USEEIO v1.1 - Description of Satellite Table Updates

Aug 18, 2017

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USEEIO v1.1 is a minor update to the original USEEIO model, described in Yang et al. 2017 (1). This release includes two new satellite tables, Value Added and Employment, to support the calculation of socio-economic indicators. USEEIO v1.1 includes minor updates to all satellite tables. The updates include improvements to the modeling of animal manure-based nutrient emissions to water and corrections to crop N&P emissions, removal of GHG sequestration to balance the lack of inclusion of biogenic emissions and improvements to transportation-related emissions allocation, an update to the definition of energy for renewables, inclusion of biomass energy, and more precise allocation of renewable energy inputs to sectors, and an improvements in the PestLCI model used to estimate pesticide emissions. Agricultural pesticide emissions were removed from NEI because of their presence in the Pesticide table. Minor original name-to-USEEIO name mapping changes were made in NEI and TRI but those changes are reflected in the 'USEEIOv1.1 Elementary Flows and LCIA Factors' dataset. The BEA (2) released updated detailed output data and chain-type price indices for 2013 and 2014, which we have used to update all the satellite tables.

1. Value Added Satellite Table

The Value Added table is new for USEEIO. This dataset has value added per dollar industry sector output, based on the BEA input-output data (2), where value added is defined as the sum of compensation of employees, taxes on production and imports less subsidies, and gross operating surplus. BEA only provides data for value added for years since 2007 at the level of 71 sectors, whereas USEEIO covers 385 goods and services, and therefore an estimation procedure was required for using the most recent value added data for USEEIO. The value added coefficients are based on 2007 value added:output ratios that are adjusted for 2015 compensation levels. The following procedure is used to estimate value added coefficients for the detailed sectors for 2015.

1. Determine the ratio of value added 2007:total output 2007 per detailed industry, $VAR_{i.2007}$
2. Estimate 2015 value added by adjusting for 2015 totals

$$EVA_{i,2015} = VAR_{i,2007} * O_{i,2015} \qquad \text{[Eq. 1]}$$

where $EVA_{i,2015}$ is the initial estimate of value added for 2015, $VAR_{i,2007}$ is the value added:output ratio for industry i in 2007, and $O_{i,2015}$ is the reported gross output for the industry in 2015.

This results in a value added scaled to 2015 output, but the sum of the detailed industry (i, 389 overall) estimates within a sector (s, 71 overall) does not necessarily match the reported value added for the sector level, so therefore this must be adjusted.

3. The value added adjustment procedure is described in equations 3 and 4.

$$a_{i\ in\ s} = \sum_{i\ in\ s} \frac{EVA_{i,2015}}{VA_{s,2015}} \qquad \text{[Eq. 2]}$$

$$VA_{i,2015} = \frac{EVA_{i,2015}}{a_{i\ in\ s}} \qquad \text{[Eq. 3]}$$

where $VA_{s,2015}$ is the reported value added at the 71 sector level that includes industry i; $a_{i\ in\ s}$ is the adjustment factor for all industries i within sector s; $VA_{i,2015}$ is the adjusted estimate of value added for 2015 for industry i.

Following this procedure, the sum of the estimated value added at the detail levels for 2015 equals the sum of the value added reported. The adjustments for those detailed sectors within a 71 sector level are the same across that sector level. Reported $ value added/output for 2007 can be compared to the estimated $ value added/output for 2007. For instance, the farm sectors see a 10% decrease in value added/$ output. Figure 1 presents a box plot of the relative change in the estimate value added coefficients for 2015 relative to those reported coefficients in 2007.

