The SAM used in our CGE model is constructed in five steps. Firstly, we build a preliminary SAM using IMPLAN data. Next, we clean the entries in this SAM to make it workable with our CGE model. Thirdly, we use biomass waste data to create a biomass sector that depends on other biomass-producing sectors. Then, we introduce a theoretical BECCS sector that uses this sector as an input. Fifth, we process the electricity generation sectors into three bundles – renewables, fossil fuels, and BECCS – which are themselves nested into a general electricity bundle. Finally, we balance the SAM and format it into a usable form for our CGE model.

To start, we build the preliminary SAM by first collecting US economic data from IMPLAN. We consider states in the PJM region[[1]](#footnote-1) and the Northeastern region.[[2]](#footnote-2) For each region, we aggregate economic data for all relevant states using IMPLAN. This procedure sums all economic activity for each sector across states. Next, we aggregate the region’s sectors according to the scheme described in Table 1. Using the aggregated data, we construct the social accounting matrix in IMPLAN and export it using IMPLAN’s Industry Detail format. This produces a table of industry inputs and outputs in millions of dollars which essentially describes each element of the SAM. We further process this table to produce a workable SAM.

|  |  |  |
| --- | --- | --- |
| Table 1. IMPLAN Sector Aggregation Scheme | | |
| **Aggregated Sector Name** | **Name in SAM** | **IMPLAN Sector Codes[[3]](#footnote-3)** |
| Crop Agriculture | AGR\_CRP | 1-10 |
| Livestock Agriculture | AGR\_LIV | 11-14 |
| Manufacturing | MAN | 17-18, 20-40, 50-145, 154-394 |
| Services | SER | 395-517 |
| Electricity Distribution | ELC\_DIST | 49 |
| Other Electricity Sources | ELC\_OTHER | 48 |
| Electricity from Fossil Fuels | ELC\_FF | 42 |
| Electricity from Hydroelectric Plants | ELC\_HYDRO | 41 |
| Electricity from Nuclear Power | ELC\_NUC | 43 |
| Electricity from Solar Power | ELC\_SOLAR | 44 |
| Electricity from Wind Power | ELC\_WIND | 45 |
| Electricity from Geothermal Power | ELC\_GEO | 46 |
| Electricity from Biomass | ELC\_BIOMASS | 47 |
| Forestry | FORE | 15,16,19 |
| Paper | PAP | 146-153 |
| Federal Government Enterprises | GOV\_FED\_ENT | 518-520 |
| State Government Enterprises | GOV\_STT\_ENT | 521-526 |
| Federal Government Employment | GOV\_FED\_EMP | 535-536 |
| State Government Employment | GOV\_STT\_EMP | 531-534 |
| Non-Industry Sectors | NonIndustry | 527-530 |
|  | | |

Now, we adjust the SAM by shifting certain transactions in each sector to make it compatible with our CGE model. Firstly, we remove self-transfers for three accounts: the federal government, the state government, and the representative household sector. Then, we modify the non-industry sector, so that it can be modelled as a good. To do so, we first shift non-industry transfers to the household sector instead into the labor sector; this adjustment essentially makes non-industries, such as scrap metal processing, dependent on household labor rather than households themselves. Then, we remove transfers from the non-industry sector into the investment sector. Lastly, we rescale the non-industry sector to its original size from before these changes. Next, we push industry tax payments into a tax sector which then transfers to the government. So, for example, if the paper sector transferred $5 million to the government, we modify the SAM such that the paper sector transfers this amount to a tax sector which then transfers its total tax revenue to the government. Finally, we zero entries below $1 million in the SAM to prevent numerical problems when running the CGE model. For the PJM region, this step drops 34 entries which make up $27 billion in transactions; this is a reasonably small amount, since this value comprises only 0.1% of the total transactions in the SAM.

Next, we add a biomass sector based on pre-existing biowaste production. We use biowaste production data for 2016 obtained from the US Department of Energy to record the total amount of biomass produced. Specifically, we collect data for three types of biomass – ag residues, manure, and forestry residues– which are produced by the crop agriculture, forestry, and livestock agriculture sectors in our SAM; this data is shown in Table 2 which lists biomass production by feedstock. We convert this production data into kWh using estimates of the bioenergy content of each feedstock; we then sum the bioenergy content of the feedstocks for the three biomass types. We add this information to the SAM by including a transfer from each biomass type’s respective sector to a biomass bundle. This biomass bundle then transfers its output to the biomass electricity sector. We also zero out any previous transfers from the livestock agriculture sector to the biomass electricity sector to prevent double counting use the same biomass. On the other hand, we do not zero out transfers from the crop agriculture and forestry sectors to the biomass electricity sector; this is because some crops and forestry products are purposefully produced for their energy content. In contrast, the ag and forestry waste in the biomass data consists of biomass waste that is not being used for any purpose. Hence, we do not need to zero out previous transfers in these sectors when adding the biowaste production data to the SAM.

