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Calculating Carbon Intensity: Implications of Projection Horizon and Future Land Use

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I. Introduction and Overview

This brief report supplements our earlier analysis (NERA 2009) of alternative methods of computing the levelized carbon intensity of land-use changes (LUC) that might be caused indirectly by increased production of corn-based ethanol. In particular, we focus on the impacts of two factors: (1) varying the assumed time over which corn-based ethanol would be produced and (2) adjusting the LUC emissions profile to reflect that land converted now because of increased ethanol production should reduce the amount of land converted to cropland after the production of corn-based ethanol ceases and the land becomes available for other crops.

A. Background

In evaluating the relative carbon intensity of corn-based ethanol, CARB staff have recommended including indirect emissions associated with possible indirect LUC. In an earlier report (NERA 2009) we addressed alternative ways of aggregating these uneven indirect emission streams over time into a measure that can be compared meaningfully to direct emissions (from production and consumption) from various ethanol pathways and gasoline. We showed that the FWP and FWPe methods developed by O'Hare et al. (2009) and presented in the Initial Statement of Reasons (ISOR; CARB 2009) overweight early emissions compared to later ones because their arbitrary "analytic horizon" means that later emissions are tracked for fewer years in the atmosphere. If that problem is addressed either by using a very long analytic horizon or modifying the measure to track CO_2 in the atmosphere for the same amount of time regardless of when it is emitted, one gets the same relative weights as with simpler approaches based on emissions. In particular, the FWP converges to the Annualized (averaging) method and FWPe converges to the NPV method described in ISOR. We also showed that accounting for likely growth in the monetized value of controlling CO_2 emissions (the Social Cost of Carbon or *SCC*) results in using an effective discount rate for emissions equal to the preferred discount for monetized costs and benefits (*r*) minus the growth rate (*s*) of *SCC*. As a result, we do not believe it is appropriate to use either of the FWP(e) methods.

In the earlier report, we did not analyze the emission streams themselves, but rather used "representative" estimates made by CARB staff to illustrate the potential impacts of different methods and discount rates (where relevant) on the levelized LUC CI. In this supplemental report we address two aspects of these emission profiles: (1) the length of the "project horizon" and (2) assumptions about the use of converted land after corn-based ethanol is assumed to be displaced by other renewable fuels that are presumed to become more cost effective over time.

B. Overview and Summary

A simple assessment suggests that shortening the assumed project horizon would increase the levelized carbon intensity of LUC, because initial increases in emissions from land use changes would be amortized over fewer years. A full assessment is more complicated, however, as one must take account of how current LUC affects future LUC. In particular, once production of corn-based ethanol ends—at the end of what is called the "Project Horizon"—the land converted to cropland as the result of indirect market effects would be freed for other purposes. Calculations by CARB staff at present ignore the changes in emissions due to these other, later land use changes. In this paper we consider one possible such later use of the land—once it is not needed to produce corn for ethanol, converted cropland could be used for purposes such as increased food production or production of other crops for biofuel production. The key point is that these uses would avoid the conversion of other land to produce these products. As a result, this scenario would lead to a substantial credit starting after the end of production of corn-based ethanol. In its simplest form, the profile of this credit would be the mirror image of the profile of

