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Climate for Ideas

Berkeley, California

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Dear California Air Resources Board,

Please accept these comments regarding the State of California’s strategic planning regarding Short-Live Climate Pollutants (SLCP). I am making these comments with particular insights I have gained as a member of the US Technical Advisory Group to the International Standards Organization, as an official US Delegate and Expert to ISO Environmental Management Committee, and as a long-time proponent of good accounting for carbon footprints and life cycle assessment. I also send these comments as the coordinator of a coalition of environmental NGOs worldwide seeking reforms in both Life Cycle Assessment and climate metrics.

California has been a leader in fighting climate change, but I believe critical changes are required for California to have the desired impact on mitigating climate change. If certain changes are made in the strategy and regulatory framework, California could vault itself again into the primary leadership position in the world given new insights into climate accounting based on scientific studies, UNEP, IPCC and the WMO in recent reports.

The key reforms that the State of California should adopt are the following:

* Assessment of all Short-Lived Climate Pollutants (including methane, fluorinated gases, and black carbon, plus coolants, tropospheric ozone precursors and brown carbon) as well as long-lived greenhouse gases on the basis of comparative Radiative Forcing.
* Ensure that upstream impacts from all major economic sectors and products consumed in California are assessed and become part of the regulatory framework.
* Include all major climate impacts, especially including livestock management and the consumption of agricultural products.
* Include an accounting of the added climate impacts from the loss of negative climate forcers such as sulfate aerosols as these unhealthy air pollutants are reduced through ongoing pollution prevention efforts.
* Recalculate the California carbon footprint to incorporate the cumulative historic emissions of greenhouse gases that are still present in the atmosphere today and actively contributing to climate change.

Many of the observations and recommendations contained in this document reflect my work with scientists who have analyzed the State of California’s contribution to radiative forcing. Their preliminary findings are in an addendum to this letter.

**Specific Comments:**

In order to keep below +2°C, California must understand that latest science from the IPCC AR5 that radiative forcing is a critical measure. Currently, the world is at 2.3 W/m2. However, in the very near future, we are likely to reach 2.6 W/m2, the point beyond which the planet will surpass +2°C. Given global needs and California’s drought crisis, more urgent action is required to prevent radiative forcing from crossing this 2.6 W/m2 threshold. While long-term elimination of CO2 and other long-lived greenhouse gas (GHG) emissions is needed, short-term needs are critical and analysis of this problem via radiative forcing is required.

1. The title of the first section of this strategy is "Showing the Way to 2°C". The Intergovernmental Panel on Climate Change (IPCC) has stated that temperatures could “most likely” be kept below this level if global mean radiative forcing is stabilized below 2.6 W/m²; yet radiative forcing is currently 2.3 W/m² and will likely exceed 2.6 W/m² by 2025. In order to avoid the 2°C temperature increase, radiative forcing must be reduced immediately. While radiative forcing is mentioned in this report, it is only cursorily discussed and the immediate timeframe for action required in order to stabilize temperatures beneath 2°C is not discussed.

**RECOMMENDATION: A discussion of current and projected radiative forcing should be included in this introductory section, along with a discussion of the immediate reductions in radiative forcing needed to stabilize radiative forcing below 2.6 W/m2.**

2. In its Fifth Assessment Report (2013), the IPCC published a set of Representative Concentration Pathway (RCP) scenarios. In these scenarios, IPCC established the historic increases in global radiative forcing since pre-industrial times, and projected changes in radiative forcing under different mitigations scenarios until 2100. In one of these scenarios, called RCP2.6, IPCC projected the required forcing needed to stay below 2.6 W/m2, which is needed to stay below 2C. We can find no reference to the RCP scenarios anywhere in this report, nor specifically any references to the RCP2.6.

