact over time. Many technologies start at high cost, high carbon emissions but decline rapidly in cost and carbon content and may be superior to another technology that has a lower cost but slower technology/carbon improvements. The chart below from the McKinsey Global Institute highlights a potential timeline – the period that support is needed, giving technologists/investors/policymakers time to experiment and increase the variety of options available to us. We believe biofuels will decline far more rapidly in cost and in carbon content than many other "low carbon transportation" options (indeed, we foresee a faster timeline than the generic timeline outlined by McKinsey below) and have low adoption risk. The single most critical variable in biofuels may be their land efficiency (gallons of ethanol equivalent fuel produced per acre) and food and non-food biofuels have very different land efficiency trajectories. In our estimation, non-food biofuels are likely to be more than 300-500% more efficient in their use of land, when and if they need any incremental land.



Source: McKinsey analysis [11]

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[11] "The Carbon productivity challenge: curbing climate change and sustaining economic growth", McKinsey Global Institute, June 2008

- Cost is key: AB32 must encourage the lowest cost ways to reduce carbon emissions per ton; a solution that is viable in the US for initial penetration may not, if it does not have a rapidly declining key technologies cost curve, penetrate a large percentage of the California market, and eventually may not be cost effective in China/India. They are likely to have limited impact**. If it can't compete unsubsidized, it cannot compete in the long run.** Reduction using specialty waste (e.g. walnut husks or restaurant waste grease) that is not largely scalable does not lead to replicable solutions. Cost ineffective solutions (McKinsey has estimated that the carbon abatement cost with parallel hybrids is as high as $90/ton [12]) that have high adoption risk in countries like India and China are helpful but not as helpful as carbon reduction technologies that will be adopted broadly and help other countries and help California develop global businesses. Expensive technologies are unlikely over the long term to penetrate 50-80% of the automotive market; such penetration is key to having a low carbon personal transportation system over the long term. In a world with limited investment dollars, it is important to drive it to technologies that give us the greatest marginal value. Biofuels are one of the few technologies that can be cost effective enough to achieve long term penetration exceeding 80% in automobiles both in California and worldwide. Equally importantly, given the large number of biofuels efforts in California, the state can be the economic beneficiary of massive new business opportunities and help create the next Google in the clean fuels space. The key question of course is, including indirect land use impacts (which we are in favor of measuring when each class of fuels start to scale), can we over the long term produce biofuels that substantially reduce carbon emissions (greater than 50% per mile driven)?
- Policy should be forward looking: Policy should not accept past practice as an indicator of the future patterns but should send economic signals to the marketplace that cause innovation to happen along the right direction. Not only do Searchinger et. al. and many other academics fail to include the impact of this most critical consideration but they also fail to look at likely changes in land use patterns driven by the biofuels economic signals. Academics have often used economic signals driven by other considerations (like deforestation driven by timber value) and assume without justification that it is a reasonable estimate of land use changes driven by biofuels. Policy must direct the future and allow for its development, not accept the past. Some of the current proposals being discussed are roughly equivalent to treating all electric cars as if they are running on the global average electricity grid which is principally powered by coal.

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[12] Reducing U.S Greenhouse Gas Emissions: How Much at What Cost?", McKinsey – December 2007

We should treat electric cars as if they are on trajectory in the future to run on lower carbon electricity.

In essence, its vital to determine what California's goal is with AB 32 – is it to (a) reduce California emissions? (b) reduce California emissions and start worldwide trajectory? (c) Do (b) plus start California businesses that grow into the Googles of energy and establish California, once again, as the global epicenter for clean technology? The case for considering the McKinsey curve is important. In the early phase of a technology, modeling based results based on "current assumptions" or "free market competition" in open markets is likely to sub-optimize the social benefit of the capitalist system by prematurely reducing the number of competitors. The specific issue of "when" each technology should cross that curve is a matter of judgment based on the specific technologies' trajectory. In general, our best guess is seven years or so from the start of scaling of the technology. This is likely to maximize cumulative carbon reduction and build up of carbon response capability.

AB 32 – Biofuels Proposals

One significant aspect of AB 32 will be its policies towards biofuels – the right decisions and framework could go a ways towards setting ground rules for biofuels that would result in the right evolution of biofuels and biomass feedstock development. It should meet the criteria outlined above. In light of the broader technology prescriptions outlined above, we'd like to highlight specific policies for consideration for the AB 32 Biofuels Assessment.

- Distinguish between food-based and non-food based crops: It is critical that food and non-food based crops be treated with separate land use models; while food-based crops (such as corn and oil seed) are used today, most evidence suggests that food-based feedstocks the ability to scale beyond a niche role (for example, it is generally estimated that corn ethanol can realistically scale to about 15B gallons in the US but not more). Estimating the land use of corn ethanol as if it can produce 150B gallons is illogical and fear-mongering. Given the trajectory and cost curves of cellulosic feedstocks (likely to be much less expensive per gallon at $1.00per gallon production cost), we believe that in the long run, corn ethanol (and traditional biodiesel) may end up as uneconomic solutions, unable to compete with low-cost cellulosic fuels. There are material differences between food and non-food biofuels in the trajectories of their indirect land use impacts, their cost and their carbon reduction.

- Differential amongst various biofuels: It is critical that each biofuel be assessed separately be it corn ethanol, cellulosic ethanol (Mascoma, Range, Coskata, Lanza), butanol (Gevo), biodiesel , cellulosic diesel (LS9, Amyris), cellulosic crude(Kior) or others – each biofuel brings with it specific attributes, and assessing them with a broad, crude measure is misleading and does not encourage development of more carbon efficient biofuels. An effective system should not try and pick winners (such as today's varying subsidies for biodiesel and ethanol) – rather, it should open the door to any fuel that meets specific environmental and economic thresholds, allowing the best technologies to rise to the top. This lets public policy set the desired parameters, without encroaching on the market's role of picking the most viable solution. We do believe steps need to be taken to disqualify fuels that do not meet his goals, or even exacerbate the environmental problems (Indonesian palm oil based biodiesel, to take one example) and policy encouragement should be withheld form fuels that are likely to have poor trajectories.
- Differentiate among countries as sources of biofuels or biofuel feedstocks Policy can then be used as a tool to reduce inappropriate land use, for example, restricting (or outright banning) the import of biofuels or feedstocks form countries that don't meet deforestation reduction targets would discourage deforestation and change the assumptions dramatically in indirect land use models. Such state and hopefully national policies may make biofuels a tool for achieving desired land use patterns. This alone could invalidate the land use assumptions in the Searchinger model and could be a very valuable contribution to (along with carbon credits for forests as part of a global cap & trade treaty) global GHG reductions by incentivizing preservation of forests. India's National Climate Plan has targeted the afforestation of 6 million hectares, increasing the national area under forest and tree cover to 33%[13].
- Assess fuels on a facility by facility basis: A facility by facility rating systems is critical to develop. We have proposed a LEEDS-like CLAW rating (Carbon, Land, Air and Water impact rating) for each non-food fuel facility as essential to proper life cycle analysis (LCA) including direct carbon and indirect land use related carbon impacts (iLUC). No other system is likely to be accurate. Carbon LCA varies by fuel, by process, by yields, by facility, by biomass source & yield/acre – a facility specific measure eliminates many of these problems and encourages development of technologies and feedstocks that have lower life cycle carbon emissions. Non-food biofuel facilities, be they waste or biomass, are likely to source their feedstock from local sources (given the high cost of

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[13] www.pmindia.nic.in/Pg01-52.pdf

transportation) making local feedstock assessment possible (for e.g. assessment of crop displacement in equivalent of "productive corn acres" displaced). Direct and indirect land use impact is likely to be more accurately assessed over time by including local carbon changes, local productivity changes if the land is used in long rotation crop cycles (ref: Where will Biomass Come From), relative to a generic Searchinger model. Given the small number of facilities likely in the next few decades, the task should be much simpler than a building by building LEEDS points calculation. This approach will create incentives for true low carbon fuels while expediting technology development and feedstock development for low carbon feedstocks (including indirect land use) and low carbon fuels. A similar system is essential for food based fuels because changing the fuel into a facility (coal, natural gas, biomass), changing the feedstock (sugarcane, corn, wheat, sorghum…), or drying or not drying the distiller grain can completely invalidate the assumptions of the Searchinger modeling and change the outcome (we address our criticism of Searchinger et. al. later in the paper). This assessment can only be done on a facility by facility basis, though for portable feedstocks (like corn and wheat) a separate global feedstock carbon assessment may be necessary. A displaced acre will probably be different if measured in "equivalent productive (or reference) corn acre" terms, and once timeline considerations are added (such as in crop rotation) may not be a displaced acre at all if it increases corn productivity later and is returned to the same food crop production after the rotation cycle.

