Update Log for China's Electricity Database

Feb, 2023 by Dr. Xu, reviewed by Bill Kung

Background: With the advancement of China's power generation technology and the adjustment of power structure, the reduction of fossil fuels required per kWh of electricity supplied by the power grid, and the improvement of environmental monitoring data, the emission of carbon dioxide, methane, nitrous oxide and other pollutants per unit of electricity will also change accordingly. Therefore, the electricity data in the database also needs to be adjusted and updated according to the actual situation, and if outdated energy data is used as input, it may lead to high product life cycle emissions. Based on this, to truly reflect the environmental impact of products due to electricity consumption, this article updates the consumption of fossil fuels per unit kWh of electricity (electricity) in the whole country, region and provinces, as well as greenhouse gas emissions.

Update steps:

1. Obtain the provincial thermal power generation and fossil fuels consumption from the *Statistical Yearbook of China's Energy 2021*;
2. Obtain the net calorific values and the default carbon dioxide emission factors of different types of fossil fuels from *Statistical Yearbook of China's Energy 2021* and *National Guidelines for Provincial Greenhouse Gas Inventories;*

Table 1 Carbon content, oxidation rate, and lower heating value of different kinds of fossil fuels

	Carbon Content	Oxidation rate	Lower heating value
	g carbon/MJ	%	MJ/t fuel or MJ/10,000 m^3 gas
Raw Coal	26.37	98	20,908
Cleaned Coal	25.41	98	26,344
Other Washed Coal	25.41	98	10,454
Briquette	33.56	98	17,584

Coke	29.42	93	28,435
Coke Oven Gas	13.58	99	173,535
Other Gas	12.20	99	202,218
Crude Oil	20.08	98	41,816
Gasoline	18.90	98	43,070
Diesel	20.20	98	42,652
Fuel Oil	21.10	98	41,816
Liquefied Petroleum Gas	17.20	99	50,179
Refinery Gas	18.20	99	45,998
Natural Gas	15.32	99	389,310
Other Petroleum Products	20.0	98	35,168
Other Coking Products	29.42	93	38,099
Gangue	25.8	98	8,363
Blast Furnace Gas	70.8	99	37,630
Converter Gas	46.9	99	79,450
Petroleum Coke	27.5	98	31,947
LNG	15.32	99	51,434

CO_2 emission factor can be calculated as follow:

$$Co_{CO2,k} = CC_k \times R_{C,k}/100 \times 44/12$$

Where, $Co_{CO2,k}$ denotes CO_2 emission factor (g CO_2/MJ) of fossil fuel type k, $R_{C,k}$denotes oxidation rate (%), CC_kdenotes carbon content (g carbon/MJ).

3. Obtain the default methane and nitrous oxide emission factors from *2006 IPCC Guidelines for National Greenhouse Gas Inventories*;
4. Calculate calorific value of different types of fossil fuels and the carbon dioxide, methane, nitrous oxide emission of different types of fossil fuels based on the methods proposed in *2006 IPCC Guidelines for National Greenhouse Gas Inventories*;

$$Cal_{i,k} = C_{i,k} \times H_k \times 10000$$

$$E_{CO2,i,k} = Cal_{i,k} \times Co_{CO2,k}/1000$$

$$E_{CH4,i,k} = Cal_{i,k} \times Co_{CH4,k}/1000$$

$$E_{N2O,i,k} = Cal_{i,k} \times Co_{N2O,k}/1000$$

Where, $Cal_{i,k}$ denotes calorific value of province i and fossil fuel type k (MJ), $C_{i,k}$ denotes fossil fuel type k consumption in province i (10^4 t or 10^8 m^3); H_k denotes lower heating value of fossil fuel type k (MJ/t fuel or MJ/10,000 m^3 gas), $E_{CO2,i,k}$ denotes CO_2 emissions of fossil fuel type k in province i (kg CO_2), $E_{CH4,i,k}$ denotes CH_4 emissions of fossil fuel type k in province i (kg CH_4), $E_{N20,i,k}$ denotes N_2O emissions of fossil fuel type k in province i (kg N_2O), $Co_{CH4,k}$ denotes CH_4 emission factor of fossil fuel type k(g CH_4/MJ), $Co_{N2O,k}$ denotes N_2O emissions of fossil fuel type k (g N_2O/MJ)。

5. Thermal power plants consist of coal-fired power plant, oil-fired power plant, gas-fired power plant. There are several kinds of fossil fuels used as inputs in the three kinds of thermal power plants, shown in the Table 2.