**RECOMMENDATION: In the introduction, the required global emissions reductions of SLCPs and GHGs needed to align with the RCP2.6 should be presented for context. It should be highlighted that immediate stabilization and reduction is required if there is any hope of actually stabilizing temperatures below 2°C.**

3. The Science-Based Targets which ARB outlines are not based on achieving the RCP2.6 pathway, and are not consistent with stabilization below 2°C. While laudable, these targets are not sufficient to stabilize temperatures below +2°C, given the rapid rise in radiative forcing. The targets are described as "aligned with leading scientific assessments for what levels of SLCP reductions can, and should be, achieved globally," as well as with “with other countries' commitments to reducing SLCP emissions." However, these targets do not accurately reflect the level of effort required to meet the RCP2.6 pathway within the short timeframe remaining before radiative forcing levels reach 2.6 W/m2.

**RECOMMENDATION. As the Strategy document takes shape, it is extremely important for ARB to transparently describe not only the strengths, but also the limitations, of the targets and goals set by the state, here in this report and elsewhere in designing the AB 32 policy and implementation. If it is unable to achieve the RCP2.6 in order to stabilize temperatures below 2°C, this should be clearly stated to ensure that the public is fully informed, to ensure that policy setters have the most accurate information to work with, and to reinforce efforts to strengthen the response. Without such transparency, the public could be led to believe that the problem has been solved, which could lead to incorrect policy choices, and poor public resource and business investment decisions. Given the pace of change, goals that far more aggressive than what than what was originally envisioned in AB32 are now required.**

4. The US and California are major contributors to current radiative forcing as described in the IPCC RCPs. A carbon footprint that only reports annual emissions in CO2e reflects only a small part of the actual footprint, as it does not include the real climate effects of 200+ years of emissions in California and their contribution to current global forcing. The State of California must come to terms with its historic impact on current radiative forcing, including the continuing legacy of past long-lived and mid-lived emissions in the present day, in order to design mitigation strategies sufficiently scaled to meet RCP2.6 goals and stabilize global mean temperature below +2°C.

**RECOMMENDATION. ARB should develop and publish the state's contribution to the IPCC AR5's Representative Concentration Pathway (RCP). This requires establishing the state's contribution to global mean radiative forcing compared to preindustrial levels, measured in mW/m2, considering all climate pollutants and losses of biogenic carbon storage (including aboveground forest losses at a minimum). This will highlight the state’s contribution to the current global issue of radiative forcing, and the historic contribution to the current radiative forcing represented in the IPCC defined RCP. The state’s contribution to radiative forcing should be evaluated in W/m2, but can also be evaluated relative to CO2 in units of tons or ppm CO2e.**

**RECOMMENDATION. The state’s RCP contribution should be evaluated in the present year, and then out to at least 2050, per year, based on current policy and economic growth projections. Additionally, the levels of emission reduction required to be consistent with the radiative forcing in RCP2.6 should be determined.**

**RECOMMENDATION. The state should evaluate its RCP contribution from the present to 2035, year by year, in a contribution analysis by pollutant. This evaluation should distinguish between historic accumulated pollutants (i.e., CO2, N2O, CFCs, CH4, etc.), and the radiative forcing caused by emissions from 2015 going forward. Such an assessment would illustrate the relative** **importance of historic CO2 accumulation, and looking forward, help identify the best avenues for mitigating radiative forcing. The mitigation program under AB 32 should then be based upon this contribution analysis, by pollutant. The contribution analysis would reinforce the importance of focusing on in-state methane emissions, which are today responsible for roughly 4 mW/m2. It will also highlight the potential CO2 absorption that could be realized through afforestation and reforestation. (Preliminary estimates suggest that aggressive reforestation and improved forest management in California could result in additional absorption of almost 50 million tons of CO2 each year, an amount sufficient to reduce radiative forcing by 2 mW/m2 by 2035.)**

