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# Proper accounting for time increases crop-based biofuels' greenhouse gas deficit versus petroleum

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**Abstract**
The global warming intensities of crop-based biofuels and fossil fuels differ not only in amount but also in their discharge patterns over time. Early discharges, for example, from market-mediated land use change, will have created more global warming by any time in the future than later discharges, owing to the slow decay of atmospheric $CO_2$. A spreadsheet model of this process, BTIME, captures this important time pattern effect using the Bern $CO_2$ decay model to allow fuels to be compared for policy decisions on the basis of their real warming effects with a variety of user-supplied parameter values. The model also allows economic discounting of climate effects extended far into the future. Compared to approaches that simply sum greenhouse gas emissions over time, recognizing the physics of atmospheric $CO_2$ decay significantly increases the deficit relative to fossil fuel of any biofuel causing land use change.

**Keywords:** biofuels, greenhouse gas emissions, life cycle assessment, land use change

## 1. Introduction

Performance-based regulations under development in several jurisdictions promote transportation fuels with lower life cycle greenhouse gas (GHG) emissions than petroleum-based fuels. For this comparison, they use a performance metric that aggregates each fuel's direct and indirect GHG emissions into a global warming intensity (GWI). Recent studies of the effects of expanding biofuel feedstock production find large GHG emissions from land use change (LUC) for biofuels that compete for land with other uses such as the production of food. Changes in land use are transmitted across global markets linked by commodity substitutability and competition for land. These market-mediated LUC emissions are not only separated from the biofuel production process by several economic links and physical distance, but also follow a time profile very different from the direct emissions from fossil and biofuel use, being released quickly upon expansion of biofuel production [19].

To obtain a GWI, previous analysts average the total indirect emissions over the total fuel produced during a predicted production period and add these to the direct emissions, implicitly treating a unit GHG emission released today as though it has the same consequences as one released decades in the future. This 'straight-line amortization', for example, is proposed for the California Air Resources Board's implementation of that state's Low Carbon Fuel Standard [3]. Economic discounting can in principle be used to compare costs and benefits over time, but annual GHG flows are, in general, a poor proxy for economic costs: most GW costs are imposed by GHG *stocks* in the atmosphere. Furthermore, consideration of long time frames requires realistic predictions

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about technological innovation and land use changes over that timeframe, including post-cultivation changes in land use.

We define a framework to aggregate GHG emissions and other radiative forcing effects that occur over a significant span of time into a GWI metric that better represents the climate effects of fuel substitution, applicable to any estimate of discharges that are not uniform over time. Our framework accommodates changes in the duration of the production period and post-production LUC, and converts physical effects to economic damages that can properly be discounted. These corrections to previous practice increase the relative importance of early emissions, and in turn the GWI of biofuels that cause LUC.

### *1.1. Treatment of time in life cycle assessment*

In life cycle assessment (LCA), emissions of pollutants are typically summed without regard for when or where these emissions occur [10]. For well-mixed greenhouse gases, it is appropriate to ignore the location of the emissions, as these are global pollutants. However, for long-lived pollutants, summing emissions over time masks potentially important differences among processes, especially if effects are measured at a fixed target date. In these situations, early emissions are in the environment longer relative to the target date, and thus cause greater environmental damage.

In the case of greenhouse gases (GHGs), global warming effects are usually aggregated by summing emissions of three gases ($CO_2$, $CH_4$, and $N_2O$) weighted by their respective global warming potentials (GWP). GWP is the measure of the cumulative radiative forcing (CRF) over a fixed time horizon (e.g., 20 or 100 years) of a pulse of some gas compared to the CRF of an equal mass of $CO_2$ over the same period [7]. Most LCAs use the 100 year GWPs published by the IPCC [7].

In an LCA, it is appropriate to sum GWP-weighted GHG emissions for a process whose emissions are largely coincident with production and use. Summing GWP-weighted GHG emissions also makes sense in a national emissions inventory for a single year, because over the standard 100 year time horizon the specific release date *within* the inventory year is inconsequential to the total CRF. In both of these cases, emissions are implicitly summed or compared using a consistent integration period.

Since LCAs are defined in terms of a functional unit (e.g., emissions per MJ of fuel) [14], emissions from preparatory processes, such facility construction, must be allocated over the assumed lifetime of the facility to place these emissions in terms of the functional unit [1]. In practice, these amortized emissions are generally assumed negligible and ignored in LCA, resulting in a well-recognized 'truncation error' [9].

However, when considering indirect LUC caused by land-competitive biofuels, the assumptions that (i) emissions are largely coincident with production and use, or (ii) that preparatory emissions are negligible, no longer hold. The up-front iLUC emissions from land-competitive biofuels must be allocated over (that is, causally linked to) a quantity of fuel produced over decades, and the biofuel must be compared with a petroleum fuel with relatively small up-front emissions. When we compare processes with very different emission profiles over decades, the simple summation approach is no longer valid because it incorrectly sums the CRF of releases measured over overlapping, but distinct, integration periods. This is not the same as summing the CRF of these releases over a consistent, short time horizon during which all emissions occur. Discounting emission flows, as some have proposed, only compounds the error, since GWPs apply no discounting within their defined time horizon, and 100% discounting beyond the time horizon.

We recognize that GWPs represent an imperfect compromise in their treatment of time, but this compromise has been broadly accepted. Comparing the CRF as implemented in our model of two processes with different emission profiles, over a single time horizon, is consistent with the use of GWPs in national inventories, and therefore it is an appropriate approach for use with policies intended to mitigate climate change.

### *1.2. Time horizons*

Estimating LUC GW effects for biofuels requires careful distinction of three characteristic time periods often confused in political discourse. The first of these is the *analytic horizon*, the period over which consequences are 'counted' in analysis. This may be one hundred years or more. The second is the *production period*, the time during which the analysis assumes a biofuel will be produced and displace fossil fuel. The appropriate production period is no longer than the time until the biofuel will be economically displaced by other fuels or cease production for other reasons. This value is very important for GWI estimation because it affects how long biofuel production has to 'pay back' its initial LUC emissions [8, 6], and because it determines when post-production LUC must be considered.

The third important period runs from the present to a *policy target date*. For example, the California low carbon fuel standard (LCFS) requires a 10% reduction in transportation fuels' average GWI by 2020, and the US Energy Independence and Security Act of 2007 (EISA) requires 21 billion gallons (80 GL) of 'advanced renewable fuels', that achieve a 50% GWI reduction compared to their petroleum counterparts, to be used by 2022 [4, 2]. However, neither policy specifies the date at which measurement of the GWI should be taken. The standard approach used in life cycle assessment, summing GHG emissions weighted by their global warming potential (GWP) regardless of when they occur in time [10], is incoherent (as noted earlier) and it underestimates the climate effects of LUC. A flawed protocol for calculating fuel GWI could inadvertently drive a wedge between the policy and its larger purposes, causing increased global warming rather than less. Our analysis focuses on assuring that GWI calculations implementing a biofuels policy will advance the goal of mitigating climate change.

## 2. Conceptual framework

To determine whether substituting a particular biofuel for petroleum increases or decreases global warming requires

decisions about the analytic and production timeframes, and whether only physical quantities, or their costs and benefits in social and economic terms, are to be assessed. Our analysis proceeds first from discharges to warming consequences, and then (prospectively) to improved benefit/cost assessment.

### *2.1. Physical approach*

Fuel production and use increases climatic warming not only via the release of GHGs but also by direct perturbation of the earth's energy balance through land use changes that alter biophysical land surface properties such as albedo and evapotranspiration. These effects can be aggregated into a time-dependent annual radiative forcing term attributable to fuel $i$'s use, $\mathrm{RF}_i(t)$.

$$\mathrm{RF}_i(t) = \sum_j a_j G_{ij}(t) + B_i(t) \tag{1}$$

$G_{ij}(t)$ is the additional atmospheric abundance of GHG $j$ at time $t$ attributable to the use of fuel $i$, $a_j$ is the radiative efficiency of GHG $j$. Given the projected time profile of discharges for fuel $i$ and GHG $j$, the time-dependent abundance, $G_{ji}(t)$, is obtained using models such as the Bern carbon cycle model [15, 7]. $B_i(t)$ represents all non-GHG radiative forcing effects of fuel $i$ at time $t$.

Integrating the radiative forcing term over the analytic timeframe, $0 < t < t_\mathrm{a}$, gives the cumulative radiative forcing:

$$\mathrm{CRF}_i = \mathrm{CRF}_i(t_\mathrm{a}) = \int_0^{t_\mathrm{a}} \mathrm{RF}_i(t)\,\mathrm{d}t \tag{2}$$

a physically plausible proxy for the total damage to the planet from the $CO_2$ emissions stream up to a particular analytic horizon $t_\mathrm{a}$. The ratio of the CRF for the biofuel $b$ to that of the reference fuel $g$, provides a physical *fuel warming potential,* or $\mathrm{FWP_p}$,

$$\mathrm{FWP_p} \equiv \frac{\mathrm{CRF}_b}{\mathrm{CRF}_g}. \tag{3}$$

This $\mathrm{FWP_p}$ (generally a function of $t_\mathrm{a}$) is a more meaningful physical quantity on which to evaluate biofuel lifecycle emissions than the aggregated emissions over time. Moreover, $\mathrm{FWP_p}$ follows the approach of the Global Warming Potential metric, or GWP, used to convert emissions from non-$CO_2$ GHGs into their $CO_2$ equivalencies, an approach well established in policy and science [7].