- Timelines matter: Timelines are important for measurement of indirect land use impact- when does land displacement start to happen? We believe that indirect land use impacts are unlikely for the next 15 years in the US for non-food biofuels and should not have a penalty associated with it. Most non-food feedstock likely to be used in the next fifteen years will be from currently existing "waste" sources like forest waste, crop residues, etc[14]. We do support significant effort in research to be directed at measuring land use impact during this period; however it should be made clear that indirect and direct land use will be assessed over time as the science becomes more accurate to encourage investors to asses the risks correctly and to develop low land impact feedstocks. This will encourage thoughtful biofuels conversion processes and feedstock choices. For food based biofuels, indirect land use impacts are more immediate but trajectory and optionality considerations may warrant special treatment for some

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[14] "Biomass as a Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion Ton Supply", Robert D. Perlack, Lynn L. Wright, Anthony F. Turhollow, Robin L. Graham, Bryce J. Stokes, Donald C. Erbach – April 2005

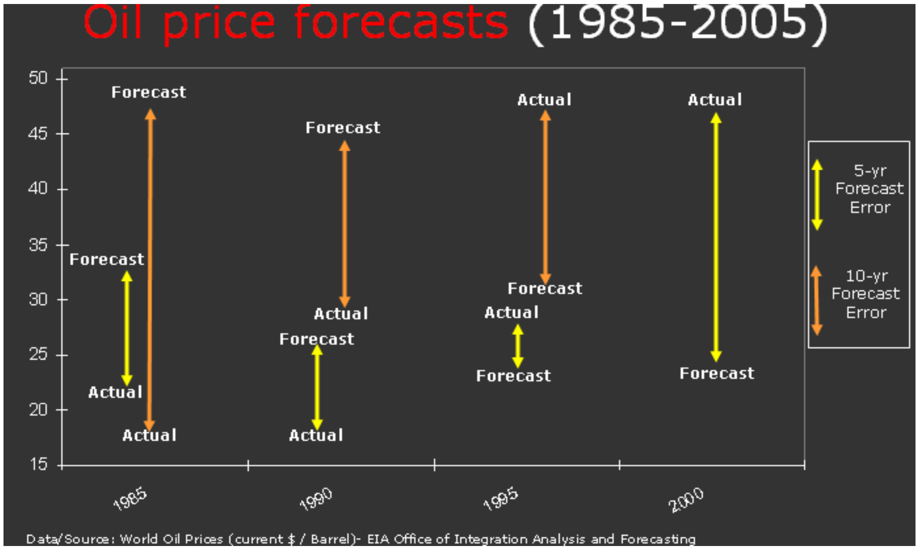
biofuels. There are material differences between food and non-food biofuels in the timeframes of their indirect land use impacts.

- A critical goal for AB32 in the early years should be to increase the number of options we have by 2025 when significantly larger carbon response may be needed. Discouraging developments of our most promising options for transportation (biofuels) when the science is relatively immature, and the potential successful paths to low carbon feedstocks many, by using old historical and largely inaccurate and (causally) unproven and probably incorrect models of land use using global averages for land use would be a major dis-service to a promising avenue. Errors in analysis like that of Searchinger et. al. can be 500-700% as we shall see later, without even considering the impact of policy directed changes in land use patterns rendering the analysis for even carbon sequestration irrelevant and inaccurate under probable real world scenarios.

Biofuels have a significant role to play in reducing GHG emissions, and the AB32 legislation presents a landmark opportunity to set standards and a model for regulating them going forward. The onus is on us to produce a standard that encourages low-cost, low carbon fuel solutions that have the potential and ability to scale rapidly to meet a significant percentage of our transportation fuel needs – not just in California, but in the US but the world at large.

Early Stage Modeling and its flaws: The case for nuanced use

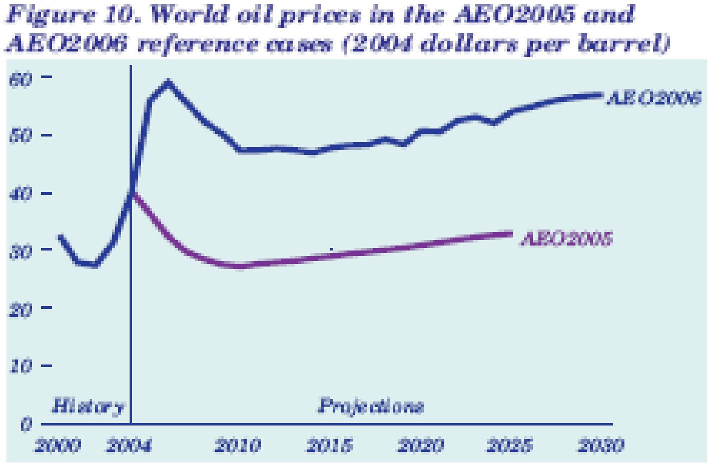
An important aspect of setting public policy (such as AB32 and other policy actions aimed at targeting GHG emissions) is understanding the scale of the problem we face, and assessing the potential impact of would be solutions. Models and forecasts are a useful tool in helping us to assess what could happen, and what the actual impact of our specific policy tools is likely to be. Nonetheless, forecasting and modeling is often an inexact science – as multiple examples over the years have shown us. In particular, a lot of economic forecasting and modeling is essentially a regression of old data; it cannot account for technological shocks. Energy Information Administration forecasts for oil prices are shown below (five and ten years forecasts starting in 1980) – as the graph shows, the gaps between forecast and reality is often immense, rendering forecasts mostly irrelevant, even misleading.



Data/Source: World Oil Prices (current $ / Barrel)- EIA Office of Integration Analysis and Forecasting

Though the energy price forecast models (for oil and gas) are different than those for the indirect land use change (iLUC), it is fair to say that the iLUC model is subject to similar inaccuracies, especially given the relative immaturity of the models, the long term nature of the forecasts and the change in the drivers for land use change. Delucchi et. al. in opposing excluding iLUC cite its use by many international agencies, but does the level of accuracy justify using the models until they are proven to be accurate? A model used by McKinsey to forecast (in 1980) mobile phone use in the US in the year 2000 underestimated the actual number of phones by over 10,000%! We would submit that mobile phones are easier to model than shifts in indirect land use attributable to biofuels. An EIA forecast similarly shows the ridiculous nature of the forecast errors (see below).

