

1. When discussing comparison of the estimates with other work I miss reference to at least trends observed in ambient air. There exist measurements of primary and secondary components of PM for several urban areas in China and few rural locations and it might be useful to have a closer look at those to compare the trends in the last years (the measurements do not cover the whole period but at least the last years, say about 1999-2005). Incorporating this comment could result in modification of the statement on page 17157 (line 14) and possibly adding a small paragraph in section 5.

Answer: We agree. We added a section (Sect 5.2) in our revised manuscript to address this comment.

2. There is no mention of the off-road machinery (agricultural tractors, construction machinery, railways, etc.); typically this source is poorly controlled and its role in emissions in a strongly growing economy could quickly increase. I suggest adding brief discussion of these sources, especially in relation to the potential contribution to BC emissions owing to typically high share of engines in this sector using diesel fuel. Consider it in section 3 and 5 and depending on magnitude in sector 4

Answer: In our revised manuscript, we added a section (Sect 4.2.7) discussing our estimates of off-road emissions. Several lines have also been added in Sect. 4.1.2 presenting this result. BC emissions from off-road mobile sources are higher than which from on-road vehicles. Since there's no emission standard for off-road mobile sources until 2005, we assume constant PM EFs from 1990 to 2005. As BC emissions from diesel engines could be considerable, and emission control on on-road vehicles is moving forward quickly, off-road sources need to be addressed more in China's future policy making.

3. Throughout the paper the authors refer to 'power plant boilers' but from the text I gather that respective sections might also include industrial boilers. If this is so, I would suggest making it more explicit and the international audience typically expects such distinction. Furthermore, this might have implications on discussion of impact of legislation that is typically different for power sector and industrial boilers since several of them are of smaller capacity. Sections 3.1, 4.2.1, and 5.1.2 would be affected.

Answer: We agree. In the revised version, we added a paragraph in Sect 3.1 and Sect 4.1.1, respectively, to discuss the trend of EF and PM emissions from industrial boilers.

4. One more comment on industrial boilers; in my own work I have been often confronted with opinion from Chinese experts that the knowledge on the

actual number, coal use and operating practices of smaller boilers in industry was and is quite poor implying that this sector might be more important than often estimated but most of all more uncertain than some of the other sources.

Answer: Thanks for this comment. We agree that the contribution of industrial boilers might be underestimated due to the possible poor operation conditions. Unfortunately, this can not be confirmed by any publications or statistics. In current inventory, we have to use energy consumption data from energy statistics, and emission factors from limited measurements. Resolving this problem will need a comprehensive survey in the whole industry sector.

5. On page 17159 (line 13), while nearly 10 years ago we indeed had no data to assume otherwise, there are measurements and papers showing that it is not the case and I would recommend to review this assumption and refer to the respective literature, for example for stoves please see Roden et al (2006; EST) and Rodaen et al (2009; Atmospheric Env); I do not remember immediately sources for transport

Answer: Thanks for suggestion. We agree that this assumption is more or less unrealistic. Actually Roden et al. (2006, 2009) and Bond et al. (2004) discussed how a control technology such as improved stove or chimney could generate different BC/TC ratio and thus introduce different removal efficiency for BC, OC and PM_{2.5}. The different removal efficiency is mainly attributed to the combustion condition which impacts the formation process of BC and OC in different way. However, unfortunately to date we lack adequate local tests to quantify the mass ratio of BC or OC on PM_{2.5} before and after control technologies. Therefore we have no choice but to assume same removal efficiency for PM_{2.5}, BC and OC, despite the possibility to introduce additional uncertainty. We have added some discussion on this issue in Sect 2.1 of revised manuscript.

6. On page 17163 (line 3) the authors refer to the BC and OC shares in PM_{2.5} in Bond et al (2004); I believe this is not correct, unless the authors made some additional assumptions that are not shown. Bond et al (2004) has developed BC and OC shares in PM₁ and put this also in relation to PM₁₀ rather than PM_{2.5}. While for some sources it might not matter much, e.g., diesel engines or biofuel combustion, it does matter more for coal combustion in stoves and industry.

