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Comments Regarding Renewal of Low Carbon Fuel Standard

Roughly at the same time California adopted the low carbon fuel standard, the European Union instituted its renewable fuel standard, and both provided strong incentives to use biofuels. Since this initial adoption, Europe has implicitly acknowledged that its turn to crop-based biofuels was a mistake. It has capped the use of crop-based biofuels in its new renewable fuel standard. It has mandated that aviation and the maritime industry greatly increase their use of alternative fuels, but crop-based biofuels will not qualify for these targets.

The reason for this is the recognition of the largescale global competition for land. To solve climate change, the world needs to dramatically increase food supplies, probably by 50% or more over the next several decades while increasing the quantity of land left in natural habitats (T. Searchinger et al. 2023). We also now know that the world is dramatically expanding global cropland and at an accelerating rate, probably more than 10 million hectares per year in the last decade (more than a third the area of cropland in California each year) (Potapov et al. 2021). The costs in lost carbon and biodiversity are extremely high.

CARB should follow the lessons of Europe and first place a cap and then phase out the use of crop-based biofuels. The incentives to produce biodiesel are particularly harmful due to their high land-use requirements and the key role increased demand for vegetable oil is playing in global deforestation.

True Carbon and Land Use Costs of Crop-Based Biofuels

Biofuels (other than from wastes) are a way of using land to grow plants to replace fossil fuels, which is their climate benefit. The climate cost is not using this land to produce plants for other purposes that also benefit the climate.

This is explicit in the lifecycle analyses used by CARB and others. Burning biofuels emits the same quantity of carbon from the tailpipe of a car as burning gasoline or diesel. (When making ethanol, another 50% of this carbon is released during refining.) The reason LCA's can estimate a climate benefit is that they do not count this carbon. The theory is that these emissions are offset by the carbon absorbed by the growth of the crop used to make the biofuel. But if land is not used for biofuels, it still grows plants that absorb carbon and that benefit the climate in other ways. That is either from storing carbon directly or producing food, which allows other land to store carbon.

The most straightforward way to examine these costs is to ask how much carbon is lost from land on average to produce the crops that go into a megajoule of biofuel. In a paper in *Nature*, my co-authors and I calculated this average and then divided the carbon loss over 30 years as has been CARB policy for land use change.(Timothy D. Searchinger et al. 2018). These calculations generously credit biofuel by-products. As shown in Figure 1 below, this cost for various crops used for vegetable oils is roughly three to four times the savings in reduced use of diesel. When using an ethanol from grain, the costs are roughly two to three times the savings from reduced use of gasoline.

This average provides a useful guide to the carbon that will likely be lost to replace crops diverted to biofuels. If these carbon losses per ton of crop are even a fraction of the carbon losses per ton of crop in the past, biofuels must result in more carbon in the air (even without counting the emissions from their production process).

When CARB was first modeling land use change, its model claimed that this level of land use change would not occur in part because farmers would instead replace the food by increasing their crop yields. This is one reason CARB's estimated emissions from indirect land use change are around one tenth these average costs. Although yields for corn and soybeans have continued to grow close to prior trend lines, there has been no acceleration in yield gains for any of the major crops used for biofuels. Palm oil, which is the other major additional source of vegetable, has had stagnant yields. Overall, there is no economic evidence that biofuels have spurred faster yield growth. Accordingly, contrary to projections, there is good reason to believe that the real emissions from land use change to replace diverted crops are similar to these prior averages.

In short, devoting land to produce crops for biofuels has very likely increased carbon in the atmosphere and is very likely to continue to do so.

The Vast Climate Cost of Using Biofuels Versus PV

Another development since origination of the low carbon fuel standard has been the emergence of competitive solar power, which can then be used to power cars or heat pumps. Both solar and biofuels use solar radiation as their source of energy. Yet, even on good agricultural land, these solar and electric pathways will generate roughly 300 times the transportation or residential heat per hectare as biofuels. Figures 2 and 3 (T. D. Searchinger, Beringer, and Strong 2017).