AOE 2005 vs. 2006: Projection of Oil Prices[15]



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[15] EIA, Annual Energy Outlook 2006, February 2006

In 2005 the EIA base-case forecast for oil prices had a price variation for oil prices over twenty years of less than $10 per barrel, as seen above (ranging from $20 to $30 per barrel). In 2006 they had a similar range of price forecasts but it was different than the 2005 forecast by more than the 20 years price variability forecast in 2025 – as the AOE 2006 noted, "The price in 2025 is approximately $21 per barrel higher than the corresponding price projection in the AEO2005 reference case."[16] Furthermore, it should be noted that subsequent prices movements have rendered both the 2005 and 2006 cases as extremely optimistic – oil prices today are approximately $120 per barrel. The key question: are such forecasts valuable? Indicative in any way of reality? Are there alternatives ways to inform policy? It gets worse. The "experts" choose not to change the model to allow for these variations so the 2006 "model" incorporates the same assumptions (bias?) of short term decline in prices followed by a gradual increase (which has been subsequently proven to be false as witnessed by 2007 and 2008 oil prices. Vastly different models can be created with vastly different results. The science that can be accurately quantified and the science that is not quantified yet or not quantifiable is constrained in the form of assumptions (here, the assumption that economic signals for the 1990's were the same as are likely to exist if iLUC expands because of biofuels - and hence the likely change is reasonable represented by the past history of change). In fact the standard error on this model could be many hundreds of percent rendering the models useless, especially if the policy is used as a driver of the desirable economic signals and land use change patterns (if any – even the fact that there will be need for change is far from established in our view; our models indicate no material new land is required in the US, the most prolific consumer of gasoline).

Oil price models are one thing, (similar errors exist in the price forecasts for natural gas and even a relatively stable commodity like coal – see our FIRE presentation) but can the same errors happen in relatively slow moving global indicators like land use or carbon emissions (which are principally tied to slow moving socio-economic development worldwide)?

	2008 Estimated Emissions – GT CO_2e	2050 BAU* Emissions – GT CO_2e	2050 target Emissions – GT CO_2e
(1) Original Globe Report – 450 ppmv, no overshoot	42	85	10

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[16] ibid

(2) Updated baseline and target – 450 ppmv, no overshoot	55	85	13
(3) MGI Report – 450 ppmv with overshoot to 500 ppm; updated baseline and target	55	85	20
* Business as Usual (1) Emissions baseline from IEA (2002) (2) Emissions baseline from IPCC (2008); 2050 target based on Stern Review 450 ppmv scenario (3) 2050 target based on Meinshausen (2007) and consistent with G8 proposals			

The chart above (adapted from McKinsey)[17] shows the shifts in the forecast of carbon emissions by two such reputable sources. The IEA in 2000 forecast in the GLOBE report that 2008 emissions in 2008 would be 42 Gt per year with only a doubling from 2008 to 2050 (under business as usual scenarios). The updated report only five years later forecasts 2008 emissions at 55Gt or more than 30% higher in the short span of five years. We must ask if long term models in areas like land use, with the uncertainties in their assumptions, inaccuracies in their inputs and immaturities on the models, are really useful? The more likely pattern of evolution, given the large amount of uncertainty and opportunity for both positive and negative surprises, is likely to be the Black Swan model[18]. Standard statistical assumptions embedded in these traditional models are just as likely to be untrue as true.

To their credit, scientists have noted the flaws and the risks inherent in the modeling process (even for established science like the climate change process). In a recent New Scientist article, Tim Palmer from the European Center for Medium-Range Weather Forecasts notes that “models often share the same biases and blind spots about features of the climate system that are critical for regional forecasts.”[19] Others share similar opinions – the journal notes that ‘a panel on climate modeling that was preparing the ground for next week's summit concluded that current models "have serious limitations" and that their uncertainties "compromise the goal of providing society with reliable predictions of regional climate change". The panel, chaired by Jagadish Shukla of George Mason University in Claverton, Maryland, dismissed many current regional predictions as "laughable".’ With regards to climate change, the science

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[17] McKinsey Global Institute, June 2008

[18] “The Black Swan: The Impact of the Highly Improbable”, Nassim Nicholas Taleb, 2007

[19] http://environment.newscientist.com/channel/earth/climate-change/mg19826543.700-poor-forecasting-undermines-climate-debate.html

around the specific problem is fairly well-established – nonetheless, forecasts still have significant room for uncertainty.

To prove the level of inaccuracy in the current models that is possible, it is useful to examine why some of the forecasts and models were wrong and if they same types of errors are possible in the indirect land use models. One of the more famous examples (as cited above) is McKinsey's 1980 estimation of the mobile phone market in the 2000 (for AT&T) – they predicted a market size of less than 1 million phones – the actual market in 2000 exceeded 100 million – an error of approximately 10,000%. At its roots, the forecast failed to take into account the power of technology change. A 6-8 pound car mounted cell phone of 1980 was used to make forecasts about 2000 when the actual available phone in the year 2000 was a highly mobile, pocket size weighing a few ounces with functionality unimagined in the year 1980. It is all about the assumptions: Take the case of food prices – using similar models, the USDA and the World Bank came up with widely disparate results for the price impact of food based biofuels. It varied from about a 3% price change (USDA) to 75% of the total run-up (World Bank) based on "assumptions" by each party as to what to assign various factors to. For e.g. the World Banks assumed that price speculation was because of biofuels - even while they failed to account for the speculation in other unrelated commodities like steel or nickel. The USDA (legitimately in our view) assumed otherwise. As with the World Bank here, a given approach often incorporates misguided assumptions, which are buried in models and lead to inaccuracies.

Are the kinds of errors listed above possible in the land use models (we do recognize the above is not a proof that current indirect land use models are inaccurate, though we do contend that there is no validation of their accuracy)?

Steven Long (U of Ill) has just published a study[20] that Miscanthus can yield today, even in relatively northern climates like Illinois, a yield 2.5 times greater than switchgrass which was modeled in the Searchinger report. If 250% errors are possible in a few months what is the error rate over 25 years? What might the yield be after 25 years of crop optimization using the latest marker assisted breeding and genetic engineering techniques? Are yields 2-4X higher than today's bets miscanthus yields possible over time? Are even better yielding crops and better ecology feasible? Almost certainly! What impact would that have on the models? Would this invalidate the assumptions of the Searchinger paper? More importantly, should we be

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[20] http://news.cnet.com/8301-11128_3-10002885-54.html

precluding options and years of technology development because we choose to look backwards in land use change rather than looking forward at potential ways to ameliorate or eliminate these changes? Do we want to discourage investment in this option or encourage experimentation and innovation?

The emphasis here to highlight the risks prevalent in forecasting technology as a whole – recognizing when technology has the potential to be a "Black Swan". To reiterate, we are not arguing for abandoning the use of quantitative modeling – it is an essential tool to understand the actual impact of decision making processes. A model is only as good as the inputs that are fed into it – and at an early stage of technology development, accurate input data is still somewhat lacking. **We are suggesting the use of more nuanced strategies on when to use models, picking the timing of commitment to model based strategies/policies, and considering other non-model factors like trajectory, optionality and others discussed here, especially when the future assumptions can be significantly changed based on new invention, new learning, new economic signals or new policy.** We would submit that especially during the nascent stages of a technology's development, qualitative assessments are more likely to be valuable during the early phase than quantitative models that make the classic scientific mistake of having great precision without having valid accuracy.