Answer: Thanks for correcting our mistake. Actually we have converted the BC/OC shares in PM₁ in Bond et al. (2004) into the share in PM_{2.5} by the following equation:

$$F_{BC/OC} = f_{BC/OC} * f_1 * \frac{EF_{10}}{EF_{2.5}} = f_{BC/OC} * f_1 * (1 + EF_{2.5-10} / EF_{2.5})$$

where $F_{BC/OC}$ represents the mass ratio of BC or OC in $PM_{2.5}$; $f_{BC/OC}$ refers to the mass ratio of BC or OC in PM_1 from Bond et al. (2004), f_1 refers to the mass ratio of PM_1 in PM_{10} from Bond et al. (2004); EF_{10} , $EF_{2.5-10}$ and $EF_{2.5}$ is the unabated EFs of PM_{10} , $PM_{2.5-10}$ and $PM_{2.5}$, respectively.

But we put some wrong number into Table 6 by mistake, and we didn't explain the converting in the context of original manuscript. In the revised manuscript we corrected the wrong numbers in the table, which lies in power plants, grate furnace, diesel boiler and fuel oil consumption. As for the emissions from coal stoves, they are calculated based on the factors from Chen et al (2009).

7. On page 17158 (line 9-11) the authors refer to the key innovation of this work. I believe that few previous studies had a similar approach, actually already Bond et al (2004) made assumptions on technology penetration, although distinguishing only few key elements and lacking the level of detail you are presenting. However, some other papers, e.g., Zhang et al., 2009 or Klimont et al. (2009; Tellus B) have used several sectors and technologies and in the latter paper discussed also evolution over time. I'd suggest to add a reference to the Klimont et al. 2009 in general as well as Bond et al 2007 (on historical emissions) [both could be mentioned already in the introduction; see page 17156 as well as in further discussion and comparisons, specifically for BC and OC as they do not present $PM_{2.5}$ or PM_{10}]. However, I am not questioning that this paper does not an innovative/valuable component, quite the contrary, it goes beyond the mentioned papers as it adds new material, its detailed evaluation, improved spatial resolution, annual time-series, uncertainty analysis.

Answer: Thanks for clarifying this. We have added those two references in Sect 1 and Sect 5.1.4. We also would thank the reviewer for recognizing the improvements our study has made,

8. On page 17163 (line 4) I would suggest to add also reference (and actually look into the paper too) to the Atmospheric Environment paper (Kupiainen and Klimont, 2007); it contains some more discussion of emissions factors and some updates and was peer reviewed.

Answer: Thanks for reminding us the reference. We have added it into section 2.2.6.

9. Page 17158 (line 8); please mention for clarity that Hong-Kong is not included and why.

Answer: We didn't include Hong Kong and Macao into this study because the detailed technology information of these cities is inadequate to support our analysis. We have added one sentence into section 2 for clarity.

10. Page 1712, section 2.2.4.; One could add few references here where legislation and legislation issues in China has been discussed, e.g., Xu et al., 2009 (Energy & Environmental Science) [it is a SO₂ paper but the mechanisms are discussed and I feel it could be used here] and also Zhang et al, ACP, Intex paper; and also mentioned earlier Klimont et al (2009; in Tellus B). Finally also the IEA Coal database does give information on implementation of PM abatement in power sector.

Answer: Thanks for suggestion. It's a good idea to add references here to give the audience a general idea of the approach we used to estimate the penetration of control technologies. We have added some sentences in section 2.2.4. In Sect 3.1 we discussed the approach configuring penetrations of PM control technologies in power sector. Compared with other emission sources, there was more PM control information for power sector, such as statistics by SEPA (1996a) and by China Electricity Council. We believe the information from IEA database is derived from these statistics.

11. Page 17167, line 15-20; I wonder if there is any substantive evidence for these trends, something could be quoted or there is nothing and the authors choose to reply on the assumptions of others.

