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An Exploratory Study of Material Flow Cost Accounting: A Case of Coal–Fired Thermal Power Plants in Vietnam

To Tam NGUYEN[1]

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Abstract

The purpose of this paper is to examine the use of material flow cost accounting (MFCA) in Vietnam's coal-fired thermal power plants. This study is based on the contingency and system theories to explain the application of management tools and analyze steps of input, output, and process in manufacturing. Costs in producing process-based MFCA include material cost, energy cost, system cost, and waste management cost. The exploratory case study methodology is used to describe and answer two questions, namely "How coal flow cost is recognized?" and "Why waste in material consumption can be harmful to the environment?". By analyzing the Quang Ninh and Pha Lai coal-fired thermal power plants that are the typical plants, this paper identifies the flow of primary material in these plants as a basis for determining losses for the business. The material flow of coal-fired thermal power plants provides the basis for the use of the MFCA. The manufacturing of electrical items in these plants is divided into four stages, each with its own set of losses. As a result, some phases in the application of MFCA are suggested, as well as some other elements required for MFCA application in coal-fired thermal power plants.

Keywords: Material Flow Analysis, Material Flow Cost Accounting, Coal-Fired Thermal Power Plant

JEL Classification Code: M40, M41, Q32, Q40, Q49

1. Introduction

Electricity demand is increasing all over the world, in developed and emerging countries (Hong & Lee, 2018). Vietnam is an emerging economy (OECD, 2019) and has generally been raising the total generation from GWh 90,482 in 2010 to GWh 217,470 in 2020 (MOIT, 2021). To ensure energy security, some technology choices are in Vietnam's Power Development Plan VIII, and power resources have been changed to eliminate environmental impact (Melissa Brown, 2021). Twenty-six coal-fired thermal power plants are contributed 21% of generation capacity in Vietnam (MOIT, 2021) and requirements of technology to reduce emissions and harm to the surroundings (Melissa Brown, 2021). In the long run, Vietnam is looking for and studying renewable energy that could make some change in the power plan and achieve sustainable generation. With the low cost of coal-fired thermal power plants and the high rate of the total power, these plants - important elements of the national power system are still operating. Therefore, the coal-fired thermal power plants are interested in the research of new technology and innovation and management in the best response to the demand of customers and society. Besides, eliminating negative impacts on the environment and ensuring sustainable production for the economy are required.

The coal flow in coal-fired thermal power plants is considered a process of moving this material from stages (Suresh & Kolar, 2011). Recognition of the moving of material in manufacturing businesses is an important issue for management to find the failure and waste. The material flow helps the management to enhance efficiency and towards clean production. Material flow cost accounting (MFCA) is a useful tool to reduce material waste, enhance business performance and reduce environmental impact (Doorasamy, 2016; Katsuhiko Kokubu, 2013; Tran & Herzig, 2020). The application of MFCA in developing countries was limited to data recognition and insufficient allocation (Tran & Herzig, 2020).

[1]First author and Corresponding Author. Faculty of Economics and Management, Electric Power University, Hanoi, Vietnam [Postal Address: 235 Hoang Quoc Viet, Co Nhue, Bac Tu Liem, Hanoi, Vietnam] Email: tamnt@epu.edu.vn

According to the Power Planning VIII, the power source capacity structure of Vietnam in the year 2020 is as follows (Figure 1).

In Figure 1, coal-fired thermal power represents a large portion of Vietnam's power source capacity in the year 2020. In the coming time, many large power centers will be built and put into operation such as Duyen Hai, Long Phu, Song Hau, Van Phong, Vinh Tan, Quang Tri, Vung Ang, Quang Trach, Nghi Son, Nam Dinh, Thai Binh, Hai Duong, etc. This increases significantly the power generating capacity from thermal power sources. Total coal-fired thermal power capacity in 2020 accounted for 48% of total installed capacity, producing about 46.8% of the electricity for manufacturing. By 2030, the figures will increase to 51.6% and 56.4 %, respectively. The total capacity of natural gas (including LNG) used by 2020 will account for 16.5% of the total installed capacity, producing about 24% of the electricity for manufacturing; by 2030, these numbers will be 11.8% and 14.8%, respectively. In 2020, the total capacity of thermal power plants (coal and gas) was planned to be about 64.5% of the total installed capacity, producing about 70.8% of the electricity, and by 2030 the figures will be 63.4% 71.2% in that order. In TPPs, high fuel costs typically account for 53% of COGS. For coal-fired thermal power plants, coal is the main fuel (about 50% of the cost price) (MOIT, 2021). This research is valuable for Vietnam's coal-fired thermal power plant management.