Science Magazine: The Searchinger Article

Having referenced it earlier, we would like to address some of our criticisms of the now-famous Searchinger paper[21]: perhaps the most egregious flaw is the idea of viewing it as an all encompassing study – rather, it defines one possible scenario with many assumptions, many of which we find to be flawed. For a more accurate analysis of biofuels as a whole, it should have made a probabilistic analysis of a range of probable scenarios and then computed an expected value across them weighted by their probability of occurrence (or used an alternative multiple scenario analysis technique). The model is scientifically inaccurate in assessing only one scenario using historical land use patterns that predate biofuels crops and are unrelated to biofuels use. Assuming that a policy directed future land use pattern with strong economic signals driven by a price of carbon is the same as happened in an environment driven by unrelated economic signals (timber being an important signal for deforestation for example) is inappropriate for a scientific paper. Not computing an expected values given multiple possible

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[21] http://www.sciencemag.org/cgi/content/abstract/1151861

scenarios is fundamentally flawed – the scenario reflects “life cycle carbon analysis (LCA)” only if all of the (misguided, in our view) assumptions were true. The iLUC calculation fails to account for much more likely land use scenarios than the paper’s assumptions and fails to anticipate future changes with a carbon pricing regime (especially a cap-and-trade system), policy both globally and regionally, and the time dependent need for land for biomass or biofuel crop lands. In fact, we find persistent flaws throughout the paper:

- Significant land displacement: The idea that all biofuels by their nature need large tracts of land (direct or indirect) is wrong. While some biofuels will require land usage (especially food-based biofuels) there are biofuels (especially non-food biofuels) that will have little to no marginal land impact – by noting that “most biofuels need land”, Searchinger et. al. implicitly note that some don't or seem to ignore the likely near term trajectory of non-food biofuels. From the usage of municipal sewage waste, flue gases from steel mills, to agricultural byproducts many if not most of the advanced cellulosic fuels efforts initial plans call for the use of existing waste feedstocks. Moreover, the advantages of future new practices are ignored: many agronomic techniques are available including polyculture, perennials to eliminate tillage and hence much of the row crop carbon loss when land is converted, short rotation biomass (winter cover crops – a substantial and possibly the only source of biomass for biofuels needed for the next fifteen years), long rotation perennial cultivation(see the 10x 10 rotation proposal in our Biomass paper) that may increase row crop productivity during their food crop cultivation cycle, thus reducing food crop land use while producing biomass crops during the “rest” cycle. A directed policy for biofuels should encourage such new and innovative agronomic/land use techniques rather than assuming “loss of soil carbon” when natural grasslands are converted to energy crop use. Searchinger et. al. do not model the increase in soil carbon if a crop acre is displaced but replaced with a perennial energy crop acre which could potentially actually increase carbon sequestration than the carbon loss in the acre that is displaced. **Absence of proof does not constitute proof of absence.** Comparing pre-biofuels land use conversion patterns, often even unrelated to land use (timber is a major reason for deforestation and is included in the Searchinger et. al. land conversion calculations) is unlikely to be the scenario for land use related to biofuels going forward, especially if policy sends a carbon efficiency economic signals. In fact it is even possible that biomass crops will be engineered as perennial prairies with no tillage and no soil carbon loss, if and when land conversion is needed for energy crops.

- Cellulosic ethanol from switchgrass only: While switchgrass is certainly one potential feedstock source for cellulosic ethanol, it is a relatively low yielding crop, especially when compared to other grasses such as miscanthus; a recent study has suggested that miscanthus can yield almost 2.5 times as much ethanol feedstock than switchgrass.[22] Using obsolete switchgrass calculations with current yields and sub-optimized crops for biomass to predict future biofuels production is prone to very large errors. Furthermore, the yields for biomass crops in 2025 and 2050 are likely to be substantially higher. Miscanthus as a biomass crop is less responsive to fertilizer (and hence less likely to be fertilized), can be rain-fed, is a perennial crop requiring no tillage, and is likely to have carbon sequestration benefits. Poplar and other biomass successional communities have been shown to have global warming reduction potential. Unless one assess each non-food feedstock individually, we are unlikely to get migration towards the most cost efficient as opposed to carbon efficient feedstocks. Sorghum grown on dry land in Arizona with low water use is likely to have a very different "corn equivalent acres" than switchgrass grown on Iowa's crop land. Forest waste in Georgia or Michigan and winter cover crops in Alabama are likely to have different carbon profiles. Previous actual use of the land, new crop characteristics, actual land displacement are essential to consider in assessing the net carbon impact and global averaged contributions would lead to misleading results. Each feedstock must be assessed individually (and the local nature of biomass feedstocks makes this feasible; food crops being more transportable are difficult to asses locally) and the number of facilities is likely to be in the hundreds (with even fewer feedstock types) in the next fifteen years, making such assessment feasible. The table below (from the Land Institute[23]) illustrates the potential to design appropriate low carbon feedstocks in the future.

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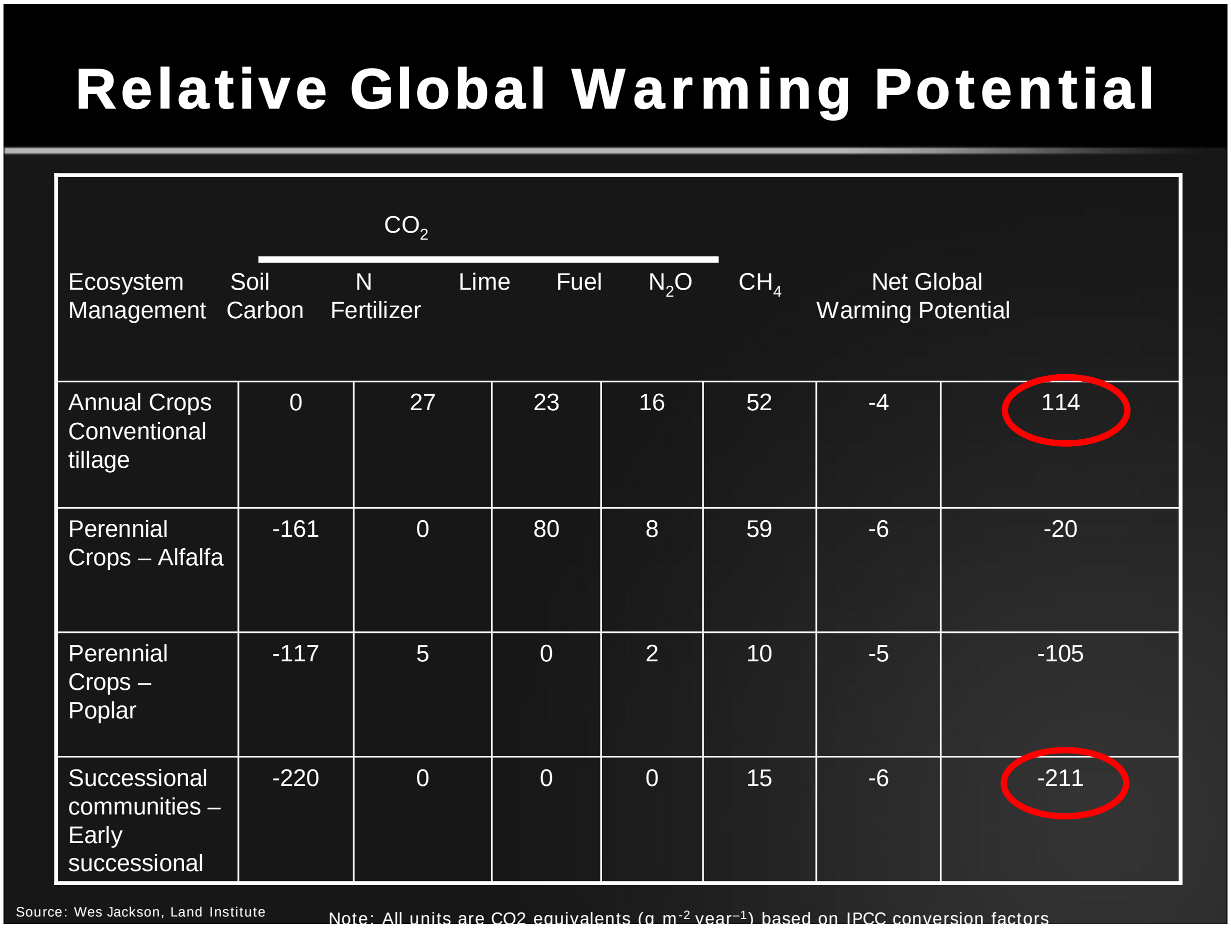
[22] http://news.cnet.com/8301-11128_3-10002885-54.html

