B14.4.3 Evaluation of technologies for supplying and utilizing fossil fuels

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Total Budget for FY1994-1996 12,153,000Yen (FY1996 4,046,000 Yen)

Abstract In FYs 1994 and 1995, to obtain the basic data for this Life-Cycle Assessment study, the amount of energy and materials input, and the number of machines and facilities used for mining coal, crude oil and natural gas in Japan were counted, based on MITI statistical data and supplementary data obtained from companies by questionnaire. In FY 1996, the ratio of CO2 emission for mining of fossil fuels to the total CO2 emission for the production of polyethylene, steel, copper and aluminum were analyzed.

Key Words: Coal, Crude oil, Natural gas, LNG, Mining, LCA

1. Introduction

Life cycle assessment (LCA), a methodology to estimate the environmental impacts of an industrial product's life cycle from cradle to grave, has been a focus of attention recently. Especially, CO2 emissions were calculated in previous Japanese studies, because of their importance to finding countermeasures for global warming. However, they focused only on the domestic technologies and do not pay attention to CO2 emissions for the production of fossil fuels because of the difficulty to collect the data in foreign countries where fossil fuels were produced.

The objectives in this study are to collect the data of CO2 emissions for the production of fossil fuels in Japan, where a few coal mines and oil wells are still operated, and to compare them with those used in the LCA case studies in Europe, and then to calculate the ratio of CO2 emissions for the production of fossil fuels to the total (life cycle) CO2 emissions for the production of basic materials such as steel, copper, polyethylene and aluminum in Japan,

2. Result

2.1 CO2 and methane emissions from coal mines in Japan.

Table 1 Calculation of CO2 emission from coal mines in Japan

	Consumption per ton-coal	emission factor	CO2 (kg/t-coal)	ratio %
Energy /				
Electricity(purchase)	30.5 kWh	421.8 g/kWh	12.86	11.55
Electricity(Own)			74.21	66.65
Coal	27.8 kg	1910.3 g/kg	(53.11)	(47.70)
Pulverized coal	12.0 kg	1337.2 g/kg	(16.05)	(14.41)
Methane	2.59 m3	1928.4 g/kg	(5.00)	(4.49)
Heavy oil	0.0178 l	3059.4 g/l	(0.05)	(0.04)
Kerosene	1.36 l	2750.2 g/l	3.74	3.36
Diesel	1.60 l	2750.2 g/l	4.40	3.95
Heavy oil	0.279 l	2750.2 g/l	0.85	0.76
Coal	1.29 kg	1910.3 g/kg	2.46	2.21
Methane	2.17 m3	1928.4 g/m3	4.18	3.75
Subtotal			102.70	92.24
Materials				
Steel	4.39 kg	1171.5 g/kg	5.14	4.62
Wood	9.06 x10-3m3	74620 g/m3	0.68	0.61
Cement	2.18 kg	712.7 g/kg	1.55	1.39
Kerosene	0.014 l	28.47 g/l	0.00	0.00
Sub total			7.37	6.62
Machines				
Steel	683 g	1171.5 g/kg	0.800	0.72
Aluminum	1.24 g	2019.7 g/kg	0.0025	0.00
Copper	3.19 g	1264.9 g/kg	0.0040	0.00
Gum	67.2 g	3375.1 g/kg	0.2268	0.20
Sub total			1.0334	0.93
Facilities				
Wooden house	0.519 cm2	0.82664 g/cm2	0.0004	0.00
Steel house	5.11 cm2	46.14 g/cm2	0.2358	0.21
sub total			0.2362	0.21
Total			111.34	100

To obtain CO2 and methane emissions from coal mines in Japan, the amount of energy and materials input, and the number of machines and facilities used for mining coal in the 1993 fiscal year in Japan were counted, primarily based on MITI statistical data and supplementary data obtained from three of the main mines by questionnaire. From compiled data shown in Table 1, 111 kg of CO2 and 15.7 kg of methane are emitted par 1 ton of clean coal output. 92% of the total CO2 emission is generated by the process of the production of energies required for coal mining. CO2 emission by the production of materials used for the coal mining is about 7% of the total CO2 emission. CO2 emission by the production of equipment and facilities for the coal mining is less than 1% of the total CO2 emissions each.

