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Life Cycle Inventory of Air Emissions from a Typical Coal-fired Power Plant in Vietnam

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Abstract: Coal is a very important resource for power production in Vietnam contributing to 13.6% of the total electricity generated in 2002. To meet the growing demand of electricity, coal fired power plants using anthracite will expand increasingly. Thus, it is necessary and timely to evaluate the environmental emissions thereof. Some of the major environmental impacts of these power plants are from emissions to the atmosphere such as CO_2, SO_x, NO_x and dust during combustion of coal. In this study, the life cycle air emissions of a 300 MW coal-fired extension power plant at Uong Bi in Vietnam are presented. The processes considered in the life cycle are coal mining, coal screening / preparation, transportation, lime and oil production, and combustion. The study quantifies the emissions from the various stages of the life cycle. Air emissions come not only from combustion at the power plant but also from many upstream and downstream processes such as coal exploitation, limestone production and transportation.

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Keywords: Air Emissions, Coal Power Plant, Life Cycle Inventory, Vietnam

Introduction

vietnam is on the way of developing its economy so it is important to attach much more interest on the master plan of development of energy. From the national strategies and policies of sustainable energy development [1], the demand of energy from coal-to-electricity generation is anticipated to expand from 650 MW at present to 2,060 MW by 2010, and 6,000-7,000 MW by 2020. On the other hand, the coal sector will boost its capacity to 15-17 million tonnes per year by 2010 and over 20 million tonnes per year by 2020 compared with the extracting output of 14 million tonnes per year at present [2]. The increasing energy output is aimed to meet electricity demand of power shortages in the near future and encourage the socio-economic development of Vietnam. Energy production from fossil fuels causes many environmental impacts, especially air emissions. For sustainable development and to ensure energy security, the environmental aspects of energy production must be considered. This research studies the Uong Bi extension coal-fired power plant in Quang Ninh Province in Vietnam. This is a typical coal-fired power plant with capacity of 300 MW being built in Uong Bi Township since 2003. It will supplement the 110 MW of the 40-year-old existing Uong Bi station. The boilers in the power plant are pulverized coal type. The new plant will produce 1.8 billion kWh electricity per year. When completed in mid-2006, the Uong Bi power station would consume 800,000 tonnes of low-quality anthracite annually from the Vang Danh coal mine mainly and other mines nearby. The project will generate jobs for 1,000 miners [3, 4].

At present, there are many of ways for assessing environmental aspects of coal-to-electricity generation, one of these being life cycle inventory (LCI). Using "cradle-to-grave" method, LCI focuses on all inputs and outputs related to whole life of power generation from coal. Carrying out LCI to find out air emissions is important not only for electricity generation but also for electricity distribution and consumption. Air emission such as CO_2, CO, N_2O, NO_x, SO_2, CH_4, Non Methane Volatile Organic Compounds ($NMVOC_s$), and PM (Particulate Matter)contribute to various global, regional and local impacts, and also affect human health adversely [5].

Methodology

The objective of the study is concentrated on the typical electricity production in Vietnam at present power plants and expected power plants in the near future. This is the reason for calculating the LCI of air emissions at the Uong Bi extension power plant which will be in operation in the next two years. Consideration of technology of the plant lays the foundation for tracing back to all suppliers and drawing the broad picture of all processes (whole system) in cradle-to-grave method. After that the consideration will go in detail in each process (sub-system) in terms of raw material acquisition manufacture and alternative transportation. In each process the resources consumption and energy use are quantified. Air emissions are subsequently estimated more accurately and holistically according to the goal of the study as well as the impact potential expectation.

Goal definition

The goal definition of the study shall unambiguously state the intended application, the reason for carrying out the study and the intended audience [6, 7]. Speaking in another way carrying the goal is to answer questions: (1) what is the purpose of the LCI? (2) Who is intended audience? (3) What can the results be used for or not? (4) What are the geographical limitations? (5) What are the temporal limitations?