[23] Wes Jackson, The Land Institute



Relative Global Warming Potential

	CO_2						
Ecosystem Management	Soil Carbon	N Fertilizer	Lime	Fuel	N_2O	CH_4	Net Global Warming Potential
Annual Crops Conventional tillage	0	27	23	16	52	-4	114
Perennial Crops – Alfalfa	-161	0	80	8	59	-6	-20
Perennial Crops – Poplar	-117	5	0	2	10	-5	-105
Successional communities – Early successional	-220	0	0	0	15	-6	-211

Source: Wes Jackson, Land Institute

Note: All units are CO2 equivalents ($g\ m^{-2}\ year^{-1}$) based on IPCC conversion factors

- <u>Limited conversion processes:</u> As discussed previously, the Searchinger paper appears to assume yields typical of biochemical process to convert biomass to ethanol, ignoring more productive thermochemical processes. The maximum theoretical yield (for switchgrass) is 111 gal/ ton for biochemical processes, and 198.4 gal/ton for thermochemical processes[24] (in practice, yields are of course, lower). For ethanol, typical yields for biochemical pathways are generally in the 60-80 gallons per ton range (Mascoma, Iogen), yields of 90-110 gallons ethanol per ton of dry biomass are feasible (though biochemical technology may more easily fit into biorefinery processes with valuable co-products in the future including animal protein from cellulosic biomass, thus further reducing land needs) using the syngas catalysis pathways (such as Range Fuels). Hybrid syngas fermentation pathways (Coskata, Lanza) could yield numbers higher than for syngas catalysis pathways because of higher practical efficiencies. If the fuel was changed to diesel (LS9, Amyris) higher ethanol equivalent gallons are possible. If

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[24] "Cellulosic Biofuel Technologies", Professor David Bransby

depolymerization pathways are used (Kior) yields between 120-150 gallons of hydrocarbons per ton of biomass are feasible and with their higher energy content could add a 200% energy content error compared to biochemical conversion pathways Searchinger et. al. model. The current reported miscanthus yields and the Kior process could add up to 500% the fuel "gallons" yield and 600-700% the energy yield of the Searchinger calculations, before accounting for yield improvements over time. Such errors would shortchange most promising biofuels if a general conversion process and land use impact assessment is done for biofuels. A facility by facility assessment is essential and better developed science is needed before we start to shortchange options.

- Apples to oranges comparison: When assessing environmental impact of gasoline to biofuels, it is important to asses them equally – measuring the marginal/incremental use of ethanol equivalent vs. that of "average" gasoline is inappropriate; a more accurate comparison would compare incremental ethanol to incremental petroleum (taking into account incremental sources like tar sands). Similarly, the assumptions of average corn ethanol makes less logical sense than a per-facility computation that looks at what is being built and utilized now (for example – more recently corn ethanol plants from Cilion are more efficient than older counterparts, reducing GREET model carbon emissions by 46%). When comparing, a one-size fits all approach is not accurate – it needs to be process and facility specific.
- False Analysis: Searchinger states that "without biofuels the amount of land reflects the demand for food and fiber" but "to produce biofuels farmers can plow up more forests and grasslands which release to the atmosphere much of the carbon previously stored in plants and soils through decomposition and fire." First there is ample evidence of excess land as witnessed by the declining need for land over the last many decades in the US as land productivity increases. The need for subsidies is an indicator of the supply of excess land, as is the inefficient use of grazing land in countries like Brazil. The paper assumes worst-case scenarios of the marginal impact of biofuels production, with limited evidence - will farmers plow up forest and grasslands or better utilize land that they have available? Should we assign the extra land use to genetically modified organism (GMO) plants not being used in certain countries (Europe and Africa) or the use of beef where each 16oz steak takes the same amount of corn (roughly) as a gallon of ethanol? Should we send policy signals encouraging African countries to use GMO crops thus saving land? Can we engineer systems to not give up carbon, maybe even increase it when converted to energy crops? While displaced land causes a previously

unfarmed acre to convert to a food crop and causes carbon sequestration, can a local acre be converted from a food crop to a perennial crop engineered to increase the carbon content of the previous food crop acre, thus resulting in zero net carbon impact? This seems plausible for non-food biomass crops. Are there other reasons forests are being depleted and should "land use" be allocated differently if that is true? Should we encourage worldwide improvement in yields with the right economic signals (worldwide yields are substantially lower than developed country yields)?

- Weak claims & missed opportunities: Searchinger et al. claim that higher soybean prices accelerate clearing of forests – that may well be the case, but is that necessarily because of biofuels? To be clear, we clearly advocate focusing support for non-food based biofuels vs. food based biofuels, but blaming biofuels for everything seems naive and simplistic. A proper assessment of the marginal impact would require an understanding of the trends before biofuels, and accounting for these before assigning the cumulative blame as a whole to biofuels (essentially, attempting to calculate the marginal impact of biofuels alone), and hopefully using the changes in economic signals in the model. Similarly, blaming biofuels for deforestation and rapid agronomic land use ignores the impact of various other factors such as past economic signals and more important the future role of directed signals driven by public policy. Biofuels offer the world a potential large economic tool to encourage the development of the right deforestation reduction policies and land conversion disincentives for grasslands, peatland and other sensitive lands.
- Understated benefits: While overstating the negative impact of biofuels, the Searchinger et. al. study severely underestimates the potential benefits. The study states existing land use provides benefits in carbon sequestration and the use of cropland dedicated land to biofuels can reduce this potential; the first part is certainly accurate, but the second part is misleading. For example, it assumes no benefits from the usage of high-diversity crops grown on marginal cropland such as the CRP land in the US, which has the potential to create carbon sinks (as highlighted by Professor David Tilman)– essentially, using feedstocks that remove carbon dioxide from the air, making it a net GHG benefit. In general, future invention and development of new techniques and technologies have the potential to render the model meaningless. Using past data to predict this future scenario is limiting and destructive towards innovation. Defining future measurement techniques, including indirect land use impact, and driving the right research and economic signals for creative new carbon efficient biofuels is the right policy approach.

Generally, the land use models assume incremental land that is used for biofuels production will be replaced by an acre of land somewhere. This is a flawed assumption because the following alternative sources of land are possible: (1) underutilized land used better as the economic value the crops increase (US and European agricultural subsidies are the cause of low prices), use of better seeds, of fertilizer, water, mechanization etc. In Brazil because of very low effective land rents, cattle grazing is highly inefficient (around 3 acres per cattle) and substantial land recovery is possible. Furthermore, if the previous use of the given acre was crops we must account for the amount of crop displaced, not the amount of land acres displaced; it must also account for increase in the productivity of that energy crop acre if, as part of a long term rotation system, it is returned to crop production at higher productivity (improving degraded lands or improving productivity of productive lands – see pictures below); (2) use of GMO crops in areas where such use is not allowed (mostly in Europe and in some African countries that follow the European model) will improve yields and free up substantial amounts of land. Land can be recovered by the use of GMO crops if biofuels are used to incentivize the increase of productivity; (3) better yields on food and energy crops. There has been little incentive in the past for dramatically higher yields given low land rents in the past. With the recent upsurge in prices, such land efficiency is likely to increase and investment (better seeds, mechanization) in improving land productivity is likely to increase. (4) many farmers in low income countries like Africa are not able to compete in the global agriculture economy because of the high input oriented agriculture of traditional food crops (fertilizer, water). Energy crops are likely to be low input (as noted in the aforementioned Long study) and more suitable for cultivation in less well of countries where low input crops are more suitable (perennials don't need annual planting, could minimize or eliminate tillage, potentially eliminate or reduce fertilizer, and can be rainfed). (5) Smart crop rotation schemes will increase yields of crops on existing lands, freeing up substantial land; we have proposed the usage of a 10 year x 10 year energy and row crop rotation. As row crops are grown in the usual corn/soy rotation, lands lose topsoil and get degraded, require increased fertilizer and water inputs, and decline in biodiversity. By growing no-till, deep rooted perennial energy crops (like miscanthus or switchgrass - see below) for ten years following a ten year row crop (i.e. - corn/soy) cycle, the carbon content of the soil and its biodiversity can be improved and the needs for inputs decreased, while growing energy crops. The land can then be returned to row crop cultivation after ten years of no-till energy crops, potentially increasing food crop yields because of improved soil carbon and ecology (the picture below shows one example of the improved benefits to future crops from a switchgrass rotation; the productivity of any given piece of crop land does not have to be constant – science offers us much hope, especially in conjunction with energy crops, to improve this productivity; the pictures show dramatic evidence, albeit qualitative, of the potential to improve land productivity for food crops in conjunction with energy crops if appropriate rotation cycles are used). (6) Most critically, over the next 15 years it is unlikely any land displacement with global displacement will happen for cellulosic fuels. Feedstock sources such as winter cover crops, forest waste, and agricultural residue are sufficient to produce many times the currently mandated amounts of biofuels.