Table 2 Fossil fuels used in thermal power plants

Type of Thermal Power Plants	Type of Fossil Fuels
Coal-fired power plant	Raw coal, Refined coal, Other coal, Briquette, Coke, Other Coking Products, Gangue, Petroleum Coke
Oil-fired power plant	Crude oil, Gasoline, Diesel, Fuel oil, Other Petroleum Products
Gas-fired power plant	Natural gas, LNG, Coke Oven Gas, Other Gas, Blast Furnace Gas, Converter Gas, Refinery Gas

6. Obtain the auxiliary power ratio in different provinces from the *2018 Statistics of Electric Power Industry.* Assuming that different kinds of thermal power plants share the same auxiliary power ratio within each province. Assuming that the electricity generation of these three kinds of thermal power plants is proportional to the calorific values of the fossil fuels they each consumed (calculated by standard coal). Then we calculate the electricity supply from coal-fired, oil-fired and gas-fired power plants. The process is expressed as:

$$Q_{s,i,j} = Q_{p,i,j} \times (1 - \varphi_{i,j})$$

where , $Q_{s,i,j}$ and $Q_{p,i,j}$ denote the electricity supply and electricity generation respectively by different provinces and techniques (10^8 kWh), $\varphi_{i,j}$ denotes the auxiliary power consumption ratio of thermal power plants in different provinces (%).

Table 3. Electricity supply by thermal power plant types and provinces

Province	Total Electricity Supply	Electricity Supply by Coal-fired Power Plants	Electricity Supply By Gas-fired Power Plants	Electricity Supply By Oil-fired Power Plants
	10^8 kWh	10^8 kWh	10^8 kWh	10^8 kWh
Beijing	445.47	8.53	360.09	0.57
Tianjin	731.51	482.24	191.70	7.97
Hebei	3260.93	1989.40	614.27	1.08
Shanxi	3284.85	2577.28	212.65	0.31
Inner Mongolia	5461.07	4445.99	46.77	0.47
Liaoning	2019.63	1261.06	131.21	1.66
Jilin	960.17	640.97	13.20	0.82
Heilongjiang	1075.10	757.29	22.95	0.29
Shanghai	821.62	611.33	149.91	1.52
Jiangsu	4991.37	3510.20	612.43	0.67
Zhejiang	3359.41	2020.51	164.95	0.47
Anhui	2688.76	2213.79	97.97	0.18
Fujian	2544.93	1323.31	102.60	0.39
Jiangxi	1384.84	995.43	60.38	0.09
Shandong	5428.13	4381.06	177.39	1.12
Henan	2780.56	2177.61	101.20	1.10
Hubei	2949.76	1043.15	70.83	1.51
Hunan	1504.40	659.36	69.78	2.22
Guangdong	4973.72	2515.12	641.85	9.70
Guangxi	1895.02	846.33	91.67	0.20
Hainan	322.76	165.00	24.27	0.01
Chongqing	799.92	433.45	38.98	0.20
Sichuan	4156.22	355.41	82.56	0.76
Guizhou	2195.98	1161.73	40.58	1.20
Yunnan	3635.86	333.78	33.98	0.20
Shaanxi	2235.84	1710.88	174.86	0.20
Gansu	1706.05	809.38	9.74	0.07
Qinghai	943.37	97.56	0.60	0.02
Ningxia	1751.60	1376.55	24.97	0.13
Xinjiang	3840.70	2937.50	56.03	0.20

7. Calculate the amount of hard coal/oil/gas consumption per kWh electricity supply by coal-fired/oil-fired/gas-fired power plants in different provinces. The process is expressed as:

$$P_{coal,i,k} = C_{i,k} \times 10000000/Q_{s,i,j}/100000000$$

$$P_{gas,i,k} = C_{i,k}/Q_{s,i,j}$$

$$P_{oil,i,k} = C_{i,k} \times 10000000/Q_{s,i,j}/100000000$$

Where , $P_{coal,i,k}$and $P_{oil,i,k}$ denote the hard coal and oil consumption respectively per kWh electricity supply by coal-fired and oil-fired power plants in different provinces (kg/kWh), $P_{gas,i,k}$ denotes the gas consumption respectively per kWh electricity supply by gas-fired power plants in different provinces (m^3/kWh).