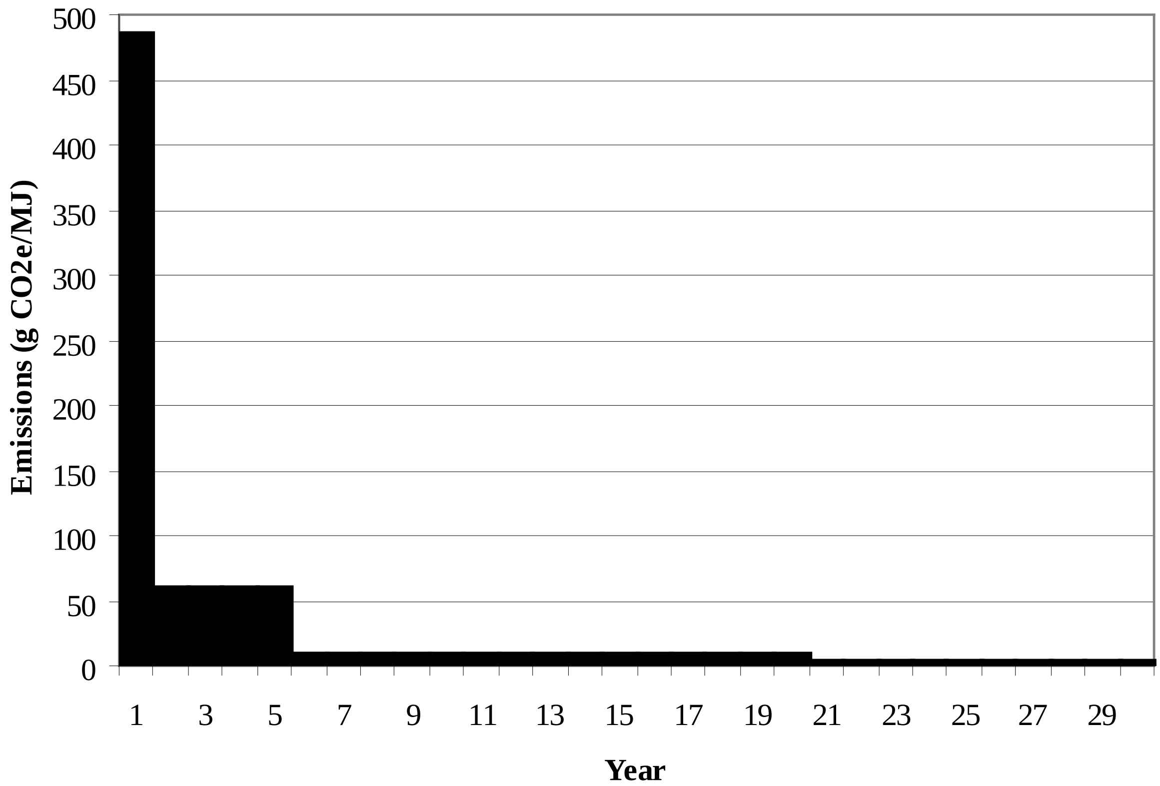
LUC emissions, but shifted forward in time. We show that taking account of this potential credit both sharply reduces the net levelized LUC CI and makes it insensitive to the assumed project horizon (i.e., the period over which corn-based ethanol is assumed to be produced).

We do not assess the reasonableness of the assumptions underlying these calculations, in particular, that land converted today as a result of indirect effects of demand for corn to produce ethanol will substitute one-for-one for similar land that otherwise would be converted to cropland after corn-based ethanol production ends. The exercise we have conducted, however, illustrates that the issues are complex and that shortening the assumed project horizon does not necessarily increase the levelized LUC CI. Taking account of indirect land effects after production of corn-based ethanol could also sharply reduce the value of the levelized LUC CI.

II. The Impact of the Project Horizon on the LUC CI

A. Summary of CARB Staff LUC Emissions Assumptions

CARB staff has estimated the indirect emissions from LUC using a general equilibrium model that predicts how changes in the value of crop land as the result of increased demand for corn to make ethanol would affect land use. In particular, CARB staff estimates the extent to which conversion from other uses (including forests) to cropland would release carbon currently stored in the vegetation and soil of the land converted. The results are sensitive to many assumptions based on limited information. Figure 1 plots CARB staff's 'representative' estimates over a 30-year period, which is the CARB staff's preferred Project Horizon. Emissions are highest in the first year, when CARB staff assume that carbon is released from whatever vegetation was on the land at the time of conversion. The profile also assumes relatively high release rates from carbon sequestered in the soil for the first five years, followed by another 15 years in which the remaining carbon sequestered in the soil is released at a slower rate. After that period, indirect emissions from LUC are small, reflecting only foregone incremental sequestration by the original vegetation. We have not addressed the reasonableness of these projected LUC emissions and use them only for illustrative purposes. (We understand that Air Improvement Resources and other consultants to the RFA have addressed those issues in separate reports submitted to CARB by the RFA.)



Note: Emissions are in gCO2e/MJ
Source: CARB 2009

Figure 1. CARB's Estimates of CO_2 Emissions from Land-Use Changes Associated with the Production of Corn-Based Ethanol

B. Sensitivity of Weights to Assumed Project Horizon

The relative weights derived from the emission-based methods can all be written in the following general form:

$$w_t = (1+d)^{t-1} \quad , \tag{1}$$

where w_t is the weight given to emissions in year t relative to emissions in year 1 (i.e., w_1=1) and d is discount rate applied to emissions. For the CARB staff's Annualized method, d = 0; for the staff's NPV method, d=r, where r is the discount rate for monetized benefits and costs; and for the value-adjusted method we recommend, $d = (r - s)/(1+s) \approx r - s$, where s is the estimated growth rate of the *SCC*.

