Anonymous Referee #2

I have read the paper "Variations of China's emission estimates response to uncertainties in energy statistics" by Hong et al. This is a well structured study that addresses an important issue. The paper will be a solid addition to the literature. The paper should have a bit more background material along with some additional methodological details, as discussed below.

Response: We thank Referee #2 for the constructive comments. We address the comments as below.

The sectoral resolution of the different datasets should be briefly discussed. First, is the sectoral resolution similar across all the datasets? I assume these data all distinguish between key sectors that have quite different emission factors - if so this should be stated? (e.g. iron and steel, vs boilers in industry; agricultural machinery vs road vehicles, etc.). If the sectoral resolution of the different datasets is not the same, then how this was treated in the data processing needs to be discussed (at least for sectors that are a signifiant portion of total emissions of one of the targeted species).

Response: The sectoral categories are consistent across all the energy datasets from NBS. In the supplement of the revised manuscript, we provide the sector information of the NBS energy statistics. The same scale factor in fuel consumption was applied for all the sub-categories in same major sector (e.g. industrial coal-fired boilers and kilns in industry sector; on-road diesel vehicles and off-road mobile sources in transportation sector). We have clarified this in the Section 2.2 of the revised manuscript.

More details on the processing of the energy data are needed. All the text says now is "five emission inventories based on different sets of energy statistics (i.e., CT-CESYOri, CT-CESY-1C, CT-CESY-2C, CT-CESY-3C and PBP-CESY) were established.". In general, energy data sets do not contain all the information needed for an inventory, so additional assumptions (such as technology splits over time and technology retirements) would likely need to be made. Some assumptions likely had to be applied at some point, and these need to be described. Basically, the process of going from the energy datasets to the data needed in MEIC needs to be described. Then how this methodology might impact the results should be discussed. (If there are differences in the sectoral resolution of the different datasets, this could be an additional source of uncertainty, for example.)

Response: The emissions in MEIC were estimated as a product of the activity rate (such as energy consumption or material production), the technology distributions of fuel/production and emission control, the unabated emission factor, and the removal efficiency. Thus, the emission estimates can be simplified as the activity rates multiplied by their respective net emission factors of different fuel/product types in different sectors. Note that the net emission factors in MEIC change dynamically driven by the technology renewal process year by year. Technology distributions within each sector are obtained from Chinese statistics, a wide range of unpublished statistics by various industrial association and technology reports. For example, technology distributions in the power sector were obtained based on unit-base database (Liu et al., 2015). Technology distributions in the transportation sector were estimated based on fleet model (Zheng et al., 2014). The methods on emission estimates has been documented in our previous work (Zhang et al., 2007; Zhang et al., 2009; Zheng et al., 2014; Liu et al., 2015). We have described this in Section 2.2 of the revised manuscript.

Also, where fuel consumption differs between the datasets, how was this mapped to the technology

detail in the inventory? For example, were the same emission factors applied for fuel consumption in a given sector in each year (even though different fuel consumption data would imply different rates of new purchases and/or retirements). Greater growth in coal consumption in one dataset as compared to another would tend to imply a greater amount of new equipment, which could have different emission factors as compared to older equipment. Note also that these assumptions would likely add additional uncertainty.

Response: For different energy datasets, the same net emission factors were applied for fuel consumption in a given sector in each year during the emission calculations. MEIC already simulates the dynamic changes in net emission factors driven by the technology renewal process year by year. In fact, energy differences might change the technology renewal process, and further change the net emission factors. However, considering that those assumptions would likely add additional uncertainty and we do not discuss the uncertainties in emission factors, such indirect impacts on emission factors are not included in this study. We have clarified this in the Section 2.2 of the revised manuscript.

My understanding is the MEIC has province level detail. Were these calculations performed with province-specific emission factors, or national average emission factors. If the former, how were differences in national data allocated to provinces?

Response: As the emission calculations were performed with province-level data, energy consumption in the national energy statistics were directly allocated to provinces by using the ratios derived from the provincial energy statistics. We have clarified this in the Section 2.2 of the revised manuscript.

It would be useful to see a bit of a discussion of how these apparent uncertainties might extend back further in time. One point in particular, it should be noted that the narrowing of the uncertainty toward 1995 is due, in part, due to fewer different datasets. Can it be presumed that the methodologies for data collection did not evolve as much during this earlier period as compared to the latter statistical surveys (in which methodologies apparently became more consistent between provincial and national statistics)?