8. Calculate the carbon dioxide, methane, nitrous oxide emissions per kWh electricity supply by coal-fired/oil-fired/gas-fired power plants in different provinces. The process is expressed as:

$$GH_{CO2,i,j} = \Sigma E_{CO2,i,k}/Q_{s,i,j}/100000000$$

$$GH_{CH4,i,j} = \Sigma E_{CH4,i,k}/Q_{s,i,j}/100000000$$

$$GH_{N2O,i,j} = \Sigma E_{N2O,i,k}/Q_{s,i,j}/100000000$$

Where , $GH_{CO2,i,j}$, $GH_{CH4,i,j}$, and $GH_{N2O,i,j}$ denote the carbon dioxide, methane, nitrous oxide emissions per kWh electricity supply respectively by coal-fired/oil-fired/gas-fired power plants in different provinces.

9. Derive the net electricity exchanged among China Six Grids (Northeast China, Northwest China, North China, Central China, East China, South China) based on *2020 Statistics of Electric Power Industry.* Figure 1 shows the electricity flows among grids.

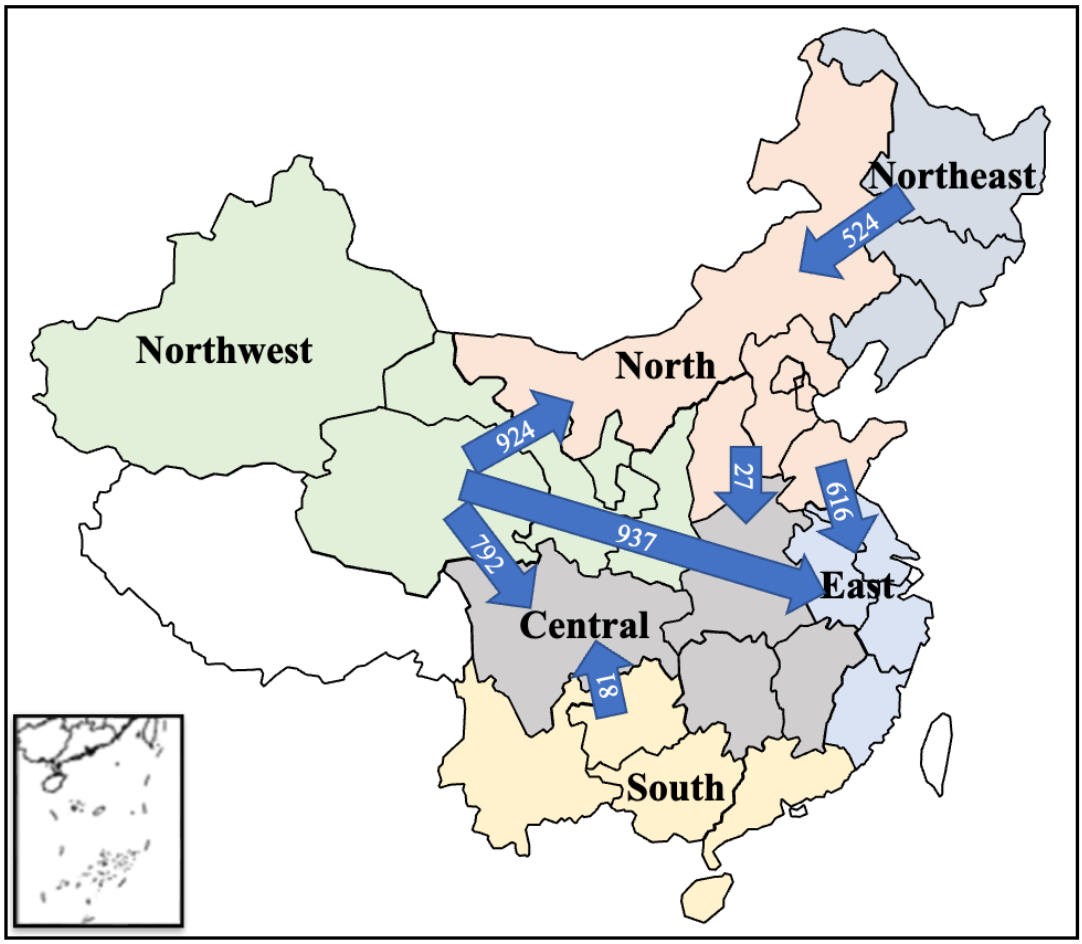

Fig1. Electricity Flows among China Six Grids (10^8 kWh)