The purpose of the LCI is for air emission diagnosis and consequently to show air emissions picture of the coal-to-electricity production in Uong Bi extension coal-fired power plant. The intended audiences are environmentalists, decision-makers of investment of coal-fired power plants and local authorities such as coal mine leaders, power plant managers and/or other related organizations. The result can be used for the present technology and/or the similar technology. If the study to be used for a new technology each sub-system needs to be considered with the necessary changes and recalculation. The geographical limitations of the study are to use in Vietnam though the results can be also used for other South-East Asian countries where the anthracite is extracted or imported. The temporal limitation is the duration of the plant lifespan, around 30 years. This assumes that the technology of other processes like coal exploiting, oil extraction does not change substantially during this time period.

Scope definition

To define the scope of the study follows the goal of the study and needs to consider following items clearly. The items are that the function of the product system, the functional unit, the product system to be studied, the product system boundary, allocation procedures, data requirements, assumptions, limitations and initial data quality requirements [6, 7]. For electricity production from Uong Bi power plant, the scope includes mainly coal extraction in Vang Danh mine, coal cleaning and power generation. In electricity generation of Uong Bi extension power plant, the combustion of coal and oil as well as flue gas cleanup using lime are considered. Figure 1 shows the broad system boundary, containing main processes of whole life of the product, electricity. Coal (main fuel for power plant) is exploited at Vang Danh Coal Mine, fuel oil (supplementary fuel for power plant) is imported from the Philippines, lime (for flue gas clean-up) is extracted from a quarry in Quang Ninh province.

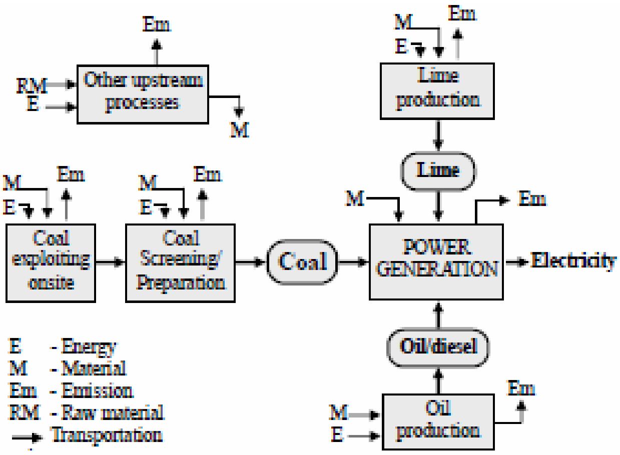

Fig. 1 The electricity production system in Uong Bi power plant

Apart from the processes of electricity generation described above, the LCI also includes the air emissions during the construction and demolition of the power plant. This means that the LCI must consider the chain of suppliers and operation of power plant, including building infrastructures, operating and finishing the operation by demolishment of these infrastructures.

The inventory of air emissions is carried out for each process block. The inputs and outputs are considered in coal extraction, cleaning coal and coal combustion. The ancillary materials are lime, oil and other products. All inputs and outputs inventoried are normalized to 1 MWh of net electricity generated (i.e. electricity after deducting the internal usage for power plant). The inputs include energy use, material consumption and the outputs include air emissions (CO_2, CO, N_2O, NO_x, SO_2, CH_4, $NMVOC_s$, and PM) and the electricity produced (1 MWh).

Results and Discussion

Results

All the data for direct and indirect processes have been obtained by on-site measurements and/or through reports and literature [8 – 13]. Databases from the softwares EM V1.4 (Environmental Manual for Power Development), SimaPro v6.0 (Life cycle assessment) and FIRE v6.24 (Factor Information Retrieval for criteria and hazardous air pollutants) [14] and the Australian National Pollutant Inventory [15] have been used to estimate air emissions related to the life cycle of coal-to-electricity generation in Uong Bi extension coal-fired power plant. As this plant is presently under construction, the calculations are based on the Norms of the Ministry of Construction in Vietnam [16, 17]. The summary of the major inputs of processes of coal-to-electricity generation in Uong Bi power plant is shown in Table 1. Coal and fuel oil (FO) are used as fuel for power plant. Cement, steel, brick, macadam and sand are used as building materials for construction of infrastructures of power plant and colliery. Lime is used for the treatment of sulfur dioxide produced during the combustion of coal. Diesel is used for transportation

Table 1 The inputs of all process related Uong Bi power plant.