Response: In the Section 3.2 of the revised manuscript, we have added a paragraph to discuss how these apparent uncertainties extend in time. It should be noted that the apparent uncertainties calculated in this study are subjected to the energy datasets used. For example, the small apparent uncertainties before 1996 might become larger if a new energy dataset that revises the data of this period is included. Apparent uncertainties during the recent period of rapid growth (2004-2012) are higher than the early period (1996-2003), implying that the discrepancies might be accumulated and expanded for a period of rapid growth. For example, underestimates of the growth trends of small enterprises might result into accumulated underestimations. Note that the energy consumption apparently became more consistent between provincial and national statistics after the three economic censuses, indicating that the new energy statistics after the economic census may include evolved methodologies for data collection and more cross-checks to reduce the discrepancies. In this case, conducting censuses in some interval years could help to reduce the accumulated discrepancies. The apparent uncertainty ratio in years economic censuses newly conducted (i.e., 2004, 2008 and 2013) is generally less than that of previous years (i.e., 2003, 2007 and 2012), as shown in Figure 4. The converging uncertainties in 2013 may also be caused by the third economic census.

For this reason, I like the author's choice of terminology of "apparent uncertainty", but this possible

bias in the results – e.g., actual uncertainty earlier in the series shown is likely be underestimated due to lack of multiple datasets – should be more explicitly discussed in the paper.

Response: In the introduction section of the revised manuscript, in order to avoid confusion, we have clarified the meaning of "apparent uncertainty" defined in this study as compared to the meaning of "actual uncertainty". Apparent uncertainty is a straightforward metric used to quantitatively gauge the apparent discrepancies between different existing datasets. Apparent uncertainty ratio is a metric to quantify the relative deviation. Thus apparent uncertainty could partly reflect actual uncertainty. In general, large apparent uncertainty reflects large discrepancies, which might indicate large actual uncertainty. However, it should be noted that apparent uncertainty could not fully represent actual uncertainty, and apparent uncertainty would likely to be conservative estimates as it might be subjected to the datasets used. Thus small apparent uncertainty does not necessarily mean to small actual uncertainty. For example, the small apparent uncertainties before 1996 might become larger if a new energy dataset that revises the data of this period is included. We have clarified this in the Section 3.2 of the revised manuscript.

It would be useful if the authors could discuss a bit more possible reasons why the provincial and national statistics agree during earlier time periods. Was this because both of these statistics contained similar biases? Or were there some potential sources of bias that increased over this time period. The authors have substantial experience with these datasets and their insights (although likely no firm answers!) into these issues, and a more complete discussion would greatly strength and add to the value of this paper.

Response: Apparent uncertainties during the recent period of rapid growth (2004-2012) are higher than the early period (1996-2003), implying that the discrepancies might be accumulated and expanded for a period of rapid growth. For example, underestimates of the growth trends of small enterprises might result into accumulated underestimations. In this case, conducting censuses in some interval years could help to reduce the accumulated discrepancies. We have discussed this in the Section 3.2 of the revised manuscript.

SPECIFIC COMMENTS

In Table 1" is described as "The energy statistics for China used in this work." and IEA data are included in this table. However, the text states that "The IEA energy statistics were excluded from the emission calculations because they are based on NBS's national Energy Balance Sheets". Please clarify (I believe it is useful to have IEA data in Table 1, since it gives context for this widely used dataset, but perhaps add a footnote that these data are not used in the current work, or re-title the table.)

Response: We have changed the title of Table 1 as "The energy statistics for China involved in this work.", and add a footnote that the IEA energy statistics were used for comparison, but they were excluded from the uncertainty calculations in the current work. The IEA energy statistics are generally based on NBS's national Energy Balance Sheets, and currently quite consistent with CT-CESY-2C. They may soon be updated based on CT-CESY-3C. We have also changed the description in Section 2 accordingly.

Page 6, line 31 "contributions (approximately 70%) from industrial process emissions". It would be useful to clarify by adding (I assume this is the case) "contributions (approximately 70%) from industrial process emissions. Note that non-combustion emission uncertainty was not addressed in this

study."

Response: We have clarified this by adding "Note that non-combustion emission uncertainty was not addressed in this study." in the Section 3.2 of the revised manuscript.

This brings up an additional point. Were all fuel consumption differences assumed to be applied to combustion sectors? Or was some portion of these differences assumed to be feedstocks? This should be clarified in the paper.

Response: We only applied all the fuel consumption differences to the combustion sectors. In fact, differences in energy consumption would imply differences in feedstocks and products. However, the possible uncertainties in feedstocks and products resulted from energy uncertainties are not included in this study for some reasons. First, energy statistics and industrial products statistics in China are independent statistics. Inconsistencies may be existed between the energy data and the production data, and some studies used them for cross-checks (Guan et al., 2012; Korsbakken et al., 2016). Also, feedstocks and products usually have more detailed categories than energy sectors (e.g., iron and steel vs. industry sector). Thus, estimates of feedstocks and products based on energy data would introduce additional uncertainties. Without considering the possible uncertainties in feedstocks and products, our estimates of emission uncertainties are likely on the conservative side. We have clarified this in Section 2.2 of the revised manuscript.