The paper uses contingency theory and system theory to help organizations to lead and make management decisions (Mühlbach, 2012). The contingency theory was used in previous research in management accounting (Duc Hieu & Tien Dung, 2020; Fuadah et al., 2020). The exploratory case study methodology is used in material cost management, material flow in Quang Ninh Thermal Power Joint Stock Company and Pha Lai Thermal Power Joint Stock Company in Vietnam. Interviewing experts and key personnel in these companies are involved in the research.

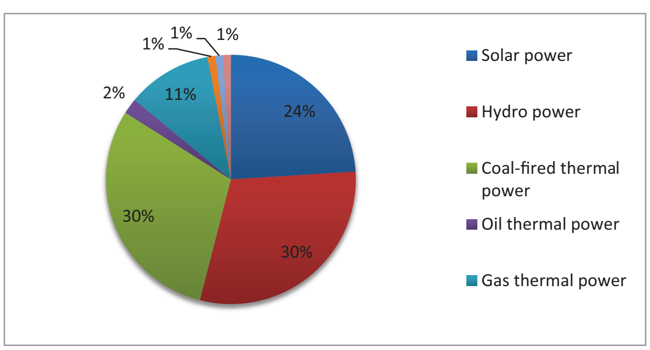

Figure 1: Chart of Vietnamese Power Source Capacity Structure in the Year 2020 (MOIT, 2021)

MFCA is a management innovation that came from projects of developed countries; however, other developing or emerging countries are also interested in the application of MFCA due to its usefulness from the economic and financial perspectives. Since Stefan Schaltegger (2017) studied the potential in the context of a beer brewing facility in Vietnam, MFCA was able to demonstrate the potential areas of inefficiency and to help ensure improvement efforts towards areas where they would make the greatest impact.

This is an exploratory application of how to use MFCA in an industry in Vietnam. Therefore, studying MFCA in the scope of the coal-fired thermal power plant could help to indicate the usefulness and recommendation of the application of MFCA (case in the Vietnamese coal-fired thermal power plant). The three main objectives of this paper are: (1) To apply the framework of MFCA to selected industries and companies; (2) To analyze the application of MFCA in typical coal-fired thermal power plants; (3) To identify the steps involved in the application MFCA in coal-fired thermal power plants.

2. Literature Review

2.1. Material Flow Cost Accounting

MFCA does not only provide material information on material flow but also links this information to its value. MFCA identifies inefficient stages of production (Hargroves et al., 2012; Shen-Ho Chang et al., 2015). The main purpose of MFCA is to serve as a decision-making tool for organizations and managers. It could also improve environmental and economic performance (Doorasamy, 2016). At the core of MFCA that the cost of the total input is equal to the total production and non-production cost (OECD, 2009).

MFCA's objectives are the motivation and support organizations' efforts to enhance both environmental and financial performance through improved material and energy use practices (ISO, 2011). ISO confirms that "the resulting information from MFCA can act as a motivator for organizations and managers to seek opportunities to simultaneously generate financial benefits and reduce adverse environmental impacts." This standard has been applied in several Asian countries and applies to any organization that uses material and energy. MFCA focuses on information for internal decision-making (ISO, 2011).

Shen-Ho Chang et al. (2015) proved that MFCA is a feasible and useful tool for decision-making in small and medium enterprises. The MFCA could also help to reduce the likelihood of abnormal decisions and determine which steps of stages need to be improved. This will reduce the cost of wastage at later stages of processing. A direct connection is created by the valuation on the same basis of data based on material information. This could provide more accurate and useful information for decision-making and control of the output.

MFCA is a tool for optimizing the production process (Hyršlová et al., 2011). The paper used a case study of a ceramic tiles company in the Czech Republic. The paper showed the application of MFCA in the plant RAKO III which belongs to the company Lasselsberger. The manufacturing process and material flow were identified in this study so that quantity centers and the calculation of material losses can be made.

