Asian Electricity LCI database

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0. Asian background data acquisition

For building LCA researchers' network and promoting LCA activities in Asian district, AIST is supporting to implement LCI case studies with financial assistance by the government of Japan. In FY2000, this project has ranched with five countries (Japan, Korea, Malaysia, Thailand, Taiwan; alphabetical order). In this year, expanding member countries to Indonesia, Singapore, Vietnam, the Philippines and Australia, we are compiling the background data for LCA.

The preliminarily acquired data were discussed among the researchers from member countries last year. In this report, only the summary of the results are reported since primitive data have to be revised and upgraded and they must make the readers confused as well as their confidential restriction. We believe these discussing members in Asian region will become key LCA promoters and develop original research activities in this region for the progress of LCA in the world.

1. Japan[1]

Since most industrial processes consume electricity, it is quite important to develop reliable inventory data for electricity. In Japan, 10 electric companies supply electricity to the various regions. There is, however, a problem that only a few figures concerning emissions related to electricity have been reported. So, Matsuno et al. developed process models of power plants for Japanese situation, which simulate the mass flows and estimate the missing figures of emissions dependent on technical parameters of the plants and fuels. Life cycle inventories for the electricity grid mixes of the 10 electric companies in 1997 were developed. Emission of CO2, SO2, NOx, CH4, CO, Non-methane volatile organic compound (NMVOC), dust (all particulates) and heavy metals (Ni, V, As, Cd, Cr, Hg, Pb, Zn) from power stations as well as those from fuel production and transport were investigated. Other pollutants into air, emissions to water, solid wastes, radiation and radioactive emissions from atomic power stations were not included due to limitation of available data.

Direct CO2 emissions related to 1 kWh of electricity distributed by companies ranged from 0.21 to 1.0 kg/kWh (average value: 0.38 kg/kWh). Direct emissions of SO2 and NOx from power stations related to 1 kWh of electricity are 2.5x10-4 and 2.2x10-4 kg/kWh in average, respectively. SO2 emissions

calculated in this work were somehow large compared with those reported by electric companies. Detailed information concerning total sulphur content in oil consumed in each oil-fired power station are required for exact calculation of SO2 emissions from oil-fired power stations. In addition, the ratio of sulphur that goes into slag in combustion must be investigated further. The average amounts of CO, CH4, NMVOC and dust emissions were 5.0x10-5, 8.2x10-6, 1.8x10-5 and 6.8x10-6 kg/kWh, respectively. Heavy metal emissions from power stations were in the order of 10-9 to 10-8 kg/kWh. Detailed information concerning heavy metal content in oil and coals consumed in fossil fuel power stations are further required for improved assessment of heavy metal emissions. Contribution of fuel production and transport to total CO2 emission was relatively small. On the other hand, contributions of fuel production and transport to total SO2 and NOx emissions were relatively large. In the case of CO, NMVOC and dust, emissions in fuel production and transport were predominant to total emissions. Heavy metal emissions into air during production and transport of fuels were in the order of 10-8 to 10-9 kg/kWh.

Table 1 (a) Emissions into air related to 1 kWh of electricity distributed by each Electric Power Company

	CO2 (10^{-1}kg/kWh)	SO2 (10^{-4}kg/kWh)	NOx (10^{-4}kg/kWh)	CO (10^{-4}kg/kWh)	Methane (10^{-4}kg/kWh)	NMVOC (10^{-4}kg/kWh)	Dust (10^{-5}kg/kWh)
HOKKAIDO Electric Co.	5.4	11	8.9	1.3	7.6	4.2	9.6
TOHOKU Electric Co.	5.9	6.2	6.6	1.3	9.6	2.1	5.8
TOKYO Electric Co.	3.8	4.6	5.0	1.1	6.2	1.9	3.1
CHUBU Electric Co.	4.6	3.8	4.2	1.1	7.5	2.4	3.4
HOKURIKU Electric Co.	4.8	4.5	5.0	1.1	7.0	2.1	6.1
KANSAI Electric Co.	3.0	3.4	3.9	0.79	4.6	1.9	3.0
CHUGOKU Electric Co.	7.9	5.9	8.7	2.5	12	3.6	7.8
SHIKOKU Electric Co.	4.5	8.0	7.5	1.2	5.4	4.5	5.8
KYUSHU Electric Co.	4.1	3.4	5.2	1.1	5.0	1.1	4.5
OKINAWA Electric Co.	10	22	15	2.3	14	7.6	13
Average of 9 Electric Co.*	4.4	4.7	5.3	1.2	6.8	2.2	4.2