5. A preliminary radiative forcing analysis based on the IPCC AR 5 RCP 2.6 indicates that the state of California’s RCP contribution in 2013 was roughly 40 W/m2, over 20 billion tons of CO2e. The current ARB-reported footprint of 459 million tons per year only represents the small fraction caused by current annual emissions. The target set by to reduce SLCP emissions from BAU by roughly 114 million tons by 2030 (Table 1, Draft Strategy, page 9) represent less than 1% of the state's contribution to radiative forcing. These targets, though aggressive, are not nearly sufficient to meet the challenge based on reduction of in-state emissions alone. In order to realize the greatest potential reductions in the most cost-effective manner, within the state’s budget, reduction targets and strategies should be extended to include projects out of state. For instance, most global black carbon emissions occur in developing countries (e.g., in Asia); resources expended to help mitigate black carbon emissions abroad could significantly reduce radiative forcing far more aggressively at less cost. Thus, focusing on in-state emissions reductions alone is not only insufficient to achieve the stated goal of maintaining global mean temperatures below 2°C, but is also not the most effective way to use funds available through the AB32 program. On the other hand, working with its sub-national and national partners on joint projects, both here in the US and abroad, could have enormous positive ramifications for climate stabilization.

**RECOMMENDATION. The ARB should recommend the inclusion of out-of-state SLCP projects within the plan scope, in order to fund projects that will have the greatest effect on total radiative forcing reduction.**

6. The current Draft Strategy is inconsistent in the GWPs it recommends. GWPs from the IPCC Fourth Assessment Report (2007) are proposed for methane and fluorinated gases to be consistent with UNFCCC reporting requirements, while the GWP for black carbon is take from the Fifth Assessment Report (from 2013). Unfortunately, continuing climate research and consensus has shown that the 2007 values are now out of date. Only updated GWPs should be used to ensure that ongoing calculations more accurately reflect the actual radiative forcing effects of each pollutant type. Also, there is an additional issue surrounding the GWP for methane. Two GWPs should be considered: 84, the value which does not include indirect effects 84 from the formation of tropospheric ozone and destruction of coolants, or 104, the value that does include these indirect effects. Using other values does not signal policy that would allow California to be most effective in reducing the state’s contribution to radiative forcing.

**RECOMMENDATION. In this document, only the latest GWPs should be used for all SLCPs. IPCC AR5 is used as a basis, but newer science can be included.**

7. The loss of climate coolants – i.e., emissions that reflect incoming solar radiation and lead to the cooling rather than warming of the planet – need to be accounted for within the ARB methodology (http://www.atmos-chem-phys-discuss.net/15/9293/2015/acpd-15-9293-2015.html). Globally, coolants have historically accounted for well over -2 W/m2, sufficient to mask the effects of other emissions that warm the planet. While it is extremely important from a health standpoint to clean up these emissions, the lost cooling from these emissions must be factored in to ensure that policy makers and ARB planners can accurately estimate the net radiative forcing from various SCLPs and GHGs.

**RECOMMENDATION: Include short-lived emissions that act as climate coolants in ARB calculations of the California climate footprint, and develop targets that take into account the loss of these pollutants and their cooling effects.**

8. The renewable energy component of the Draft Strategy is contingent upon factors that may slow deployment. For instance, California hydropower is now only producing less than half of the TWh reported based on past performance, given the drought. Much of this lost power generation is made up for with natural gas (<http://www.energy.ca.gov/drought/>). In addition, broader environmental concerns may stymie efforts at renewable deployment expansion. For example, the Sierra Club and Natural Resources Defense Council, both staunch supporters of renewable power, successfully spearheaded an effort to block construction of a large solar project planned in San Bernadino County, California, due to concerns about impacts on local habitat. A third issues relates to the degree to which renewable energy projects require back-up from fossil fuel-powered spinning reserves, and the climate implications of this added back-up power (<http://www.ieor.berkeley.edu/~oren/pubs/I.A.109.pdf>). More focus on this entire topic is needed to ensure that the environmental and climate benefits and tradeoffs of renewable power are to be fully accounted for by the state in the implementation of its plan.