### *2.2. Benefit–cost analysis*

Uniformly allocating the initial emission from LUC across the production period treats a unit of GHG discharge now as though it is equally costly as a unit emitted twenty years from now. Specifically, it means that two fuels differing only in that one has, say, 10% of its total discharge at the end of an analytic horizon of 50 years while the other discharges 10% right away, with the remaining 90% in each case distributed uniformly over the period, would be scored as equals and treated as equally costly or beneficial on a GW basis. Policy analysis conventionally recognizes discounting as the tool with which to make distinctions like this. A discounted model counts the *net present value* (NPV) of benefits of $B$ (also costs) $t$ years in the future as

$$\mathrm{NPV}(B) = \left[\frac{1}{1+r}\right]^t B \tag{4}$$

where $r$ is an annual discount rate. For example, if one knows a capital asset will wear out in about twenty years, one does not count that as the present cost of its replacement, but a smaller number, namely the amount that would have to be deposited in some sort of interest-bearing investment to attain the price of the asset twenty years from now. Discounting may also measure a pure delay effect, wherein something of value is simply worth less to us if received at a time in the future than it would be if received now. The effect on global warming decisions of economic discounting can be very large because the time spans analyzed are usually long: the present value of \$1 received twenty years in the future is only about 50c at $r = 3\%$. A current debate about the appropriate discount rate for global warming policy analysis focuses on the extremely low discount rate used in the *Stern Review* and the rapid commitment of expensive resources it implies [20, 18, 17, 22]. The controversy does *not* concern *whether* economic costs and benefits occurring over time should be discounted when calculating costs and benefits for action (though the discount rate apparently used in Stern is so low as to be nearly zero).

However, the intellectual and behavioral basis of this kind of discounting and the debate around it applies only to economic goods, in a world in which market mechanisms (like banks and contracts) exist by which goods in the future and the present can actually be traded against each other: the discounting model applies to costs and benefits, not to physical phenomena that generate them, *unless* their economic value is otherwise stable over time. Consider a simple example: let the *economic value* of a gallon of water on January 1 be $W$, and assume that a gallon of water will also sell for $W$ on July 1. The net present value on January 1, by conventional discounting, of 10 gallons of water *for delivery on July 1* is then

$$\left[\frac{1}{1+0.06}\right]^{0.5} W \tag{5}$$

at 6%, or about 0.97 $W$.

It is tempting also to say, in January, that a *gallon* of water on July 15 is worth[5] 0.97 *gallons* of water now, but if the use of the water is known and it is not available for purchase whenever desired, this easy approximation can be entirely misleading. For example, if the water is intended for a garden that would not be planted until May, it is much *more* valuable in July than in January. And if it is to be applied to a house that is on fire on January 1, delaying delivery to July makes it pretty much worthless. In both cases, conventionally discounting a physical quantity produces absurd results for reasons more fundamental than an incorrect choice of $r$. If the money values of water at each time under each assumption (garden later or fire now) are

[5] The phrase *A is worth xB* in the present context does not denote a theoretical philosophical judgment, but the precise normative behavioral claim that society should be willing to actually give up $A$ for $x$ units of $B$ indifferently. Policy choice is an act of exchange.

calculated, these may be appropriately discounted in the usual way, but discounting the physical quantity will not indicate these differential values for many cases, including the present one of iLUC GW estimation.

The purely physical assessment of radiative forcing can be amended to incorporate social preferences typically included in policy analyses, the simplest being the preference to have benefits sooner rather than later as reflected by computing a net present value (NPV) using a discount rate $r$. However, discounting is correctly applied only to economic rather than physical quantities, so before such economic analysis can be meaningfully pursued the relationship between physical and economic quantities must be established. This relationship can be described in a *damage function,* $D(\mathrm{RF}_f(t), t)$. A complete and realistic damage function is beyond the scope of this paper. However, among the relevant physical quantities discussed above, the radiative forcing $\mathrm{RF}(t)$ is the most appropriate starting point, since this is the most straightforward measurement of the extra heat absorbed by the planet as a result of biofuel use, and it is this heat that drives many of the damages caused by climate change [7, p 210]. A highly simplified approximate damage function, $D(t)$, treats economic damage as directly proportional to $\mathrm{RF}(t)$ with a proportionality constant that is invariant in time such that:

$$D(t) \cong d\mathrm{RF}(t) \tag{6}$$

where $d$ is the damage proportionality constant[6]. Using this damage function, an especially appropriate approximation for the small increments and decrements in GHG emission associated with fuel policies, and an appropriate discount rate allow computation of a net present value (NPV):

$$\mathrm{NPV} = \int_0^{t_a} \frac{d\mathrm{RF}(t)}{(1+r)^t}\,\mathrm{d}t. \tag{7}$$

We emphasize that discounting a stream of *emissions* with long residence times is not a satisfactory approximation. Comparing the NPV of the biofuel case b and reference gasoline case g over the analytic time horizon allows for the computation of an *economic* $\mathrm{FWP_e}$

$$\mathrm{FWP_e} \equiv \frac{\mathrm{NPV_b}}{\mathrm{NPV_g}}. \tag{8}$$

For the simple cost function discussed above, the damage proportionality constant $d$ cancels out of the $\mathrm{FWP_e}$ calculation. For the limiting case $r = 0$, $\mathrm{FWP_e} = \mathrm{FWP_p}$.

For use in regulations based on ratings measured in g $CO_2$e $\mathrm{MJ}^{-1}$, either FWP can be scaled by the GWI of the baseline petroleum fuel to produce a commensurate biofuel *fuel warming intensity* (FWI):

$$\mathrm{FWI}_x = \mathrm{FWP}_x \times \mathrm{GWI_{baseline}} \tag{9}$$

where $x$ is either p or e to specify a physical or economic fuel warming intensity.

[6] The authors do not suggest that the true damage is adequately captured by such a simple expression, especially the implication that the damage constant is constant over time. Reductions in radiative forcing that occur after irreversible calamities—such as the failure of the Gulf Stream, or the Greenland ice cap melting or sliding into the sea—may be described with time-dependent damage functions more complex than ours.

## 3. Methods

To demonstrate the importance of the differences between biofuel and petroleum-based GHG discharge profiles, we have developed the *Biofuels Time Integrated Model of Emissions* (BTIME)[7]. BTIME can be easily parameterized by users with values corresponding to different LUC model results. We present it here with parameters distilled from iLUC modeling results based on the GTAP model [12, 11] and ecosystem carbon data from Woods Hole Research Center [19, supporting online materials] to generate a $CO_2$ emissions scenario for maize ethanol and gasoline[8].

Emissions over time are estimated for the following streams:

(1) Immediate loss of above-ground biomass carbon.
(2) Loss of 25% of below-ground carbon in the top 1 m of soil. Of this 25%, 80% (20% of the total) is lost in the first 5 years, and 20% (5% of the total) is lost over the subsequent 20 years [5]. The model can be adjusted to reflect other emission profiles for below-ground carbon.
(3) Foregone sequestration. Following Searchinger *et al* [19], we assume that the conversion of forest to cropping results not only in loss of sequestered carbon, but in the loss of future sequestration that *would have* occurred had the forest been left standing. These are treated as 'emissions' occurring over a variable number of years, depending on model parameters.

BTIME tracks the accumulation of $CO_2$ in the atmosphere for maize ethanol capacity brought on-line in 2010, and the gasoline it displaces. To track how much of the released $CO_2$ remains in the atmosphere we use the revised version of the Bern Carbon cycle model, assuming a background $CO_2$ concentration of 378 ppm [13, 15]. Specifically, the decay of a pulse of $CO_2$ at time $t$ is given by

$$a_0 + \sum_{k=1}^{3} a_k \mathrm{e}^{\left(\frac{-t}{\tau_k}\right)} \tag{10}$$

where $a_0 = 0.217$, $a_1 = 0.259$, $a_3 = 0.338$, $\tau_1 = 172.9$ years, $\tau_2 = 18.51$ years, and $\tau_3 = 1.186$ years[9].

### 3.1. Model limitations

In the model, we make several simplifications that could be corrected in a more elaborate version:

(1) The decay rate for atmospheric $CO_2$ assumes a constant background concentration in the atmosphere.

[7] The BTIME model is described further in the supporting materials, and can be downloaded from http://rael.berkeley.edu/BTIME.

[8] BTIME does not purport to be a complete model of the climate effects of increased biofuels production. The model does not include the full range of indirect effects (e.g., changes in methane emissions from rice and livestock production or changes in fossil fuel use), nor does it include changes in biogeophysical phenomena (e.g., albedo, surface roughness, and latent heat flux) or non-GHG emissions (e.g., black carbon, aerosols, and ozone precursors). More research is required in all of these areas. The general framework presented can accommodate these factors within the globally averaged radiative forcing term once estimates exist.

[9] BTIME tracks the decay of each term in the sum separately.

(2) We assume that the radiative efficiency of the GHG is constant.
(3) We treat iLUC and ongoing emissions as if they were entirely $CO_2$.
(4) We neglect non-GHG radiative forcing effects.

The radiative forcing of a pulse of a particular GHG depends both on its radiative efficiency and the quantity of gas remaining in the atmosphere. Radiative efficiency for a marginal unit of $CO_2$ decreases non-linearly as the background concentration of $CO_2$ in the atmosphere increases, while for methane and $N_2O$ the relationship is approximately linear [7]. At the same time as radiative efficiency decreases, $CO_2$'s residence time in the atmosphere will *increase* owing to a slowing of $CO_2$ removal from the atmosphere. Decreasing marginal radiative efficiency for $CO_2$ and a slowing decay rate for atmospheric $CO_2$ partially balance out [16]. Indeed, the IPCC's GWPs ignore the effect of changing background concentration as well. Both corrections are absent in our model. A more complete analysis should include both of these corrections, and should also account for GHGs other than $CO_2$.