The application of MFCA in manufacturing and service industries in Asia countries is reviewed comprehensively and examined in the case study methodology (Tran & Herzig, 2020). The paper indicates the limitation in the publication of MFCA research; MFCA has been used in several large companies with the support of top management. The industries of the case studies in the paper review focused mainly on the pollution-intensive plants, such as iron, steel, paper, oil, and metal. Service and other industries were suggested in future research (Tran & Herzig, 2020). In Europe, the MFCA is applied company-wide with the support of the advanced IT option that integrates the MFCA with the Enterprise Resource Planning (ERP) systems (Christ, 2014).

The MFCA application in industries was detailed in manufacturing companies that have used material and energy (Tran & Herzig, 2020; Matthias Walz, 2020), and the case studies were examined in these studies. By synthesizing 73 cases involving MFCA studies, Matthias Walz (2020) indicated the effect of MFCA application in these organizations. MFCA could influence profit maximization and strategy. The analysis of the case studies of MFCA showed that several companies experienced improvements in costs, elimination of environmental impact, or both.

Existing case studies demonstrated substantial potential for organizations to reduce their overall environmental costs by the systematic approach to MFCA (Katsuhiko Kokubu, 2013). While many studies empirically supported cost reductions and environmental improvements of organizations (Christine Jasch, 2005; Scavone, 2005). Moreover, beyond the technology, MFCA provided a catalyst for the development of the newer and more efficient tool (Hyršlová et al., 2011). MFCA was recommended in the case that the organization applied the environmental management accounting (EMA) tool and a future-oriented or long-term focus (Christ, 2014).

MFCA can be applied to identify production costs and material losses. In many cases, costs are more significant than previously assumed. At the same time, MFCA sets a final goal of "zero cost of material losses", which could encourage organizations to make promptly an improvement. Important elements used in MFCA are Quantity center, material balance, cost calculation, and material flow model (APO, 2014). To implement material flow cost accounting, five steps were recommended as well as required (APO, 2014); (1) Embedding management in the process and identifying responsibilities; (2) Identification the scope and boundary of the process and building the material flow model; (3) Allocating costs based material flow cost accounting method divided to Material costs, Energy costs, System costs, and Waste management costs; (4) Interpreting and communicating of MFCA results; and (5) Improving production and minimizing material wastage through MFCA result.

The success factors of the MFCA application reviewed included management support, using an enterprise resource planning system and MFCA integrated, internal communication related to MFCA, team composition at different levels, the monetary effect due to MFCA, performance evaluation due to MFCA, recognition of the usefulness of MFCA, and collaborations with suppliers in requirements of the supply chain. Besides, some factors should limit MFCA application, such as human resources, insufficient accounting system, collecting data system, lack of knowledge of MFCA, manufacturing process, and material flow (Matthias Walz, 2020).

Christine Jasch (2005) examined findings in a comparative study of environmental management accounting in Austria and Costa Rica and suggested that MFCA could assist in identifying opportunities for 'good housekeeping', which are more common in emerging economies given environmental regulations tend to be less stringent in these settings. Furthermore, MFCA demonstrated the potential for material and energy flow cost assessments that were a post-hoc tool for environmental investment appraisal at a rice mill located in the Philippines (e.g. material and energy flow cost assessment was used to evaluate previous investment decisions in retrospect) (Burritt et al., 2009). Indeed, as developing nations move to compete in a global marketplace that they have demanded increasingly stringent forms of environmental management and innovation tools, MFCA may offer organizations in these countries a means of controlling resources and how demonstrate their commitment to economic and environmental efficiency (Christ, 2014). With high levels of economic growth in recent years, it could be argued this is likely to be especially important in countries like China and India (Xiaomei, 2004). This is confirmed in the study of many scholars (Tran & Herzig, 2020; Matthias Walz, 2020).

2.2. Material Management in Thermal Power Plants

In coal-fired TPPs, coal inventory management was important to optimize stock safety and gain more profit (Wang Zhanwu et al., 2011). The author used the case study in H corporation in the north of China and analysed the changing in coal's price and the application material model to manage stock. Some previous researchers have focused on inventory optimization mode that is different in material flow (Wang Zhanwu et al., 2011).

Some reports from IEA (The International Energy Agency) or other energy organizations mentioned and recommended policies for better regulating coal-fired TPPs. Process boundaries should be advised to cover the entire plant with input data requirements (coal, fuel, etc.) and enhance performance benchmarking in one plant and one country. Environmental and financial performances give a question to manage coal in boundary and relevant methodology (CIAB, 2010).