As California is learning, siting all the necessary solar power is challenging. Although cropland need not be used for all or even most PV, some must be used, and this use is likely to be limited by the needs for global food production. In this context, devoting cropland to biofuels sacrifices 300 times the potential energy and therefore roughly the same quantity of carbon savings that could be produced by using this land for PV. And even if cropland were to become surplus, devoting one hectare to PV and reforesting the remainder would generate the same useable energy and at least 300 times the greenhouse gas reduction as devoting that hectare to biofuels (even factoring in by-products).

Claiming Climate Benefits for Reduced Food Consumption by The World's Poor

One reason CARB has estimated low emissions from ILUC is that the GTAP model has projected that much of the food diverted to biofuels is not replaced. For corn ethanol, the GTAP model used by CARB projects that half of the food is not replaced because the ethanol causes higher prices and the world's poor eat less. Physically, this results in fewer carbon emissions that literally occur because people who eat less food emit less carbon dioxide through their respiration.

A paper in *Science* in 2015 co-authored by Richard Plevin, a long-term CARB consultant on the low carbon fuel standard, showed that all of the actual greenhouse gas reductions CARB attributed to corn ethanol were the result of this reduced food consumption (T.D. Searchinger et al. 2015). To be clear, this is CARB's projection and if this reduced food consumption did not occur, the emissions counted by CARB would be accordingly higher. In effect, the implicit policy of California has therefore been to reduce emissions through biofuels by causing higher global food prices that cause the world's poor to eat less and respire less carbon.

There has never been any rebuttal to this paper as an accurate interpretation of CARB's modeling. Some have doubted this level of food reduction, but if so, the emissions would be higher. I personally believe that over the longer term, there is much less reduction in food consumption because farmers catch up and clear more land. But that means California's biofuel policies are increasing global hunger in the short-term and more deforestation and carbon emissions in the mid- to long-term.

Relying on reduced food consumption by the world's poor should be an unacceptable policy goal of California.

Biodiesel is the Most Serious Threat to Tropical Forests and Climate

California's proposed revisions would create large incentives to increase use of biodiesel. Biodiesel from vegetable oil must realistically cause more land use change than corn ethanol because it requires more land to produce that oil than corn – even after accounting for byproducts such as soybean meal. That is why the average carbon lost to make cropland to produce vegetable oil is around 300 grams per mega joule when amortized over 30 years, roughly *four-times* the savings from fossil fuels over 30 years (Figure 1).

Biodiesel poses the even greater global threat to tropical forests because, as can be seen from Figure 4, the vast majority of the growth in vegetable oil comes from palm oil grown on land that was tropical forests, or from soybeans, whose expansion has primarily occurred in the tropics (Weisse and Goldman 2021).

Models such as CARB's that recognize high emissions from making biodiesel from palm oil, but low emissions from U.S. soybean biodiesel, are not credible. (These models have no cross-price elasticities to base these types of estimates on, and they result primarily from other model features, such as fixed trade rules.) As Figure 5 shows, the prices of global vegetable oils are closely linked, particularly over the course of years. This linkage demonstrates almost complete substitution at the margin between vegetable oils. As a result, increases in demand for any vegetable oil translate into comparable increases in demand for all vegetable oils worldwide. Any increase in demand for biodiesel from any vegetable oil will primarily be met by the combined expansion of soybean and palm oil in the tropics. To put this in perspective, there are large incentives already to the aviation industry to use HEFA, which is essentially biodiesel. If even one quarter of 2050 aviation fuel were to come from biodiesel, the world would need to double global vegetable oil production.[1]

California has so far claimed to avoid this responsibility for increased use of vegetable oils by having incentives that have led to claims that biodiesel is primarily coming from used cooking oil. Even used cooking oil has high costs as it is a valuable animal feed. Regardless, California's existing incentives, combined with Europe's strong incentives to use used cooking oil for both aviation and maritime industry biofuels, guarantees that there is no surplus used cooking oil to supply more California biodiesel. (It is also likely that much used cooking oil in the U.S. is actually virgin vegetable oil based on an ICCT study .) As the ICCT has shown, proposed new targets will lead to expansive additional use of vegetable oil (Malins and Sandford 2022). In any event, the possibility of using used cooking oil provides no justification for allowing future targets to be met by vegetable oil.