10. Assume that each Grid first mix the electricity generated from the provinces, the mixed electricity also covers the net electricity it receives from other Grids, then the mixed electricity is exported to other Grids which are net electricity receiver. Based on the above statistical assumption, we derive the percentage of electricity contributed by each provincial in each Grid.
11. The update of China's electricity data in Ecoinvent database (China regionalized dataset renamed as EI-CN-2020) is demonstrated in Figure 2.

i. Update the China's high voltage electricity data. First, update the amount of hard coal/oil/gas consumption and carbon dioxide, methane, nitrous oxide emissions per unit of electricity supply by coal-fired/oil-fired/gas-fired power plants in different provinces. Second, update the share of electricity supply from different electricity generation technologies, such as hydropower, wind power and nuclear, at province level. Third, update the share of electricity supply from different provinces at the

Six regional electricity grids in China.

ii. Update the Six Grid's medium voltage electricity data by adopting the updated high voltage electricity data (2020) as input for the medium voltage electricity.

iii. Update the Six Grid's low voltage electricity data by adopting the updated medium voltage electricity data (2020) as input for the low voltage electricity.

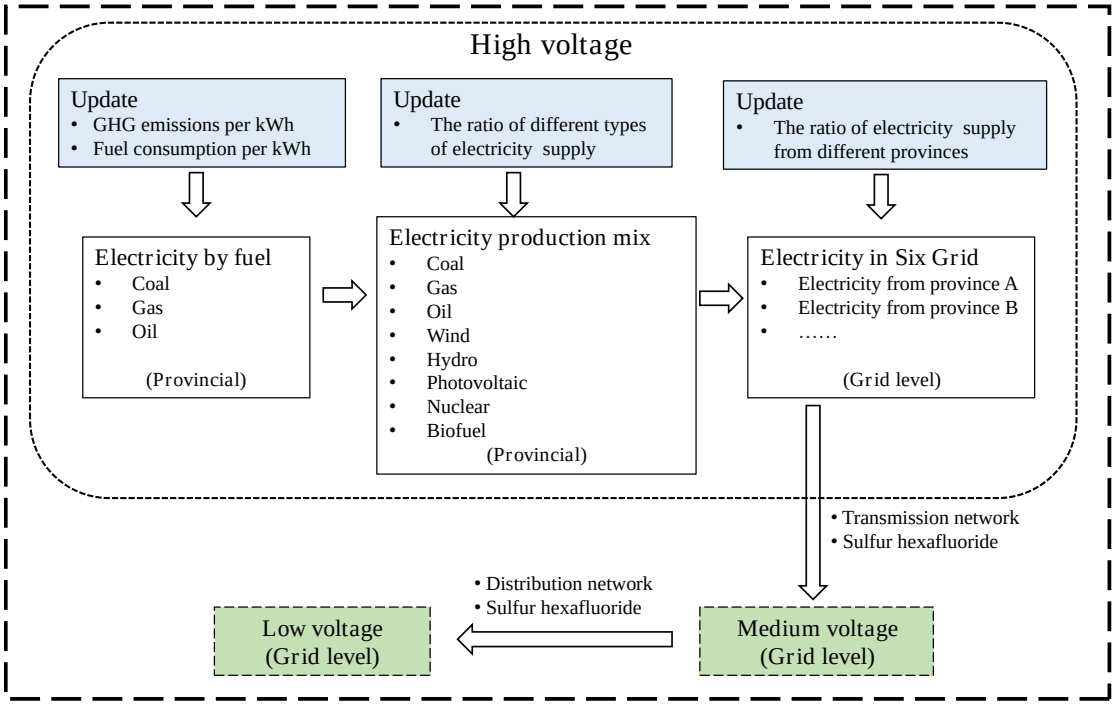

Fig 2. The steps of updating Six Grid's electricity data

12. Regionalization using updated electricity data

Considering the lack of data on the national life cycle inventory, the background data such as raw materials and processes used in most cases when engaged in the LCA evaluation of domestic products are derived from EU and global average data, and these background data basically consume electricity. In some cases, the environmental impact of electricity consumption is large, sometimes as high as 80% or more (e.g. the preparation of certain energy-intensive raw materials). Therefore, it is recommended to use China's local electricity data in the process of carrying out local LCA research, SimaPro and 1mi1 platform user can select the 1mi1-dataset which include the updated Chinese electricity data through 1mi1 platform, so that the LCA evaluation results are closer to the actual

