A Comparison of Methods and Results from the 2007 Benchmark USEEIO model and the 2002 EIO-LCA Model

By Yu Gan and H. Scott Matthews
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The following synthesis describes the various differences in how these models were constructed, so as to help users of these models (especially teachers of LCA courses that include content on IO-LCA models) better understand and explain differences in results. The goal is not to suggest that a particular model is better or worse, but given the long history of EIO-LCA model usage on the eiolca.net website, we sought to anticipate various inevitable user questions. We focus the comparison on economic, conventional air pollutant, and greenhouse gas emissions results. This report is intended to be the single "answers to Frequently Asked Questions" of this kind.

Introduction

By making the commitment of funding the development of a transparent and publicly available USEEIO model, the US EPA took a giant step forward in establishing capacity to support input-output based LCA models (aka IO-LCA models, or also Environmentally Extended Input-Output (EEIO) Models). As such, when EPA's intentions for USEEIO were announced several years ago, the Green Design Institute researchers at Carnegie Mellon ceased development of future EIO-LCA models since the effort would be costly (and, as generally true historically, unfunded) and duplicative – there is no reason to compete! Admittedly, we were pleased to not have to continue this long-term labor of love.

We have spent time familiarizing ourselves with the details of the USEEIO model. It is an exceptionally useful contribution and we are pleased to be allowed to include it on the www.eiolca.net website as a service to our colleagues who have been using these models in the past. But even amongst ourselves, we were curious whether the models were created differently, and how results would be different with a new team creating the relevant datasets. Knowing that many of our colleagues would begin using the USEEIO model via the website's interface, and knowing from experience that we would get e-mails asking for answers about why results differed, we undertook a detailed review of methods and results for two of the most popularly used datasets – conventional air pollutants and greenhouse gases. The following pages detail our findings and, more importantly, attempt to summarize what we have learned so that you may get up to speed on using the USEEIO model as well.

Let us be clear – our comparison was academic with no intended bias. We merely found the differences and generalized. While there are comparisons below that highlight stark differences in methods and results, none of our findings should be interpreted as being for or against either of the methods. Our team knows from experience over the past 20 years that the development of IO-LCA/EEIO datasets inevitably involves using best available or most appropriate data sources (even if imperfect) and more importantly, compromises. The same is true for what EPA's team had to do for the USEEIO model.

In the end, we believe USEEIO is a valuable contribution to the IO-LCA community and once again applaud EPA for having made such a significant investment in the field. It continues the legacy of developing datasets that be effectively used as screening tools to help create better LCA models.

1. Comparison of Economic Data and Results

As motivated in other places on our website and in other materials (e.g., our free LCA textbook at www.lcatextbook.com), the ideal type of economic input-output tables to use when making an IO-LCA model is the use of a "benchmark" table, which may be done less frequently than an annual table but typically has more resources devoted to its creation. Fortunately, the comparison we need to make is between two benchmark-sourced tables.

In this report, the "2002 model" referenced was developed by the Green Design Institute at Carnegie Mellon University (as the 2002 US EIO-LCA model) around the year 2007, using the official 2002 benchmark input-output table provided by the Bureau of Economic Analysis (BEA) of the Department of Commerce. The 2002 model fairly consistently uses economic data only from the year 2002 in the model.

The "2007 model" used in USEEIO was developed by US EPA in 2017 and uses the official 2007 benchmark input-output table from BEA. A slightly different effect is present in the model in that year 2013 dollars are used as the basis for demand (and normalizing environmental information, as described below). USEEIO's published analysis shows that this change in year basis (2013 instead of 2007) does not have a substantial effect on results, but its not negligible.

2. Comparisons of Conventional Air Pollutant Emissions

This section compares the conventional air pollutant (CAP) intensity used in the 2002 and 2007 models defined above.