Without a cap and phase-out, given other rising demands for biodiesel from used cooking oil, CARB will become a significant driver of global deforestation and associated losses of carbon and biodiversity.

[1] USDOE projects that global aviation fuel in 2050 will reach 230 billion gallons. USDOE, Sustainable Aviation Fuel: Review of Technical Pathways (2020). Global vegetable oil production last year was 62.3 billion gallons (217.62 million tonnes.) It takes slightly more than 1 gallon of vegetable oil to produce one equivalent gallon of kerosene.

New ILUC Studies Have Found High Emissions from Biofuels

The best way to assess the true land use and carbon costs of biofuels is the straightforward method of asking how much carbon could be stored on land without devoting that land to biofuels – as shown in Figure 1. However, even using economic models to estimate ILUC – models that credit biofuels for such adverse consequences as reduced food consumption – also reveals likely increases in emissions. Just recently, researchers at the Potsdam Institute for Climate Impact Research published a study finding that even using energy crops with high assumed yields increases carbon in the atmosphere for more than 30 years from land use change alone (Merfort et al. 2023a) (Merfort et al. 2023b). Other researchers have found that emissions from land use change for corn ethanol in the U.S. caused corn ethanol to increase emissions (Lark et al. 2022). These last results would have been even worse had the authors assessed global ILUC emissions, which are typically estimated as much larger than domestic effects.

Conclusion

Crop-based biofuels represent an extraordinarily inefficient use of land. The world's global land use competition is already heating up as the world simultaneously is increasing its expansion of agricultural land while climate solutions require stopping that expansion and even reforesting land. California should follow Europe's lead and start to phase-out use of crop-based biofuels.

Figure 1:

Average Carbon Loss to Make Cropland Per Megajoule of Biofuel

Biofuel	Carbon Benefits (COCs)	GLOBIOM-EU	GTAP-CAL
Wheat ethanol	140	23	
Corn ethanol	200	9	22
Sugarcane ethanol	110	11	14
Soybean Biodiesel	330	100	27
Rapeseed Biodiesel	270	43	13
Palm oil Biodiesel	260	230	71

Grams of CO_2 per mega joule of fuel;
Reference: gasoline = 74

Numbers in oval = average carbon lost from vegetation and soils, amortized over 30 years as in EPA ILUC regulations, to produce the crops for 1 mega joule of ethanol after crediting by-products.

For corn ethanol = ~3X displaced fossil fuels emissions.
For biodiesel = ~4X displaced fossil emissions

Assessing the efficiency of changes in land use for mitigating climate change

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Figure 2: Solar conversion efficiencies of PV are overwhelmingly higher than biofuels.

