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Geoscientific
Model Development
Discussions

Interactive comment on "Modeling framework for exploring emission impacts of alternative future scenarios" *by* D. H. Loughlin et al.

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The authors thank the referee for providing thoughtful comments and appreciate the referee's comment regarding the groundbreaking nature of our work. Addressing the referee's comments will undoubtedly result in a stronger paper. Below, we list each of the comments and our responses. The manuscript is being revised to address the comments.

———— Comment: Literature review on air pollution projections can be strengthened to provide readers a sense about the state-of-the-art air pollution projections, what they achieved, what are the gaps, and how this research intends to fill an important gap.

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Response: One of our primary goals is to develop a set of very different air pollutant emission scenarios through 2050. The emission scenarios will be used in the U.S. Environmental Protection Agency's Global Change Air Quality Assessment (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=203459) and made available to other researchers and the public. The current manuscript describes an important step in the process of generating those scenarios. We expect many aspects of the modeling process to be refined over the next several years. This context has driven many of our choices in designing and implementing the methodology. We concur that additional background on our objectives would be very useful to the reader.

We will strengthen the background section to highlight the current state-of-the-art air pollutant emission projections and the gap that our methodology fills. The new text will describe briefly the state-of-practice for producing bottom-up emission inventories and will highlight some difficulties in applying such an approach in an exploratory modeling context and for analyses that extend beyond the typical regulatory modeling time horizon. We will also contrast how our approach, by providing more source category and regional detail, differs from top-down approaches, such as those used in IPCC SRES analyses.

———— Comment: Is there any calibration of matching the SCC emissions with MARKAL emissions based on the crosswalk provided in Table 1? How do we know, and how kind of criteria can be used to evaluate, the validity and degree of confidence for the 5-step process described in pages 2026-2027.

Response: The mapping of MARKAL emission categories to SCC codes is generally straightforward and does not require calibration per se. We implement this mapping at the 3- and 4-digit SCC level. Therefore, 10100000 represents external combustion from the electric sector. MARKAL's emissions can be aggregated easily at this level. As discussed in the paper, aggregation requires some compromises in specificity (e.g., a single multiplicative external combustion emission growth factor is applied to modify the emissions of each region's electricity generating sources, whether they are coal

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plants, natural gas units, etc.). When projecting emissions three or more decades out into the future, we feel that these compromises are reasonable since our goal is to capture the differences in long term regional and sectoral emission trends in different scenarios rather than source-to-source changes in emissions.

Another calibration-related topic is the extent to which MARKAL's emission projections and the growth factors derived from those projections are realistic. Since the growth factors are calculated by dividing future-year MARKAL-projected emissions by base-year MARKAL-projected emissions, the general consistency of MARKAL's base-year emissions with the U.S. EPA's National Emission Inventory is important. As the purpose of this manuscript is to discuss the MARKAL-to-SMOKE linkage rather than describing and evaluating specific scenarios, we do not address this topic explicitly here. However, achieving consistency with the NEI base year is an important part of the ongoing MARKAL database development and calibration efforts, and we are actively working in this area.

For example, in ongoing work, we are comparing MARKAL's 2005 emission values (produced with a newer version of the database than used for this manuscript) with the 2005 U.S. EPA's National Emission Inventory. This is helping us understand how well MARKAL emission values match the NEI, where emissions coverage should be expanded, and which emission factors in MARKAL should be re-examined. The results of this comparison also will provide guidance and interpretive information to others wishing to use the U.S. EPA MARKAL databases for scenario-based emission projections. We aim to present these results in the future.

We do not expect that the five-step MARKAL-to-SMOKE methodology itself will change considerably as a result of that process, although it may be refined further based on the activities identified in the future directions part of this manuscript.

———— Comment: Page 2026. Lines 9-20. "Point sources are represented by 8-digit SCCs. : : : regardless of industry." This subparagraph can be deleted. Interested

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readers can refer to the SCC codes by themselves.

Response: We would prefer to keep this text in the paper because the use of wildcards in the SCC codes is a very important part of the methodology. We will review the text and examine if it can be shortened.

———— Comment: Page 2027. Due to the lack of data, growth factors for CO2, PM10 and NOx are used as surrogates for other species, including CO, VOC, and NH2 (CO2), PM2.5 (PM10), and CO, VOC, and NH3 (NOx). This seems to be a grossly over simplistic assumption. Can the author provide a Supporting Information to justify the rationale for this assumption even within an order of magnitude accuracy? This assumption may be ok if there is no significant technological change within the modeling period. However, with significant technological change (scenarios 1 vs 2), there can be significant changes in technology and fuel types within each matching SCC codes, such as within industrial sector (except refineries), within refineries, residential and commercial (combustion), and even within light-duty vehicles. Should sensitivity analysis be conducted to test the robustness of the outcomes to this assumption?

Response: Our modeling team discussed a number of options about how to model emissions that were not explicitly represented in MARKAL. For some categories, identifying appropriate surrogates was relatively easy. For example, it is common to have PM2.5 growth assumed to be directly proportional to PM10 growth (although this is an assumption that should be revisited). For other categories, we attempted to use a surrogate based on whether or not the pollutant-surrogate pair is subject to emission control requirements. In our future work discussion of the manuscript, we will mention that the most appropriate selection of surrogates is a topic that needs more consideration.

In our ongoing work to improve the U.S. EPA MARKAL databases, we are explicitly representing additional pollutant species. For example, we have recently added emission factors for VOCs, PM2.5, CO, methane, black carbon and organic carbon. Integration

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of emission factors for these pollutants will allow us to project their future values without relying upon other emissions as surrogates.

———— Comment: Table 2. Electric sector emission factors for Scenarios 1 and 2 show a drastic different emission growth rate for CO2 (4 percent vs 96) percent. Yet, the emission factors for NOx and PM2.5 remain almost the same between scenarios 1 and 2? It order to achieve almost no emission growth in the electric sector between 2000-2050, significant technological change will be needed. However, for example, vast amount of renewables, nuclear, and even coal/natural gas with CCS can significantly reduce CO2 and NOx and PM2.5 emissions.

Response: Since the development of this manuscript, the emission factors for gasified coal have been revised and have resulted in lower electric sector emissions of NOx and PM under the policy case. We will highlight this in the text and discuss the implications of the emission factor revisions on the results. The purpose of the manuscript is to present the methodology and not to focus on the details of these particular results. We plan to leave the results as they are, with a more in-depth analysis of the emission implications of alternative scenarios reserved for follow-up work.

———— Comment: Future work. There is definite a lot of future work worth exploring. Many of which are not mentioned perhaps due to the length limitation. Examples such as improved spatial allocation methods, more scenario analysis, sensitivity analysis, or even methods to optimize (minimize) future air pollution impacts given growing demand. But this is definitely an exciting area for future work.

Response: We appreciate the reviewer's interest and enthusiasm, and we agree that this is an exciting area for future work. We will add more detail to our description of ongoing and future work. The items mentioned by the reviewer are part of this effort and will be added to the discussion.

Interactive comment on Geosci. Model Dev. Discuss., 3, 2021, 2010.