environmental potential impact level of Chinese products. To use the Chinese localized data for evaluation, please register to log in **www.1mi1.org**, users who have purchased SimaPro can send an email (**email: simapro@1mi1.cn or support@1mi1.cn**) to apply for a discount code for the use of the platform.

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13. Global Warming Results using updated electricity data

IPCC2021 method was applied to evaluate global warming results comparison of 1kWh electricity supply in Six Grids between the year 2015, 2018 and 2020 (Fig. 3).

Global warming results of Six Grids in 2020 show that North China Grid has the highest impact (1.26 kg CO_2 eq), followed by Northeast China Grid (1.18 kg CO_2 eq), Northwest China Grid (0.79 kg CO_2 eq), East China Grid (0.87 kg CO_2 eq) and Central China Grid (0.61 kg CO_2 eq). South China Grid (0.44 kg CO_2 eq) has the lowest global warming impacts.

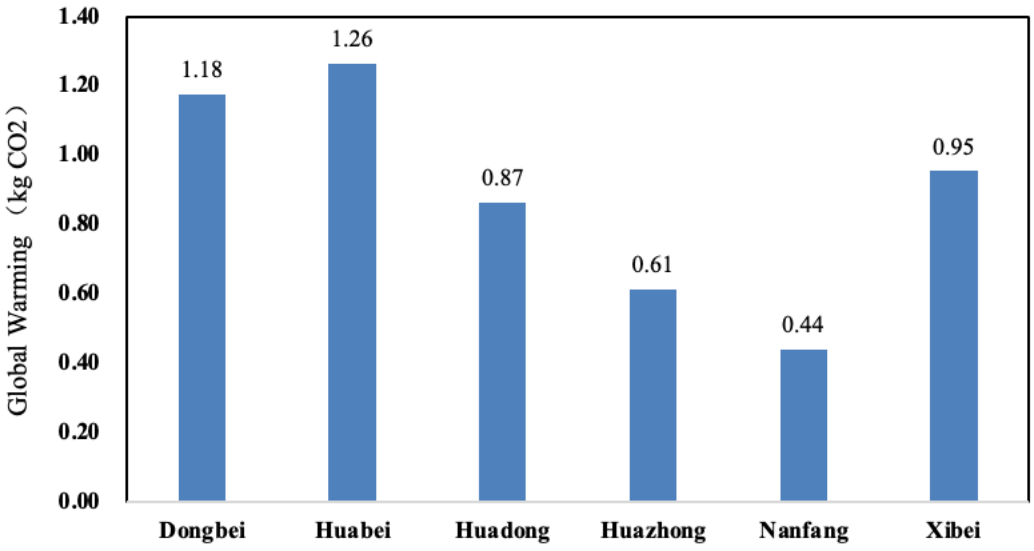

Fig 3. Global warming results of 1kWh electricity supply in Six Grids of 2020

If you want to know more about the emissions of medium and low voltage regional grids, as well as the emission factors of electricity in each province, you can log on to the www.1mi1.org, we will provide you with the latest 1mi1 (one-Metric) local database in the latest platform version 4.2, including updated

electricity and other energy data. If you have any questions or feedback, please email us (support@1mi1.cn).

Notes:

1. In this update. We use the assumption that the auxiliary power ratio for internal usage is identical for coal, gas and oil fueled electricity in each province by adopting the ratio of thermal power plant in the provinces as default. In reality the ratio is different for the three types of electricity. When detailed data is available, more accurate estimation can be done.
2. The auxiliary power ratio of fossil fuel-based electricity, solar electricity, wind electricity, hydro-electricity, and nuclear based electricity in different provinces are sourced from the book of *2020 Statistics of Electric Power Industry*.