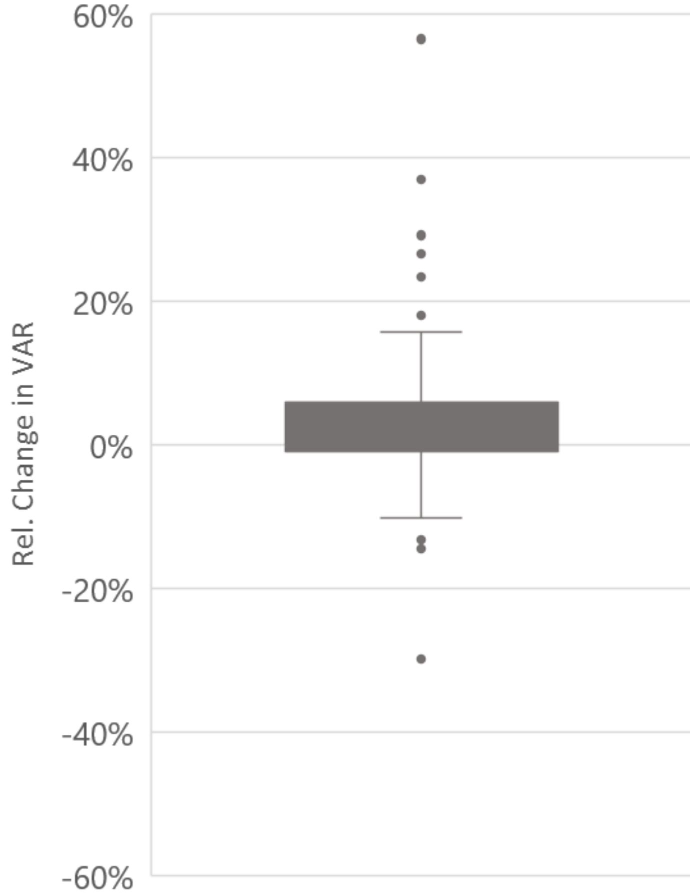

Figure 1. A box plot of relative change in Value Added Ratio from 2007 to 2015 for 389 industries, where the box represents the 25-75 percentile and the whiskers the 0 and 100 percentiles. One extreme point (97% for ‘Funds, trusts and other financial vehicles’) is not depicted.

The largest changes of 97% (‘Funds, trusts and other financial vehicles’) and 57% (‘Pipeline transportation’) are not based on estimate because the reported data matched the USEEIO sectors, and allocation was unnecessary. This result suggests that this estimated 2015 value added coefficients are largely within ±15% of 2007 coefficients.

2. Employment Satellite Table

The Employment satellite table is also new for USEEIO. Employment is tracked at a detailed level by the Bureau of Labor Statistics. We used 2014 data from the National Employment Matrix (3) to create a satellite table with value of jobs per dollar output. The ‘Total, all occupations’ item is selected as the measure of total employment (or jobs), and the data are filtered to select the best fit of the NAICS levels. The result are 228 employment totals that still required allocation to the 389 detailed industries in USEEIO except for the 1-to-1 correspondences. For that allocation, the same procedure – used for value added to get an adjusted estimated compensation by detail sector for 2015 – is applied, except that just the compensation values, and not total value added, are used.

1. Determine the ratio of compensation 2007:output 2007 per detailed industry, $CR_{i.2007}$
2. Estimate 2015 compensation by adjusting for 2015 totals, using equation 5,

$$EC_{i,2015} = CR_{i,2007} * O_{i,2015} \qquad \text{[Eq. 4]}$$

   where $EC_{i,2015}$ is the initial estimate of compensation added for 2015 and $O_{i,2015}$ is the reported gross output for the industry.

   This results in an estimated compensation scaled to 2015 output, but the sum of the detailed industry (i, 389 overall) estimates within a sector (s, 71 overall) does not necessarily match the reported compensation for the sector level, so therefore this must be adjusted.