**RECOMMENDATION. The actual performance and impacts of various renewable power options by source — hydro, wind, solar, biomass, and biogas-derived sources – needs careful examination to support the best informed decisions.**

9. According to a 2015 National Academy of Sciences report, anthropogenic warming from radiative forcing increases the probability that California’s current drought actually signals a transition in climate toward a more semi-arid to arid climate ([www.sequoiaparksfoundation.org/2013/heat-and-hadley-cells](http://www.sequoiaparksfoundation.org/2013/heat-and-hadley-cells)). Climate models now predict that, within a few decades, this type of drought will become the new normal for a climate in California a pattern also being seen elsewhere at comparable latitudes around the world ([www.pnas.org/content/112/13/3931.full.pdf](http://www.pnas.org/content/112/13/3931.full.pdf); [www.pnas.org/content/112/12/3630](http://www.pnas.org/content/112/12/3630)). These findings are consistent with UC Davis research that has been tracking changes in wildflower species over the past several years (<http://conservationmagazine.org/2015/06/climate-change-drives-away-californias-stunning-wildflowers>/).

**RECOMMENDATION: ARB could further emphasize the urgency of this climate issue for the state of California, in light of these findings, to motivate accelerated action.**

**Radiative Forcing Accounting Protocols —**

**Proposed Approach for Consideration by the California Air Resources Board**

(Addendum to Comments and Recommendations by James Ford)

Prepared by SCS Global Services

October 30, 2015

**The Need for Radiative Forcing Accounting**

While the State of California currently uses the standard GWP carbon footprint protocols as its basis of planning and AB 32 implementation, such accounting protocols have significant shortcomings in providing an accurate measure of the State’s contribution to total global Radiative Forcing.

The Intergovernmental Panel on Climate Change (IPCC) has stated that the global mean temperature (GMT) could “most likely” be kept below 2°C if global mean radiative forcing is stabilized below 2.6 W/m²; yet radiative forcing is currently 2.3 W/m²,, and will likely exceed 2.6 W/m² by 2025. Even more troubling, projected emissions of various climate pollutants, such as methane and black carbon, and the loss of sulfate coolants, are projected to push the total RF well above +3.5 W/m2 by 2035.

Based on these data from IPCC, radiative forcing must be reduced immediately in order to avoid the 2°C temperature increase. Yet the current assumption that the 2°C GMT target will not be reached until about 2050 has given a false sense of the time remaining to put mitigation strategies into place to prevent crossing this dangerous threshold. That’s because temperature increases lag behind radiative forcing. 2.6 W/m² could be passed in 10 years or less, but it will take several decades for the GMT to “catch up” and pass 2°C. This is analogous to putting cold pot of water on the stove, which takes several minutes to come to a boil; this level of radiative forcing will take several years to push the GMT over the tipping point. The confusion on this point has led to policy planning that is misaligned with the timeframe actually needed to keep radiative forcing below dangerous levels.

Additionally, all official reports (UNEP, IPCC AR 5, WMO) confirm that reliance on current GHG footprint protocols (the same protocols used for AB 32 implementation) does not offer a realistic chance of leveling off GMT at +2°C, but will result in the 3.7 to 4.5°C range increase by 2100. This will be hottest conditions on Earth in 15 million years.

**Radiative Forcing Accounting Protocols**

Radiative Forcing Accounting Protocols are based solely on the IPCC AR5 Representative Concentration Pathway (RCP) analytical structure, and can be used to identify the major projected changes in forcing by pollutant. These protocols can shine a light on policies that could help to stabilize global radiative forcing within the next 5-10 years. The importance of moving beyond the current annual GHG inventory footprint can be highlighted in Figure 1, which shows how misleading it can be to develop policies based solely on consideration of current annual emission rates, without considering the effect on radiative forcing from the long-term build up of CO2 linked to the state’s historical activities. As shown in the figure, while the current stated annual emissions of CO2 in 2013 were 397 million tonnes, this does not represent the fact that, over the past few decades, over 12,000 million tonnes of CO2 have accumulated in the atmosphere.

Table 1. The blue line shows how many million tonnes of CO2 remain in the atmosphere (starting from 1945 as zero), the red line shows the accumulated emission before decay over time. Due to data limitations, this figure only includes estimated emissions going back to 1945. The accumulated CO2 from emissions is likely higher due to emissions occurring prior to 1945.