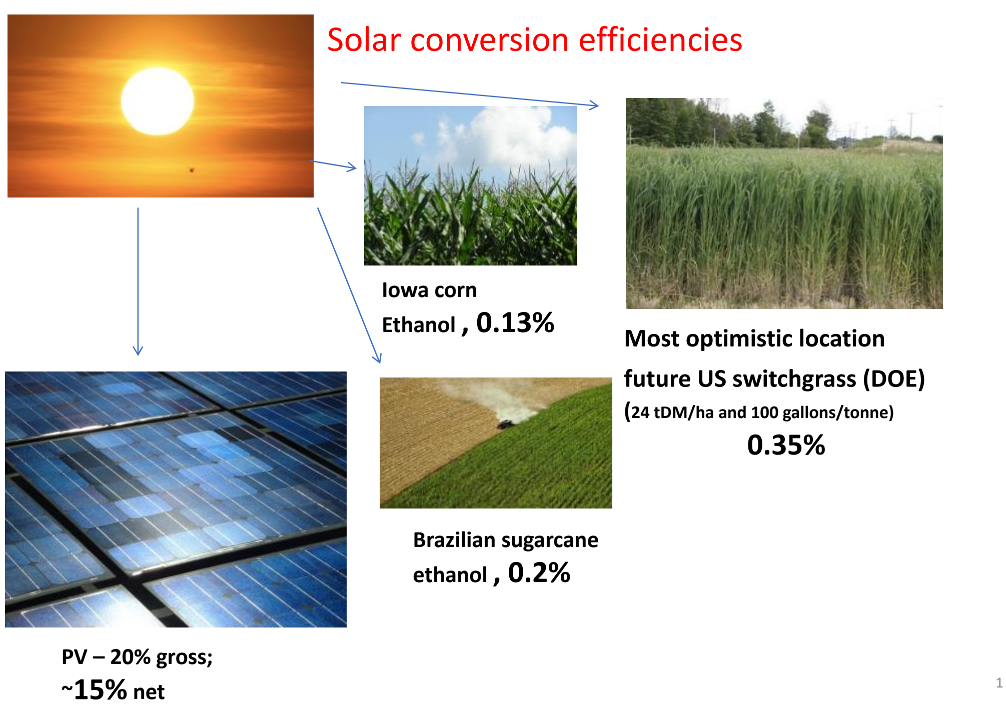
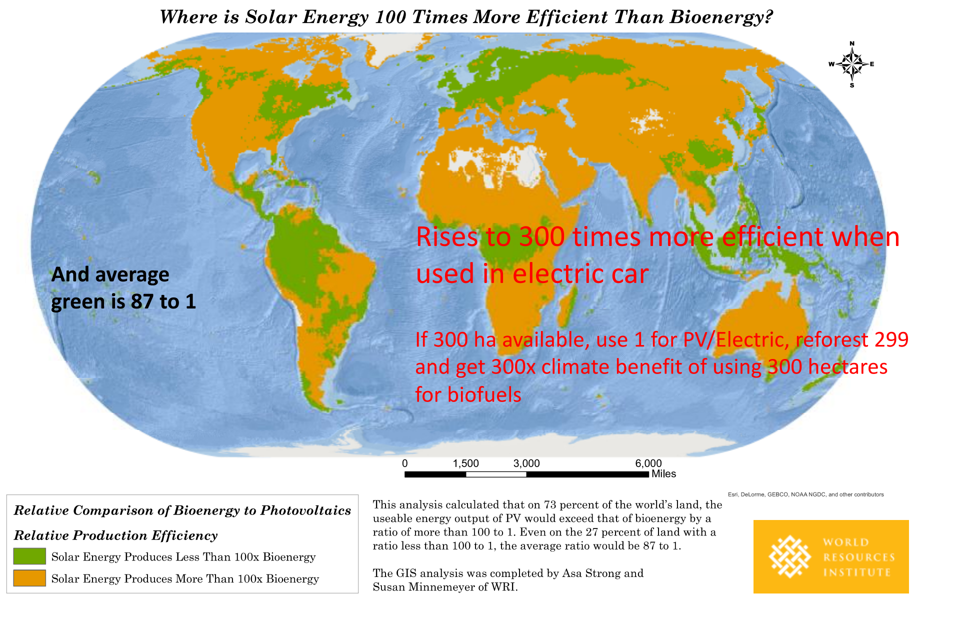


Figure 3: On 75% of the world's land, the efficiency of today's PV in producing useable energy is at least 100 times higher than even, likely future cellulosic ethanol. Using that electricity in an electric cars means cars can travel at least 300 times farther than using ethanol.



Source for Figures 2 & 3: Searchinger et al. *Energy Policy* (2017)

Figure 4: Expansion of palm and soybean oil is supplying the vast majority of the world's expanded demand for all vegetable oils.

