Notice of Retraction

After careful and considered review of the content of this paper by a duly constituted expert committee, this paper has been found to be in violation of IEEE’s Publication Principles.

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Study on the Calculation Method of Carbon Dioxide Emissions for a City

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Abstract—A calculation method of carbon dioxide emissions for a city was studied in this paper. Based on the NICE model developed by AIST Japan, power supply was taken into account; a power carbon emission coefficient for a city was defined and calculated in a case study. The calculation work of carbon dioxide emissions in a city was for six departments: agriculture, industry, and construction, tertiary-industry, transportation and the people’s living. This method amends the problem existing in traditional methods that neglect accounting the emissions of carbon dioxide produced during exogenous power. Finally, the paper took the case of Suzhou city as an example, and it is found that this calculation method is efficient to audit a city and also an industrial park.

Keywords- CO$_2$ emission factor of electricity supply; carbon dioxide emissions of a city

I. THE DOMESTIC CONDITION

The study of CO$_2$ emission calculation method in our country started fairly late. The main approach is to work out the total quantity of main energy, such as coal, oil and gas in a city firstly, and multiply the CO$_2$ equivalent coefficient to get the amount of CO$_2$ by using energy, and finally the data will be added for total CO$_2$ emissions for a city [1]. The disadvantage is that the regional network for the city which will provide the electrical discharge of CO$_2$ is not calculated, or inaccurate, and this should be part of the total emission and sometimes even important component.

II. THE COMPUTATIONAL METHOD OF CO$_2$ EMISSION FACTOR OF ELECTRICITY SUPPLY FOR A CITY

In the CO$_2$ emission factors of all the energies, the one of electricity supply is the only one which requires a series of calculations to be obtained. So we will focus on the computational method of the CO$_2$ emission factor of electricity supply here.

The electricity supply mode of an area should be known firstly in order to calculate the CO$_2$ emission factor of electricity supply of the area. Different areas have different modes of electricity supply, but they can be generally divided into 3 situations following: (1) supplied by the thermal power plants of the area; (2) supplied by the region power grid; (3) supplied by both the thermal power plants and the region power grid, the CO$_2$ emission factor for this situation should be calculated as the weighted average of the CO$_2$ emission factors for the power system and the thermal power plants. Because the computational method of the third situation includes the ones for the former 2 situations, so the third electricity supply mode will be highlighted in this paper.

A. Calculate electric power and proportion supplied by both the thermal power plants and the region power grid

Firstly, the power supply volume of the thermal power plants is needed as the Q$_1$, the data can refer to the local statistical yearbook. If the Q$_2$ which is the power supply volume from the region power grid is hard to be consulted, use the following formula to compute: Q$_2$(power volume from the region power grid) = Q(the total power consumption of the region) – Q$_1$(power supply volume from the thermal power plants). And the Q can then refer to the statistical yearbook.

The W$_1$(the proportion of power supply from the thermal power plants in the region), and W$_2$(the proportion of the power supply from the regional power grid in the region) can then be calculated with Q$_1$, Q$_2$, Q.

B. Calculate the CO$_2$ emission factor for electricity supplied by the thermal power plants

CO$_2$ emission can be calculated by multiplying the consumption of a certain energy by a emission factor. “Fig 1” lists some CO$_2$ emission factors of certain energies. [2]

<table>
<thead>
<tr>
<th>Certain energy</th>
<th>SCE</th>
<th>Coke</th>
<th>Crude oil</th>
<th>Petrochemical products</th>
<th>Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission factors</td>
<td>0.67</td>
<td>0.796</td>
<td>0.543</td>
<td>0.543</td>
<td>0.404</td>
</tr>
</tbody>
</table>

Firstly, the energy consumption of the thermal power plants could be found in the Local Statistical Yearbook. CO$_2$ emission can be found by the equation:

\[ \text{Total carbon dioxide emissions} = \Sigma \text{Energy consumption} \times \text{Emission factor} \] (1)

C. Calculate the CO$_2$ emission factor of the region power grid

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Because a region is a part of the region power grid. For example, East China Grid Company Limited provides electric power to Shanghai, Zhejiang, Jiangsu, Fujian and Anhui provinces. Calculation on the CO₂ emission factor of the region power grid can be divided into the following three steps.

1) Search electric power and proportion supplied by the region power grid
   “Fig 2” could be obtained through access to relevant information.