Answer: Unfortunately we didn't find any evidence showed the national trend. This might be the only existing assumption we could follow. Now we are preparing for a survey investigating the activities of coal use in residential sector. We hope this could help us to conduct more reasonable and reliable estimates in future study.

12. Page 17167-17168; section 3.6; maybe a brief discussion of the enforcement of legislation in transport and its regional variation can be added. Both will have impact on emissions, specially its spatial distribution. By enforcement I mean, how (if at all) you consider deterioration of vehicles, especially if annual testing is not required and in some areas regular maintenance might be of poorer quality.

Answer: Thanks for the suggestion. Strict regulations, including banning Yellow Label Vehicles in some large cities such as Beijing, Shanghai and Guangzhou did suppressed the using of old vehicles and thus lowered the average EFs. We have taken the regional regulations into consideration when we develop the inter-annual EFs for different regions with MOBILE model. In our revised manuscript, we added some sentences in Sect 3.6 discussing the effect of these regulations on EFs.

13. Page 17169, line 12; 'small plants' do they include also small industrial

boilers (not just kilns in two mentioned sectors) in other sectors?

Answer: Yes, both small industrial boilers and industrial processes are included. We added some text in the revised manuscript to make it clear.

14. Page 17170, line 13; I believe the authors could refer to the more recent sectoral assessments since Bond et al work was for 1996 before strong growth in transport; examples could include Ohara et al., 2007 (JGR), Zhang et al (2006, 2009), Klimont et al (2009).

Answer: Thanks for suggestion. Here we refer to Bond et al. (2004) because we want to compare China with developed countries. To avoid misleading, we revised the text in Sect 4.1.2 to make it clear. A comparison with other Asian studies was presented in Sect. 5.1.4.

15. Page 17170, line 21; I personally do not think that stressing this regionalization of strategy is very relevant here since nowhere else in the paper there is any more extensive discussion of potential strategy. What's more, while importance of key 3-4 activities does vary from region to region, there are principally always the same sectors that are key and so a nationwide legislation might be the right way to go while there is space for local incentives so that some measures could be taken quicker in specific regions.

Answer: We agree that this stressing the strategy is unnecessary here. We have removed this sentence from our manuscript.

16. Page 17170, line 6; coking industry estimates for BC and OC are very, very uncertain as there is virtually no measurements of emission factors and the share of production in different type of ovens are also pretty uncertain; maybe something one could stress here. However, the most problematic issue is referring to the emission factors used (table 6) for this sector (in fact also for brick kilns). You refer to the study from 2002 (of which I am the lead author) and at that time we had to extrapolate from very general emission characteristics to arrive at the BC and OC shares in PM for coking plants; what's more in Europe coke ovens are not an important pollution source anymore and therefore the impact of the possibly inappropriate emission factor is practically invisible. Based on the more recent information, or newer informed judgement and discussion between several groups, including Tami Bond, we have concluded that these emission factors are very likely to be inappropriate and use in current versions of models very different values. I suggest contacting me for discussion of this issue and I will share with the authors the more recent estimates of emission rates for carbonaceous aerosols from coke making; however it should be stressed that this sector for China is contributing significantly to the overall uncertainty. . .we still wait for a

comprehensive set of measurements which as a matter of fact are in progress.

Answer: We have communicated with the reviewer about this issue. Finally we found that the emission factors used in our model are fairly close to the values in current version of GAINS model. We used mixed data source to get those numbers. The unabated TSP emission factor was 13 g/kg, which is from local measurements. Then we used BC/OC/PM_{2.5} fractions from the reviewer's work (Klimont et al., 2002; Kupiainen and Klimont, 2004) to get final emission factors. However, both values are based on very limited measures and subject to high uncertainty. Another difference between our model and GAINS is that we used time/provincial dependent penetrations of different production technology to make regional assessment. We have added some discussion on this issue in Sect 5.1.4.

17. Page 17173, line 1; is there a reference that could be added for the change in the types over time? Also are there any local measurements of PM on coke plants? It would be important to say that.