In both models, life cycle CAP emissions of a sector are calculated by multiplying its direct and/or indirect economic purchases by the sectors' CAP emissions intensities. As generalized in Equation 1, pollutant intensity (in tonnes/million dollars) is calculated as the total quantity of pollutant emissions pertaining to the activity of a certain sector divided by the economic output of the sector. The data of the quantity of pollutant emissions pertaining to each sector was sourced from National Emissions Inventory (NEI) by Environmental Protection Agency (EPA). The sector economic output was provided by Bureau of Economic Analysis (BEA). As noted in the Economic Comparison section of the report, the normalization factor is \$2002 for the 2002 model and \$2013 for the 2007 model.

$$\text{Environmental intensity} = \text{emissions from sector} / \text{economic output of sector}. \qquad (1)$$

A general goal in making an IO-LCA model is to try to "match" the years of the economic and environmental data as closely as possible, but sometimes this is not possible due to data, time, or resource constraints. The 2002 model used NEI-2002 and BEA economic output data of year 2002 (i.e., the CAP data was matched to the same year but frankly this was happenstance that they all aligned). The 2007 model uses NEI-2011 and BEA-2011 economic data (normalized in 2013 dollars) to calculate the CAP intensity by sector (i.e., the data are 'mismatched' by several years).

This 'mismatch' is not inherently a model problem, but does cause some odd results and we try to organize the reasons for the differences below.

In both models, emissions intensities were multiplied by direct and indirect economic purchases to estimate life cycle environmental burdens of economic activities of different sectors. *The differences in the CAP intensity data between 2002 and 2007 model is the primary reason for the final LCA result differences of the two models*.

MAJOR DIFFERENCES OF CAP INTENSITY OF THE 2002 AND 2007 MODELS

- The supplemental excel file "*CAP comparison"* presents the raw sectoral CAP emissions intensity for different sectors of the 2007 model and 2002 model, and also compares them. These results are color-coded in various ways to help to identify large differences.
- For the seven types of CAP emissions (NO_x, NH_3, CO, PM10, PM2.5, VOC, SO_2) pertaining to the 388 sectors of the 2007 model, about 80% of pollutant intensity levels showed significant decreases as compared to that of 2002.
- About 15% of the pollutant intensity values show an increase and were generally concentrated in service sectors (e.g., Health care service, repair and maintenance service, etc.). A majority of sectors showed increase of pollutants intensity in selected types of pollutants, while occasionally almost all types of pollutants showed simultaneous increase.
- The pollutants that exhibited the most increase in pollutant intensity level were CO and VOC. Some of the increases were higher than 100%, and again these concentrate in CO and VOC.

EXPLANATIONS OF THE DIFFERENCES

1. **DIFFERENT DATA SOURCES -** As mentioned above, the 2002 model used emissions data of EPA NEI 2002 and economic data BEA 2002 to calculate pollutant intensity by sector, while the 2007 model used data of the year 2011 for the calculation. From 2002 to 2011, there was a general trend of decreasing pollutant emissions and increase in economic output across all sectors, resulting in overall lower pollutant intensities, potentially reflecting improved technology in regards of pollution reduction. Equation 1 helps to understand the effect of the decreasing numerator and increasing denominator. Details of this trend are discussed below.
   a) According to the published data from US EPA, the total national emissions has a decreasing

trend in almost all types of conventional air pollutants, as shown in Figure 1.

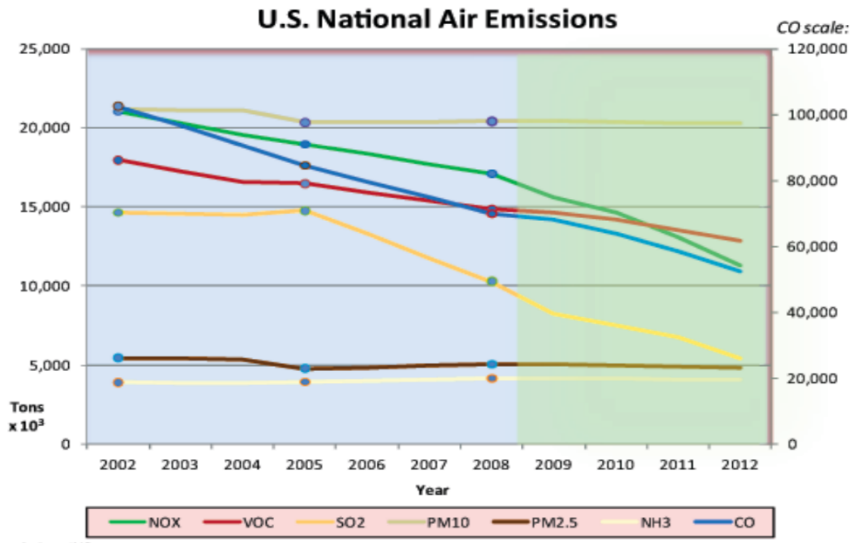

Figure 1 National Air Emissions, 2002-2012, excluding wildfires (from 2008 National Emissions Inventory[1])

Table 1 presents percentage changes of 2007 model compared to the 2002 model for four aggregated categories of air emissions (point, non-point, road, non-road).