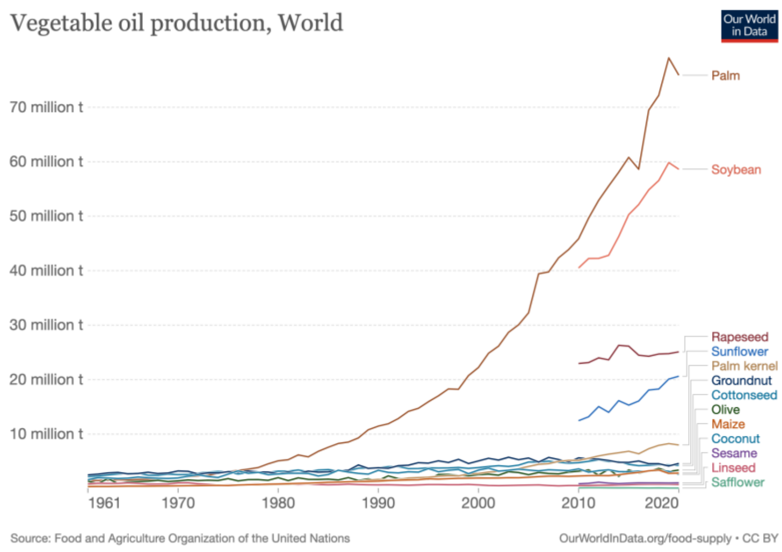
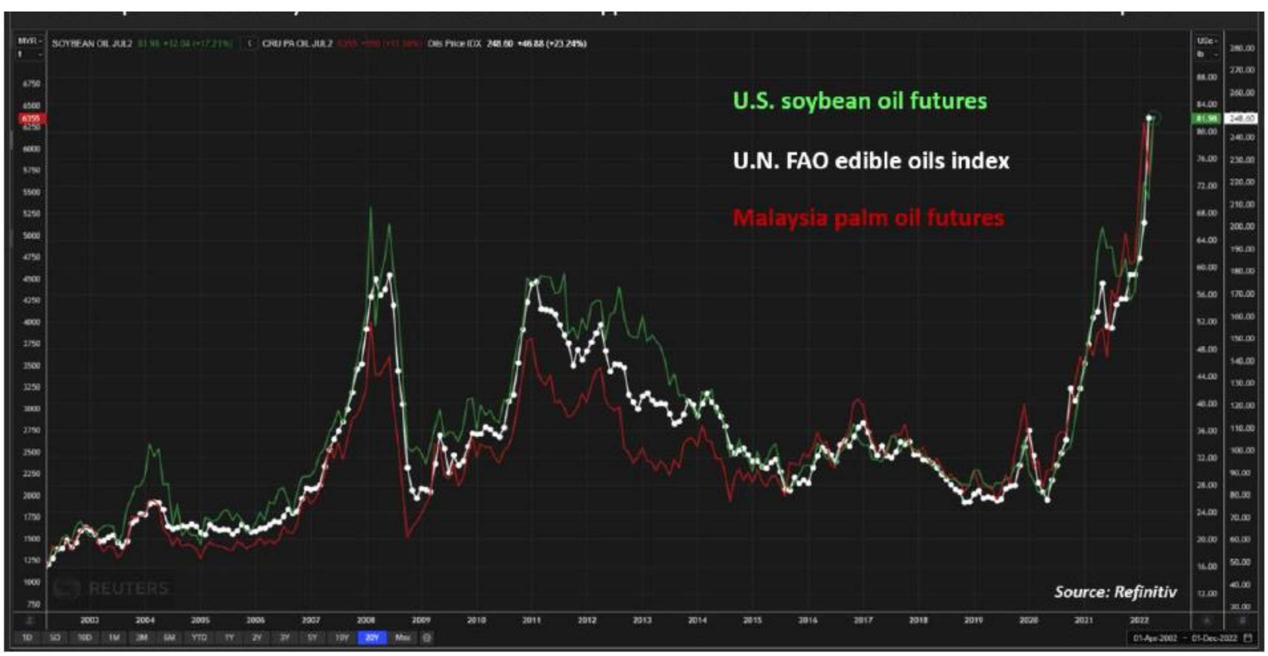


Figure 5: Close tracking of different vegetable oil prices means any increase in demand for one form of biodiesel will result in similar increases in demand for all vegetable oils.



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