|  |  |  |
| --- | --- | --- |
| Table 2. PJM Region Total Biomass Production in 2016 | | |
| **Biomass Type** | **Feedstock** | **Production (dt)** |
| Ag Residues | Barley straw | 455,933 |
|  | Corn stover | 143,086,211 |
|  | Cotton gin trash | 678,467 |
|  | Cotton residue | 2,469,185 |
|  | Noncitrus residues | 1,856,490 |
|  | Tree nut residues | 16,218 |
|  | Wheat straw | 13,648,182 |
| Forest Residues | Hardwood, lowland, residue | 13,236,393 |
|  | Hardwood, upland, residue | 9,003,948 |
|  | Mixedwood, residue | 8,635,008 |
|  | Other forest residue | 40,484,296 |
|  | Primary mill residue | 2,130,720 |
|  | Secondary mill residue | 11,920,344 |
|  | Softwood, natural, residue | 3,705,608 |
|  | Softwood, planted, residue | 2,078,731 |
| Manure | Hogs, 1000+ head | 23,844,275 |
|  | Milk cows, 500+ head | 5,152,742 |
|  | | |

Next, we add a theoretical BECCS sector to the SAM. We model transfers to and from the BECCS sector based on the transfers of the pre-existing electricity generation sectors. We then scale the BECCS sector to a size proportional to the amount of biowaste energy available. That is, for a region and year, we first compute the total amount of biowaste energy (MW) available. Next, we multiply this value by a hypothetical efficiency factor that denotes the percent of energy that a BECCS plant could capture from a source of biomass input. Finally, we multiply this value – the energy production of a BECCS plant using the biowaste of a particular region – by the average price of electricity ($/MW). [[4]](#footnote-4) This final result represents the dollar value of energy production for a hypothetical BECCS plant; therefore, it is the size of the BECCS sector in our SAM. Then, we create a strong dependency on the biomass sector; 20% total transfers out of the BECCS sector is assumed to be spent on its biomass input. Finally, we assume that the BECCS sector does not rely on any direct imports.

Fifth, we bundle the electricity sectors. To start, we create a renewable energy bundle which consists of the electricity sectors for biomass, hydroelectric power, nuclear, solar, and wind. We also include the “Other” electricity sources sector in the renewable bundle, since it is electricity generation that is not from fossil fuels. This is because fossil fuel derived electricity already appears as a bundle in the IMPLAN data. Additionally, we include a small amount factor inputs into the renewable bundle to account for the cost of electricity transmission; each factor input is set to be equal to 1% of the respective factor input into the electricity distribution sector. Now, at this stage, we have three separate electricity sectors of interest: renewables, fossil fuels, and BECCS. These three sectors are all bundled again into a larger electricity sector to complete the electricity nest.

Finally, we balance the SAM using the cross-entropy method. This method balances the SAM by minimizing the Kullback-Leibler (KL) divergence between each entry of the original SAM and the new SAM while balancing the input and output totals; KL divergence measures the difference in information between two probability distributions. In this case, keeping KL divergence minimized reduces the difference in information between the original and balanced SAM. As a result, the cross-entropy method helps keep the information content of our SAM stable through the balancing procedure. Once we balance the SAM, we format it into a readable file which is used by our CGE program.

1. We include any state that is partially or fully in the PJM interconnection; these states are: Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. [↑](#footnote-ref-1)
2. The Northeastern region of the US consists of Maine, New York, New Jersey, Vermont, Massachusetts, Rhode Island, Connecticut, New Hampshire, and Pennsylvania. [↑](#footnote-ref-2)
3. IMPLAN Sector Codes refers to codes for economic sectors detailed [here](https://implanhelp.zendesk.com/hc/en-us/articles/115009674428-IMPLAN-Sectoring-NAICS-Correspondences). The Name in SAM column provides shorthand notation for each sector in our SAM and CGE code. [↑](#footnote-ref-3)
4. Data on the average price of electricity is available through the EIA’s Electricity Power Monthly [dataset](https://www.eia.gov/electricity/monthly/) in Table 5.6.A. [↑](#footnote-ref-4)