Table 1 Percentage change of air emissions from 2002 model to 2007 model

	CO	NH3	NOX	PM10	PM2.5	SO2	VOC
Point	-10%	-12%	-42%	-82%	-42%	-58%	-20%
Non-point	-47%	-3%	152%	-37%	-5%	-56%	36%
Road	33%	74%	-28%	-58%	11%	-92%	-9%
Non-road	-59%	-9%	-73%	-99%	-62%	-100%	-43%
Total	-36%	-3%	-35%	-45%	-23%	-60%	6%

Note: The 2007 model used NEI 2011 as data sources to calculate the environmental intensity (R) matrix.

The total Point and Non-road emissions of 2007 model (using data NEI 2011) decreased in all seven types of conventional air pollutants when compared to the 2002 levels. For Non-point and Road emissions, a significant increase is witnessed for non-point NO_X and VOC emissions, road CO, PM2.5 and NH_3 emissions. In general, though, these decreasing trends suggest that we should expect there to be significant decreases in intensities (since the numerator of the intensity ratio is decreasing) given the nine-year difference in NEI data used.

b) According to the NEI report from EPA[1], one reason for the increase of road emissions is a change in the estimation method used. The 2007 model/NEI 2011 use the MOVES model to estimate on-road mobile source emissions, while NEI 2002 used the prior MOBILE6 model. The estimate of PM 2.5 is higher using the MOVES model than the previous model MOBILE6 because MOVES model included, amongst other factors, temperature impacts on PM2.5 and based on new emissions testing.

c) EPA has updated its estimation methods for non-point emissions for the 2007model/NEI 2011 compared to NEI 2002, especially for emissions associated with oil and gas production. EPA claimed that "the NEI likely underestimates oil and gas emissions" [3] and has developed the EPA Nonpoint Oil and Gas Emission Estimation Tool to estimate air emissions associated with upstream oil and gas production/transmission (e.g., emissions from lifting, pumping, and compressing engines, venting, flaring and fugitive emissions, etc.). These non-point emissions are not well reported in the previous NEI, thus the improvement of estimation method would cause increase of emissions intensity in oil and gas production sectors from 2002 model to 2007 model.

   The PM2.5 and VOC emissions intensity values for the sector *Oil and gas extraction* (211000) in the 2007 model has increased by 192% and 96% compared to the 2002 model, respectively. NH3 emissions intensity of *Natural gas distribution* (221200) has increased by 1907%. NO_X, CO, PM2.5 emissions of *Pipeline transportation* (486000) has increased by 760%, 128%, 2053%, respectively.

d) The economic output increases from 2002 to 2007 model (using data BEA 2011) for most of the industry sectors. According to BEA, the Gross Domestic Product increased by 41% from 2002 to 2011, and the valued add increased for most of the industry sectors in this period[2]. Like in section 1a) above, the increasing denominator of output will lead to a decrease in intensity for most sectors.

2. **A SMALL PORTION OF EMISSIONS WERE NOT ACCOUNTED FOR IN THE 2002 MODEL** In the 2002 model, for point and non-point pollutants, a small portion (less than 1%) of activity-associated emissions were not accounted for while establishing the model. The neglect of the above activities might be the reason of the extremely low (approaching zero) pollutant intensity in some related sectors in the 2002 model, which appears to be most prevalent in service sectors. In contrast, these activities were accounted for in the 2007 model,

thus there was a huge percentage increase as compared to the 2002 model, while the increase in absolute number might be trivial. Of note, the associated emissions in these sectors represents only a relatively small portion of emissions across all sectors. For example: In the 2002 model, the non-point emissions associated with the activity 2401100000 (SCC) are undercounted and not allocated to any of the sectors. However, in the 2007 model, emissions pertaining to the activity 2401100000 are accounted and allocated to the sector *Electronic and precision equipment repair and maintenance* (811200). Thus, it leads to the VOC emissions intensity of sector Electronic and precision equipment repair and maintenance increased from 0 in the 2002 model to 0.386 tonne per million dollars in the 2007 model.