The IPCC AR 5 identifies the loss of coolants as an extremely important issues to factor into projected increases in global radiative forcing. Preliminary calculations indicate that the loss of coolants in California over the past 10 years exceeds 270 million tonnes of CO2e. This is not considered in the current AB 32 policy, yet clearly needs to be factored into the overall mitigation obligation of the State of California.

Lastly, California once had the greatest storage of biological carbon in terms of our ancient redwood forests, which represented over a billion tonnes of stored CO2 that could have continued to be sequestered for thousand of years. California was a legal entity at the time of the destruction of this forest system, and therefore has responsibility for this huge loss in carbon storage and the ensuing increase in radiative forcing (Figure 1). The loss of carbon storage from other previously forested parts of the state represents another significant loss in carbon storage. In total, the reductions in extent and integrity of forests in California contributed roughly between 3 and 4 billion tonnes of CO2 to the atmosphere. (This calculation only includes above-ground carbon storage – if below-ground changes were included, this amount could be substantially higher.)

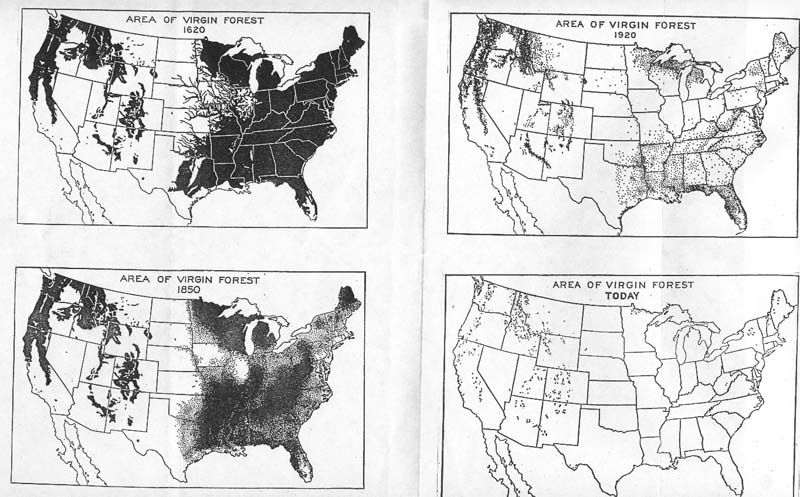


Figure 1. Primary forest in the US from preindustrial times to today. Primary forests in California have been almost completely removed.[[1]](#footnote-1) For example, according to WWF, only 4% of the original extent of redwood forests remain in California.[[2]](#footnote-2)

When these factors, as well as the build up of methane and N2O, are added to the state’s contribution to the RCP, the total exceeds 20 billion tonnes CO2e (Figure 2 and Table 2).

(a)  
(b)