2) Calculate the CO₂ emission factor of thermal power of the region power grid
   Because power supply at this stage are mainly dominated by thermal power in our country, the raw materials supplied by thermal power including coal, fuel oil and natural gas. The CO₂ emission factor of thermal power of the region power grid could be calculated according to the consumption of coal, fuel oil and natural gas used in thermal power. So “Fig 3” is to be completed.

Finally, \( Y \) is the CO₂ emission factor for thermal power of the region power grid could be calculated.

3) Calculate the CO₂ emission factor of thermal power of the region power grid
   \( Y \) could be calculated according to \( Y \) (the CO₂ emission factor of thermal power of the region power grid) and \( b_2 \) (the proportion of thermal power supplied by the region power grid) in table 3. The equation is:
   \[
   Y = Y_1 \times b_2 \tag{2}
   \]

D. Calculate the CO₂ emission factor of electricity supply in a region
   Finally, \( Z \) (the CO₂ emission factor of electricity supply in a region) could be calculated by weighted average of \( X \) (the CO₂ emission factor of electricity supplied by the thermal power plants) and \( Y \) (the CO₂ emission factor of the region power grid). The equation is:
   \[
   Z = X \times W_1 + Y \times W_2 \tag{3}
   \]

III. INTRODUCTION OF THE AUDIT METHOD OF CITY’S CARBON DIOXIDE EMISSIONS
   The CO₂ emission of a city usually considers the following sections: agriculture, industry, construction, tertiary-industry, transportation and the people’s living. Firstly, the energy consumption of each section should be calculated and the energies should be divided into electric power resources and non-electric power resources. The CO₂ emission caused by electric power resources can be calculated by multiplying the kilowatts of electric power consumption and the CO₂ emission factor for regional power which has been already calculated in the former section. The CO₂ emission caused by the non-electric power resources can be calculated by multiplying the consumption of a certain energy and the corresponding CO₂ emission factor which is shown in details in list 2. Finally, the CO₂ emissions calculated by each section could be added as the CO₂ emissions of a city. The CO₂ discharged by the exogenous power generation of the regional system could be also included with this method.

The Specific calculation steps followed as below:
   a) Compute the CO₂ emission coefficient of the city electricity. Specific methods can refer to the previous section.
   b) Compute the CO₂ emission load of six sectors including industrial, agriculture, construction industry, the service, transportation, and citizen life. As the industrial sector usually takes large CO₂ emission load, specific statistics is needed for the kinds and the quantity of energy consumption in the industrial sector. As for the industrial sector, the CO₂ emission is mostly from the use of coal, oil and natural gas; as for the agriculture, construction industry and the service sectors, it is mostly from the power consumption, as for the transportation, it is mostly from the consumption of oil and power, and as for the citizen life, it is mostly from the consumption of the natural gas and power.
   c) Add all the CO₂ emission load from the second step to the seventh step which are the all six departments to get the total CO₂ emission load of the city.

IV. THE CALCULATION OF SUZHOU CITY CARBON DIOXIDE EMISSIONS
   The following takes the case of Suzhou city as an example, and to calculate carbon dioxide emissions from 2005 to 2008 for Suzhou city.

   A. Calculate the CO₂ emission factor of electricity supply of Suzhou city
      According to the procedure described in Section III, the CO₂ emission factor for electricity supply of Suzhou city from 2005 to 2008 should be calculated firstly.
      1) Calculate the CO₂ emission factor for the region power grid of Suzhou city
         Through the investigation it is found that East China Grid Company Limited provides electric power to Shanghai, Zhejiang, Jiangsu, Fujian and Anhui provinces. The East China power grid mostly use the thermal power generation, and the proportion of the thermal power generation is about the 90%. Coal, fuel oil, natural gas are the raw materials for the thermal power generation. The regional CO₂ emission factor of the thermal power supply can be calculated with
the usage of coal, fuel oil and natural gas for the regional thermal power generation. As is to calculate the factor of Suzhou City, so only the values of Jiangsu Province are selected here.

Finally, The CO2 emission factor supplied by thermal power of East China power grid could be calculated by equation (2) combining the proportion of thermal power.