The relevant non-$CO_2$ GHGs in the biofuels life cycle are $N_2O$ and $CH_4$. $N_2O$ releases are affected by yield intensification of crops, especially crops fertilized with nitrogen compounds, and $CH_4$ is especially affected by livestock production changes. Both of these changes occur as a result of market signals associated with increased or decreased production of any biofuels that compete with food for land. The current model simply converts all GHG emissions to $CO_2$e using GWPs from the IPCC's Fourth Assessment Report [7]. This treatment does not reflect the actual behavior of the gases in the atmosphere especially with respect to $CH_4$, where it underestimates effects over shorter time horizons. $CH_4$ has a much shorter lifetime in the atmosphere than $CO_2$, which partly explains the falling standard GWP value for $CH_4$ as the time horizon of analysis grows (75 for a 20 year time horizon versus 25 for a 100 year time horizon) [7, table 2.14]. However, according to the GREET 1.8b model, $CH_4$ emissions make up less than 5% of total $CO_2$e emissions in the maize ethanol life cycle and even less in the gasoline life cycle, so we do not expect omitting its proper treatment in the current model to significantly influence the outcome [21]. $N_2O$ emissions, however, constitute about 25% of $CO_2$e emissions for maize ethanol and only 1% for gasoline [21], so its current treatment in BTIME requires explanation. The mean lifetime of $N_2O$ in the atmosphere is approximately 114 years, not too different from the average life time of $CO_2$, and its GWP only changes by 3% between a 20 and 100 year time horizon [7, p 212]. Thus, while our treatment of $N_2O$ in a $CO_2$e form is imperfect, the outcome would not change significantly from its correct treatment since its relative behavior compared to $CO_2$ does not vary significantly over the time horizons used in our model.

## 4. Results

We emphasize that this paper is concerned with the methodology embodied in BTIME, and not any particular estimate of LUC emissions for any particular biofuel. To illustrate the importance of this methodology, we report the effect of applying it to LUC estimates from our GTAP work [12] (which are much lower than Searchinger's). Assuming that maize ethanol is produced for 25 years starting in 2010 with direct life cycle emissions of 60 g $CO_2$ $MJ^{-1}$ versus 94 for gasoline, and that the converted ecosystems revert over 30 years to hold 50% of the carbon held before cultivation, we project the annual emissions streams for maize ethanol and gasoline shown in figure 1 with dashed lines. Using the Bern carbon cycle model [7] we compute the increased abundance of $CO_2$ in the atmosphere over time, (solid lines).

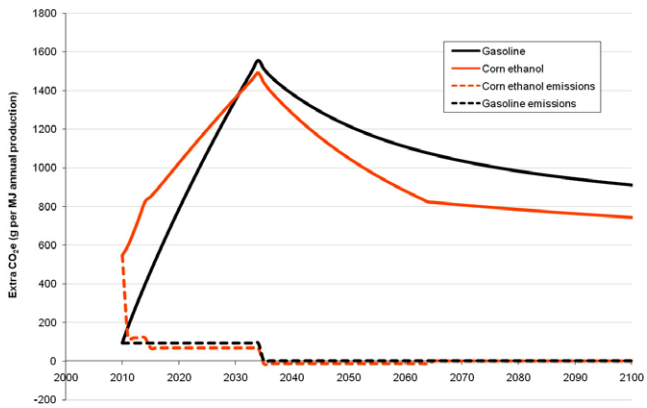


**Figure 1.** $CO_2$ emissions and resulting atmospheric abundance for gasoline (25 years at 94 g $CO_2$e $MJ^{-1}$) and maize ethanol (25 years at 60 g $CO_2$e $MJ^{-1}$ plus iLUC discharge of 776 g $CO_2$ $MJ^{-1}$ and foregone sequestration totaling 102 g $CO_2$ $MJ^{-1}$; post-cultivation recovery of 50% of the lost biomass carbon over 30 years).

The maize ethanol emissions stream depicted by the dashed orange line begins with a large release as land is cleared (directly or indirectly) for biofuels feedstock cultivation, followed by five years in which soil carbon is released rapidly and twenty years of slower release [5]. After the ethanol production ceases in 2035 we assume a small annual carbon sequestration through 2065 as land reverts in part to its original condition (other ways to handle post-cultivation LUC are discussed further in SOM). The emissions profile of gasoline displaced MJ-for-MJ has no initial release and fixed production/use emissions over the time in which biofuel is being produced. The solid lines show the abundance of extra $CO_2$ in the atmosphere for the two cases, which is the sum of new releases subject to gradual reduction through the functioning of the carbon cycle. The implicit policy choice is between obtaining the same amount of fuel energy by following the black or orange paths.

For the first 15 years of production the maize ethanol case leads to higher $CO_2$ abundance, and after that gasoline's is higher. This crossover should not be interpreted as a 'break-even' point, because at this crossover, the planet has been warmer for the preceding 15 years in the maize ethanol case, leading to damage that remains at the crossover point manifested in higher sea levels, more ecosystem damage, and retained heat in reservoirs like the ocean.

A physical 'break-even' occurs with equal *cumulative warming*, as is captured in the FWP and FWI metrics described below. We assume that after 25 years, the maize ethanol

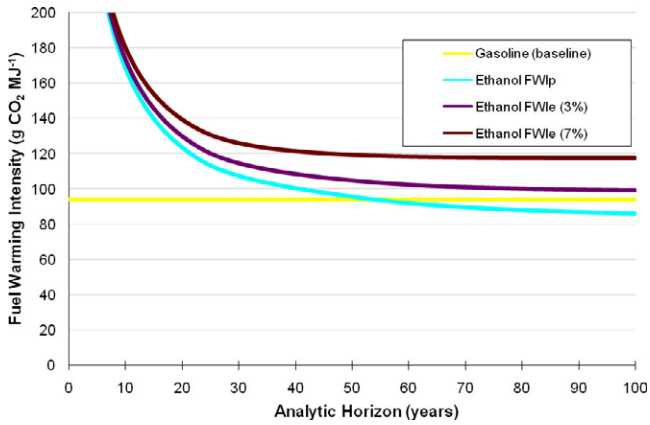


**Figure 2.** Fuel warming intensity (g $CO_2$ $MJ^{-1}$) versus analytic horizon.

production and the displaced gasoline emissions cease. The post-cultivation period has some recovery sequestration for ethanol and significant reductions in $CO_2$ abundance for both species as the carbon cycle absorbs some of the atmospheric carbon.

Figure 2 illustrates the difference between the physical and economic metrics, and the effect of discount rate on the result. In this figure, the $y$ axis indicates the relative performance of maize ethanol to gasoline and the $x$-axis reflects different analytical horizons.

The $FWI_p$ for maize ethanol (light blue line) shows that using this biofuel results in greater warming than does using gasoline over analytic horizons of less than 50 years. For a 30 year analytic horizon the ethanol's $FWI_p$ is 15% higher than gasoline's. To compare this result to earlier work, note that the parameters used in our model would show biofuel emissions 5% *lower* than gasoline's if the annual emissions were simply averaged, even over 30 production years [19]. Over a 100 year analytic horizon, biofuel production shows an 8% benefit versus gasoline, and this result is highly dependent upon the assumption that the land reverts toward a natural state following biofuel production. The extent of ecosystem recovery after biofuel production ceases decades from now is unknowable, therefore crediting a biofuel with this regrowth may be inappropriate. Excluding this credit results in the $FWI_p$ of the modeled ethanol being 4% greater than that of gasoline after 100 years.

Non-zero discount rates further degrade the benefits of projected future fuel production and reduce sensitivity to assumptions regarding post-production regrowth. With a 3% discount rate and 100 year analytic horizon, the $FWI_e$ of ethanol is 3% greater than that of gasoline; with a 7% discount rate ethanol's $FWI_e$ is 16% greater. Excluding land reversion increases these spreads to 11% and 20%, respectively.

## 5. Conclusion

### *5.1. Summary*

We developed a model of the cumulative radiative forcing caused by the production and use of biofuels and gasoline, including emissions from biofuels-induced land use change (LUC). Our model aggregates GHG emissions that occur over a significant span of time into a global warming intensity metric that better represents the climate effects of fuel substitution.

Properly treating emissions and decay over time increases the importance of near-term emissions since the cumulative warming and associated damages from those emissions, for any finite analytic horizon, are more severe. Compared to approaches that simply sum GHG emissions over time, we show that recognizing the physics of atmospheric $CO_2$ decay and radiative forcing significantly increases the estimated climate effects relative to fossil fuel for any biofuel causing LUC. We also show that economic discounting is only applicable to costs and benefits, not to physical phenomena that generate them, *unless* their economic value is stable over time. Cumulative radiative forcing is a better proxy for economic damages than the sum of GHG flows, and as such is a more appropriate quantity to which to apply discounting.

We propose a new measure of the climate performance of biofuels, *fuel warming potential* (FWP), defined as the ratio of the cumulative radiative forcing caused by the life cycle GHG emissions from a biofuel relative to that of its fossil substitute. Where discounting is desired, we propose an 'economic' version of the FWP, defined as the ratio of the net present values of the cumulative radiative forcing from the two fuels. Any positive discount rate magnifies the importance of early emissions.