Page 7, line 7 "The contributions of gas and other fuels are negligible because their emissions are relatively small." This is not necessarily true for biomass (which often contributes substantially to CO emissions in particular). I assume that uncertainty in biomass consumption was not included in this study? If uncertainty in biomass consumption was not considered this would be useful to state here (and also needs to be mentioned earlier in the methodology section).

Response: In the original manuscript, biomass emissions were put into “process emissions”. In the revised manuscript, to make it be more straightforward, biomass emissions were moved to “other fuels”, which also changed Figure 3 and Table 2. The contributions of gas and other fuels are negligible because uncertainties in biomass consumption are not included in this study and other emissions are relatively small. Note that biomass consumption, which is usually thought to be quite uncertain, would contribute more uncertainties in emissions. We have clarified this in the Section 2.2 and the Section 3.2 of the revised manuscript.

Page 8, line 23 "Third, although there is no ample evidence of such activity" ample is not quite the correct word to use here (is ambiguous). Depending on what the authors mean, a clearer words should be used.

Response: In order to avoid confusion, we have removed the sentence "although there is no ample evidence of such activity," in the revised manuscript.

Page 11, line 11 "Top-down estimates of the CO2-to-NOx emission ratios". Give the reader a short definition of how top-down differs from bottom up. Presumably this is observationally based?

Response: We have clarified this by adding "using satellite observations" in the revised manuscript.

Page 11, line 14. "The MEIC inventory reports a larger CO2 trend in China (10.4% yr-1) " it looks like this is not larger, it is well within the uncertainty of the top-down estimate.

Response: We have changed the word "larger" to "similar" in the revised manuscript.

page 11, conclusion section Re-define "apparent uncertainty" here so that the conclusion is more easily understood on its own.

Response: To re-define "apparent uncertainty" in the conclusion section of the revised manuscript, we have added the term "maximum discrepancy" after "apparent uncertainty", and the term "the ratio of the maximum discrepancy to the mean value" after "apparent uncertainty ratios".

Figure 5 is a bit difficult to interpret due to the many different parings of inventories. The authors might want to experiment to see if a consistent set of differences (e.g. showing the difference between each dataset vs one dataset that spans all years (if available) would communicate the points they wish to make, so that there is a consistent reference over the entire period). This might be more straightforward for the readers to interpret.

Response: We have combined different parings of the national statistics into one figure, and removed some figures. In the revised manuscript, Figure 5(a) compares different national statistics, showing that the coal consumption data from the national energy statistics were revised upward after the three censuses because of increasing coal production; Figure 5(b) shows that inconsistencies in interprovincial transport manifest as interprovincial net imports, resulting in a higher coal supply in the provincial energy statistics, implying that either coal production is underestimated or coal consumption is overestimated.

Reference

Guan, D. B., Liu, Z., Geng, Y., Lindner, S., and Hubacek, K.: The gigatonne gap in China's carbon dioxide inventories, Nat. Clim. Change, 2, 672–675, doi:10.1038/Nclimate1560, 2012.

Korsbakken, J. I., Peters, G. P., and Andrew, R. M.: Uncertainties around reductions in China's coal use and CO_2 emissions, Nat. Clim. Change, 1–5, doi:10.1038/ Nclimate 2963, 2016.

Liu, F., Zhang, Q., Tong, D., Zheng, B., Li, M., Huo, H., and He, K. B.: High-resolution inventory of technologies, activities, and emissions of coal-fired power plants in China from 1990 to 2010, Atmos. Chem. Phys., 15, 13299–13317, doi:10.5194/acp-15-13299-2015, 2015.

Zhang, Q., Streets, D. G., He, K., Wang, Y., Richter, A., Burrows, J. P., Uno, I., Jang, C. J., Chen, D., Yao, Z., and Lei, Y.: NOx emission trends for China, 1995-2004: The view from the ground and the view from space, J. Geophys. Res., 112, D22306, doi:10.1029/2007jd008684, 2007.

Zhang, Q., Streets, D. G., Carmichael, G. R., He, K. B., Huo, H., Kannari, A., Klimont, Z., Park, I. S., Reddy, S., Fu, J. S., Chen, D., Duan, L., Lei, Y., Wang, L. T., and Yao, Z. L.: Asian emissions in 2006 for the NASA INTEX-B mission, Atmos. Chem. Phys., 9, 5131–5153, 2009.

Zheng, B., Huo, H., Zhang, Q., Yao, Z. L., Wang, X. T., Yang, X. F., Liu, H., and He, K. B.: High-resolution mapping of vehicle emissions in China in 2008, Atmos. Chem. Phys., 14, 9787–9805, doi:10.5194/acp-14-9787-2014, 2014.