Answer: The statistic data from National Bureau of Statistics shows the gradual replacement of indigenous coke ovens by automatic, mechanized coke ovens. Unfortunately to date we don't know any measurements on the whole producing process of an indigenous coke plant. We have added some text in our revised manuscript to note the potential uncertainty on our estimation.

18. Page 17173, line 13; I believe one should add a statement about the specific (higher) uncertainty associated with estimates of fugitive emission in industry; they cannot be directly measured and true practices are largely unknown.

Answer: We have added some words in Sect 4.2.4 to emphasize the uncertainties in estimating fugitive emissions.

19. Page 17174, line 19; possibly one could add here that the stringency of road transport legislation varies across provinces with specific laws in some cities.

Answer: We agree that the regional regulations to control on-road vehicle emissions could impact the emissions in different provinces. We edited the text in the revised manuscript to remind the audience the effects by regional regulations. More discussion on this could be found in Sect 3.6.

20. Page 17177; line 19; suggest to include in the comparison also Klimont et al., 2009 (Tellus B)

Answer: We have added Klimont et al., 2009 into the comparison (Sect 5.1.4 and Fig. 14).

21. Page 17177, line 23-24; indeed these might be important sector but what I miss in the paper is discussion of the transformation in brick industry, similar in a way to the coke sector that took place in China over last decades. According to a number of Asian experts and several industrial or NGO reports countries like China, Vietnam were successful in eliminating the most primitive kilns (e.g, the ones still used in India or few other South Asian countries; often referred to as clamp kilns) and replacing them with vertical shaft kilns as well as Hoffman kilns which are much more efficient and cleaner, although often no specific abatement has been attached to them.

Answer: Yes, we agree that the brick kilns in China are relatively cleaner than South Asian countries. According to the information from China Brick Association, the transformation from the most primitive kilns to Hoffman kilns began in China as early as 1980s, however, there's no supportive information on the process and spatial characteristics of the transformation. Moreover, we are not confident on the emission factors of Chinese most primitive kilns since there's barely emission test. Besides the technology transformation you mentioned, we think another transformation will very likely be an important factor to impact the emissions from China's brick industry, that is, from traditional bricks to new wall material such as autoclaved brick and steamed brick. These materials have been promoted in recent years, but the statistics data didn't distinguish them from traditional bricks, therefore we can't conduct quantitative analysis here. Hopefully we can get further when some related data is available. In the revised manuscript we added a paragraph discussing the uncertainties on estimating emissions from brick making industry.

22. Page 17178, line 7-8; As a matter of fact the impact of the uncertainty in biofuel activity data has been discussed and estimated in the Klimont et al (2009) study that considered the variability in reported activity data from different assessment. And yes, I agree it is a very important aspect and potential source of error.

Answer: Thanks for comments. Several words have been added in section 5.1.4 of our revised manuscript to emphasis this information.

23. Page 17179; line 24-26; I cannot agree more but maybe also adding a sentence about the off-road machinery and small industrial and residential boilers would be useful.

Answer: We agree. A sentence has been added in the revised manuscript to

deliver this information.

24. Page 17179; Conclusions; I think that apart from listing trends for different PM species it would be very good to add something about the successful implementation of measures in few sectors that led to a slow down or even reversed trend for emission of PM species which has certainly health benefits. At the same time the efforts have to be accelerated to efficiently control remaining sources as PM is still an important pollutant (one can make here a reference to the concentrations measured in the cities and compare it to eh WHO standard); just suggestions.

Answer: Thanks for the suggestion. In the revised manuscript we add a section (Sect 5.2) discussing the effectiveness of PM emission control regulations. Sect 4.2.6 also discussed the effectiveness of PM emission control on on-road vehicles. In the conclusion part, a sentence has been added in our revised manuscript to highlight the successful PM emission control for cement industry, power sector and on-road vehicle. We also pointed out the gap between China's current PM concentration and WHO guideline, and raise the point that more efforts should be made in terms of PM emission control.