3. The compensation adjustment procedure is described in equations 5 and 6.

$$a_{i\ in\ s} = \sum_{i\ in\ s} \frac{EC_{i,2015}}{C_{s,2015}} \qquad \text{[Eq. 5]}$$

$$C_{i,2015} = \frac{EC_{i,2015}}{a_{i\ in\ s}} \qquad \text{[Eq. 6]}$$

where $C_{s,2015}$ is the reported compensation at the 71 sector level that includes industry i; $a_{i\ in\ s}$ is the adjustment factor for all industries i within sector s; $C_{i,2015}$ is the adjusted estimate of compensation for 2015 for industry i.

The $C_{i,2015}$ is used to allocate the BLS job numbers across multiple industries using equation 8

$$J_{i,2014} = J_{j,2014} * \frac{C_{i,2015}}{\sum C_{i\ in j,2015}} \qquad \text{[Eq. 7]}$$

where $J_{j,2014}$ are the jobs in a given BLS sector that contain industry i, and $J_{i,2014}$ are the estimated number of jobs in an USEEIO industry, i. These values are then divided by industry output for 2014 and converted into 2013 USD.

3. N&P Satellite Table Updates

A. Nutrient releases to water from manure

In USEEIO v1.0 (1), we followed a simplified approach used in Kim and colleagues (4) to quantify nutrient losses to water from manure, based on animal population, excrement production, and generic runoff and leaching rates. In USEEIO v1.1, we apply a similar but much more comprehensive approach that also considers regional management practices and regional nutrient runoff rates. The approach has been developed by the US Environmental Protection Agency (EPA) to estimate indirect N_2O emissions from manure in the 2015 Greenhouse Gas Inventory (GHGI) (5).

The first step is to estimate livestock population by animal type by state for the latest year for which data are available (i.e., 2015). Data on animal population at the national level are from Table A-179 in EPA's 2015 GHGI Annexes. Next, state information for animal populations for 2015 from the NEI Ammonia database (6) is used to estimate animal population at the state level.

The second step is to estimate total manure nitrogen (N) and phosphorus (P) production for each animal type, based on animal mass and N and P production rates. Animal mass data are from Table A-180 in EPA's 2015 GHGI Annexes; manure N production rates are from Tables 181 and 182 in EPA's 2015 GHGI Annexes; and manure P production rates are from Table 8 in a US Department of Agriculture (USDA) report (7).

The third step is to understand how manure is managed for different animals. Table A-183 in EPA's 2015 GHGI Annexes includes waste management system data, which are used to estimate manure managed under different management systems.

The fourth step is then to quantify the total amounts of N and P in runoff by coupling results from above with management-based and regional release rates from Table A-188 in EPA's 2015 GHGI Annexes. Note that the GHGI Table A-188 only covers nitrogen, and the same rates are assumed for phosphorus releases (8). In addition, the loss rates represent runoff only as leaching was not considered by the EPA due to data gaps. The omission of leaching will lead to small to moderate underestimates of nutirent pollution from the livestock sector, as in general, runoff is the major source of nutrient releases, especially for phosphorus, for crop agriculture in USEEIO (1). Leaching will be considered in future updates.

The last step is to calculate N and P runoff intensities (kg/$) for each Input-Output (IO) sector. Nutrient runoff results from above are first aggregated by state and animal type to derive national and sectoral totals. Then, they are divided by sector output in 2015 to calculate intensity values (kg/$) in 2015 dollars, which are further converted to 2013 dollars using the sectoral price indices provided by the Bureau of Economic analysis. This analysis is recorded in the new N&P SI2 file.

We checked the N balance across all satellite tables by looking at the N by primary emission pathways (i.e. the calculated N lost to surface water, lost as N_2O, and lost as NH_3), primarily to verify that there was not an error in the mass balance. The results are summarized in Table 1.

Ammonia is the dominant pathway for losses, as the other losses are less than 1% of N generated. It is noteworthy that the GHG and NEI use different methods for estimating animal populations and total N generation rates.

Table 1. Manure N losses in USEEIO as a percent of N generated as estimated in this approach.