We also define a metric called fuel warming intensity (FWI), which simply multiplies either version of FWP by the global warming intensity of direct emissions (in units of g $CO_2e$ $MJ^{-1}$) of the fossil fuel (e.g., gasoline) to produce a quantity with suitable units for use in fuel regulations.

Finally, we note that large initial GHG discharges are not unique to crop-based biofuels. Analysis of any GHG-reducing technology with large up-front capital investments (nuclear, tidal, wind, photovoltaics) should similarly account for up-front GHG discharges (for example, from cement manufacture) as we do here.

### *5.2. Policy considerations*

To achieve real climate benefits, 'low carbon' biofuel policy must recognize the importance of early emissions, and climate policies should use performance metrics that reflect cumulative warming rather than GHG flows.

Operationalizing the approach recommended herein forces the regulator to choose values for several influential model parameters, particularly the analytic horizon. An analytic horizon extending into decades requires predictions about the expected cultivation period and post-cultivation LUC, decisions on how post-cultivation LUC emissions should be credited, and assessment of the time-value of benefits and costs. Benefit–cost analysis brings with it the need to settle on a reasonable damage function and an appropriate discount rate as well. Policymakers may find it appropriate to focus on more certain, near-term climate impacts, in which case a short horizon physical FWI is sufficient. For short analytic horizons, discounting has little effect and post-cultivation LUC occurs beyond the system boundary.

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# Technical Advisory

## CEQA AND CLIMATE CHANGE: Addressing Climate Change Through California Environmental Quality Act (CEQA) Review

This technical advisory is one in a series of advisories provided by the Governor's Office of Planning and Research (OPR) as a service to professional planners, land use officials and CEQA practitioners. OPR issues technical guidance from time to time on issues that broadly affect the practice of CEQA and land use planning. The emerging role of CEQA in addressing climate change and greenhouse gas emissions has been the topic of much discussion and debate in recent months. This document provides OPR's perspective on the issue.

### I. PURPOSE

General scientific consensus and increasing public awareness regarding global warming and climate change have placed new focus on the California Environmental Quality Act (CEQA) review process as a means to address the effects of greenhouse gas (GHG) emissions from proposed projects on climate change. Many public agencies—along with academic, business, and community organizations—are striving to determine the appropriate means by which to evaluate and mitigate the impacts of proposed projects on climate change. Approaches and methodologies for calculating GHG emissions and addressing the environmental impacts through CEQA review are rapidly evolving and are increasingly available to assist public agencies to prepare their CEQA documents and make informed decisions.

JUNE 19, 2008

STATE OF CALIFORNIA
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The Governor's Office of Planning and Research (OPR) will develop, and the California Resources Agency (Resources Agency) will certify and adopt amendments to the Guidelines implementing the California Environmental Quality Act ("CEQA Guidelines"), on or before January 1, 2010, pursuant to Senate Bill 97 (Dutton, 2007). These new CEQA Guidelines will provide regulatory guidance on the analysis and mitigation of GHG emissions in CEQA documents. In the interim, OPR offers the following informal guidance regarding the steps lead agencies should take to address climate change in their CEQA documents. This guidance was developed in cooperation with the Resources Agency, the California Environmental Protection Agency (Cal/EPA), and the California Air Resources Board (ARB).

## II. BACKGROUND

Climate change refers to any significant change in measures of climate, such as average temperature, precipitation, or wind patterns over a period of time. Climate change may result from natural factors, natural processes, and human activities that change the composition of the atmosphere and alter the surface and features of the land. Significant changes in global climate patterns have recently been associated with global warming, an average increase in the temperature of the atmosphere near the Earth's surface, attributed to accumulation of GHG emissions in the atmosphere. Greenhouse gases trap heat in the atmosphere, which in turn heats the surface of the Earth. Some GHGs occur naturally and are emitted to the atmosphere through natural processes, while others are created and emitted solely through human activities. The emission of GHGs through the combustion of fossil fuels (i.e., fuels containing carbon) in conjunction with other human activities, appears to be closely associated with global warming.

State law defines GHG to include the following: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (Health and Safety Code, section 38505(g).) The most common GHG that results from human activity is carbon dioxide, followed by methane and nitrous oxide.

### Requirements of AB 32 and SB 97

Assembly Bill 32 (AB 32), the California Global Warming Solutions Act of 2006 (Nunez, 2006), recognizes that California is the source of substantial amounts of GHG emissions. The statute begins with several legislative findings and declarations of intent, including the following:

> Global warming poses a serious threat to the economic well-being, public health, natural resources, and the environment of California. The potential adverse impacts of global warming include the exacerbation of air quality problems, a reduction in the quality and supply of water to the state from the Sierra snow pack, a rise in sea levels resulting in the displacement of thousands of coastal businesses and residences, damage to marine ecosystems and the natural environment, and an increase in the incidences of infectious diseases, asthma, and other human health-related problems. (Health and Safety Code, section 38501.)

In order to avert these consequences, AB 32 establishes a state goal of reducing GHG emissions to 1990 levels by the year 2020 (a reduction of approximately 25 percent from forecast emission levels) with further reductions to follow. The law requires the ARB to establish a program to track and report GHG emissions; approve a scoping plan for achieving the maximum technologically feasible and cost effective reductions from sources of GHG emissions; adopt early reduction measures to begin moving forward; and adopt, implement and enforce regulations – including market mechanisms such as "cap-and-trade" programs – to ensure the required reductions occur. The ARB recently adopted a statewide GHG emissions limit and an emissions inventory, along with requirements to measure, track, and report GHG emissions by the industries it determined to be significant sources of GHG emissions.

CEQA requires public agencies to identify the potentially significant effects on the environment of projects they intend to carry out or approve, and to mitigate significant effects whenever it is feasible to do so. While AB 32 did not amend CEQA to require new analytic processes to account for the environmental impacts of GHG emissions from projects subject to CEQA, it does acknowledge that such emissions cause significant adverse impacts to human health and the environment.

Senate Bill 97, enacted in 2007, amends the CEQA statute to clearly establish that GHG emissions and the effects of GHG emissions are appropriate subjects for CEQA analysis. It directs OPR to develop draft CEQA Guidelines "for the mitigation of greenhouse gas emissions or the effects of greenhouse gas emissions" by July 1, 2009 and directs the Resources Agency to certify and adopt the CEQA Guidelines by January 1, 2010.

## Requirements of CEQA

CEQA is a public disclosure law that requires public agencies to make a

good-faith, reasoned effort, based upon available information, to identify the potentially significant direct and indirect environmental impacts—including cumulative impacts— of a proposed project or activity. The CEQA process is intended to inform the public of the potential environmental effects of proposed government decisions and to encourage informed decision-making by public agencies. In addition, CEQA obligates public agencies to consider less environmentally-damaging alternatives and adopt feasible mitigation measures to reduce or avoid a project's significant impacts.

The lead agency is required to prepare an Environmental Impact Report (EIR), a Mitigated Negative Declaration, or equivalent document, when it determines that the project's impacts on the environment are potentially significant. This determination of significance must be based upon substantial evidence in light of all the information before the agency.

Although the CEQA Guidelines, at Appendix G, provide a checklist of suggested issues that should be addressed in an EIR, neither the CEQA statute nor the CEQA Guidelines prescribe thresholds of significance or particular methodologies for performing an impact analysis. This is left to lead agency judgment and discretion, based upon factual data and guidance from regulatory agencies and other sources where available and applicable. A threshold of significance is essentially a regulatory standard or set of criteria that represent the level at which a lead agency finds a particular environmental effect of a project to be significant. Compliance with a given threshold means the effect normally will be considered less than significant. Public agencies are encouraged but not required to adopt thresholds of significance for environmental impacts. Even in the absence of clearly defined thresholds for GHG emissions, the law requires that such emissions from CEQA projects must be disclosed and mitigated to the extent feasible whenever the lead agency determines that the project contributes to a significant, cumulative climate change impact.

We realize that perhaps the most difficult part of the climate change analysis will be the determination of significance. Although lead agencies typically rely on local or regional definitions of significance for most environmental issues, the global nature of climate change warrants investigation of a statewide threshold of significance for GHG emissions. To this end, OPR has asked ARB technical staff to recommend a method for setting thresholds which will encourage consistency and uniformity in the CEQA analysis of GHG emissions throughout the state. Until such time as state guidance is available on thresholds of significance for GHG emissions, we recommend the following approach to your CEQA analysis.

## III. RECOMMENDED APPROACH

Each public agency that is a lead agency for complying with CEQA needs to develop its own approach to performing a climate change analysis for projects that generate GHG emissions. A consistent approach should be applied for the analysis of all such projects, and the analysis must be based on best available information. For these projects, compliance with CEQA entails three basic steps: identify and quantify the GHG emissions; assess the significance of the impact on climate change; and if the impact is found to be significant, identify alternatives and/or mitigation measures that will reduce the impact below significance.

Lead agencies should determine whether greenhouse gases may be generated by a proposed project, and if so, quantify or estimate the GHG emissions by type and source. Second, the lead agency must assess whether those emissions are individually or cumulatively significant. When assessing whether a project's effects on climate change are "cumulatively considerable" even though its GHG contribution may be individually limited, the lead agency must consider the impact of the project when viewed in connection with the effects of past, current, and probable future projects. Finally, if the lead agency determines that the GHG emissions from the project as proposed are potentially significant, it must investigate and implement ways to avoid, reduce, or otherwise mitigate the impacts of those emissions. Although the scientific knowledge and understanding of how best to perform this analysis is rudimentary and still evolving, many useful resources are available (see Attachment 1).

Until such time as further state guidance is available on thresholds of significance, public agencies should consider the following general factors when analyzing whether a proposed project has the potential to cause a significant climate change impact on the environment.