Pictures of previously fallow land [25]

The models are irrelevant for the short term for non-food biofuels because land displacement is unlikely over the next decade or two. The DOE's "billion ton report"[26] notes that "an annual biomass supply of more than 1.3 billion dry tons can be accomplished with relatively modest changes in land use and agricultural and forestry practices." Economic theory predicts that the lowest cost feedstocks will be used which in the US are likely to be waste feedstocks – the DOE reports notes that 368 million dry tons of "forestland-derived biomass" can be sustainably produced – given that approximately 142 million dry tons are consumed today, there is an excess of 226 million dry tons[27]. Agricultural lands as a whole can produce nearly 1 billion dry tons of biomass – of that, Crop residue of 428 million tons will add to availability with minimal additional land impact[28]. This is sufficient to proved most of the US RFS needs through 2022.

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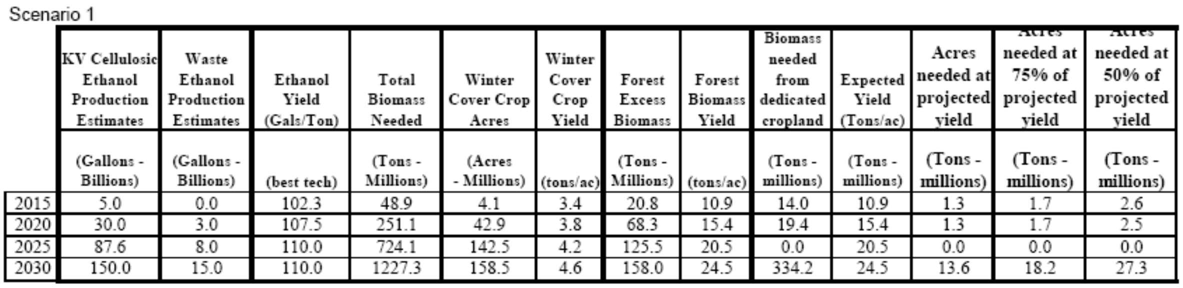
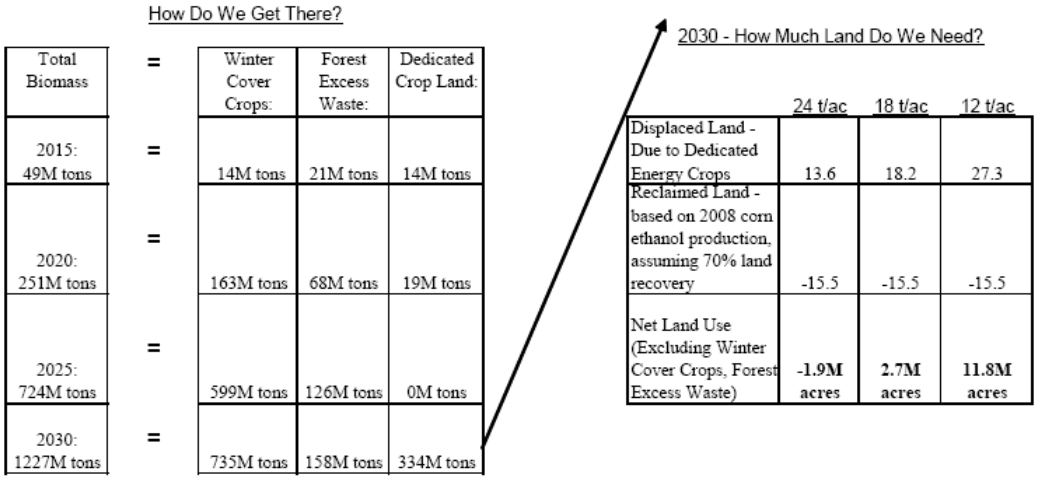
[25] Professor David Bransby
[26] Perlack et al
[27] Ibid
[28] Ibid

An alternative source of biomass will be winter cover crops which are currently not grown on most of the US land as they have minimal value. Winter cover crops have the potential, starting immediately, to produce all the biomass requirements for cellulosic biofuels without using an acre of additional land while generating income for the farmers and improving summer food crop ecology and reducing the need for fertilizers. Our estimates show it is unlikely the US will need to go beyond winter cover crops for biomass sources for the next fifteen years. This alone, especially in conjunction with facility by facility assessment of carbon emissions of a fuel, has the potential to invalidate the indirect land use assumptions.
In our analysis (presented in our "Where Will Biomass Come From" white paper), we project more than 700M tons from this source by 2030 – and we project minimal to negative net land use.[29] Using potential optimized winter cover crop yields in 2030 we arrive at the following numbers:



Scenario 1

	KV Cellulosic Ethanol Production Estimates (Gallons - Billions)	Waste Ethanol Production Estimates (Gallons - Billions)	Ethanol Yield (Gals/Ton) (best tech)	Total Biomass Needed (Tons - Millions)	Winter Cover Crop Acres (Acres - Millions)	Winter Cover Crop Yield (tons/ac)	Forest Excess Biomass (Tons - Millions)	Forest Biomass Yield (tons/ac)	Biomass needed from dedicated cropland (Tons - millions)	Expected Yield (Tons/ac) (Tons - millions)	Acres needed at projected yield (Tons - millions)	Acres needed at 75% of projected yield (Tons - millions)	Acres needed at 50% of projected yield (Tons - millions)
2015	5.0	0.0	102.3	48.9	4.1	3.4	20.8	10.9	14.0	10.9	1.3	1.7	2.6
2020	30.0	3.0	107.5	251.1	42.9	3.8	68.3	15.4	19.4	15.4	1.3	1.7	2.5
2025	87.6	8.0	110.0	724.1	142.5	4.2	125.5	20.5	0.0	20.5	0.0	0.0	0.0
2030	150.0	15.0	110.0	1227.3	158.5	4.6	158.0	24.5	334.2	24.5	13.6	18.2	27.3



How Do We Get There?

Total Biomass		Winter Cover Crops:	Forest Excess Waste:	Dedicated Crop Land:
2015: 49M tons	=	14M tons	21M tons	14M tons
2020: 251M tons	=	163M tons	68M tons	19M tons
2025: 724M tons	=	599M tons	126M tons	0M tons
2030: 1227M tons	=	735M tons	158M tons	334M tons

2030 - How Much Land Do We Need?