3. DIFFERENT METHODS FOR MAPPING NEI EMISSIONS TO SECTORS IN THE IO TABLE In both models, the emissions pertaining to various activities in EPA NEI were independently mapped by researchers to a list of sectors in the IO-LCA Model. The potential difference between the 2002 and 2007 models regarding mapping would lead to different total emissions in the related sectors, resulting in different calculated pollutant intensity levels.

a) In the 2002 Model, 428 sectors were included while 388 sectors were included in the 2007 model, reflecting the difference in sector aggregation by BEA, thus the end-point of mapping. In the excel file *"CAP comparison",* the two versions were adjusted to the same aggregation level by combining certain branch sections, however residual difference may still exist.

b) More specifically for non-point pollutants, EPA NEI recorded the SCC of the activity of emissions, which were mapped to corresponding sectors in the IO Model. In most cases, the emission pertaining to each SCC code is allocated to multiple sectors in the associated IO Model. In 2002, allocation is solely based on economic output. While in 2007 model, the allocation is mainly based on industrial output, in some cases it was based on purchase of fertilizers and pesticides, and cropland area. For example, in 2007 model the emissions of the activity 2801000000 are allocated to different farming sectors 1111A0, 1111B0, 111200, 111300, 11190 according to farming area pertaining to different farming sectors. The difference in allocation leads to different final results of mapping, thus different pollutant emission intensities.

c) For on-road pollutants, in 2002 model emissions are mapped to 6 sectors (484000, 492000, S00201, 420000, 4A0000, 491000). However, in the 2007 model, on-road emissions are allocated to only two sectors (484000 and 485000).

To help understand the main comparative differences in a visual way, a color-coded table in the supplemental file "Categorized reasons of CAP changes" summarized the primary reason categories of CAP emission intensity changes and colored each intensity change by its corresponding reasons category defined above.

Beyond these comparisons, hopefully it is now more appreciable how different underlying datasets, techniques, and assumptions will have the effect of generating different intensities for sectors (and again, none of them being 'better'). We separately developed a research paper looking at how those differing sources and techniques could lead to variations in intensities at the sectoral level of IO-LCA models, recently published in Chen et al (2018)[5]. Copies available upon request.

References for the CAP subsection

1 Rao, V., Tooly, L., & Drukenbrod, J. (2013). *2008 National Emissions Inventory: Review, Analysis and Highlights* (No. EPA-454/R-13-005).
2 Website of U.S. Bureau of Economic Analysis (BEA): *https://www.bea.gov/national/.*
3 United States Environmental Protection Agency. EPA Inspector General Report 2013.
4.Eastern Research Group. 2011 Nonpoint Oil and Gas Emission Estimation Tool report
5. Xiaoju Chen, W. Michael Griffin, H. Scott Matthews, "Representing and visualizing data uncertainty in input-output life cycle assessment models", Resources, Conservation, and Recycling, Volume 137, October 2018, pp. 316-325. DOI: https://doi.org/10.1016/j.resconrec.2018.06.011

3. Comparisons of Greenhouse Gas Emissions

This section compares the greenhouse gas (GHG) emissions intensities in the 2002 and 2007 models defined above.

In both models, life cycle GHG emissions of a sector are calculated by multiplying its direct and indirect economic purchases by related sectors' GHG emissions intensities. The GHG emissions intensity (presented in tonnes/million dollars) is calculated as the total quantity of GHG emissions pertaining to the activity of a certain sector divided by the economic output of the sector. The GHG emissions pertaining to each sector was estimated by public energy consumption data and GHG inventory data by Environmental Protection Agency (EPA). The sector economic output was provided by Bureau of Economic Analysis (BEA).

As noted in the CAP section, a general goal is to try to "match" the years of the economic and emissions data as closely as possible, but sometimes this is not possible due to data, time, or resource constraints. The economic and GHG emissions data used in the 2002 model are from the year 2002. The 2007 model used GHG inventory data of year 2013 and BEA-2011 economic data (converted to 2013 dollars). Again, this 'mismatch' is not inherently a model problem, but does cause some comparative differences and we try to organize the reasons below.