### Identify GHG Emissions

- Lead agencies should make a good-faith effort, based on available information, to calculate, model, or estimate the amount of $CO_2$ and other GHG emissions from a project, including the emissions associated with vehicular traffic, energy consumption, water usage and construction activities.
- Technical resources, including a variety of modeling tools, are available to assist public agencies to quantify GHG emissions. OPR recognizes that more sophisticated emissions models for particular types of projects are continually being developed and that the state-of-the-art quantification

models are rapidly changing. OPR will periodically update the examples of modeling tools identified in Attachment 2.

- There is no standard format for including the analysis in a CEQA document. A GHG/climate change analysis can be included in one or more of the typical sections of an EIR (e.g., air quality, transportation, energy) or may be provided in a separate section on cumulative impacts or climate change.

## Determine Significance

- When assessing a project's GHG emissions, lead agencies must describe the existing environmental conditions or setting, without the project, which normally constitutes the baseline physical conditions for determining whether a project's impacts are significant.
- As with any environmental impact, lead agencies must determine what constitutes a significant impact. In the absence of regulatory standards for GHG emissions or other scientific data to clearly define what constitutes a "significant impact", individual lead agencies may undertake a project-by-project analysis, consistent with available guidance and current CEQA practice.
- The potential effects of a project may be individually limited but cumulatively considerable. Lead agencies should not dismiss a proposed project's direct and/or indirect climate change impacts without careful consideration, supported by substantial evidence. Documentation of available information and analysis should be provided for any project that may significantly contribute new GHG emissions, either individually or cumulatively, directly or indirectly (e.g., transportation impacts).
- Although climate change is ultimately a cumulative impact, not every individual project that emits GHGs must necessarily be found to contribute to a significant cumulative impact on the environment. CEQA authorizes reliance on previously approved plans and mitigation programs that have adequately analyzed and mitigated GHG emissions to a less than significant level as a means to avoid or substantially reduce the cumulative impact of a project.

## Mitigate Impacts

- Mitigation measures will vary with the type of project being contemplated, but may include alternative project designs or locations that conserve energy and water, measures that reduce vehicle miles traveled

(VMT) by fossil-fueled vehicles, measures that contribute to established regional or programmatic mitigation strategies, and measures that sequester carbon to offset the emissions from the project.

- The lead agency must impose all mitigation measures that are necessary to reduce GHG emissions to a less than significant level. CEQA does not require mitigation measures that are infeasible for specific legal, economic, technological, or other reasons. A lead agency is not responsible for wholly eliminating all GHG emissions from a project; the CEQA standard is to mitigate to a level that is "less than significant".
- If there are not sufficient mitigation measures that the lead agency determines are feasible to achieve the less than significant level, the lead agency should adopt those measures that are feasible, and adopt a Statement of Overriding Considerations that explains why further mitigation is not feasible. A Statement of Overriding Considerations must be prepared when the lead agency has determined to approve a project for which certain impacts are unavoidable. These statements should explain the reasons why the impacts cannot be adequately mitigated in sufficient detail, and must be based on specific facts, so as not to be conclusory.
- Agencies are encouraged to develop standard GHG emission reduction or mitigation measures that can be applied on a project-by-project basis. Attachment 3 contains a preliminary menu of measures that lead agencies may wish to consider. This list is by no means exhaustive or prescriptive. Lead agencies are encouraged to develop their own measures and/or propose project alternatives to reduce GHG emissions, either at a programmatic level or on a case-by-case review.
- In some cases GHG emission reduction measures will not be feasible or may not be effective at a project level. Rather, it may be more appropriate and more effective to develop and adopt program-level plans, policies and measures that will result in a reduction of GHG emissions on a regional level.

## IV. ADDITIONAL LAND USE CONSIDERATIONS

CEQA can be a more effective tool for GHG emissions analysis and mitigation if it is supported and supplemented by sound development policies and practices that will reduce GHG emissions on a broad planning scale and that can provide the basis for a programmatic approach to project-specific CEQA analysis and mitigation.

Local governments with land use authority are beginning to establish policies that result in land use patterns and practices that will result in less energy use and reduce GHG emissions. For example, some cities and counties have adopted general plans and policies that encourage the development of compact, mixed-use, transit-oriented development that reduces VMT; encourage alternative fuel vehicle use; conserve energy and water usage; and promote carbon sequestration. Models of such developments exist throughout the state (see OPR climate change website for examples of city and county plans and policies, referenced in Attachment 1).

For local government lead agencies, adoption of general plan policies and certification of general plan EIRs that analyze broad jurisdiction-wide impacts of GHG emissions can be part of an effective strategy for addressing cumulative impacts and for streamlining later project-specific CEQA reviews.

International, national, and statewide organizations such as ICLEI (Local Governments for Sustainability), the Cities for Climate Protection, and the Clean Cities Coalition —to name just a few — have published guidebooks to help local governments reduce GHG emissions through land use planning techniques and improved municipal operations. Links to these resources are provided at the end of this advisory.

Regional agencies can also employ a variety of strategies to reduce GHG emissions through their planning processes. For example, regional transportation planning agencies adopt plans and programs that address congestion relief, jobs-to-housing balance, reduction of vehicle miles traveled (VMT), and other issues that have implications for GHG emission reductions.

State agencies are also tackling the issue of climate change. Some have adopted or support policies and programs that take climate change into account, including the Department of Water Resources' State Water Plan; the Department of Transportation's State Transportation Plan; and the Business, Housing and Transportation Agency's Regional Blueprint Planning Program. These efforts not only raise public awareness of climate change and how the State can reduce GHG emissions, but also offer specific information and resources for lead agencies to consider.

## V. NEXT STEPS

OPR has asked ARB technical staff to recommend a method for setting a threshold of significance for GHG emissions. OPR has requested that the ARB identify a range of feasible options, including qualitative and quantitative options.

OPR is actively seeking input from the public and stakeholder groups, as it develops draft CEQA Guidelines for GHG emissions. OPR is engaged with the Resources Agency and other expert state agencies, local governments, builders and developers, environmental organizations, and others with expertise or an interest in the development of the Guidelines.

OPR will conduct public workshops later this year to receive input on the scope and content of the CEQA Guidelines amendments. It is OPR's intent to release a preliminary draft of the CEQA Guidelines amendments for public review and comment in the fall. This will enable OPR to deliver a proposed package of CEQA Guidelines amendments to the Resources Agency as early as January 2009, well before the statutory due date of July 1, 2009.

We encourage public agencies and the public to refer to the OPR website at www.opr.ca.gov for information about the CEQA Guidelines development process and to subscribe to OPR's notification system for announcements and updates.

For more information about this technical advisory and assistance in addressing the impacts of GHG emissions on the environment, please contact:

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## ATTACHMENTS

1. References and Information Sources
2. Technical Resources/Modeling Tools to Estimate GHG Emissions
3. Examples of GHG Reduction Measures

# Attachment 1

## References and Information Sources

The following is a list of websites of organizations that can offer additional information regarding methods to characterize, quantify, assess and reduce GHG emissions. In addition, a list of useful resources and reference materials is provided on the subject of climate change and greenhouse gases.

### ORGANIZATIONS

- Governor's Office of Planning and Research
  http://www.opr.ca.gov
- California Climate Action Team
  http://www.climatechange.ca.gov/climate_action_team/
- California Climate Change Portal
  http://www.climatechange.ca.gov
- California Air Resources Board Climate Change Website
  http://www.arb.ca.gov/cc/cc.htm
- California Climate Action Registry
  http://www.climateregistry.org/
- California Department of Water Resources, Climate Change and California Water Plan Website
  http://www.waterplan.water.ca.gov/climate/
- California Energy Commission Climate Change Proceedings
  http://www.energy.ca.gov/global_climate_change/index.html
- California Public Utilities Commission, Climate Change Website
  http://www.cpuc.ca.gov/static/energy/electric/climate+change/_index.htm
- Green California Website
  http://www.green.ca.gov/default.htm
- Western Climate Initiative
  http://www.westernclimateinitiative.org

- California Air Pollution Control Officers Association
  http://www.capcoa.org
- Local Governments for Sustainability (ICLEI)
  http://www.iclei.org/
- ICLEI Cities for Climate Protection (CCP)
  http://www.iclei.org/index.php?id=800
- United Nations Framework Convention on Climate Change
  http://unfccc.int/2860.php
- Intergovernmental Panel on Climate Change
  http://www.ipcc.ch
- United States Environmental Protection Agency
  http://www.epa.gov/climatechange/
- City of Seattle U.S. Mayors Climate Protection Agreement
  http://www.seattle.gov/mayor/climate/
- Mayors for Climate Protection
  http://www..coolmayors.com
- U.S. Conference of Mayors Climate Protection Web Page
  http://usmayors.org/climateprotection
- Institute for Local Government California Climate Action Network
  http://www.ca-ilg.org/climatechange

## STATUTES, REGULATIONS, AND EXECUTIVE ORDERS

- SB 97
  http://opr.ca.gov/ceqa/pdfs/SB_97_bill_20070824_chaptered.pdf
- SB 97 Governor's Signing Message
  http://opr.ca.gov/ceqa/pdfs/SB-97-signing-message.pdf
- AB 32
  http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf
- AB 1493
  http://www.leginfo.ca.gov/pub/01-02/bill/asm/ab_1451-1500/ab_1493_bill_20020722_chaptered.pdf

- Regulations implementing AB 1493

  http://www.arb.ca.gov/regact/grnhsgas/revfro.pdf and http://www.arb.ca.gov/regact/grnhsgas/revtp.pdf