1) Average emissions of HOKKAIDO, TOHOKU, TOKYO, CHUBU, HOKURIKU, KANSAI, CHUGOKU, SHIKOKU, KYUSHU electric companies

Table 1 (b) Emissions into air related to 1 kWh of electricity distributed by each Electric Power Company (continued)

	Ni (10^{-7}kg/kWh)	V (10^{-7}kg/kWh)	As (10^{-9}kg/kWh)	Cd (10^{-9}kg/kWh)	Cr (10^{-8}kg/kWh)	Hg (10^{-9}kg/kWh)	Pb (10^{-8}kg/kWh)	Zn (10^{-8}kg/kWh)
HOKKAIDO Electric Co.	1	1	19	2	2	10	6	9
TOHOKU Electric Co.	0.7	0.9	7	1	0.8	7	2	3
TOKYO Electric Co.	0.8	1	8	1	1	4	3	2
CHUBU Electric Co.	0.9	1	5	1	0.7	4	2	2
HOKURIKU Electric Co.	0.9	0.5	8	0.8	1	7	3	4
KANSAI Electric Co.	0.6	0.9	8	1	1	4	3	3
CHUGOKU Electric Co.	2	0.8	7	1	0.9	8	2	3
SHIKOKU Electric Co.	3	1	8	1	1	5	3	3
KYUSHU Electric Co.	0.4	0.4	8	0.8	1	5	3	3
OKINAWA Electric Co.	4	3	6	1	1	12	2	4
Average of 9 Electric Co.*	0.9	0.9	8	1	1	5	3	3

*) Average emissions of HOKKAIDO, TOHOKU, TOKYO, CHUBU, HOKURIKU, KANSAI, CHUGOKU, SHIKOKU, KYUSHU electric companies

LCI for electricity of Japanese electricity grid mixes in 1998

Recently, Sugita et al. updated LCI for electricity of Japanese grid mixes using the same methodology, based on the statistics of 1998. In his work, effect of electricity exchange between electric companies on LCI was investigated. The results are shown in Tables 1(a) and (b).

2. Taiwan

This study conducts a preliminary analysis of LCI of electricity and compares an existing study in Taiwan. Two sets of inventory data based on the variations of time and methodology are, therefore, constructed or compared. Conclusively, the resource inputs per unit of electricity use are between 2.05 and 2.35 heat content unit. The CO2 emission is about 0.7kg per kWh of electricity use in Taiwan in 1999. Other than the resource inputs and CO2 emissions, the two databases vary significantly. During the period of conducting the investigation, the researchers intend to collect the data of air emission, fly ash production, and nuclear fuel consumption directly from Taipower. For some uncontrollable reasons, these data are not acquired in time. Therefore, some further extensions should be made in spite of the ending of the investigation. With the information compiled for the re-evaluation of constructing the fourth nuclear power plant and the conjunction with a study for a master thesis, the future extension of the investigation appears to be optimistic.

3. Korea

The first preliminary analysis of the electricity production system in Korea from the point of view of LCI was carried out in 1995 using the national average data of the Ministry of Environment (MOE) and the Korea Electric Power Corporation (KEPCO). The Industrial Advancement Administration (IAA) supported the study to identify the inputs and outputs associated with thermal power generation since it has the greatest portion among electricity generation by type in Korea and produces significant amounts of environmental emissions. In addition, a comparison of the environmental characteristics between different fuels used such as anthracite, bituminous coal, oil, diesel, and liquefied natural gas (LNG) has been carried out.

The Korean Energy Management Corporation (KEMCO) expressed interest in developing an LCI database detailing the raw materials use, emissions and solid wastes associated with energy production, delivery, and use in Korea. In 1996, it was decided to conduct a pilot study that would consider power generation at one power plant facility (the MokDong Kangseo District Energy Facility in Seoul). The life cycle inventory with key gross raw material requirements and resulting emissions to produce and deliver 1 TJ of heat and 1 TJ of electricity were obtained, respectively.

