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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global emission projections for the transportation sector using dynamic technology modeling" *by* F. Yan et al.

Anonymous Referee #2

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I have read the paper "Global emission projections for the transportation sector using dynamic technology modeling" by Yan et al. The paper presents estimate for criteria pollutant emissions regionally and globally over the period 1990 through 2050. The underlying work in this paper will be a useful contribution to the literature. The authors expand on previous methodologies by incorporating vehicle purchases, aging (degradation), and super-emitters.

The paper, however, lacks detail in a number of areas and should be revised. The standard for a peer reviewed paper is that enough information needs to be supplied such that a researchers with appropriate background could replicate the work. Certainly with respect to the development of emissions data this can't be done literally, however, enough information needs to be supplied so that readers can understand the under-

lying assumptions (and potentially replicate the work). Overall, however, too much of the methodology is not described sufficiently. There are many assumptions make for uncertain parameters. This if, of course, fine and necessary, but these assumptions needs to be more clearly and completely communicated so that the community can move forward in trying to better quantify some of these key parameters.

Also, the rather small section at the end of the paper that compares with existing estimates needs to be expanded in order to put these results into context. The results are also only presented as sparse summary tables and graphs. More detailed results should be provided in supplemental material (for example as excel spreadsheets) so that these can be actually used.

The dependence of these results on

Winijkul, E., et al. : Modeling of current and future global emission from land- based non-road engines, in preparation, 2013

is problematic, since those results form a key part of this work. I do not see a problem with proceeding with review (after revision), but I do not feel this paper should be accepted for peer-reviewed published until Winijkul et al. is accepted. Otherwise, if Winijkul et al. was never published, a portion of the results in this paper would not be documented at all. Alternatively, the paper could be re-written without including these results, although it would be better if all emissions were included.

Specific comments below:

Future fuel consumption is a critical assumption. Total fuel consumption and shares should be given (in a supplement is fine) with some summary of these results in the main text (as in Table 6) is fine, but more details need to be provided in the supplement (e.g., at the regional level). It will also be useful to also give values for historical fuel consumption, since the IEA data does not provide information at the technology level, and, thus, can also be interpreted in different ways.

pg 23376, line 5 Emission factors depend on technology improvements, which in turn may be related to economic growth, but a more important factor is environmental legislation. – And also enforcement, which should be mentioned here. This is a large uncertainty in all regions, likely even more so in developing countries.

pg 23379 - text on fuel use

The use of SRES scenarios is understandable even though these are somewhat dated (now 15 years old!). While a new set of socio-economic scenarios is under development these have not been finalized yet (see further comments below). What is not clear, however, is how newer historical data and trends have been merged with the older SRES IMAGE scenarios used here. I suspect that the near-term trends in the IMAGE scenarios differ in many cases from historical reality. Transportation fuel use is now available to at least 2010 from IEA. Some of the questions that need to be answered (briefly in the text, with further details in the supplement) include: up until what year are historical data used? How are the IMAGE projections modified to be consistent with updated historical trends?

The RCP scenarios are not appropriate for use in this exercise (as suggested by another reviewer) since: 1) they were not designed to span a range of socio-economic conditions, and 2) they span a range of climate polices, not reference (no policy) scenarios as used here (see comments below).

However, what is not done here, but needs to be done, is to compare road transport fuel use as used here (from IMAGE, perhaps modified?) with long-term projections from other similar models. There are a number of models that are used for this purpose (for example in the RCP scenario process, but there are quite a few others). It is critically important to get a sense of how the fuel consumption trends used in this work compares with other results, since this is a large driver of emission trends.

pg 23380, lines 11-12 Meaning of the second part of "We assume that the technology shares are the same as in the previous studies, and no details about technological

changes are provided, thus only time-dependent, fleet-average emission factors are considered." is not clear. Seems this is trying to make two statements. 1) that "details about technological changes are provided **in this paper**"? (since the previous text emphasizes that the focus of this paper is technological changes over time). Then there is a statement saying something about the use of fleet-average emission factors. It is not clear what "thus only time-dependent, fleet-average emission factors are considered" means. (given the focus of this paper on technology modeling and *not* using just average emission factors!)

23381 - bottom. It would be very helpful if an example of factors (2) - (6) in action could be given. Perhaps a two panel graph with total emissions for 2 example sectors showing all these pieces playing out for the parameters used in the model.

23383 - line 29 (bottom) phrase "the years that emission factors for CO, NOx, and THC start to increase or stabilize are the same as for PM " needs more context. Without actually reading Yan et al, it is not clear what this means. (Implementing a graph along the lines as suggested in the previous comment would help with this.)