MAIN FINDINGS OF THE COMPARISON

1. **The life cycle GHG emissions results of the two models are presented in different ways.** The 2002 model reported the GHG emissions in five GHG groups (fossil CO_2, process CO_2, CH_4, N_2O, HFC/PFC_s) measured in the unit of tonne of CO_2 equivalent (100 years global warming potential, GWP). The 2007 model presents 14 types of greenhouse gases, including CO_2, N_2O, CH_4, ethane 1,1,1,2-tetrafluoro-, ethane pentafluoro-, methane difluoro-, ethane 1,1,1-trifluoro-, propane 1,1,1,3,3,3-hexafluoro-, sulfur hexafluoride, methane trifluoro-, methane tetrafluoro-, ethane hexafluoro-, nitrogen fluoride, propane perfluoro-, and butane, perfluorocyclo-. The 2007 model reports the physical quantities of these 14 types of GHG emissions in the unit of kg. The 2007 model also reported the 100 years GWP of the total GHG emissions, which is calculated with the quantities of 14 GHG emissions and their corresponding GWP characterization factors.

2. **The GWP characterization factors used in the 2002 and 2007 model are different.** The characterization factors in 2002 model are adapted from the IPCC second assessment report (IPCC 1995)[1], which was still widely used at the time of making the 2002 model, while the 2007 model used the characterization factors adapted from the IPCC fourth assessment report (IPCC 2007)[2]. Appendix Table A-1 presents the differences of characterization factors in the two models (some are substantial). The differences of GWP characterization factors would lead to different results in GWP even if the physical quantity of GHG emissions were the same in the two models.

3. **There are no large differences between the life cycle GHG emissions results of the 2002 and 2007 models.** The attached excel file "*Comparison 2002 with 2007-GHG*" presents and compares the life cycle GHG emissions of 1 million dollar based economic activities of five representative sectors of *automobile (33611), electricity (221100), agriculture (115000), truck transport (484000),wholesale trade(420000)* estimated by the 2002 and 2007 models. In general, the GHG emissions of unit economic activities of the 5 sectors estimated by the 2002 model are of the same order of magnitude comparing with those of the 2007 model. The Excel file "*Comparison 2002 with 2007-GHG*" also lists the top 20 sectors contributing to the life cycle GHG emissions of the five sectors for the 2002 model and 2007 model respectively. Most of the top 20 sectors effected by the economic activities of the five sectors of the two models are overlapped (i.e., they are the same top 20 but might have moved up or down a few places).

4. **More than 70% of the GHG emissions intensities of sectors in 2007 model showed decreases as compared to the 2002 model.** The attached excel file "GHG emissions intensity comparison" presents both the absolute and percentage changes of the GHG emissions intensities for different sectors of the 2007 model compared with the 2002 model. According to the comparison, more than 70% of the sectors' GHG emissions intensities in 2007 model decreased from those of the 2002 model. About 10% of the sectors' GHG intensities of the model 2007 showed significant increase (increasing by more than 100%) when comparing with the 2002 model.

As mentioned above, the differences in the GHG intensity data between 2002 and 2007 model is the primary reason for the final LCA result differences of the two models. The following section will discuss the main reasons for the differences in the GHG emissions intensity of 2002 and 2007 model.

EXPLANATIONS FOR THE DIFFERENCES OF GHG INTENSITY OF THE TWO MODELS

The potential explanations of the GHG emissions intensity differences between the two models might be:

1. **The economic output of sectors used to calculate GHG emissions intensities in the two models are different.** The sector economic output data was provided by Bureau of Economic Analysis (BEA). The 2002 model used the BEA economic output data of year 2002, while the 2007 model used BEA-2011 economic data (converted in 2013 dollar[1]) to calculate the GHG emissions intensity by sector. The economic output increases from 2002 to 2007 model (using data BEA 2011) for most of the industry sectors. According to BEA, the Gross Domestic Product increased by 41% from 2002 to 2011, and the valued add increased for most of the industry sectors in this period[3].