The levelized CI for LUC emissions is the ratio of the weighted sum of LUC emissions divided by the weighted sum of emissions from gasoline times the CI for gasoline:

$$\text{LUC CI} = \left(\frac{\sum_{t=1}^{H_P} L_t (1+d)^{-(t-1)}}{\sum_{t=1}^{H_p} G(1+d)^{-(t-1)}} \right) G = \frac{\sum_{t=1}^{H_p} L_t (1+d)^{-(t-1)}}{\sum_{t=1}^{H_p} (1+d)^{-(t-1)}}, \qquad \textbf{(2)}$$

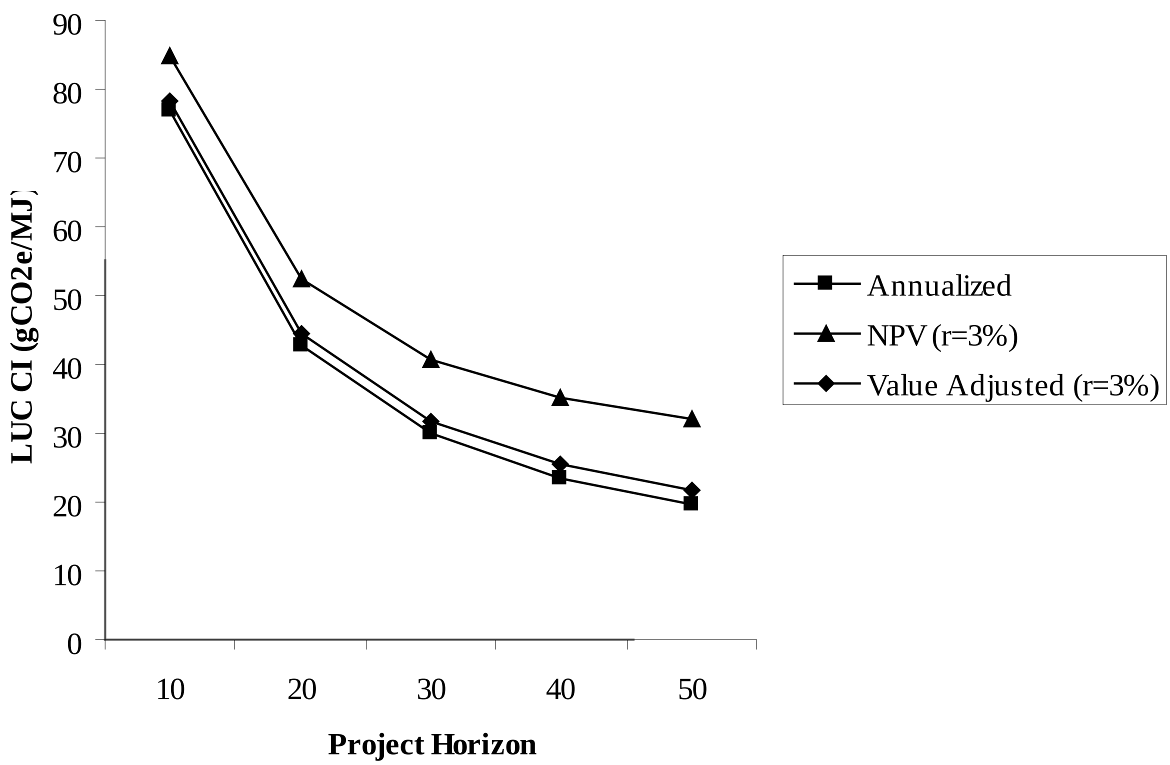
where L_t is land-use emissions in year t, G is unit emissions from gasoline (assumed constant over time), and H_P is the Project Horizon, the period assumed in the analysis over which corn-based ethanol will be produced. The final expression in Equation 2 shows that the LUC CI calculated in this manner is equivalent to amortizing (or levelizing) emissions over the project horizon at the discount rate d.

Figure 2 plots the resulting values of the LUC CI for three methods with the parameter values shown below:

1. Annualized (averaging method) with d = 0%;
2. NPV method with $d = r$ =3 percent; and
3. Value-adjusted method with r = 3%, s = 2.4%, and hence d = 0.6%.