	24 t/ac	18 t/ac	12 t/ac
Displaced Land - Due to Dedicated Energy Crops	13.6	18.2	27.3
Reclaimed Land - based on 2008 corn ethanol production, assuming 70% land recovery	-15.5	-15.5	-15.5
Net Land Use (Excluding Winter Cover Crops, Forest Excess Waste)	**-1.9M acres**	**2.7M acres**	**11.8M acres**

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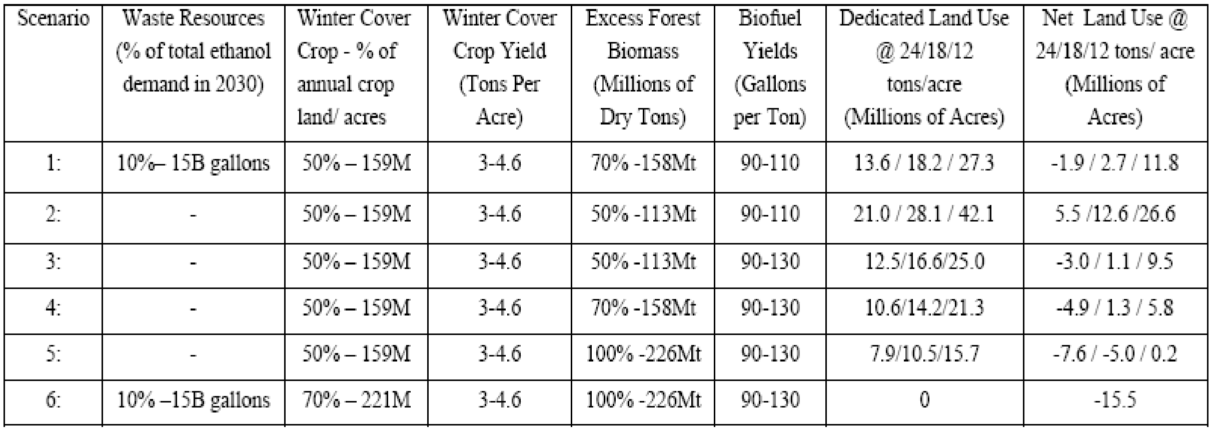
[29] http://khoslaventures.com/presentations/WhereWillBiomassComeFrom.pdf



Scenario	Waste Resources (% of total ethanol demand in 2030)	Winter Cover Crop - % of annual crop land/ acres	Winter Cover Crop Yield (Tons Per Acre)	Excess Forest Biomass (Millions of Dry Tons)	Biofuel Yields (Gallons per Ton)	Dedicated Land Use @ 24/18/12 tons/acre (Millions of Acres)	Net Land Use @ 24/18/12 tons/ acre (Millions of Acres)
1:	10%– 15B gallons	50% – 159M	3-4.6	70% -158Mt	90-110	13.6 / 18.2 / 27.3	-1.9 / 2.7 / 11.8
2:	-	50% – 159M	3-4.6	50% -113Mt	90-110	21.0 / 28.1 / 42.1	5.5 /12.6 /26.6
3:	-	50% – 159M	3-4.6	50% -113Mt	90-130	12.5/16.6/25.0	-3.0 / 1.1 / 9.5
4:	-	50% – 159M	3-4.6	70% -158Mt	90-130	10.6/14.2/21.3	-4.9 / 1.3 / 5.8
5:	-	50% – 159M	3-4.6	100% -226Mt	90-130	7.9/10.5/15.7	-7.6 / -5.0 / 0.2
6:	10% –15B gallons	70% – 221M	3-4.6	100% -226Mt	90-130	0	-15.5

As we note in that paper:

> "While our projections above are based on our most likely scenario, other scenarios are possible. We project a range of scenarios using 50% or 70% of our annual crop lands for winter cover crops, using 50%, 70%, 100% of sustainable, harvestable forest waste, energy crop yields 12,18,24 tons/acre by 2030 with and without usage of waste like municipal sewage and organic waste, and yields of 110 and 130 gallons ethanol equivalent fuel per dry ton. Early experimental data have shown that other biofuels may produce yields equivalent to 150 gallons of ethanol equivalent biofuels per ton (as opposed to the 110 projected in the table above), long before 2030; (based on data disclosed confidentially to us). In this (optimistic) scenario, ALL of our light-vehicle transportation needs would be met without using any additional devoted energy cropland! Going further, the USDA projects corn ethanol production of 9.3 billion gallons in 2008 – at 2.8 gallons per bushel and 150 bushels per acre, that suggests that 22M acres of corn crop is being devoted to corn ethanol today – 70% of this land could be "released" and reused for other purposes (we assume that all ethanol production by 2030 will be cellulosic)."

Could our forecasts be wrong? Certainly – and having detailed the flaws with forecasting methodology, we would be remiss not to point out the assumptions that we have made (see our Biomass paper for more details). Nonetheless, our scenarios above are not meant to be a precise path that is absolutely reflective of what will happen, but rather as one possible set of scenarios that can be "invented" with the right trajectory and policies – an approximation of what can be. There are hurdles - sometimes this approach is possible, and other times it is not (i.e., we cannot build a hydrogen infrastructure in 5-10 years). Nonetheless, our assumptions are driven by science and are a reasonable outlay of what's plausible – with the right guidance and continued improvements, the plausible can become the probable. The emphasis has to be on making new things happen that provide exponential leaps in productivity/capability, as opposed to utilizing old economic data and signals to extrapolate past events.

Searchinger notes that “proper accounting must count the net impact on the carbon” – we agree. However, it is next to impossible to accurately compute this impact; any computation would be far from “proper” if we pick one potential scenario with a specific set of assumptions, Searchinger provides us with the likely impact in that scenario alone. A more complete picture would require a similar assessment across various assumptions including some of which we have defined above, with a probabilistic weighting to account for their likelihood. As a whole, the danger is that the hierarchy of assumptions in each study will persist, with subsequent studies working of the same misconceptions and adding similar fallacies to the literature – thus the desire to address the issues early. While scientific assessment of land use changes is urgently needed in order to design policies that prevent unintended consequences from biofuels production, conclusions based on speculative land use change assumptions will lead to erroneous results and shut off promising options. There is a critical difference between the forward looking approach for incentivizing development of the right facilities and processes (with the right local feedstocks) we recommend and backward looking models like Searchinger. Searchinger’s global macro analysis fails to account for these variations which are critical to desirable solutions.

Delucchi et al – the iLUC standard

Recently, Delucchi et. al signed a letter to the California Air Resources Board opposing the idea of setting the iLUC impact when assessing biofuels at zero, noting that “While the science of iLUC impacts is evolving, zero is most certainly not the most likely or scientifically most soundly supported value, and we see no evidence that it will be in the foreseeable future.”[30] We disagree, for a multitude of reasons, including many cited above - we don't have enough evidence that this number cannot be achieved or even that iLUC change is supported by data, especially for non-food biofuels; higher prices may result in other responses like higher yields, better seeds , water etc. In fact it is likely that (a) the additional sources of land (some of which are cited above) and/or land efficiency improvements will disprove this analysis (b) it is possible that engineered biomass crops/practices with strong polyculture perennial root

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[30] Delucchi et al

systems and with rainfed agriculture (6 b acres of currently unused or underused rain-fed land is available for agriculture per FAO study/ Booze Allen**[31]**) and little fertilization will continue to sequester carbon and may sequester more below ground carbon than their current grassland state, with properly designed agronomic practices and feedstocks. In fact enough promising possibilities exist for zero net carbon from land use changes that we should be encouraging that use , not using old models and change patterns (when no economic incentives existed to optimize carbon impact) to discourage biofuels and low carbon feedstocks**.** In summary, we believe that while there is some uncertainly about iLUC impact today, the evidence suggesting substantial iLUC impact is impossible to quantify adequately and does not sufficiently account for new technology and other future developments related to biofuels. **Values of zero net impact in properly crafted systems maybe possible, even plausible.**

