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Geoscientific Model Development Discussions

Interactive comment on "Estimating Criteria Pollutant Emissions Using the California Regional Multisector Air Quality Emissions (CA-REMARQUE) Model v1.0" *by* Christina B. Zapata et al.

Anonymous Referee #1

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———— General comments: ————

In this manuscript, the authors use the CA-REMARQUE method to develop 4km gridded emission inventories for the year 2050. Two inventories are generated: a baseline inventory and one in which GHG emissions are reduced by 80% relative to 1990 levels. The scenarios were developed using the CA-TIMES model. The authors describe their approach for translating the CA-TIMES projections into criteria pollutant values based on a variety of sector-specific procedures. The authors then examine the resulting 4 km inventories and highlight differences in scenario-, sector-, and pollutant-specific

emission trends. Furthermore, they compare the changes in emissions to those of a more generalized, expert-driven approach and suggest that considering California-specific conditions (e.g., regulatory environment, existing stock, renewable resources) yield very different changes in emissions than a more generalized approach found in the literature.

Scientific signficance: This work tackles an important objective - developing emissions inventories that can be used to examine the air quality implications of specific energy system scenarios. While others have also tackled this problem, this work adds important detail. However, because the literature review is very limited, the authors are not able to explicitly identify how they advance the science. (see "Specific Comments" for suggestions about expanding the literature review)

Scientific quality: I believe that the scientific approach and methods are underlying the work presented here are valid.

Scientific reproducibility: The authors do an very good job of describing the process that they used to develop future-year inventories from energy system modeling results. While replicating the work for this or another state or geographic region would undoubtedly be a large and difficult task, that difficulty would not be due to lack of information on the method.

Presentation quality: In general, I feel as if this manuscript is well written and that the experimental design and results reinforce the arguments presented by the authors. Nonetheless, I think the presentation quality could be improved substantially if the graphics provided in the results section were revised. One particular area of improvement is in the graphics that map PM emissions for both scenarios. I believe the intent of these graphics was to illustrate (i) the ability to develop spatially explicit inventories, and (ii) the changes in these emissionsfrom one scenario to another. By using different scales on each image, however, the differences are not readily apparent. I suggeste using the same scale or perhaps showing a graphic for the business as usual

case and another with deltas associated with the GHG mitigation case. The stacked bar graphs that showed pollutant specific changes were also confusing and it was not clear what stacking of percents was intended to indicate. Those data could be much more easily presented and compared using a table.

——— Specific comments: ———

I feel that the manuscript has several deficiciencies, and that it could be improved substantially if these deficiencies are addressed. Please see the "Specific Comments" below. My main concern is related to the literature review which could be expanded. I suggest that the authors include addition studies that examine the emissions or air quality impacts of alternative policy scenarios. A few for the U.S. are listed below (although I do not think that all of these necessarily need to be referenced):

* Keshavarzmohammadian A, DK Henze, and JB Milford (2017). Emission impacts of electric vehicles in the US transportation sector following optimistic cost and efficiency projections. Envir. Sci. Technol., 51(12), 6665-6673.

* Loughlin DH, WG Benjey, CG Nolte (2011). ESP v1.0: methodology for exploring emission impacts of future scenarios in the United States. Geosci. Model Dev., 4, 287-297.

* Ran L, DH Loughlin, D Yang, Z Adelman, BH Baek, and CG Nolte (2015). ESP v2.0: enhanced method for exploring emission impacts of future scenarios in the United States - addressing spatial allocation. Geosci. Model Dev., 8, 1775-1787.

* Rudokas J, PJ Miller, MA Trail, and AG Armistead (2015). Regional air quality management aspects of climate change: Impact of climate mitigation options on regional air emissions. Environ. Sci. Technol., 49(8), 5170-5177.

* Trail MA, AP Tsimpidi, P Liu, K Tsigaridis, Y Hu, JR Rudokas, PJ Miller, A Nenes, and AG Russell (2015), Impacts of potential CO2-reduction policies on air quality in the United States. 49(8), 5133-5141.

Similar to this manuscript, the Loughlin et al. 2011 paper also illustrates the development of region-, sectoral- and pollutant-specific implications of a climate policy and discusses how an energy system model's emission projections can be used to develop inputs to air quality modeling. Ran et al. (2015) build on that by adding a land use change compontent to spatially re-allocate emissions for some sectors. This manuscript would benefit greatly by a comparison to the Loughlin et al. and Ran et al papers. In such a comparison, I feel that the work presented here has much to add. For example, it explicitly tackles a state's regulations, goes into much greater detail regarding specific sectors (e.g., nonroad and marine), tackles the siting of new biomass-related emission sources, examines speciated emissions changes from fuel switching (e.g., fossil to biofuels), incorporates consideration of the PM benefits of regenerative braking, and seeks to examine the impact of controls on particle size distribution. Described in the context of these advances, I think the merits of the work presented here are much more clear and point to areas where other analyses could be improved.