The discussion about degradation could be clarified. It is not clear what "do not degrade beyond the level of opacity standards," means.

The phrase "but do degrade after implementation of the most advanced current standards such as Tier 2 and Euro VI that require vehicles to be equipped with after treatment devices." should be re-written to be clearer. I'm guessing this means that, where standards require 'end-of-pipe' treatment, its logical to assume some degradation/failure rate over time for these devices?

Again, it would be useful to see a graph showing examples of these emissions factors changing over time for different types of regions (developed, developing) and a few specific vehicle types (perhaps largely in supplement, but at least one figure in the text would be helpful since this is such a key assumption). This would also help quite a bit in explaining the "durability, degradation, and stabilizing phases" concepts, which are

a bit murky in the present text.

The assumptions actually used for super-emitters are not clear and should be provided (perhaps in a supplement table). In particular, the fraction of vehicles in each class/region that are assumed to be super emitters, and the emissions factors (or perhaps ratio of supper emitter EF to average "normal" EF.)

A critical assumptions is the assumed mix of vehicles by emissions standard, both at present, and into the future. I presume this is particularly important for road vehicles, but perhaps also for other sectors. An overview of these assumptions (particularly developed vs developing country) needs to be provided, with more detailed information in the supplement.

I assume trucks treated separately from LDVs? If so, it would be useful to see some discussion and results for emissions of cars/light trucks vs freight trucks.

Page 23384, section 3.2.1 It would be useful to provide slightly more details in this paper about those results. A brief discussion about the uncertainty in current off-road fuel use would be helpful, as would a brief description of how fuel use is extrapolated into the future. "and project future fuel consumption based on IPCC scenarios." is not sufficient description.

line 14-17 "There is no other consumption category in the IEA data that is large enough to include the difference between the regional fuel consumption estimate and the IEA reported bunker fuel use." – This is unclear. Should "bunker fuel" be inserted here to read "regional bunker fuel consumption estimate"?

line 17 " While we presume that the difference is unreported consumption, no adjustment to the IEA consumption data has been made for historical emission estimates." – This is a good discussion, but it is unclear, in the end, what was used in this work for bunker fuel consumption estimates. Please clarify. Were IEA base-year data used (which the literature seems to show are underestimates for many countries) or were

other data used? If IEA data were used, then shipping emissions would likely be underestimated.

p 23387 line 21 – can oxidation catalysts actually be used with high sulfur bunker fuels?

p 23388 line 22 "which the sulfur content of marine fuels is still rather high," – This seems to implicitly assume that the MARPOL standards are not met?

p 23389 line 19 "Electricity shares about 30 % of the global rail energy ..." – on final or primary energy basis? – awkward wording "Electricity shares about"

Results and Discussion: p 23391 line 10

The statement "The major reason for the decrease in near-term emissions is the implementation of stringent emission standards, particularly for on-road vehicles (Yan et al., 2011), which contribute more than 60 % of the total fuel use." seems a little problematic given that there is not enough information in the paper to evaluate the assumptions about how stringently emissions controls were assumed to be enforced and the assumed retirement rate of vehicles. (There are equations in Table 1, but no results. A supplement table with age class fractions for historical and future years by region, and fraction of super emitters by region and year would be very helpful in this respect.)

It is clear that these factors differ in different parts of the world. Also the effect of older vintages will vary by region. In many developing countries there are clouds of black smoke spewing from nearly every vehicle, most of them old and with effectively no emission controls. The retirement rate of vehicles appears to be very low. The bottom line is that sufficient information needs to be provided so that readers can make their own judgement in this respect.

(The later discussion points out differences between these estimates and GAINS being due to different vintaging assumptions. So more explicit information needs to be given so readers can evaluate this.)

It would be useful in the above paragraph that a bit more discussion about the impact of emissions in developing vs developed countries. A sensitivity study for developed countries with alternative assumptions for vehicle retirement and standards enforcement (or other variables the authors find are important) would be valuable.

These assumptions are uncertain, and need to be brought out in the literature so that the community can make progress on resolving some of these issue. But in order to do that, more details need to be provided when results are published.

Results and Discussion:

I am left with a few further questions.

It appears that the only model assumptions that depend on scenario are fuel use (and, see below, therefore purchase rates)? This needs to be stated in the discussion (and methods) sections where emissions from the different SRES scenarios are presented. In reality, one would expect that emissions enforcement would tend to vary with the level of socio-economic development (with lower incomes societies, in general, lacking the regulatory infrastructure to enforce emission standards). This might add greater spread to the results. (Another way to ask this question is: it seems that, as far as I can guess from the manuscript that, for a given vintage of vehicle, emission factors are constant across the SRES scenarios in this study.)