No.	Item	Unit	Quantity
1	Raw Coal	kg/MWh	535
2	Fuel oil	kg/MWh	2
3	Brick	kg/MWh	2.8
4	Cement	kg/MWh	1.6
5	Lime	kg/MWh	30
6	Macadam	kg/MWh	2.0×10^{-3}
7	Sand	kg/MWh	3.1×10^{-3}
8	Steel	kg/MWh	3.6×10^{-1}
9	Diesel	liter/MWh	4.7

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The air emissions from all stages and processes of the whole life cycle are shown in Table 2. The results consist of emissions released mainly from burning fuel in vehicles and machines working in building, operation, demolition stage of colliery as well as of power plant. Besides the emissions from extracting coal and burning coal in the power plant, the emissions from the production of ancillary materials are also included.

Table 2 The air emissions in the power plant life cycle

Unit: g/MWh

Pollutant	Power plant			Coal production	FO production	Lime production	Transport
	Building	Operation	Demolition				
PM10	4	49	1	27	1	39	2
SO_2	5	1,268	1	296	5	60	4
NO_x	6	4,250	15	163	4	30	15
CO_2	2,435	987,140	1,742	46,773	846	41,309	1,517
CO	23	535	6	55	1	13	7
N_2O	$8.6\text{x}10^{-2}$	35	$4.8\text{x}10^{-2}$	$7.5\text{x}10^{-1}$	$2.2\text{x}10^{-2}$	$1.8\text{x}10^{-1}$	$4.6\text{x}10^{-1}$
CH_4	5	22	$9.4\text{x}10^{-2}$	2,002	8.5	39	$5.1\text{x}10^{-1}$
NMVOC	14	22	1	513	16	5	4

The transportation is divided into three parts (shown in Figure 2). Firstly, materials for mining and raw coal are transported from mine mouth to screening/preparation plant Secondly, fuel (coal, fuel oil) and materials are transported to power plant Thirdly, the solid waste from coal mine, preparation plant and power plant are transported to landfill.

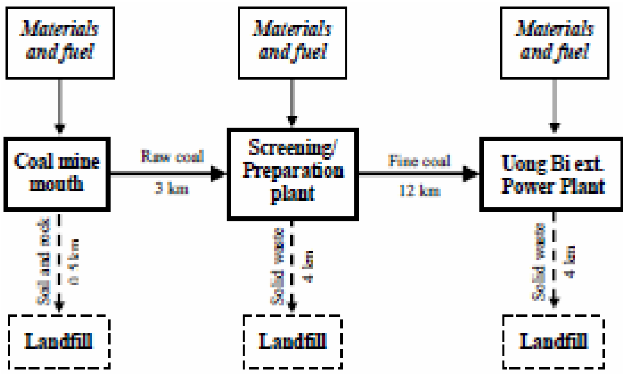

Fig. 2 The transportation system of coal-electricity generation

Discussion

The above results show that the emissions are not limited tom the process of burning coal to produce electricity but are also quite high in material production in building stage of power plant, demolishment of plant and transportation. Besides the air emissions from burning fuel, the air emission releases through production processes of ancillary materials, e.g. lime, are also high.

CO_2: The highest emissions come from burning fuel in each stage, in which the highest is in burning coal and fuel oil to generate electricity (91% of total emission). Due to the use of coal and fuel in the whole life cycle of power plant, therefore the emissions from transport is also quite high (mainly from transporting fuel for power plant: 1,039 g/MWh). CO_2 emitted from coal and lime production are 4.3% and 3.8% of total emission, respectively. The emission from production of materials is high because no production processes operate without using energy and electricity. Fuel is burned to get energy for transport and operation of machines for manufacturing these products.