Reducing the discount rate, r, would shift the curves for the second and third methods downward, while increasing r would shift the curves upward. If $r<s$ the curve for the value-adjusted method falls below the Annualized (averaging) method. The key point for our purposes here is that the LUC CIs calculated in these ways are very sensitive to the project horizon. For

example, using the parameter values in Figure 2, reducing the project horizon from 30 to 20 years increases the LUC CI by 43 percent using the Annualized method (*d*=0%), by 29 percent using the NPV method (*d*=3%), and by 40 percent using the Value-adjusted method (*d*=0.6%). Had we calculated the FWP or FWPe using these alternative project horizons, the impact of changing the project horizon would have been even more dramatic and the LUC CI values would have been higher for any given project horizon and discount rate.



Note: Value-adjusted method uses a value of *s*=2.4% for the growth rate of the *SCC*.
Source: NERA calculations as explained in text.

Figure 2. Impact of Project Horizon on Alternative Methods of Computing the Levelized LUC CI

III. The Importance of Land Use After Production of Corn-Based Ethanol Ends

Determining the appropriate project horizon to use for calculating the LUC CI is not a straightforward issue. It is important to note that the project horizon relates to indirect changes in emissions associated with use of *land*. Thus it is not appropriate to use the economic life of an ethanol production plant, because once converted the crop land could continue to be used to grow corn for use in replacement production plants if demand continued past the useful life of the original plant. A somewhat more reasonable value to use is how long one expects corn-based ethanol to be an economically viable fuel, before it would be displaced by other fuels as they are presumed to become more cost-effective. That concept appears to be the one that the ISOR uses. It assumes implicitly that there are no LUC emissions (positive or negative) after production of ethanol ceases.

A. Future Use of Land Initially Converted to Cropland

This approach fails to account for the net impact of the LUC on land use and associated emissions after corn-based ethanol ceases to be produced. Will the land revert to its former use or to another that sequesters carbon in the soil and in vegetation? In general, one would expect that the LUC emissions would be negative after production ceased. O'Hare et al.'s BTIME model, for example, allows the user to model recovery of this sort. However, although an ISOR appendix considers the possibility of accounting for recovery, the values preferred by CARB staff and used in the body of the ISOR do not include any such recovery; they simply assume that LUC emissions are zero after production ceases.

Another scenario that should be considered is that land converted today as the indirect result of corn-based ethanol production will substitute, after production of such ethanol ceases, for land that otherwise would have been converted to cropland in the future. Under this scenario, for example, if the economic lifetime of corn-based ethanol is 25 years, an acre cleared today for corn used in ethanol will substitute for an acre that other would be converted to cropland in 25 years later. The availability of that land will decrease the price of cropland, thus reducing the incentive to convert other types of land to cropland. It is hard to predict how much land conversion would otherwise take place in, say, 20 to 40 years and the extent to which such demand would be met by land freed from producing corn for ethanol. However, this effect is just the conceptual mirror image of the general equilibrium effects currently modeled for the initial impact of increased production of corn-based ethanol. Merely because production of corn-based ethanol may end does not necessarily mean that demand for cropland will not continue to grow as population and income expand. Under this scenario, LUC that occurs today as a result of increased production of corn-based ethanol effectively shifts LUC emissions closer in time. Although LUC emissions occur starting now, LUC emissions that otherwise would have started later will not occur.

B. Impact of Credits on Net Profile for LUC Emissions

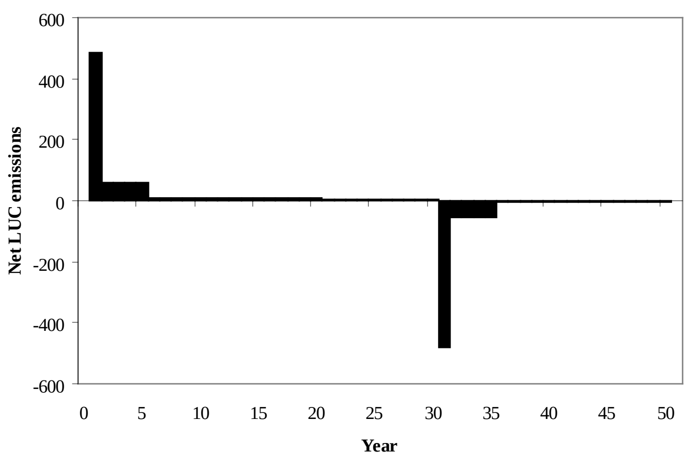
Under the simplest form of this scenario, the estimated profile of net LUC emissions is the same as previously calculated through the production period for corn-based ethanol, but subsequently there are credits with the same profile because of avoided LUC. Thus, for example, if the expected production period for corn-based ethanol is 25 years, we have the same profile of emissions up through year 25. Starting in year 26, however, net emissions are year 26 emissions *minus* year 1 emissions (because land is not converted in year 26 that otherwise would have been converted in that year. Similarly, net emissions in year 27 are year 27 emissions from the original profile minus year 2 emissions from the profile, and so forth Thus, net LUC emissions in year are:

$$N_t = L_t, \text{ for } t \leq H_P \quad \textbf{(3)}$$

and

$$N_t = L_t - L_{t-H_p}, \text{ for } t > H_{p.} \quad . \quad \textbf{(4)}$$

Figure 3 plots net emissions assuming a 30-year production period.. Starting in year 31, there is a net credit through year 50. After year 50, there are no net emissions, because the credit for avoided future conversion is equal to the debit for the original conversion. For comparison, Figure 4 plots net emissions for the same original profile, but for a production period of 20 years. Note that with a shorter production period, the net credits begin sooner.



Note:
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Figure 3. Net LUC Emissions Assuming Substitution and 30-year Production Period

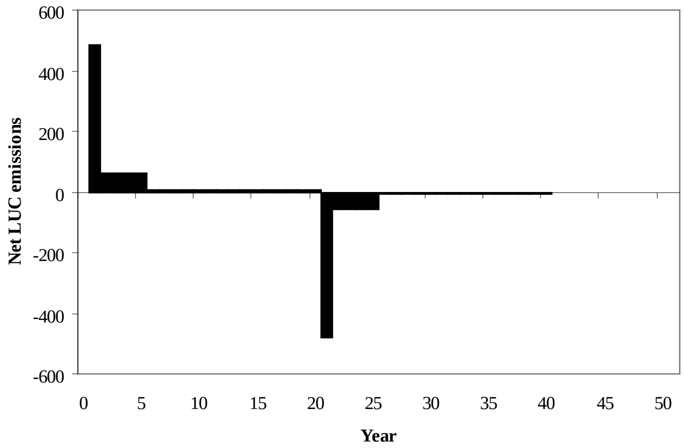

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Figure 4. Net LUC Emissions Assuming Substitution and 20-year Production Period

C. Computing Levelized LUC CIs with Credits

With such credits, we can write the levelized CI for LUC in the following form:

$$= \frac{\sum_{t=1}^{H_I} L_t (1+d)^{-(t-1)} - (1+d)^{-H_p} \sum_{t=1}^{H_I} L_t (1+d)^{-(t-1)}}{\sum_{t=1}^{H_p} (1+d)^{-(t-1)}}, \qquad \textbf{(5)}$$

Where H_I is the time horizon over which there are indirect emissions from LUC. Note that this horizon need not be the same as the "project horizon," H_P; the two are independent of one another.[1] After some algebraic operations, Equation 5 simplifies to:

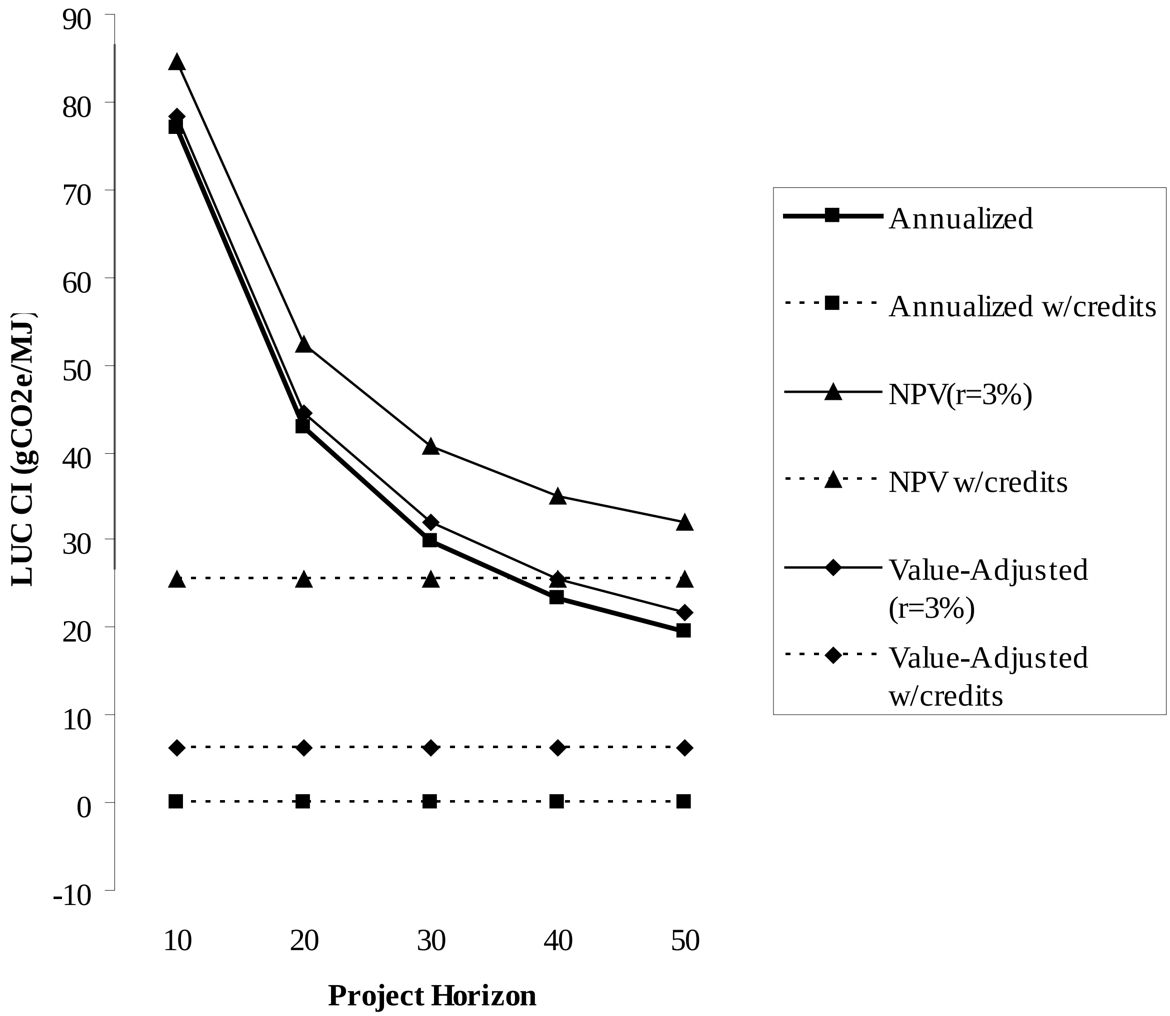
$$r\left[\sum_{t=1}^{H_I} L_t (1+r)^{-(t+1)}\right]. \qquad \textbf{(6)}$$

Note that this expression does not depend on H_P, the project horizon. With the credits, the following two factors exactly offset one another as the project horizon shrinks:

[1] If LUC emissions remain constant after year T, then the results are insensitive to H_I so long as $H_I \geq H_P + T$. After that year, net emissions are 0 because the credit for avoided future conversion is equal to the debit for the original conversion.

1. the LUC emissions are amortized over fewer years, thus increasing the levelized LUC CI; but
2. the period when the net flow of LUC emissions becomes negative moves up in time, thus reducing the levelized LUC CI.

To see how credits for avoided future land conversion affects the value of LUC CI, Figure 5 supplements Figure 2, which showed the impact of changing the project horizon with the original emission profile, to show the value of the LUC CI with the credit for avoided future LUC emissions for each of the three accounting methods. As demonstrated in Equation 6, this value is independent of the project horizon. For all three accounting methods, crediting avoided future LUC sharply reduces the net levelized LUC CI, as shown by the fact that each dashed line in Figure 5 is well below its corresponding solid line. The shorter the Project Horizon used, the large the effect of the credit for any given time-accounting method. The lower the effective discount rate on emissions, the larger the effect. Compared to the CARB staff's preferred project horizon of 30 years, crediting avoided future emissions. reduces the levelized LUC CI by 100 percent using the Annualized (averaging) method, by 38 percent using the NPV method with a discount rate of r=3 percent and by 80 percent using a discount rate of 3 percent and a growth rate of 2.4 percent for the *SCC*.



Source: NERA calculations as explained in text

Figure 5. The Impact of Assigning Credit for Future Avoided LUC Emissions Compared to the Impact of Changing the Project Horizon

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