In China, India, and others emerging countries, electricity has been generated mainly from coal. Even in developed countries, coal will remain to be an important source of fossil primary energy in the next future. Therefore, the specific method and system that contributes toward coal efficiency are elaborated in a study on ABB Corporation (Mühlbach, 2012). This system was introduced by ABB using a module of material tracking. The module gathers material information, monitors volumes on the way to the stockpiles via belt conveyors, trace material at the discharge point, balances input, stored, output material quantity, and records data in the system. As a result, material flow is the basis of this module. ABB conveys into this module and integrates into the system to handle coal from input to generate electricity.

In the previous studies, MFCA was specifically mentioned about its usefulness and its application in large companies and several SME manufacturing organizations. Coal-fired thermal power plants or other thermal power plants have been examined in technical aspects of environmental protection. With a huge impact on the environment, using natural resources, and closely relating to suppliers, the study of MFCA application in a coal-fired thermal power plant is necessary for academics and practice. To fill the gap of MFCA in specific industries and to add more fruitful use of the management tool, the case of coal-fired thermal power plants is suggested in an emerging country.

3. Theoretical Framework

3.1. Conceptual Theories

The conceptual framework has been adopted mainly from the system theory. MFCA is a management tool to identify and recognize material cost and waste through the manufacturing process. System theory has been provided as a powerful tool to analyze steps of material flow and the integration of departments and functions of the flow (Heylighen, 1992; Alexander Laszlo, 1997).

MFCA has been published by ISO under a standard 14051:2011. According to this standard, defective products should be treated as negative products, and the cost of redoing those damaged products should be considered a negative or non-product cost. This tool helps managers evaluate waste and efforts to reduce waste, which is the basis for improving production efficiency and optimizing costs. According to the Japanese guidelines (METI, 2010), the purpose of the MFCA is to reduce costs and minimize environmental impacts caused by manufacturing activities. It is used as a decision-making tool for managers.

The framework of MFCA is based on the material flow and the physical balance. In material flow, the physical components are processes, and the connection links the processes through flows. The system boundaries are defined in time and space (Brunner, 2005).

The material balance in the quantity center is depicted in Figure 2. A key principle of MFCA is material or physical equilibrium. The conversion of input to output takes place in

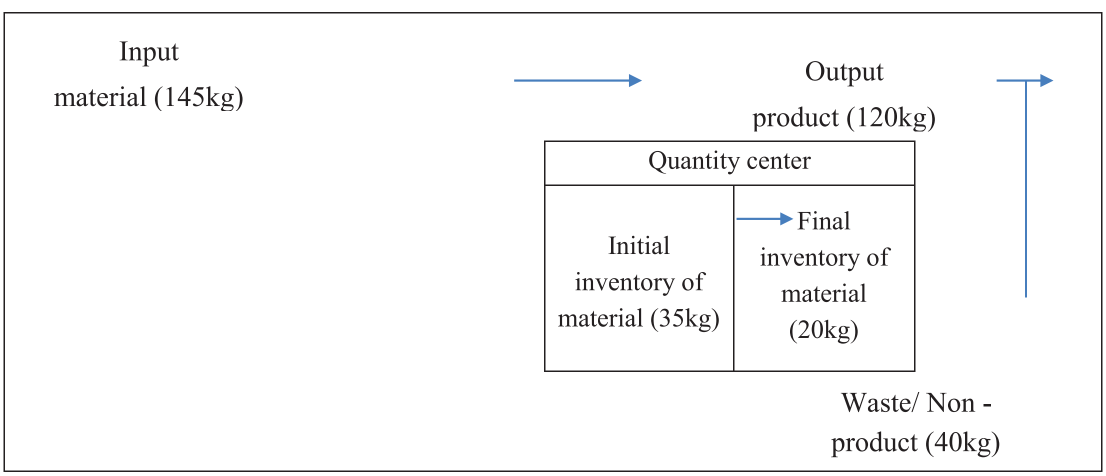

Figure 2: The Physical Balance of Inputs and Outputs in the Quantity Center (APO, 2014)

the quantity center. There are two types of outputs: products and non-products. Non-products might be wasted resources or repurposed materials; products can be semi-finished or finished. That is, total input costs are the same as total product and non-product costs.