During 1996 – 1997, the establishment of a preliminary national database on electricity that

included not only thermal power generation but also hydro and nuclear power generation was included in the MOE project. Then, recently, an LCI database to encompass the full Korean electrical energy grid which is a single super-grid covering the whole country with all generators feeding into it and all consumers drawing from it has been developed in a MOCIE LCA project. It is found out that the national average efficiency of production and delivery of electricity in Korea is 36.2%. CO_2 emissions related to 1kWh of electricity which final user can use is around 0.487 kg/f.u. and the contribution of direct emission to total CO_2 is 94%. In the cases of SOx, NOx, and dust the contributions of fuel production and transport are relatively large, 40%, 27%, and 27%.

4. Thailand

Life Cycle Inventory (LCI) for the electricity grid mix in Thailand was developed for the first time. The results of the study were based on data obtained from the Electricity Generating Authority of Thailand and an Independent Power Producer during October 1998 to September 1999, which covered about 85% of total gross domestic electricity generation.

Total CO2, CO, NMVOC, CH4, NOx, N2O, and dust emissions from power plants were 54,527,721 ton, 12,338 ton, 2,601 ton, 1,140 ton, 174,421 ton, 1,705 ton, and 9,005 ton, respectively. Emissions of sulphur dioxide were estimated to have reached 93,161 ton.

Of total carbon dioxide emissions, the amount of emissions from gas-fired power plants was the highest (62%), followed by those from coal (37%) and fuel oil (0.42%). Of total sulphur dioxide emissions, the amount of emissions from coal-fired power plants was the highest (78%) while those from gas-fired power plants were the smallest (9.8%). Of total NOx emissions, the amount of emissions from coal-fired power plants was the highest (53%) while those from fuel-fired power plants were the smallest (2%).

Direct SO2, CO2, and NOx emission intensities from power stations were 1.28x10-03, 0.75, and 2.40x10-03 kg-air pollutants/kWh of electricity consumed by users (kg/kWh) in average, respectively. The average amount of CH4, CO, NMVOC, and particulate emission intensities were 1.57x10-05, 1.70x10-04, 3.58x10-05 and 1.24x10-04 kg/kWh, respectively. The highest SO2, CO2, and NOx emission intensities (related to 1 kWh of electricity consumed by users) were 6.41x10-04, 2.58x10-01, and 1.17x10-03, respectively. The smallest emission intensities of SO2, CO2 and NOx were 1.20x10-08, 1.25x10-05, and 1.40x10-07 kg/kWh of consuming electricity, respectively.

5. Malaysia

Life cycle inventories for the electricity grid mix of electricity generating power stations in Peninsula Malaysia in 1999 were developed. The functional unit investigated was 1 kWh net electricity delivered to consumers in the study area. The scope of the study was limited to the estimation of the emissions of CO2, NOx, SO2, CH4, CO, NMVOC, dust, and heavy metals (Ni, V, As, Cd, Cr, Hg, Pb, Zn).

The preliminary calculated weighted average emissions from the grid per kWh net electricity production in 1999 were 5.6x10-1kg-CO2/kWh, 1.3x10-3kg-SO2/kWh, 6.0x10-4kg-NOx/kWh, 6.6x10-05 kg-CO/kWh, 1.2x10-5kg-CH4/kWh, 3.8x10-5kg-NMVOC/kWh, 4.4x10-5 kg-dust/kWh, 4.6x10-7kg-Ni/kWh, 6.5x10-7kg-V/kWh, 7.6x10-8 kg-As/kWh, 8.3x10-9kg-Cd/kWh, 6.1x10-7kg-Cr/kWh, 4.2x10-9kg-Hg/kWh, 3.8x10-7kg-Pb/kWh and 6.9x10-7 kg-Zn/kWh, respectively. The emission intensities calculated need to be validated and verified with the actual emissions monitoring data for each of the power stations under study. As of the time of investigation, actual emissions data could not be obtained from the relevant authorities. Data verification is critical, as the parameters for estimation of emissions may not reflect the actual situation in Malaysian power stations.

6.Reference

[1] Matsuno Y. and Betz M.; Development of Life Cycle Inventories for Electricity Grid Mixes in Japan, Int. J. LCA, 5 (5) 295-305(2000)