- SB 1368

  http://www.leginfo.ca.gov/pub/05-06/bill/sen/sb_1351-1400/sb_1368_bill_20060929_chaptered.pdf

- Executive Order S-01-07 regarding low carbon standard for transportation fuels

  http://gov.ca.gov/index.php?/executive-order/5172/

- Executive Order S-20-06 regarding implementation of AB 32

  http://gov.ca.gov/index.php?/executive-order/4484/

- Executive Order S-3-05 regarding greenhouse gas goals

  http://gov.ca.gov/index.php?/executive-order/1861/

- Executive Order S-20-04 regarding energy conservation by state

  http://gov.ca.gov/index.php?/executive-order/3360/

## REPORTS

- OPR List of Environmental Documents Addressing Climate Change

  http://opr.ca.gov/ceqa/pdfs/Environmental_Assessment_Climate_Change.pdf

- OPR List of Local Plans Addressing Climate Change

  http://opr.ca.gov/ceqa/pdfs/City_and_County_Plans_Addressing_Climate_Change.pdf

- *Climate Action Team Proposed Early Action Measures to Mitigate Climate Change in California*, April 2007

  http://www.climatechange.ca.gov/climate_action_team/reports/2007-04-20_CAT_REPORT.PDF

- California Air Resources Board, *Early Action Items to Mitigate Climate Change in California*, October 2007

  http://www.arb.ca.gov/cc/ccea/meetings/ea_final_report.pdf

- California Air Resourced Board, *Draft Greenhouse Gas Inventory*, November 2007

  http://www.arb.ca.gov/cc/inventory/data/tables/rpt_Inventory_IPCC_All_2007-11-19.pdf

- *Climate Action Team Report to the Governor and Legislature*, March 2006, http://www.climatechange.ca.gov/climate_action_team/reports/index.html

- California Climate Change Center, *Our Changing Planet: Assessing the Risks to California - Summary Report*

  http://www.energy.ca.gov/2006publications/CEC-500-2006-077/CEC-500-2006-077.PDF

  Detailed reports available at: http://www.climatechange.ca.gov/biennial_reports/2006report/index.html

- California Energy Commission, *2007 Integrated Energy Policy Report Update*

  http://www.energy.ca.gov/2007publications/CEC-100-2007-008/CEC-100-2007-008-CMF.PDF

- California Department of Water Resources, *Progress on Incorporating Climate Change into Management of California's Water Resources*

  http://baydeltaoffice.water.ca.gov/climatechange/DWRClimateChangeJuly06.pdf - pagemode=bookmarks&page=1

- *Climate Action Program at Caltrans*, December 2006

  http://www.dot.ca.gov/docs/ClimateReport.pdf

- California Air Pollution Control Officers Association, *CEQA & Climate Change,* January 2008

  http://www.capcoa.org/ceqa/CAPCOA%20White%20Paper%20-%20CEQA%20and%20Climate%20Change.pdf

- West Coast Governors' Global Warming Initiative, November 2004

  http://www.climatechange.ca.gov/westcoast/documents/2004-11_final_report/2004-11-18_STAFF_RECOMMENDS.PDF

- Western Climate Initiative Work Plan, October 2007

  http://www.westernclimateinitiative.org/ewebeditpro/items/O104F13792.pdf

- California Climate Change Center, University of California at Berkeley, *Managing Greenhouse Gas Emissions in California,* 2007

  http://calclimate.berkeley.edu/managing_GHGs_in_CA.html

- U.S. Conference of Mayors, *Energy & Environment Best Practices*

  http://www.usmayors.org/climateprotection/AtlantaEESummitCDROMVersion.pdf

- *U.S. Mayors Climate Protection Agreement Climate Action Handbook*, 2006

  http://www.seattle.gov/climate/docs/ClimateActionHandbook.pdf

- Natural Capitalism Solutions *Climate Protection Manual for Cities*, June 2007

  http://www.climatemanual.org

- National Governor's Association Center for Best Practices *Growing with Less Greenhouse Gases*, November 2002

  http://www.nga.org/cda/files/112002ghg.pdf

- National Governor's Association Center for Best Practices *State and Regional Greenhouse Gas* Initiatives, October 2006

  http://www.nga.org/Files/pdf/0610GREENHOUSE.PDF

- United States Climate Change Program *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*, May 2008

  http://www.usda.gov/oce/global_change/sap_2007_FinalReport.htm

# Attachment 2

## Technical Resources/Modeling Tools to Estimate GHG Emissions

| TOOL | AVAILABILITY | SCOPE LOCAL/ REGIONAL | SCOPE TRANSPORTATION/ BUILDINGS | DATA INPUT REQUIREMENTS | DATA OUTPUT |
|---|---|---|---|---|---|
| **URBEMIS** | • Download<br>• Public domain (free) | • Local project level | • Transportation<br>• Some building (area source) outputs<br>• Construction | • Land use information<br>• Construction, area source, and transportation assumptions | • CO2 (pounds per day)<br>• Mitigation impacts |
| **Clean Air and Climate Protection (CACP) Software** | • Download<br>• Available to public agencies (free) | • Local project level | • Buildings<br>• Communities<br>• Governments | • Energy usage<br>• Waste generation and disposal<br>• Transportation fuel usage or VMT | • CO2e (tons per year) |
| **Sustainable Communities Model (SCM)** | • Custom model | • Regional<br>• Scalable to site level | • Transportation<br>• Buildings<br>• Neighborhoods<br>• Master planned communities | • Location and site specific information<br>• Transportation assumptions<br>• On-site energy usage | • CO2e (tons per year) |
| **Internet-accessed Planning for Community Energy, Economic and Environmental Sustainability I-PLACE$^3$S** | • Web-based<br>• Small access fee<br>• Full model now available in eight CA counties | • Regional<br>• Scalable to site level | • Transportation<br>• Housing<br>• Land Use<br>• Buildings<br>• Energy<br>• Economics | • Parcel level land use data (ability to work with less data)<br>• Project-level data for alternative comparisons | • CO2 (any quantity over any time) |
| **Climate Action Registry Reporting On-Line Tool (CARROT)** | • Web-based<br>• Available to Registry members<br>• General public can view entity reports | • Regional, scalable to entity and facility level | • General Reporting and Certification Protocols<br>o Transportation<br>o Buildings/facilities<br>• Specific protocols for some sectors | • Mobile source combustion (VMT or fuel usage)<br>• Stationary combustion (fuel usage)<br>• Indirect emissions (electricity usage) | • Each GHG and CO2e (tons per year) |
| **EMFAC** | • Download<br>• Public domain (free) | • Statewide<br>• Regional (air basin level) | • Transportation emission factors | • Travel activity data to calculate CO2 from projects. | • CO2 and methane (grams per mile) emission factors |

VMT = Vehicle miles traveled
eCO2 = Carbon dioxide equivalent emissions
**Note: This is not meant to be a definitive list of modeling tools to estimate climate change emissions impacts. Other tools may be available.**

# Description of Modeling Tools

## URBEMIS

The Urban Emissions Model is used extensively during the CEQA process by local air districts and consultants to determine the impacts of projects on criteria pollutants. It was recently updated to calculate CO2 emissions as well. Future updates will include additional greenhouse gases. URBEMIS uses the ITE Trip Generation Rate Manual and the Air Resources Board's (ARB) motor vehicle emissions model (EMFAC) to calculate transportation-related CO2 emissions and ARB's OFFROAD2007 model for CO2 emissions from off-road equipment. Area source outputs include natural gas use, landscaping equipment, consumer products, architectural coatings, and fireplaces. It also estimates construction impacts and impacts of mitigation options. Web site: http://www.urbemis.com.

## Clean Air and Climate Protection (CACP) Software

This tool is available to state and local governments and members of ICLEI, NACAA, NASEO and NARUC to determine greenhouse gas and criteria pollutant emissions from government operations and communities as a whole. The user must input aggregate information about energy (usage), waste (quantity and type generated, disposal method, and methane recovery rate) and transportation (VMT) for community analyses. CACP uses emission factors from EPA, DOE, and DOT to translate the energy, waste and transportation inputs into greenhouse gas (in carbon dioxide equivalents) and criteria air pollutant emissions. If associated energy, waste and transportation reduction are provided, the model can also calculate emission reductions and money saved from policy alternatives. Web site: http://cacpsoftware.org.

## Sustainable Communities Model (SCM)

This model quantifies total CO2e emissions allowing communities the ability to optimize planning decisions that result in the greatest environmental benefit for the least cost. Total CO2e emissions are based on emissions from energy usage, water consumption and transportation. The model provides an interactive comparison of various scenarios to provide environmental performance, economic performance, and cost benefit analysis.