I have an additional concern that is perhaps less critical. My concern is related to the presentation of the scenarios themselves. The first scenario is relatively easy to understand as it is just a baseline or business as usual scenario. Nonetheless, California has a very unique energy system, so the underlying trends and dynamics there may not be readily apparent to readers. The second scenario is a GHG reduction scenario, although how the GHG constraint is implemented is not completely clear. Since the authors only compare emissions between a base year, 2010, and a future year, 2050, they have chosen to show the CA-TIMES results only for those years. To convey the scenarios and underlying dynamics more fully, however, I believe the authors should show several model outputs for the period from 2010 *through* 2050, not just in 2010 and 2050. These outputs would include at a minimum, and for both scenarios: (i) CO2 emissions by sector, and (ii) electricity production by technology, and (iii) energy system fuel use. Additionally, displaying fuel used or technologies adopted in the transportation and transportation sub-sectors could be of interest but are not necessary. Stacked area plots would be one form of presenting these graphics. The sectoral GHG graphic

would be particularly useful in understanding how the GHG policy is represented in the model. For example, is it a constraint represented only from 2050 onward as the text seems to imply? If so, how did the model respond to such a shock, and did it begin to make structural changes to the energy system with foresight or respond in more of a myopic way? These results wouldn't necessarily need to be in the main body of the manuscript, and instead could be in the supplemental information.

Additional substantive comments are listed below, preceded by page number:

55: The text refers to other modeling efforts as over-simplifying the California economy. This statement, I think, implies that CA-TIMES includes a much more detailed representation of the economy. I advise care with that description, however. I suspect that CA-TIMES respresents the "energy economy" only, which is only a portion of the larger economy, and may represent interactions with the rest of the economy via simple elasticities for energy demands or perhaps with a function that links to regional GDP. Many readers will assume that a model of the economy would take the form of a Computable General Equilibrium model, which would represent things like tradeoffs between labor and capital, employment, household income, etc.

76: I suggest adding additional information to the description of CA-TIMES. For example, listing the sectors included would be helpful, as would listing the pollutants included in the model. Does it just represent CO2, or does it add other GHGs? What about air pollutants? Are demands fixed or elastic? How the model handles the rest of the country and the rest of the world? How trade with region(s) outside of CA is considered and constrained? Answers to some of these questions are alluded to later in the paper (as we see what CA-TIMES has produced and how it is used), but it would be very useful to have these types of questions answered explicitly when the model is introduced.

Fig 8: What is driving the reduction in commercial energy usage in 2050 GHG-Step? Is it elastic demands? More efficient technologies? Or is there commercial (on-site) solar power that isn't being shown?

Fig 10: At first glance these look the same. It isn't until you examine the legend that it is clear that there has been a 2/3 reduction. I suggest having the scale the same on all the graphs. Alternatively, you could show the 2050 emissions and another graph showing deltas (e.g., where they increase or decrease). The latter approach may be more useful in conveying air pollutant emission co-benefits (or dis-benefits).

689 - Stacking percentages are difficult to interpret? Was a single % change then apportioned to components? If not, it may not be appropriate to stack these values. Perhaps you could show the actual quantities? I feel like a table would convey the information better.

——— Editorial comments and corrections: ———

My other comments, which are more editorial in nature, are listed below. I hope that these are helpful in revising what I feel is a very interesting manuscript.

Line #: comment

54: Editorial suggestion - Here and throughout, avoid using "/". Also, where you have "and/or" I suggest just using "or", which is not necessarily mutually exclusive.

86: CAFE should be spelled without the accent mark on the E

87: References to the regulations affecting CA would be helpful

105: The statement is made that "vehicular emissions for the year 2050 were extrapoled", which left me wondering how. I see that you explain this later in the paper, but is there a way to reorganize so the reader doesn't ask this question, or, if they do, the answer if provided sooner? I had a similar concern with the text "vehicular activity and fuel consumption splits were applied..." in line 108.

Figure 2: The abbreviation EIC is used prior to being defined

Figure 2: Minor suggestion: for the "2050 CA-TIMES Scenario on-road Emissions" box, I suggest renaming this "On-road emissions consistent with a 2050 CA-TIMES

Scenario".

128: A meteorological scaling factor is mentioned, but it isn't clear what is assumed about meteorology in the future.

128: It appears that the methodology does not explicitly consider expansion of existing roadways or the addition of new roadways. Similarly, I did not see a mention of the impact of land use change. If not, perhaps they could be mentioned in the discussion section as ways in which the analysis could be expanded?

145: There are two equations listed as (1). I suggest making each its own.

155: Please provide definitions for the vehicle sub-categories

209: Replace "$\sim$" with "approximately"?

223: "Fueled" misspelled?

345: Perhaps a better way to state "CA-TIMES finds that it is too expensive to adopt biomass-based fuels for ships in the GHG-Step scenario in 2050" is that the model identifies other approaches for meeting the GHG target more cost-effectively?

376: awkward

388: Were wood and distillate held constant, or were they allowed to compete in CA-TIMES... but just not allowed to increase?

Fig 9: Too many significant figures are shown in the table. Perhaps limit to 3 for each value shown?

431: CA-GREET1.8b is argued to have the highest accuracy. But it isn't clear what that means or to what it is being compared to evaluate accuracy.

447: Replace "predicted" with "determined"? CA-TIMES and similar models aren't typically referred to as predictive models. Instead, they are used to evaluate how tech-nonology and fuel choices play out under particular scenarios and assumptions.

450: Do you know the amount of reduced usage vs. switching to imports?

453: Where "Assumed to increase" is used, I think the authors are refering to a model result, not an assumption. Perhaps reword to clarify.

711: The legend for Fig 18a should include at least one more significant digit to be more comparable with the other graphics.

744: You should probably be clear that the CA-TIMES model "code" isn't part of this package (assuming that it is not).

734: "does not have significant impact on criteria..." I understand the point, but this is worded awkwardly.

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