Figure 3 shows an example of cost calculation based on the material balance at one of the quantity centers of the manufacturing plant. Here, the total costs of the quantity center are allocated to the output based on the proportion of input that becomes a product and the proportion that becomes part of the material losses (APO, 2014).

Figure 4 gives data on a material flow model. It indicates a representation of the process that shows all the quantity centers in which the materials are transformed, stocked, or used, as well as the flow of these materials within the system boundary (APO, 2014).

Generally, MFCA includes several elements: quantity center, material balance, cost calculation, and material flow model (ISO, 2011; APO, 2014). Details are explained below:

(i) A quantity center is typically one or multiple unit processes. The center is when the material balance will be calculated both in physical and monetary units. One quantity center can include either a single process or multiple processes, depending on the amount of material losses identified at the production unit.

(ii) The amounts of inputs and outputs for each quantity center should be quantified in physical units. All physical units should be convertible to a single standardized unit (e.g., mass) to conduct material balances for each quantity center. It is preferable to use existing on-site basic units for production management.

(iii) Through MFCA, the material balance of inputs and outputs is linked to monetary units by assigning and/or allocating costs to all products and material losses. MFCA considers four types of cost, all of which are allocated to both products and material loss.

(iv) It refers to the visual representation of the process that shows all the quantity centers in which the materials are transformed, stocked, or used, as well as the ow of these materials within the system boundary.

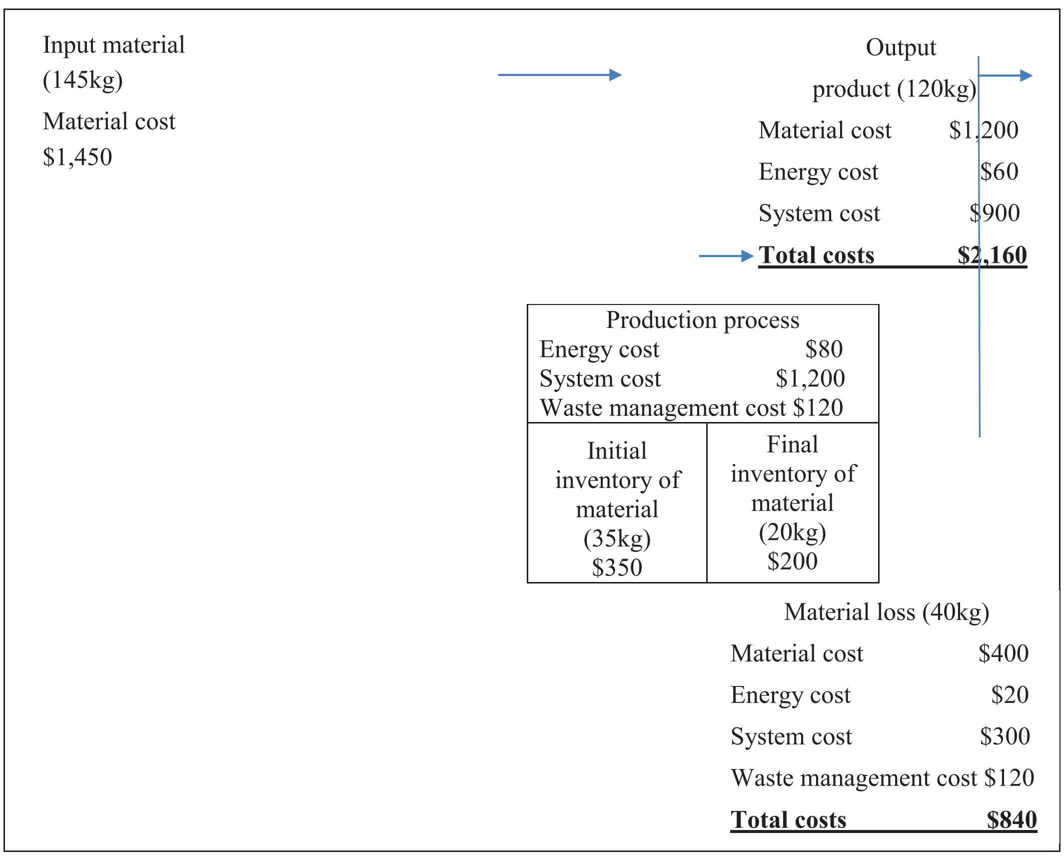

Figure 3: Material Balance and Costs Based on MFCA (APO, 2014)