2.2 CO2 emissions for the production of crude oil and natural gas

The amount of energy and materials input used for producing crude oil and natural gas were counted, primarily based on data in the 1994 fiscal year obtained from the main mine in Japan by questionnaire, which produced about 11×10^{15} J of natural gas and 1.6×10^{15} J of crude oil by 18 wells in the 1994 fiscal year. From the compiled data shown in Table 2, CO2

Table 2 CO2 emission for the production of crude oil and natural gas in Japan

	Consumption	Emission factor	CO2 emission	Ratio %	Ratio %
Exploration					
Steel	14.3 t	1.17 t/t	16.7	0.4	1.1
Cement	71.4 t	0.173 t/t	12.4	0.3	0.9
Diesel	61.9 kl	2.75 t/t	170.	4.1	11.7
Natural gas	0.02 TJ	47.1 t/TJ	0.94	0.02	0.06
Sub total			200.	4.8	13.8
Production					
Energy					
Electricity(Purchase)	68.3 MWh	0.422 t/MWh	28.8	0.7	1.9
Natural gas	24.9 TJ	47.1 t/TJ	1170.	28.0	80.5
Facilities					
Steel	67 t	1.17 t/t	43.3	1.0	3.0
Stainless steel	3.3 t	3.27 t/t	10.8	0.3	0.7
Sub total			1252.9	30.0	82.6
Total			1452.9		100.
CO2 in gas produced(6%)			2720	65.1	
Total			4172.9	100	

emissions from crude oil and natural gas mining were calculated to be 4200 t-CO2/PJ-crude oil and natural gas. On the total CO2 emissions, 65% is a result of CO2 emissions of gas produced from the wells, and 28% is a result of the natural gas combustion for energy utilization relating to the mining operation.

2.3 The ratio of CO2 emissions for the production of fossil fuels to the total CO2 emission for the production of basic materials in Japan

It was assumed in this study that bauxite, iron ore and coal were imported from Australia, and copper concentrate was imported from Chile.

Table 3 Energy input for the production of resources

	Bauxite[1]	Bauxite[5]	Metal ore[5]	Metal ore concentrate[5]	Non-metal ore[5]
Country	Australia		Japan	Japan	Japan
Reference	This study	BUWAL	Statistic	Statistic	Statistic
Electricity kWh/t	27	2	62	136	3
Others x10^3 kcal/t	21	126	49	108	7
Total* x10^3kcal/t	45	128	102	225	10

* 1kWh=860.5kcal

Table 4 Energy input for the production of resources

	Iron ore[5]	Coal[5] Open cut	Coal[5] Under ground	Coal Japan	Cu [2] concentrate
Reference	BUWAL	BUWAL	BUWAL	Sec. 2.1	This study
Electricity kWh/t	31	13	124	86.3	420
Others x10^3kcal/t	124	90	204	59.6	-
Total* x10^3kcal/t	151	101	310	134.8	361

1kWh=860.5kcal

Table 5 Energy input for the production of crude oil, natural gas and LNG

	Crude oil[3]	Crude oil	Crude oil[5]	Crude oil[4]	NG	NG[5]	LNG[4]
Reference	This study	Sec. 2.2	BUWAL	Hondo	Sec. 2.2	BUWAL	Hondo
Elec. kWh	-	-	22.3	n.a.	-	47.59	n.a.
Others x10^3kcal/t	379	244	37.4	n.a.	274	542	n.a.
Total x10^3kcal/t	379	244	57	102	274	583	1625

Energy input for the production of bauxite in Australia was estimated from the data published by the major aluminum production company[1], which was shown in Table 3. The data was also used as energy input for the production of coal and iron ore in Australia in this study because of the difficulty of collecting data for their productions. Energy consumption for the production of copper concentrate[2] in Table 4 was also estimated from the data published by the private company.