Higher rates of income growth would tend to lead to higher rates of vehicle purchases and a higher share of vehicles with more up to date emission control equipment. It appears, from reading Yan et al. 2011, that this effect is included in the model. But it this is not clear from the current text. Its an important point, and should be clarified. The extent to which this effect plays a role in the different future trends by scenario should be briefly discussed.

4.3 Comparison with other studies

While it is useful to compare global emissions, more complete comparisons of regional

estimates are needed, not just for two sample regions. This could be done in tabular form. The RCP scenarios, for example, are all benchmarked to a common year 2000 estimate (Larmarque et al. 2010). This paper has been widely cited, so a more detailed comparison here is needed. That dataset, for example, uses estimates of emissions from each country's internal inventory values for OECD countries. Are the estimates in this paper different from those? (Actually it would be useful to do this comparison using updated values – which are available in database format from the UNFCCC submissions from 1990- 2010. Look on the UNFCCC web site for "flexible queries") If these values are different, it would imply that country level estimates used for regulatory purposes may not be correct. This would be quite important if true. Alternatively, the differences could stem more from estimates in developing countries, where emissions are more uncertain (see also Granier et al. 2011). This also would be important to know.

The text "RCPs have been developed for AR5, but they provide climate forcing pathways rather than prescribed changes in socioeconomic conditions." Needs to be corrected. The RCP scenarios also, of course, have socioeconomic assumptions. However, the more important point here is that the RCP scenarios, unlike the SRES, were not designed to provide a range of socioeconomic scenarios. So perhaps replace "prescribed changes", with "a range of socioeconomic assumptions". (3 of the four scenarios have very similar "central case" assumptions.) Also, the A2 scenario used in the submitted paper is rather out of date – the RCP4.5 is based on a revised A2 scenario with a lower population. This should probably be pointed out.

Perhaps even more important, and not mentioned here, is that three of the four RCP scenarios are climate policy scenarios. In some of these scenarios the structure of transportation is changed from reference case conditions, lowering pollutant emissions (see, for example, van Vuuren etal 2011). So they cannot be compared 1:1 with the other reference case scenarios otherwise shown. This needs to be made clear. Reference case emissions from the journal papers that describe the RCP scenarios could

be used instead: these would be comparable. (Data could be requested from those authors.)

This statement "in general, only one emission factor is assigned to each subsector, e.g. on-road gasoline engines, and such treatment of emission factors cannot reflect technology shares or changes in shares, which tends to lead to overestimation of emissions. " is not supported by any analysis. Even if one emissions factor is assigned per sector, as defined in the text (I suspect this is, indeed, the case for most if not all of these analyses) this could easily lead to either over or underestimates in trends. The actual direction of any bias would depend on how that emission factor was assumed to change over time.

The authors state that: "Whether differences of emission projections may also be due to differences in energy consumption or socioeconomic assumptions such as GDP and population is beyond the scope of this paper and will not be discussed here." I disagree. It would not only be relatively easy to at least compare energy consumption between scenarios, I believe it is rather crucial - given that the underlying scenarios used for this work are now about 15 years old. Once energy consumption is compared, this will give a strong indication if the differences are caused by differences in the trends in fuel consumption or differences in trends in emission factors.

In comparing to other studies, it needs to be noted that for some of these other studies, emissions from non-road vehicles may not be included in the transportation sector. It would be useful to provide regional, annual values in the supplement that do not include non-road vehicles so that these results can be more easily compared to other studies.

5.2.1 Updates of scenarios The authors seem to be unaware that there is already an effort well underway to produce updated socio-economic pathways, the so-called SSPs. See Kriegler etal 2012 and Vuuren et al. 2012. This text needs to be updated to reflect these references.

GENERAL

The authors make a point at several places in the text about the assumptions made in order to provide annual data. This data should be supplied annually, at at least the region level, as this would be useful for many readers. (Perhaps in an excel supplement.)

Need to clarify if Total Hydrocarbons (THC) includes methane. One common nomenclature for this is NMVOC - authors should clarify if THC = NMVOC.

OTHER QUESTIONS What are the assumptions for the fraction of superemitters? Is this constant over time and vintage?

Is export of vehicles considered? (e.g., secondary markets?) If all new demand in developing countries is assumed to be made up of new vehicles this would likely overestimate emissions.

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