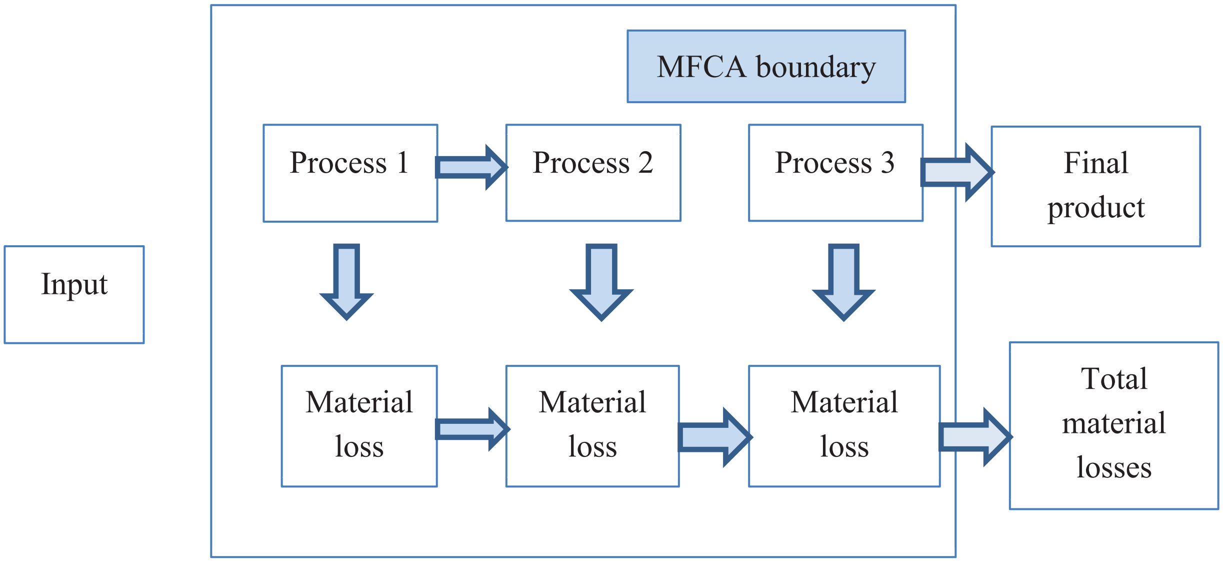

Figure 4: Material Flow Model for a Process within the MFCA Boundary (APO, 2014)

In practice, MFCA extends MFA's material balancing principle, which states that the sum of inputs equals the amount of outputs. All necessary resources for the manufacturing process are included in the input, such as main raw materials used in the initial stage, secondary materials used in the intermediate stage, auxiliary materials, direct and indirect labor, utilities, equipment depreciation, and so on. As a result, the MFCA is concentrating on elucidating the cost of material flow and should prescribe proper measurement. This reduces raw material consumption and saves money when receiving and handling commodities and garbage.

3.2. Characteristics of Thermal Power Plants Used Coal-Fired

A thermal power plant transforms fossil fuels into heat, which is subsequently converted into mechanical energy to turn a generator. Coal, diesel, gas, and other fossil fuels are the primary raw materials used in TPP. Coal-fired TPP is widely used in developing countries.

According to Bercen (2003), material flow and material waste problems are described through fuel flow movement in TPP. A coal-fired TPP consists of three main components: the boiler that produces steam, the turbo-generator that converts steam energy into electricity, and the fuel gas clean-up (Rasul, 2013). Material flow in TPP moved from the Coal Storage through the Boiler and to the Power Generation. The flow of coal is strictly managed, which assures the quantity and quality of the electricity production process and pays attention to environmental protection issues.

However, coal management in TPP is different compared with other materials. Wang Zhanwu et al. (2011) indicated the difference in the requirement for safe coal storage, the fluctuation of coal demand, the fluctuation of coal price during the year, and the uncertainty of inventory procurement. Wang Zhanwu et al. (2011) built a coal management model from the point of view of profit to minimize waste affecting corporate profits.

4. Research Methodology

In the literature, several scholars who studied MFCA used the desk method and case study method. The desk method applied these papers that reviewed previous and focused theories. The case study method was used in one or more organizations to describe the application or applied conditions. In this study, an exploratory case study method is used to study the application of MFCA in a specific industry.