CO: Similar to CO_2, CO emission is highest in fuel combustion in electricity generation (84%). The second highest CO emissions (9%) are from material production for the coal extraction. CH_4: Methane emission is highest in coal extraction because the methane contained in coal seams is released when exploiting coal [18]. Methane emission is about 80 times higher in coal extraction stage than methane emitted in the stack of power plant. In other processes, methane emission is very low.

N_2O: The highest emission is from combustion of coal in the power plant (96 %) corresponding to a high volume of air burned in chamber and nitrogen contained in coal. In other processes the nitrous oxide emitted is quite low.

NO_x: Like N_2O, nitrogen oxides emission is highest in stack of power plant. In coal production, the emission is 94 % of total emission. In other processes, it is below 4 %. SO_2: The sulfur dioxide emission is mainly from power plant operation (77 %). Part of this is due to high sulfur content in coal and fuel oil which is released as SO_2 during combustion. The other part is from the use of sulfur as material for manufacturing chemicals (e.g. H_2SO_4 and Alum). The emission from coal production is 8 %.

PM10 (particulate matter < 10 μm): This emission has only been estimated from burning fuel, so the inventory of PM is not completed in mining activities and building and demolition stages due to lack of information. Therefore, the emission from stack of power plant and production of materials for power plant (mainly from lime production) is higher than from coal production.

NMVOCs: These are high in the production of FO and in combustion chamber of power plant due to crude oil extraction and refining, and coal burning.

When considering Global warming potential (GWP), the greenhouse gases (GHGs) such as CO_2, CH_4, N_2O and CO have been converted to CO_2-equivalents using equivalency factors for a time scale of 100 years from the IPCC (Intergovernmental Panel on Climate Change) [19]. In the whole life cycle of coal-to-electricity generation, GHG emissions coming from colliery are mainly from methane released from coal seams. GHG emissions from lime production are mainly from CO_2 emitted from the thermal reaction of $CaCO_3$ for CaO production. GHG emissions from fuel oil production and transportation are small (Shown in Fig.3).

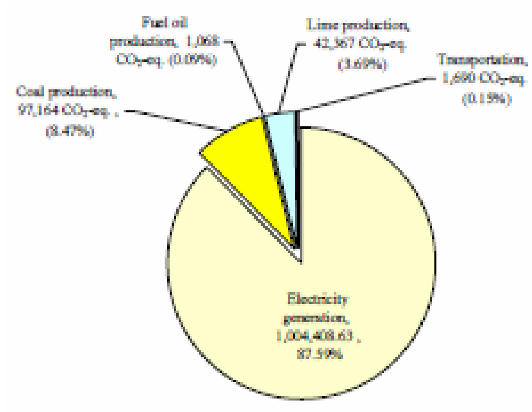

Fig 3 GWP of the various phrases of the life cycle of electricity production at Uong Bi extension power plant.

In summary, The LCI carried out from a typical thermal power plant, in particular, and for electricity generation from coal in Vietnam in general, in terms of green house gases emission gives the holistic picture of environmental aspects and shows the phases from which emissions are generated in the whole life cycle of coal-to-electricity in Uong Bi extension thermal power plant.

Conclusion

Coal is a very important resource abundantly in Vietnam. Taking advantage of the coal potential to meet the growing demand of electricity is quite suitable for socio-economic development in Vietnam and South-east Asian countries. However, it is necessary and timely to evaluate the environmental emissions thereof. Air emissions come not only from fuel combustion in power plant (87.59%), but also from coal (8.47%) via extraction and preparation of raw coal, and lime (3.69 %) through extracting limestone in quarry and burning the limestone. Therefore, LCI of air emissions gives a holistic view considering all processes of coal-to-electricity generation. It is a database for estimation of contributing emissions in any production using electricity in this region.

It is recommended that the LCI of energy generation from other of other sources (e.g. natural gas, hydropower, etc.) should be studied to obtain the emission for the overall electricity mix in Vietnam.

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