Figure 2. California’s contribution to the Representative Concentration Pathway from 2000-2013. (A) The contribution in units of mW/m2. (B) The contribution in CO2e, using the CO2 radiative efficiency from the IPCC Fifth Assessment Report (0.001772 mW/m2 per million tons CO2). These results are based on extrapolation of data from the California GHG Inventory, first collected in 1990. CO2 emissions before 1945 are not included. If they were included, the result would be higher.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | TOTAL | CO2 | Historic deforestation | Historic forest degradation | CH4 | N2O | SO2 | Black Carbon - (excl. wildfires) | Black Carbon (wildfires) | NOx- preliminary estimate. | Other GHGs |
| 2000 | **34.5** | 18.1 | 5.1 | 3.1 | 4.4 | 0.6 | -0.7 | 0.9 | 2.2 | 34.5 | Not incl. |
| 2001 | **34.9** | 18.5 | 5.1 | 3.1 | 4.4 | 0.6 | -0.7 | 0.9 | 2.1 | 34.9 | Not incl. |
| 2002 | **35.4** | 18.9 | 5.1 | 3.1 | 4.5 | 0.7 | -0.7 | 0.9 | 2.1 | 35.4 | Not incl. |
| 2003 | **35.8** | 19.3 | 5.1 | 3.1 | 4.5 | 0.7 | -0.7 | 0.9 | 2.1 | 35.8 | Not incl. |
| 2004 | **36.2** | 19.7 | 5.1 | 3.1 | 4.6 | 0.7 | -0.7 | 0.9 | 2.1 | 36.2 | Not incl. |
| 2005 | **36.6** | 20.1 | 5.1 | 3.1 | 4.6 | 0.7 | -0.7 | 0.9 | 2.0 | 36.6 | Not incl. |
| 2006 | **37.1** | 20.5 | 5.1 | 3.1 | 4.7 | 0.7 | -0.7 | 0.9 | 2.0 | 37.1 | Not incl. |
| 2007 | **37.6** | 20.9 | 5.1 | 3.1 | 4.7 | 0.7 | -0.6 | 0.8 | 1.9 | 37.6 | Not incl. |
| 2008 | **38.0** | 21.3 | 5.1 | 3.1 | 4.8 | 0.7 | -0.5 | 0.8 | 1.9 | 38.0 | Not incl. |
| 2009 | **38.4** | 21.6 | 5.1 | 3.1 | 4.9 | 0.7 | -0.4 | 0.8 | 1.8 | 38.4 | Not incl. |
| 2010 | **38.8** | 21.9 | 5.1 | 3.1 | 4.9 | 0.7 | -0.3 | 0.8 | 1.8 | 38.8 | Not incl. |
| 2011 | **39.1** | 22.3 | 5.1 | 3.1 | 5.0 | 0.8 | -0.3 | 0.8 | 1.7 | 39.1 | Not incl. |
| 2012 | **39.4** | 22.6 | 5.1 | 3.1 | 5.0 | 0.8 | -0.3 | 0.7 | 1.7 | 39.4 | Not incl. |
| 2013 | **39.8** | 22.9 | 5.1 | 3.1 | 5.1 | 0.8 | -0.3 | 0.7 | 1.7 | 39.8 | Not incl. |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (B) California RCP, Million tons of CO2e | | | | | | | | | | | |
| Year | TOTAL | CO2 | Historic deforestation | Historic forest degradation | CH4 | N2O | SO2 | Black Carbon - (excl. wildfires) | Black Carbon (wildfires) | NOx- preliminary estimate. | Other GHGs |
| 2000 | **19,457** | 10,198 | 2,900 | 1,749 | 2,457 | 358 | -422 | 531 | 1,215 | 235 | Not incl. |
| 2001 | **19,707** | 10,435 | 2,900 | 1,749 | 2,485 | 366 | -421 | 525 | 1,202 | 228 | Not incl. |
| 2002 | **19,955** | 10,665 | 2,900 | 1,749 | 2,519 | 373 | -420 | 519 | 1,188 | 221 | Not incl. |
| 2003 | **20,199** | 10,895 | 2,900 | 1,749 | 2,549 | 380 | -419 | 513 | 1,175 | 214 | Not incl. |
| 2004 | **20,443** | 11,131 | 2,900 | 1,749 | 2,574 | 387 | -418 | 507 | 1,161 | 207 | Not incl. |
| 2005 | **20,679** | 11,357 | 2,900 | 1,749 | 2,601 | 393 | -418 | 501 | 1,148 | 199 | Not incl. |
| 2006 | **20,935** | 11,576 | 2,900 | 1,749 | 2,633 | 400 | -370 | 489 | 1,120 | 188 | Not incl. |
| 2007 | **21,202** | 11,799 | 2,900 | 1,749 | 2,671 | 406 | -322 | 477 | 1,093 | 177 | Not incl. |
| 2008 | **21,461** | 12,015 | 2,900 | 1,749 | 2,710 | 412 | -274 | 465 | 1,066 | 166 | Not incl. |
| 2009 | **21,687** | 12,202 | 2,900 | 1,749 | 2,746 | 417 | -227 | 453 | 1,038 | 155 | Not incl. |
| 2010 | **21,899** | 12,382 | 2,900 | 1,749 | 2,775 | 422 | -179 | 441 | 1,011 | 144 | Not incl. |
| 2011 | **22,076** | 12,560 | 2,900 | 1,749 | 2,805 | 428 | -166 | 428 | 981 | 137 | Not incl. |
| 2012 | **22,257** | 12,743 | 2,900 | 1,749 | 2,834 | 433 | -153 | 415 | 951 | 131 | Not incl. |
| 2013 | **22,468** | 12,923 | 2,900 | 1,749 | 2,863 | 438 | -145 | 413 | 946 | 128 | Not incl. |