In this paper, we used the case study to indicate the material flow and material management of coal in two TPPs in Northern Vietnam. These TPPs are typical coal-fired TPPs. Both of them have used coal that has been from internal sources (20 TPPs used coal from Vietnam and 6 TPPs used coal from import resources) (MOIT, 2021). The case study is one of social science methodology and to answer two main research questions that are "how" and "why". Besides, this method focuses on contemporary phenomena with the case in the "real–world context" (Yin, 2014). The reason for choosing a case study that is relevant to this method.

Our paper has the objectives of examining how material flows in TPP and supply information to help management optimize power production and why TPP does not minimize water to acceptable levels.

The study examined TPP papers, material (physic and value amount over time), and material flows. Following that, inquiring and observation were carried out in these scenarios to describe and recognize the actual material flow situations. Coal is a primary material that is thoroughly investigated. The movement of coal was examined and illustrated using value amounts.

The typical coal-fired thermal power plants analyzed in this research are Quang Ninh thermal power plants (Quang Ninh TPPs) and Pha Lai thermal power plants (Pha Lai TPPs). These TPPs have a total capacity of 1,200 MW and have been operational for over ten years. Internal coal resources from Northern Vietnam are used (MOIT, 2021).

The research looked at records from TPPs in Quang Ninh and Pha Lai that were connected to the material and other costs over a three-year period from 2015 to 2017. These accounting records were examined, summarised, and classed into four MFCA elements. Other manufacturing process papers, as well as basic material, flows from Quang Ninh and Pha Lai TPPs, are provided for examination and analysis. In-depth interviews with important persons were conducted for the study. They play a vital role in raising environmental awareness (Nguyen, 2020). The Board of Directors, Management, Planning Department, Technical Department, Fuel Department, Boiler Department, Accounting Department, and Environmental Supervisor were all interrogated. Material flows, recognitions, reporting, and the MFCA application's capacity are all defined in detail. Material flows in the electrical process were observed at two Quang Ninh TPPs and two Pha Lai TPPS in 2018. The MFCA and material flow model were used to assess and illustrate the coal flow model (APO, 2014). These steps of application of MFCA were examined to identify waste.

Questions were answered in a planned structure using the deep interview method. (1) Confirm and add material flow information for TPPs; (2) Describe their department or responsibilities for material management; (3) Assess material cost affecting business decision making; (4) Give their opinions on the complexity of the material operation and management that influenced adjustment and change managerial tools; (5) Apply material flow analysis to ensure physical balance in TPPs; (6) Separate the production costs, which include material, energy, system, and waste management costs. (7) Improve material flow management in TPPs and personnel; (8) Create paperwork and reports for used and discarded materials; 9) collect and record used and waste materials in TPPs; 10) collect non-product or waste cost data. Coal flow and management are examined based on responses from key personnel at Quang Ninh and Pha Lai TPPs.

5. Research Results

5.1. The Material Flow Model of The Coal–Fired Thermal Power Plants

5.1.1. Quang Ninh TPPs

TPPs in Quang Ninh are owned by the Quang Ninh Thermal Power Joint Stock Company and Power Generation Corporation No. 1. (EVN Genco No.1). Because it is a public corporation, individuals in charge of governance are concerned about the company's performance and image. Quang Ninh TPPs have a total capacity of 1,200MW, with four units connecting to the national electricity grid via the 500kV Quang Ninh substation, which has voltage levels of 500kV and 220kV, with a designed output of 7.2 billion kWh per year. Quang Ninh TPPs employ innovative blast furnace technology and contemporary equipment to handle emissions into the environment, reducing the plant's environmental impact. The TPPs have installed automatic environmental parameter monitoring devices to measure the concentration of O_2, CO_2, CO, NOx, SOx, ash, and exhaust smoke to adjust the environmental treatment systems.

The boiler cluster, which produces steam, and the turbine-generator cluster, which converts steam energy into electricity, are the two primary components of a coal-fired thermal power plant. A supporting boiler, cooling water system, fuel preparation system (coal storage, conveyor belt, coal mill), pneumatic production system, fly ash recovery system, bottom ash gathering, dust filtering, and waste gas treatment are also included. Quang Ninh TPPs employ innovative blast furnace technology and contemporary equipment to handle emissions into the environment, reducing the plant's environmental impact.