Table 4. The CO2 emission factor of electricity supplied by East China power grid

<table>
<thead>
<tr>
<th>Year</th>
<th>Proportion</th>
<th>Emission factor</th>
<th>Emission factor</th>
<th>The CO2 emission factor of electricity supplied by East China power grid (g-C/KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>46.41%</td>
<td>223.11</td>
<td>53.59%</td>
<td>208.23</td>
</tr>
<tr>
<td>2006</td>
<td>80.35%</td>
<td>221.77</td>
<td>19.65%</td>
<td>208.02</td>
</tr>
<tr>
<td>2007</td>
<td>85.52%</td>
<td>217.08</td>
<td>14.48%</td>
<td>189.42</td>
</tr>
<tr>
<td>2008</td>
<td>81.31%</td>
<td>215.07</td>
<td>18.69%</td>
<td>189.42</td>
</tr>
</tbody>
</table>

2) Calculate the CO2 emission factor of electricity supply of Suzhou city

The CO2 emission factor of electricity supply of Suzhou city could be calculated by weighted average of the CO2 emission factor of electricity supplied by the thermal power plants and the CO2 emission factor of East China power grid.

Table 5. The CO2 emission factor of electricity supply of Suzhou city

<table>
<thead>
<tr>
<th>Year</th>
<th>Proportion</th>
<th>Emission factor</th>
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<tbody>
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</tr>
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</table>

B. The energy consumption of the various departments in Suzhou

With all the methods stated above, separately calculation is needed in the six departments including industry, agriculture, construction, tertiary industry, transportation, and people’s living. First of all collective statistics of energy consumption in every department with the different kinds of energy it consumed. As for the agriculture, industry, construction and service sectors, the main energy consumption is power consumption; as for the industry, energy consumption mostly by coal, oil and natural gas; as for the transportation, mainly power and oil consumption; as for the people’s living, mostly power and natural gas consumption.

The specific energy consumption data in “Fig 6” is from the Statistical Yearbook of Suzhou City. The energy consumption statistic of the industrial sector is more complex, so the energy consumption statistic of the industrial sector is not listed due to limited space. (The unit of electricity consumption is Million kwh. The units of fuel and natural gas consumption are million liters and million cubic meters.)

Table 6. The energy consumption of the various departments in Suzhou

<table>
<thead>
<tr>
<th>Departments</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>78489965</td>
<td>85507462</td>
<td>89169432</td>
<td>104397836</td>
</tr>
<tr>
<td>Agriculture</td>
<td>233861</td>
<td>235771</td>
<td>242033</td>
<td>238700</td>
</tr>
<tr>
<td>Construction industry</td>
<td>574233</td>
<td>522067</td>
<td>494129</td>
<td>559394</td>
</tr>
<tr>
<td>Tertiary industry</td>
<td>2788227</td>
<td>3489130</td>
<td>3957627</td>
<td>4575098</td>
</tr>
<tr>
<td>Transport</td>
<td>802149</td>
<td>936962</td>
<td>1118355</td>
<td>1432123</td>
</tr>
<tr>
<td>Citizen life</td>
<td>3041119</td>
<td>4013962</td>
<td>37903</td>
<td>37348</td>
</tr>
</tbody>
</table>

C. Total carbon dioxide emission of Suzhou city

The CO2 emission of Suzhou city could be calculated by adding the CO2 emissions of the six departments. If the sector is power consuming one, multiply the power consumption with the CO2 emission index of the city to get the CO2 emission load of this sector, if it is not power consuming one, multiply the energy consumption with the related index to get the CO2 emission load of this sector.

Table 7. Total carbon dioxide emission of Suzhou city

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</table>

V. CONCLUSIONS

The CO2 calculation of a city in our country is still at an elementary stage. This paper describes a new set of computation to calculate CO2 emissions of a city. Some problems of the traditional way which ignores CO2 emission from the exogenous generation or not accurate enough are fixed. The total emissions of a city are the sum of CO2 emissions from agriculture, industry and construction, tertiary-industry, transportation and the people’s living.

This method calculates the discharge of CO2 by electricity both in the regional area and in the town. With this calculation, the reduction of CO2 emission from local power stations will effectively reduce the city CO2 emissions. And this will greatly push forward using new energy and low carbon energy in urban areas, and make contributions to emissions reduction of CO2. Certainly, the calculation method also needs to be improved. Accordance with this method, it is more suitable for calculating the power discharge of CO2 in provinces, cities, counties and industry gardens, not for a small area.
REFERENCES