2. **The total GHG emissions decreased in the period 2002 to 2013 (the year of data used to calculate GHG intensities of the 2007 model).** According to the EPA GHG emissions inventory, the U.S. total GHG emission decreased by 8% from 2002 to 2013, as shown in Figure 1. Given the trends of increasing economic output and decreasing GHG emissions, in general, we should expect the GHG emissions intensity decrease by 35% if the GWP characterization factors are not changed between the two models.

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[1] The life cycle inventory results of 2007 model are presented as total environmental emissions or resource use associated with producing one 2013 dollar worth of a commodity.

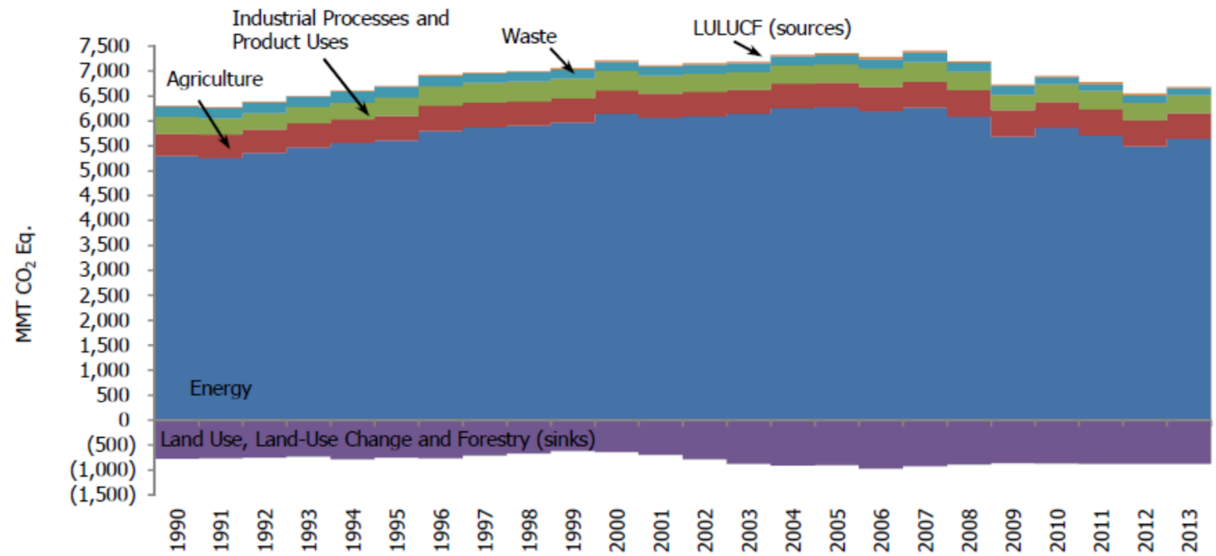

Figure 1: U.S. Greenhouse gas emissions and sinks 1990-2013. (Sourced from Inventory of U.S Greenhouse Gas Emissions and Sinks: 1990-2013[4])

3. **Data sources and methods to estimate GHG emissions of fuel combustion in the 2002 and 2007 model are different.** The GHG emissions include emissions from fossil fuel combustion and process (or non-combustion). Data sources and methods used to estimate GHG emissions from fuel combustion in the 2002 and 2007 model are different.

For the 2002 model, the estimation of GHG emissions from fossil fuel combustion was calculated by multiplying the quantity of fuel consumption (separately estimated as a dataset by sector) with their corresponding GHG emissions factors. The fuel use data of mineral, agriculture, manufacturing and transportation sectors in 2002 model were sourced from *2002 Fuel and Electric Energy Report*, 2002 Census of Agriculture, *2002 Manufacturing Energy Consumption Survey*, and *Transportation Energy Data Book*, respectively.

For the 2007 model, the GHG emissions associated with fossil fuel combustion of each sector are more grossly estimated by allocating the 2013 EPA's GHG inventory[5] to different sectors. In general, the emissions allocations are based on sectors' purchases of energy in the IO use table and public energy use data of sectors (such as EIA's *Manufacturing Energy Consumption Survey*, etc.). The detailed allocation method for the 2007 model can be found on EPA's website[5].

The different data sources and calculation methods resulted in different estimates of GHG emissions of fossil fuel combustion in the two models, leading to different GHG intensity of sectors.