USEEIO/BEA Sector Name	% of N released to surface water	% of N emitted as N_2O[a]	% of N emitted as NH_3[b]
Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming	0.37%	0.2%	13%
Dairy cattle and milk production	0.54%	0.4%	18%
Animal production, except cattle and poultry and eggs	0.29%	0.4%	56%
Poultry and egg production	0.03%	0.2%	52%

[a] N_2O as N from the GHG satellite table, divided by N generated as estimated in this method
[b] NH_3 as N from the NEI satellite table, divided by N generated as estimated in this method

B. Corrections to crop N&P emissions

In the supporting information 1 (SI1) EXCEL file for N&P emissions in USEEIO v1.0, crop nitrogen runoff values were mis-referenced and have been corrected. In addition, an error in the molecular mass of phosphate fertilizer used to convert phosphate to phosphorus corrected.

4. GHG Satellite Table Updates

A. Removal of carbon sequestration

The primary source for the GHG satellite table is the US EPA GHG Inventory (GHGI) (5). In general, the GHGI separates out biogenic carbon activities, including those related to land use and land use change, from the primary inventory, according to UNFCC national GHG inventory conventions. As biogenic emissions are not included in USEEIO, it would not be appropriate to consider sequestration, or the biogenic carbon cycle would not be properly balanced. Ideally a proper accounting of both carbon sequestration in biomass and timed emissions of biogenic carbon could be accounted for. One challenge is to appropriately allocate sequestration to economic sectors. Forest sequestration was assigned to the forestry sector in USEEIO v1.0, but the majority of forest land in the US where sequestration is occurring is not regularly harvested and used in this sector. Additionally, lack of appropriate data on timing of biogenic emissions in reference to sequestration also prevents a proper accounting for the temporal aspect of global warming (9). Therefore, in the absence of both the proper inventory data and impact assessmemt methods for handling of biogenic carbon sequestration and release, biogenic sequestration is removed to avoid a misbalance of carbon accounting.

B. Improvements to transportation emissions allocation

Transportation fuel use data by fuel and vehicle type from the GHGI Annex are used. Vehicle types are assigned to the most appropriate transportation or industrial sector, or to personal consumption. These assignments are used to allocate non-CO_2 emissions, which are reported in the GHGI by vehicle type. For transportation-related CO_2 emissions that are provided by fuel rather than vehicle type in the GHGI, total percentage consumption of each transportation fuel by sector is derived, and these percentages are used to allocate the emissions.

5. Energy Satellite Table Updates

A. Redefinition of energy for hydro, wind, solar and geothermal

In USEEIO v1.0, there were differences in the way that total renewable energy was counted and estimated. EIA estimates primary energy of wind, solar, geothermal, and hydro based on applying the average efficiency of fossil fuel to steam electricity conversion to the electricity generation from these sources to estimate potential fossil energy replacement of renewables. In better keeping with a definition of primary energy as potential energy or exergy, the primary energy is assumed to be potential energy available in USEEIO v1.1. To get these estimates, notional efficiencies for electricity generation from Table F1 of the Annual Energy Review (10) are instead used. This requires a correction to the energy reported by EIA for renewables using the following equation:

$$RE_r * \frac{e_{fe}}{e_n} = RE_a \qquad \text{[Eq. 8]}$$

where RE_r is the renewable energy amount for a renewable source reported by EIA, e_{fe} is the fossil equivalent efficiency, or average efficiency of fossil fuel conversion to electricity for the given year (35.6% in 2015), e_n is the national average efficiency for electricity conversation for a given renewable fuel source and RE_a is the adjusted renewable energy for the fuel source. $\frac{e_{fe}}{e_n}$ is the adjustment ratio. See Table 2 for the adjustment ratios for the four energy sources.

Table 2. Notional efficiencies and energy adjustment ratios for hydro, wind, solar and geothermal.