Delucchi et. al. note a few other issues, which we respond to below:

- <u>The authors state that "CBO, USDA and WTO among others use these models to analyze implications of agricultural policy and changes"</u>: Perhaps, but as our section on forecasting details, even the mature energy models used by reputable agencies shows dramatic flaws in their results – often wildly so, and often in extremely short time frames. The EIA's Energy outlook retrospective noted that on average, the EIA's forecast of average oil prices was off by 52%; natural gas prices were of by 64%, and coal prices were of by 47%.[32] Imagine the errors in immature models over the course of the next 30-40 years, especially if the economic signals and incentives are changed! More specifically, land use models are far less mature than other models discussed here, and more importantly subject to change based on practices.
- <u>They state "no scientifically respectable alternative way to predict how human systems will respond to policy than to use what we know about the behavior of economic systems":</u> Again, that is under old assumptions which have mostly changed and are likely to change further under a global cap & trade system. We would suggest that the current models are not sufficiently accurate in predictive forecasts to be scientifically respectable. Moreover, the validity of a model is almost entirely dependent on the inputs into the model; historical data sets that don't accurately capture the effects of new technology or new economic signals are likely to yield results in line with past trends and projections, not accurate predictive results.

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[31] FAO, 2003. "World agriculture towards 2015/2030. An FAO Perspective." ISBN: 9251048355 FAO, Rome (Italy)

[32] "Annual Energy Outlook: Retrospective Review", EIA, April 2007

- They claim that "no peer reviewed models have been advanced that come up with values for iLUC that are significantly lower": The absence of alternatives does not validate their model. We believe that qualitative analysis (at this early stage) leads to better results and encourage the design of systems that meet the goals we've outlined, rather than using inaccurate and gross estimates that assumes the world will be as it has been under old, irrelevant (to biofuels) economic signals; there is an appearance of precision as they are translated into hard numbers but have huge error bands around them if the true range of alternative assumptions are accurately considered. These are faux calculations that appear quantitative but in fact are not reliable.
- They state that the iLUC model "is consistent with the best science" to asses the full life cycle impacts of fuel choices. This is fundamentally wrong. The best science is currently being invented and the most likely scenarios suggest that the highest probability scenarios are substantially different. These future scenarios have not been "proven" but excluding them will be a self-fulfilling prophecy, killing these valuable options. The models further completely ignore different potential scenarios, locking into a model based on old and irrelevant data. This would be akin to using postal service data to estimate the potential market for email.
- Their claim that "we are explicitly modeling the effect of real uncertainties in the parameter values of these models" : But can they cover the real range of uncertainties including policy changes? What impact of policy? The famous computer scientist Alan Kay said the best way to predict the future is to invent it. They completely ignore this possibility. The goal of policy in the short run should not be to compute the model based on obsolete data but to do a forward likelihood projection, to encourage the right choices among investors, inventors, scientists and technologists but more importantly, to increase the options we are developing to respond to future needs for increased capacity. We should project conversion processes, feedstock choices and yields, agronomic practices and other technological improvements over the next few decades to accurately asses the likely impact of these models. The next ten years should be devoted to increases our response capability and choices and options to global climate change needs - developing a multitude of alternatives is key in the short run and we should be engineering systems to determine what is possible. For biofuels, the analysis assumes worst-case incremental land use compared to average gasoline; however, our real practical choice is likely to be incremental sources of oil, such as tar sands, oil shales and other marginal sources with 200-300% the carbon emissions of the reference average oil used in many of these computational models.

- They state that “ an underestimate of iLUC is probably worse than an overestimate since it would create incentives for over –production of crop based biofuels. … social effects of biofuels should lead ARB to be wary of over-incentivizing agricultural biofuels”: Unfortunately, there are a number of problems with this argument. Primarily, the authors don't place any value on optionality in the early stages of technology development and are misinformed as to the investment it encourages in low carbon fuels. Order of magnitude improvements in fuels are possible if a facility by facility assessment is made and it encourages development of low carbon assessment fuels and feedstocks. They clearly don't understand the power of venture capital that has substantially changed the art of the possible in many other areas and is doing so currently in biofuels. Policy should encourage, not discourage such innovation. Judging the results prematurely is like judging the personal computer when it had fuzzy green screens in the 1980’s or judging the 2008 mobile phone by comparing it to the multi-pound monster “portable phone” of 1980 and shutting off the option.
- Their concession that “ lands degraded through past unsustainable agricultural practices may be improved through energy crop production”…”but these practices have not yet been modeled and further research is definitely required”: That may well be the case, but should that penalize energy crop systems in advance? Again, the lack of quantitative modeling and study should not discount the possibility especially since it is likely, even if unproven, that such land recovery is possible. Early research tends to support this assertion, though we certainly believe that further research and optimization is needed.
- They state “modeling done to date describes what would happen, not what would happen if the world were different. Implementing performance based standards that can be effectively applied is crucial to ensuring sustainable supplies” … “the state should be careful not to arbitrarily or unintentionally eliminate options for improving land and environmental quality”. We agree completely – it is vital to do this right, and be willing to adapt as we continue to learn more about the potential benefits and side-effects of biofuel usage. But it is vital not to let the perfect be the enemy of the good.

In our view, the iLUC standard appears to be a distraction of questionable merit at this early stage, especially for non-food fuels – as we learn more about biofuels and research continues, we support the adoption of standards to reflect them. California needs to reduce its emissions but the authors miss the fundament goal of trying to start the technology that also permeates other parts of the world. No global warming solution is possible without technological solutions being adopted in developing countries like India and China. Alternatives like hybrids and electric cars are expected to be irrelevant in those contexts because of their higher capital costs in the next decade or two. (Realistically, Honda may sell 500 Civic Hybrids in India next year – the Tata Nano is expect to sell at least a 100X that. The lesson: cost matters). California should focus on technologies and emission abatement options whose trajectories lead to adoption by the developing world - biofuels from non-food crops and waste meet that criteria and will help California companies dominate this new growth segment; at the same time, their scalability will sharply increase global carbon reduction capability.

Conclusion

Technology offers limitless possibilities: when harnessed, it allows us to make exponential leaps in productivity, irrespective of past trends. Today, California is at a crossroads: the AB32 Bill offers a significant opportunity to determine our future as a continued leader in technology solutions. As mentioned earlier, the legislation presents a landmark opportunity to set standards for emissions reductions and a model for regulating them going forward. If done right, we can foster a climate that encourages significant investment and development in new technologies, while presenting a large established market to serve as a learning curve and base of development. In our view, the key point of importance for California is to recognize the scope of the GHG problem as a worldwide one**. As referenced throughout this paper, optionality is a key goal towards achieving this – rather than build towards a solution that can reduce the most emission now in 2008, we ought to work towards solutions that will reduce the most emissions cumulatively from 2008-2030 and beyond, and can be expanded beyond California to the world.** There are a multitude of proposed solutions, but cellulosic fuels appear to us to be the primary short-to-medium term solution that can scale cheaply, rapidly, and with significant emissions reductions. As the science improves and specific studies are conducted, indirect land use should be included but only when the models have been reasonably proven to be accurate predictors, and when non-land consuming, non-food feedstocks have been reasonably depleted. We continually find ourselves in a role where the environmentalists ("do everything, no matter what the cost") and academic analysis (with no reasonable trajectory to implementation) clash with the cynics and pessimists ("do nothing - its all too expensive") – we should take the approach of pragmentalists, working towards solutions that can function with the market mechanisms that are in place or will be in the near future (such as a cap-and-trade scheme). We must encourage this middle ground, guided by good policy signals that results in the right future being invented.