Energy input for the production of crude oil was calculated by the amount of flare gas burned in production countries[3], shown in Table 5. Energy required for the production of LNG was cited from the reference[4], shown in Table 5.

In Tables 3, 4 and 5, these energy inputs for resources productions are compared with those used in the LCA case study[5] and energy input for the production of resources in Japan calculated from the statistics[6].

To produce basic materials in Japan, fossil fuels and resources must be imported. Energy required for the overseas transportation are shown in Table 6.

Table 6 Energy for overseas transportation (x10^{3}kcal/t)

Aluminum[7]	Iron ore[7]	Cu concentrate[7]	Coal[7]	Crude oil[4]	LNG[4]
487	76	500	80	158	473

CO_2 emissions for the production of aluminum, copper, steel and polyethylene in Japan are shown in Tables 8, 9, 10 and 11, which were calculated using CO_2 emissions for the production of electricity in Japan ,shown in Table 7, and for the production and the transportation of each resource.

Table 7 CO_2 emission for the production of electricity in Japan (kg-CO_2/kWh)

	Japan	Overseas	Mining
Crude oil	0.203	0.0032	0.0050
Coal	0.096	0.0010	0.0009
LNG	0.109	0.004	0.0136
Total	0.410	0.0082	0.0195
Ratio %	93.7	1.9	4.5

For the production of aluminum in Japan, CO_2 emissions for bauxite mining is less than 1% of the total CO_2 emissions. On the other hand, in the production of copper and polyethylene, CO_2 emissions for mining resources are calculated to be about 30% and 10% of the total emissions

Table 8 CO_2 emission for aluminum production (t-CO_2/t)

	In Japan	Overseas	Production	Mining
Electricity	0.33	0.0653		0.0157
Others	1.55			
Aluminum		0.0945	11.454	0.0790
Crude oil		0.0245		0.0386
LNG		0.0005		0.0017
Total	1.86	0.1848	11.454	0.1350
Ratio %	13.6	1.4	84.0	1.0

respectively. In the steel production, about 5% of the total CO2 is emitted from the resource production in this calculation, but there is a possibility that it would be over 20% of the total CO2 emissions if CO2 emissions for the transportation of coal and iron ore from mines to the ports in Australia and the accuracy of energy input for mining were taken into account.

3. Conclusion

The ratios of CO2 emissions for the mining fossil fuels and other resources to the total CO2 emissions for the production of basic materials are different in materials. If we had to focus on the steel production when we carried out the life cycle study of an industrial product, we could not ignore CO2 emissions for mining coal and iron ore in Australia. CO2 emissions from their transportation in Australia would also correspond to CO2 emissions for mining them. We have to collect more data in foreign countries and international cooperation is required in this kind of studies.

Table 9 CO2 emission for Cu production

(t-CO2/t)

	In Japan	Oversea	Mining
Electricity	0.291	0.0058	0.0139
Others	0.779		
Concentrate		0.4468	0.6256
Crude oil		0.0063	0.0100
Coal		0.0033	0.0029
LNG		0.0004	0.0014
Total	1.070	0.4626	0.7438
Ratio %	47.0	20.3	32.7

Table 10 CO2 emission for steel production

(t-CO2/t)

	In Japan	Overseas	Mining
Electricity	0.133	0.0264	0.0063
Others	0.843		
Iron ore		0.0256	0.0245
Crude oil		0.0004	0.0006
Coal		0.0124	0.0144
Total	0.976	0.0648	0.0426
Ratio %	90.1	6.0	3.9

Table 11 CO2 emission for PE production

(t-CO2/t)

	In Japan	Overseas	Mining
Electricity	0.182	0.0361	0.0037
Others	0.958		
Crude oil		0.0774	0.1220
Total	1.140	0.1134	0.1307
Ratio %	82.4	8.2	9.4

Reference

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