Energy source	**Notional efficiency(e_n)**	**Adjustment ratio ($\frac{e_{fe}}{e_n}$)**
Hydro	90%	0.4
Wind	26%	1.37
Solar	12%	2.97
Geothermal	16%	2.23

B. More precise allocation of renewable energy to sectors

The allocation of the renewables to USEEIO sectors has been drastically improved. Previously allocation of all renewable for the non-electricity sector was done based on total energy purchased, without regard to their specific usage of renewables. In this update, a new energy source, the detailed EIA-923 survey (11) is used to allocate the renewables based on reported electricity generation from the specific renewable source. EIA-923 provides information on fuel use by fuel types for each reporter, as well as a NAICS code. Each facility is mapped to a USEEIO code by NAICS. A correspondence is created between the fuel types reported in EIA-923 and four renewable types, hydro, solar, biomass, and wind (no geothermal reported to be generated outside the electricity sector). Total energy minus energy captured directly by residences is aggregated by the renewable type and by USEEIO sector. For each sector, energy use of that type is divided by the use across all sectors to get an allocation factor. The total adjusted primary energy use for hydro, solar, wind and biomass where each allocated to the USEEIO sectors using those allocation factors. This update has improved the technological correlation data quality score for these exchanges from 5 to 1, except where the NAICS codes reported in EIA-923 do not correspond directly to a USEEIO sector and allocation across USEEIO sectors is needed, in which case a score of 2 is assigned. Table 3 shows the primary sectors where renewables were allocated.

Table 3. Sectors with greater than 1% of a share of the allocation of total renewable energy.

Sector Code	Sector Name	Biomass	Hydro	Solar	Wind
221100	Electric power generation, transmission, and distribution	38%	99%	98%	100%
322120	Paper mills	26%	<0.5%	<0.5%	<0.5%
322130	Paperboard mills	15%	<0.5%	<0.5%	<0.5%
322110	Pulp mills	14%	<0.5%	<0.5%	<0.5%
321100	Sawmills and wood preservation	3%	<0.5%	<0.5%	<0.5%
322210	Paperboard container manufacturing	3%	<0.5%	<0.5%	<0.5%

C. Inclusion of biomass and biofuel energy

Biomass-based energy was excluded in USEEIO v1.0, and is now included in v1.1. The total biomass energy value reported by EIA, minus the amount consumed by residential uses, is allocated to the sectors based on reported usage in EIA-923. It is notable that EIA-923 is a survey of biomass-based electricity and not other biomass-based energy sources (e.g., bioethanol).

6. Pesticide Satellite Table Updates

The pesticide emissions are estimated based on runs of specific crop-pesticide-location application scenarios using the PestLCI model as described in the USEEIO v1.0 manuscript (1). Since the completion of v1.0, additional runs of the model have been completed and minor corrections have been made. The model details are described in a manuscript that is still under review (12). Generally, the changes resulted in an increase in average estimated emissions to water and air (from 4.6% to 5.9%; and from 31.7% to 34.7% of pesticide applied to water and air, respectively), and a reduction in the emissions to groundwater (from 14.7% to 12.3%) of the pesticide applied. These results vary for specific pesticide and crop combinations.

7. Criteria Air Pollutant Satellite Table Update

The National Emissions Inventory (NEI) nonpoint source emissions dataset – one of the four components of the NEI used for creating this satellite table – reports emissions based by source classification codes (SCC) that describe specific emissions-generating activities. The SCC code 2461850000 describes agricultural pesticide application emissions, which includes pesticide active ingredient emissions as well as solvents. The pesticide active ingredient emissions to air are already considered with more recent data and more detailed modeling in the Pesticide Satellite table, and therefore active pesticide ingredient emissions from this SCC code were omitted from the Criteria Air Pollutant satellite table to prevent double counting. Emissions of individual VOCs associated with this SCC code were kept in the satellite table.

Appendix

Relative changes in all the direct emissions and resource use coefficients between USEEIOv1.0 and v1.1 are summarized in the USEEIO1.0vs1.1.xslx file.

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