Web site: www.ctg-net.com/energetics/documents/doc_SCM_070731.pdf

## I-PLACE$^3$S

This model is an internet-accessed land use and transportation model designed specifically for regional and local governments to help understand how their growth and development decisions can contribute to improved sustainability. It estimates CO2, criteria pollutant and energy impacts on a neighborhood or

regional level for existing, long-term baseline and alternative land use plans. The data input requirements are extensive and require a fiscal commitment from the Metropolitan Planning Organization and its member local governments. Once the data is available, the IPLACES tool can be developed for that region relatively quickly, in approximately one week. The benefits include a multifunctional tool that provides immediate outputs to compare alternatives during public meetings, multilevel password protected on-line access, as well as providing access for local development project CEQA analyses. This tool also supports regional travel models and integrated land use and transportation assessments. Web site: http://www.sacregionblueprint.org/sacregionblueprint/the_project/technology.cfm and http://www.places.energy.ca.gov/places

### CARROT

The California Climate Action Registry offers the Climate Action Registry Reporting On-Line Tool (CARROT) for Registry members to calculate and report annual greenhouse gas (GHG) emissions. CARROT calculates direct and indirect GHG emissions for the following emission categories by source: stationary combustion, process emissions, mobile source combustion, fugitive emissions and electricity use by source. It calculates emissions using entity collected data such as fuel purchase records, VMT and utility bills. While reporting and certification through CARROT is only available to members, the public may access entity reports online. Reporting protocols are also available to the public, including the General Reporting Protocol (www.climateregistry.org/docs/PROTOCOLS/GRP%20V2-March2007_web.pdf) and cement, forestry and power/utility sector protocols. Additional sector protocols are under development. Website: www.climateregistry.org/CARROT/

### EMFAC

The Air Resources Board's EMission FACtors (EMFAC) model is used to calculate emission rates from all motor vehicles in California. The emission factors are combined with data on vehicle activity (miles traveled and average speeds) to assess emission impacts. The URBEMIS model described above uses EMFAC to calculate the transportation emission impacts of local projects. Web site: http://www.arb.ca.gov/msei/onroad/onroad.htm

# Attachment 3

## Examples of GHG Reduction Measures

The following are examples of measures that have been employed by some public agencies to reduce greenhouse gas emissions, either as general development policies or on a project-by-project basis. These are provided for illustrative purposes only.

### LAND USE AND TRANSPORTATION

- Implement land use strategies to encourage jobs/housing proximity, promote transit-oriented development, and encourage high density development along transit corridors. Encourage compact, mixed-use projects, forming urban villages designed to maximize affordable housing and encourage walking, bicycling and the use of public transit systems.
- Encourage infill, redevelopment, and higher density development, whether in incorporated or unincorporated settings
- Encourage new developments to integrate housing, civic and retail amenities (jobs, schools, parks, shopping opportunities) to help reduce VMT resulting from discretionary automobile trips.
- Apply advanced technology systems and management strategies to improve operational efficiency of transportation systems and movement of people, goods and services.
- Incorporate features into project design that would accommodate the supply of frequent, reliable and convenient public transit.
- Implement street improvements that are designed to relieve pressure on a region's most congested roadways and intersections.
- Limit idling time for commercial vehicles, including delivery and construction vehicles.

### URBAN FORESTRY

- Plant trees and vegetation near structures to shade buildings and reduce energy requirements for heating/cooling.
- Preserve or replace onsite trees (that are removed due to development) as a means of providing carbon storage.

## GREEN BUILDINGS

- Encourage public and private construction of LEED (Leadership in Energy and Environmental Design) certified (or equivalent) buildings.

## ENERGY CONSERVATION POLICIES AND ACTIONS

- Recognize and promote energy saving measures beyond Title 24 requirements for residential and commercial projects
- Where feasible, include in new buildings facilities to support the use of low/zero carbon fueled vehicles, such as the charging of electric vehicles from green electricity sources.
- Educate the public, schools, other jurisdictions, professional associations, business and industry about reducing GHG emissions.
- Replace traffic lights, street lights, and other electrical uses to energy efficient bulbs and appliances.
- Purchase Energy Star equipment and appliances for public agency use.
- Incorporate on-site renewable energy production, including installation of photovoltaic cells or other solar options.
- Execute an Energy Savings Performance Contract with a private entity to retrofit public buildings. This type of contract allows the private entity to fund all energy improvements in exchange for a share of the energy savings over a period of time.
- Design, build, and operate schools that meet the Collaborative for High Performance Schools (CHPS) best practices.
- Retrofit municipal water and wastewater systems with energy efficient motors, pumps and other equipment, and recover wastewater treatment methane for energy production.
- Convert landfill gas into energy sources for use in fueling vehicles, operating equipment, and heating buildings.
- Purchase government vehicles and buses that use alternatives fuels or technology, such as electric hybrids, biodiesel, and ethanol. Where feasible, require fleet vehicles to be low emission vehicles. Promote the use of these vehicles in the general community.
- Offer government incentives to private businesses for developing buildings with energy and water efficient features and recycled materials. The incentives can include expedited plan checks and reduced permit fees.
- Offer rebates and low-interest loans to residents that make energy-saving improvements on their homes.

- Create bicycle lanes and walking paths directed to the location of schools, parks and other destination points.

## PROGRAMS TO REDUCE VEHICLE MILES TRAVELED

- Offer government employees financial incentives to carpool, use public transportation, or use other modes of travel for daily commutes.
- Encourage large businesses to develop commute trip reduction plans that encourage employees who commute alone to consider alternative transportation modes.
- Develop shuttle systems around business district parking garages to reduce congestion and create shorter commutes.
- Create an online ridesharing program that matches potential carpoolers immediately through email.
- Develop a Safe Routes to School program that allows and promotes bicycling and walking to school.

## PROGRAMS TO REDUCE SOLID WASTE

- Create incentives to increase recycling and reduce generation of solid waste by residential users.
- Implement a Construction and Demolition Waste Recycling Ordinance to reduce the solid waste created by new development.
- Add residential/commercial food waste collection to existing greenwaste collection programs.

# Forests: Opportunities for Greenhouse Gas Emission Reduction in Sonoma County

# Community Climate Action Plan

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# Forests: Opportunities for Greenhouse Gas Emission Reduction in Sonoma County

## Introduction

Sonoma County's natural endowment of forestland offers the County a significant opportunity to include its forestlands in countywide efforts to meet its greenhouse gas emission reduction goals. This report provides an overview of the connection between forests and global warming, the general types of forest activities that produce climate benefits, and recommendations that the County should implement to engage the forestland base more effectively to fulfill its climate change objectives. Specifically, these recommendations are:

1) Performance of additional research to establish a countywide forest carbon baseline and monitoring process to track overall performance in the forest sector
2) Establishment of an overall emissions reduction target and emissions "floor" for the forest sector to complement the County's overall greenhouse gas reduction goals
3) Adoption of additional regulatory and incentive-based policies, including zoning, conservation easements and fees, related to greenhouse mitigation and land use planning

## Background

Forests are both a part of the global warming problem and part of the solution. Unlike other emission sectors, forests have the unique capacity to remove carbon dioxide ($CO_2$) from the atmosphere and store this gas as carbon for long periods of time in their biomass (e.g., trunks, branches, leaves, roots, etc). In fact, California's coastal redwoods (sequoia sempervirens), like those in Sonoma County[1], are capable of absorbing and storing enormous amounts of carbon for hundreds, if not thousands, of years.

While forests are a natural $CO_2$ reservoir, or "sink", they are also a source of $CO_2$ emissions. On a global level, forests are responsible for roughly 20 – 25% of overall CO2 emissions, largely to due conversion of forestland and the associated depletion of carbon stocks. When forests are disturbed through events such as conversion to development or agriculture, fire or harvest, the carbon that is stored in tree biomass is emitted to the atmosphere. When harvested for timber, a percentage of forest carbon is

[1] According to Save the Redwoods League there are roughly 3,000 to 4,000 acres of old-growth redwoods left in Sonoma County today, which is substantially less than their historic extent. Personal correspondence with Laura Kindsvater, July 31, 2007.

stored in wood products for periods of time. These wood products decay over time, releasing $CO_2$ at an average decay rate of 2% annually.[2]

Given forests' unique capacity to be a greenhouse gas (GHG) emissions source and sink, they can and should play a critical role in global warming mitigation policy both nationally and locally. Through forest activities, such as changes in forest management, forest restoration and conservation, direct $CO_2$ emissions from forests can be prevented and minimized and additional $CO_2$ can be removed from the atmosphere and stored in our forests. Restoration and management for retention of bigger trees and older forests[3] can result in greater amounts of $CO_2$ removed from the atmosphere than what would occur otherwise. Furthermore, forests can be protected from conversion to other uses and development patterns can be managed to minimize emissions that result directly from forestland conversion to non-forest uses. Such activities would foster not only the climate benefits of forests, but also the many other public benefits that forests provide – such as water quality, biodiversity, recreation, forest economies and wildlife habitat.

## Forest and Climate Opportunities and Actions for Sonoma County

With approximately 480,000 acres of forestland[4] within its boundaries, including oak woodlands and productive timberland, Sonoma County has an opportunity to take specific measures to incorporate its forestlands in its climate change goals. The County has roughly 375,000 acres of land that is capable of growing timber (and hence, sequestering more carbon), with 230,000 acres that are currently functioning as timberland.[5] These lands can be conserved to minimize the $CO_2$ emissions associated with conversion of timberland to other uses, such as vineyards. Additionally, these lands can be restored and managed to remove additional $CO_2$ from the atmosphere, while also providing wood products and many other public benefits. Likewise, the County can protect and restore its oak woodlands to maintain and enhance the climate service that its oak woodlands provide.

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[2] Turner, D.P. et al. 1995. A carbon budget for forests of the coterminous United States. Ecological Applications 5(2):421. Turner, D.P. et al. 1995. A Carbon sequestration by forests of the United States: current status and projections to the year 2040. Tellus 47B:232. Harmon, M.E., B. Marks, N.R. Hejeebu. 1996. A users guide to STANDCARB version 1.0: a model to simulate the carbon stores in forest stands. Department of Forest Science, Oregon State University, Corvallis, Oregon.

[3] The management for older forests (i.e., greater carbon stocks on the landscape) can include the production of wood products and the remaining carbon value that wood products hold.