4. **The methods to allocate process or *__non-combustion (process)__* GHG emissions of the two models are different.** In both models, the data of non-combustion GHG emissions are sourced from EPA's GHG inventory. The 2002 model used EPA's 2002 GHG inventory, and the 2007 model used EPA's GHG inventory of the year 2013. However, the methods for allocating the non-combustion emissions to sectors in the two models are different. For example, the CO_2 emissions associated with *non-energy use of fuels* are unallocated in the 2002 model, while in the 2007 model, these emissions were allocated to sectors based on sectors' energy use data, which might result in the increase of GHG emissions of the 2007 model comparing with the 2002 model. In the 2002 model, the GHG emissions associated with the *land use, land use change and forestry* (including emissions categories such as *Forest Land Remaining Forest Land, Cropland Remaining Cropland* in the EPA's GHG inventory) were unallocated in the 2002 model, while in the 2007 model, these emissions are allocated to relevant agriculture sectors. This resulted in the further decrease of GHG emissions for agriculture sectors in the 2007 model. Of note, the net CO_2 emissions associated with the *land use, land use change and forestry* are negative, which means the accounting of these emissions would lead to a decrease of the total GHG emissions.

5. **As the results of effort to phase out CFC_S and other Ozone Depleting Substances (ODS), the HFCs and PFCs emissions increased significantly in sectors that use refrigeration.** According to the Montreal Protocol and Clean Air Act Amendments of 1990, HFC_S and PFCs are acceptable alternatives to Ozone Depleting Substances. HFCs and PFCs emissions resulting from substituting the CFC_S and other ODS keep increasing since 1990, contributing the largest to the total HFCs and PFCs emissions of the year 2013 (the year of data used to calculate GHG intensities of the model 2007). These are also high GWP substances.
In the 2002 model, the HFCs and PFCs emissions due to the substitution of ODS were not allocated, leading to a relative underestimate of GHG emissions in relevant sectors. For the 2007 model (using data of year 2013), HFCs and PFCs emissions increased, and also were accounted for by sector, causing a significant increase of GHG emissions in the relevant

sectors that use refrigeration, such as the sectors *Household Refrigerator and Home Freezer Manufacturing (335222)*, and *Air Conditioning, Refrigeration, and Warm Air Heating Equipment Manufacturing (333415)*. The GHG emissions intensity of the sector *Household Refrigerator and Home Freezer Manufacturing (335222)* increased from 0.018 of the 2002 model to 0.034 tonne CO_2e/million dollars in the 2007 model, increasing by 85%. The GHG emissions intensity of the sector *Air Conditioning, Refrigeration, and Warm Air Heating Equipment Manufacturing (333415)* increased from 0.014 in the 2002 model to 0.021 tonne CO_2e/million dollars in the 2007 model, increasing by 47%.

As in the CAP section, a color-coded table in the supplemental file "Categorized reasons of GHG emissions changes" summarized the reason categories of GHG emissions intensity changes and colored each intensity change by its corresponding reasons category.

References for this subsection

1. Houghton, J. T. (Ed.). (1996). Climate change 1995: The science of climate change: contribution of *working group I to the second assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2). Cambridge University Press.
2. Solomon, S. (Ed.). (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4). Cambridge university press.
3. *Website of U.S. Bureau of Economic Analysis (BEA): https://www.bea.gov/national/.*
4. USEPA. (2015). Inventory of US Greenhouse Gas Emissions and Sinks: 1990–2013. *Washington, DC, USA, EPA*.
5. *Website of USEEIO Satellite Files: https://catalog.data.gov/dataset/useeio-satellite-tables.*

Appendix

Table A1 100 years global warming potential characterization factor of 2002 and 2007 model

Gas	2002 model/IPCC 1995	2007 model/IPCC 2007
CO_2	1	1
CH_4	21	25
N_2O	310	298
HFC-23	11700	14800
HFC-125	2800	3500
HFC-134a	1300	1430
HFC-143a	3800	4470
HFC-152a	140	--
HFC-227ea	2900	--
HFC-236fa	6300	9810

HFC-4310mee	1300	--
CF_4	6500	7390
C_2F_6	9200	--
C_4F_{10}	7000	--
C_6F_{14}	7400	--
SF_6	23900	22800
HFC-32	--	675
HFC-116	--	12200
NF_3	--	17200
C_3F_8	--	8830
PFC-318	--	10300