Table 2. Radiative forcing in California’s RCP, by pollutant. This data is used to derive the information in Figure 3. (A) The contribution in units of mW/m2. (B) The contribution in CO2 equivalent, using the CO2 radiative efficiency from the IPCC Fifth Assessment Report (0.001772 mW/m2 per million tonnes CO2).

Most troubling, this build up of California’s cumulative “current account” contribution to radiative forcing will continue to increase without any measurable reduction in its rate of increase, even if the state meets its 2020 and 2030 goals. The growing climate crisis facing California and rest of the world needs more aggressive solutions. Full transparency of our “real” footprint shows that Californians the important reduction achieved thus far and planned under AB32 still represent less that 0.1% of our total contribution to current our current cumulative radiative forcing.

California is especially at risk from a changing climate according to the most recent report from the National Academy of Science, which shows tropical circulation patterns now reaching the heart of California. This report and other modeling projections show that California may now be transitioning into a semi-arid to arid climate, and that the current drought may be a more ominous signal of permanent change to our state’s climate. The California ARB and CEC need to consider mitigation options that have the potential to counter this significant change to our climate, rather than focus solely on mitigatation strategies on the margins of this crisis.

The United Nations Environmental Program (UNEP) and World Meteorological Organization (WMO), using data from advanced climate models and economic projections from the International Energy Agency, have projected changes in global radiative forcing over the next 20 years. These data are used to determine the eventual effect on GMT from business-as-usual, and to consider projects focused on reducing carbon dioxide, methane, and black carbon. Figure 3 shows the significant increase on global radiative forcing based on the business-as-usual scenario, as well as the changes in radiative forcing resulting from several possible mitigation scenarios.

Figure 3. Global radiative forcing from 2015 to 2030, according to business-as-usual and considering implementation of six different suites of project types.These scenarios include: A 30% reduction in global carbon dioxide emissions achieved by 2030 (costing roughly 1 trillion USD per year), represented by the red line; a 40% reduction in methane emissions achieved by 2030 (costing roughly 5-10 billion USD28 per year on a net basis), represented by the green line; an 80% reduction in black carbon emissions achieved by 2030 (costing roughly 25 billion USD per year on a net basis), represented by the purple line; negligible impact oceanic cooling (sulfate/nitrate), based on immediate large-scale implementation, sufficient to achieve -1 to -2 W/m2 of forcing reduction (no significant costs), represented by the orange line; black carbon and methane projects combined, represented by the light blue line; all non-CO2 projects combined, represented by the dark blue line.

UNEP and the WMO determined the eventual effect on GMT resulting from some of these different forcing projections (Figure 4).

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Figure 2. Observed temperature change through 2009 and projected temperature changes, thereafter under various emissions mitigation scenarios, all relative to the 1890-1910 mean. *Source: UNEP/WMO 2011 Integrated Assessment of Black Carbon and Tropospheric Ozone.*

It is clear that while aggressive reductions in CO2 emissions may have little effect on reducing radiative forcing before 2030, focusing on black carbon and methane has immediate benefits. Based on the modeling of the effects on GMT by UNEP/WMO, reducing black carbon and methane immediately can slow global warming sufficiently to postpone the +1.5°C and +2°C tipping points, while according to UNEP/WMO, carbon dioxide mitigation alone “does little to mitigate warming over the next 20-30 years.” Postponing these tipping points is essential to provide sufficient time to institute additional mitigation strategies.

1. William B. Greeley, The Relation of Geography to Timber Supply, Economic Geography, 1925, vol. 1, p. 1-11. [↑](#footnote-ref-1)
2. http://www.worldwildlife.org/ecoregions/na0519 [↑](#footnote-ref-2)