[4] Please note that the term forestland is a broad definition that includes all forest types in the county. Statistics for timberlands and oak woodlands in this paper are subsets of this larger definition and due to differences in definitions, the numbers will not total 480,000 acres

[5] Sonoma County Permit and Resource Management Department, Memorandum from David Schiltgen: Regulating the conversion of timberlands to nontimber uses, June 20, 2002

**Minimize and prevent direct greenhouse gas emissions associated with forestland conversion to other uses**

Over the past several years, Sonoma County has witnessed an increasing threat of forestland conversion to non-forest uses, vineyards in particular. Between 1990 and 1997, at least 1,630 acres of dense oak woodlands were converted to vineyards[6] and from 1989 to 2004, 851 acres of timberland were approved for conversion, primarily to vineyards. More recently, an application to convert approximately 1,700 acres of forestland to vineyards has been submitted to the County, which is still pending. According to Sonoma County's Permit and Resource Management Department, once the time and money has been invested to convert timberland to croplands, these lands are almost never restored to forests.

The climate impacts of this forestland conversion are twofold. First, the conversion of these forestlands results in direct emissions of $CO_2$ to the atmosphere. Second, the future capacity of the forest to remove additional $CO_2$ from the atmosphere is significantly diminished because there is very little chance that these lands will be restored to forests based on the history of conversions in Sonoma County. The potential net difference between the overall carbon stored in a vineyard and forestland could be anywhere from 15 tons of carbon per acre to over a thousand tons per acre, depending on several factors, including forest type, age, site class and maturity and management of the vineyard. Such a reduction in overall carbon stocks means net emissions of $CO_2$ to the atmosphere upon conversion of the forestland to vineyards. Likewise, net emissions can occur upon conversion of forestlands to other kinds of developed uses, like commercial or residential development.

A more refined analysis based on the specific forest carbon inventories of the converted forestland and subsequent carbon sequestered by the vineyard would provide a better estimate of net $CO_2$ emissions and foregone future sequestration caused by these conversions and depletion of forest carbon stocks. California, at the state level, is conducting a similar analysis pursuant to its recently adopted Global Warming Solutions Act of 2006, and could act as a conceptual model for how Sonoma County could perform these inventories at the County and landowner levels. Such an analysis would also give Sonoma County a better sense of the greenhouse gas emissions it could prevent through existing or new policies that minimize forestland conversion (see research and policy recommendation section).

**Remove additional carbon dioxide from the atmosphere by restoring and increasing forest carbon stocks across the landscape**

The County could also help meet its greenhouse gas emission reduction targets through activities that restore and increase forest carbon stocks on the landscape in existing forested areas and where forests once existed that are no longer in forest cover. Efforts

[6] Merenlender, Adina and Brooks, Colin. GIS in Rangeland Management, Vineyard Expansion in Sonoma County: Mapping, Monitoring, and Changing Policies

like this have been taking place in the County and additional ones could be facilitated. For instance, Creighton Ridge near Cazadero is undergoing active reforestation after losing its forest cover to a fire in 1978. The loss of this forest during the fire resulted in direct $CO_2$ emissions to the atmosphere (i.e., the stored forest carbon was emitted to the atmosphere). Restoration efforts are helping to restore the forest carbon stocks that this area once held, resulting in the absorption of $CO_2$ from the atmosphere as the restored forest area grows and matures. The County, using established greenhouse gas accounting protocols like those developed by the California Climate Action Registry, could quantify the climate benefits of this reforestation. With the help of other local partners, including the Sonoma County Open Space District, Sonoma Land Trust, and landowners, the County could also identify additional areas in the County that would benefit from reforestation, whether they are previously burned areas that have not recovered or areas that are out of forest cover due to other types of disturbances or activities.

In addition, with roughly 230,000 acres of functioning timberland, the County could implement incentives and policies to encourage forest management practices to increase overall forest carbon stocks in these areas. Management activities to increase overall forest carbon stocks could include restocking under-stocked areas and managing for older forests, while still producing wood products. A recent example from Humboldt County is the van Eck forest management project. This project is registered with the California Climate Action Registry,[7] and through changes in forest management, the project is anticipated to absorb and store over 500,000 tons of additional $CO_2$ during the project's lifetime. The project continues to be managed for wood products, but is also providing significant climate benefits, as well as enhanced protection for fish and wildlife. Projects like van Eck are also possible in Sonoma County and could be quantified using the California Climate Action Registry's Forest Protocols.

## Research and Policy Recommendations

To incorporate the forest sector most effectively in global warming mitigation strategies, the County should undertake a series of actions to attain a better sense of greenhouse gas reduction potential and monitor progress over time.

### *Establish a countywide forest carbon baseline and monitoring plan*

A countywide baseline and monitoring plan would provide the basis for tracking overall emissions and reductions within the forest sector in Sonoma County. As mentioned earlier, this countywide survey could also identify the most appropriate areas for restoring forests, avoiding or minimizing emissions due to conversion, and changes in forest management to increase overall forest carbon stocks. In this effort, the County could partner with local organizations, such as land trusts, landowners and other individuals to gather information.

[7] The California Climate Action Registry (www.climateregistry.org) is a voluntary greenhouse gas registry, which was established by California statute as a non-profit organization. The Registry provides standardized greenhouse gas accounting protocols to quantify greenhouse gas emissions from a variety of sectors, including forests, and emission reductions from forest projects.

The countywide forest carbon assessment and baseline could be established through aerial surveys or satellite imagery and substantiated with sample plot data. The County could also join the California Climate Action Registry and use its Forest Protocols to estimate and track changes in overall forest carbon stocks for at least the County's forestlands. Private landowner level emissions and emission reductions can also be effectively monitored through the California Climate Action Registry to the extent landowners join the Registry.

***Establish an overall emissions reduction target and "floor" for the forest sector***

The County should seek to establish an overall greenhouse gas reduction target for the forest sector to serve as an incentive to develop policies and programs that include the forest sector in climate change mitigation objectives. The forest sector emissions reduction goal could be developed once the county establishes a baseline for its forestlands as described earlier. Such a goal should be reflected as an overall cumulative forest carbon stock number to account for the permanence or sustainability of reductions within the forest sector. Once the County attains a better sense of where reduction opportunities exist across the landscape, sub-goals or targets, based on particular forest activities, could also be established (e.g., tons of reductions pursuant to reforestation, changes in management or conservation (avoided conversion).

The County should also consider establishing a forest "floor" or cap for the forest sector to protect against forestland conversion and substantial depletion of forest carbon stocks. Such a floor would effectively limit the amount of human-caused emissions from the forest sector by 1) limiting the amount of forestland that can be converted to other uses and 2) requiring emissions mitigation for any lands that are converted to a non-forest use.

The County could establish a floor by enhancing, or using as a model, its recent ordinance (No. 5651) to mitigate timberland conversion. Such limitations on conversion could be extended to include $CO_2$ emissions with a 1:1 ratio. The County could also amend the general plan and revise the timber production zoning district to disallow conversion of timberland and do comparable zoning for oak woodlands and other critical natural resource areas.

***Facilitate the increased use of conservation easements through zoning, dedication of public funds and mitigation fees***

The increased use of conservation easements in the County to minimize forestland conversion and encourage greater overall forest carbon stocks could provide significant, permanent climate benefits. To encourage greater use of easements, the County could enhance zoning laws to promote cluster development to minimize conversion pressure on forested lands and identify and establish "climate reserve" zones on forestlands that are secured with conservation easements. The Sonoma County Open Space District and other local land trusts could be key partners to help identify and establish these climate reserve zones. To quantify the climate benefits of these reserve zones, the county could

rely on its countywide monitoring as described earlier or it could register these lands with the California Climate Action Registry (or some combination of the two).

To support an overall cap on forest-based emissions, the County can require the quantification and mitigation of $CO_2$ emissions that result from forestland conversion to non-forest uses. As mentioned earlier, recent proposals to convert forestlands to vineyards could include requirements of CO2 mitigation either directly or through payment of a fee that would be invested in mitigation projects. Such mitigation projects should, among other things, be registered and certified with the California Climate Action Registry to ensure that any permitted mitigation produces real, permanent and verifiable reductions. Furthermore, mitigation requirements should not only consider direct emissions associated with conversion but also any foregone future climate benefits (additional sequestration) that the forest could have provided.

The County could look to its jobs-housing linkage fee as a model for conversion mitigation fees. Similar to this program, a fee could be assessed for new residential development (excepting low-income and high density) or development to other uses. This fee, in turn, can be dedicated to a fund to invest in forest-based GHG mitigation projects, which may include a "climate reserve" as mentioned earlier.

***Adopt the Coast Forest District's Southern Subdistrict harvest rules***

The County could also seek to incorporate the Coast Forest District's Southern Subdistrict harvest rules of the California Forest Practice Rules. Adopting the special harvesting methods for this subdistrict would encourage the retention of greater overall forest carbon stocks on timberlands compared to the current applicable rules for Sonoma County.

# Conclusion

As Sonoma County seeks to reduce its carbon footprint and meet its greenhouse gas reduction targets, it should take advantage of greenhouse gas reduction opportunities that are available in the forest sector. The County can include its forestlands in climate change mitigation policies and programs. To do this most effectively, the County will need to take steps to gather forest carbon data to establish a countywide forest carbon baseline and target. It should also adopt an accounting and monitoring process to track carbon dioxide emissions and reductions from forests. Some of the most effective and accessible policy tools to achieve reductions in the County include zoning ordinances, conservation easements and mitigation fees. These actions would foster significant climate benefits, as well as a host other much-needed public benefits.