5.1.2. Pha Lai TPPs

The Pha Lai Thermal Power Joint Stock Company and Power Generation Corporation No. 1 own the Pha Lai TPPs (EVN Genco No.2). It is a publicly-traded corporation. The Pha Lai TPPs have 1,040MW, with two units: Pha Lai Plant No. 1 and Pha Lai Plant No. 2. Pha Lai Plant No. 2 is designed to produce 3.68 billion kWh per year. It is Vietnam's largest coal-fired TPP, with sophisticated technology designed and built to meet international environmental requirements.

Quang Ninh TPPs and Pha Lai TPPs have the same material flow and management as described in Figure 5.

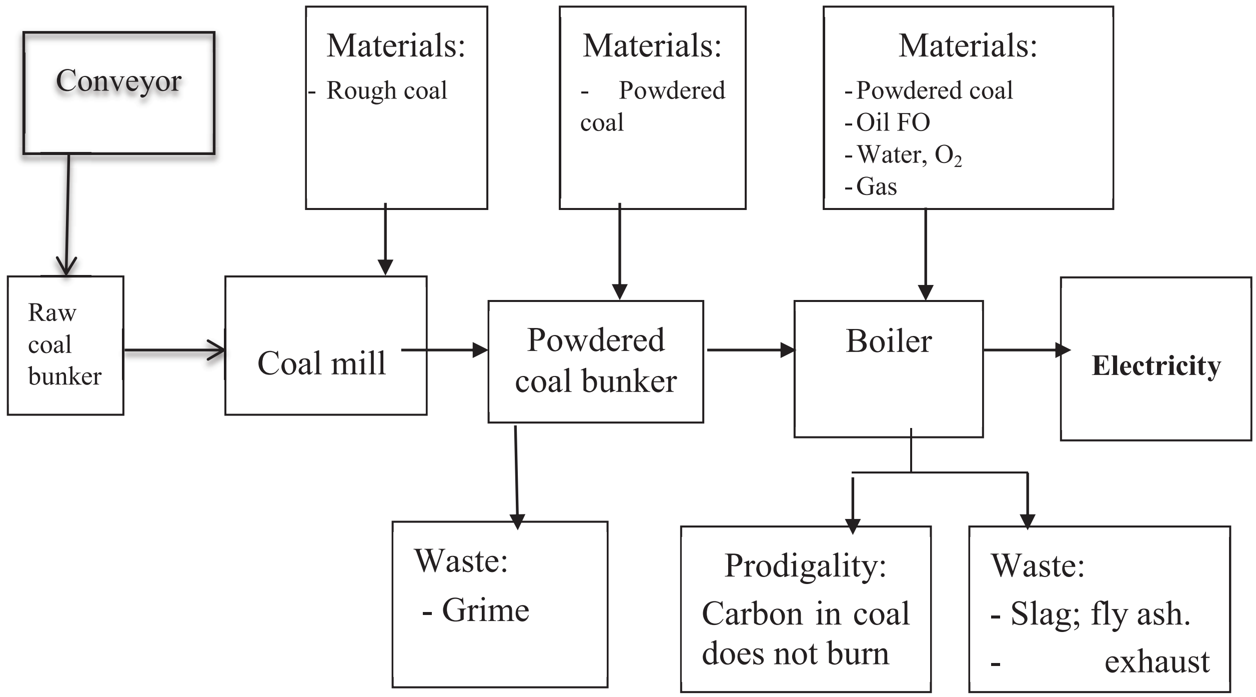

Figure 5: Model of Coal Flow Analysis in Coal-Fired Thermal Power Plant

The main raw material in the TPPs is coal. When coal is used for electricity generation, it is usually pulverized and then burned in a furnace with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines that turn generators and create electricity. In TPPs, coal is the primary material used in the electricity generating process. Rough coal is transported directly to the coal mill system or bunker via a conveyor (indoor bunker or outdoor bunker). The coal is also carried by conveyor from the coal bunker to the coal mill system. Rough coal is dried, crushed, and screened before being delivered to a powdered coal bunker with a diameter of less than 200 m. The powdered coal supply at the bottom of the powdered coal bunker transports powdered coal to the burners in the combustion chamber. The coal will be pushed into the combustion chamber by hot air pressure and transferred directly to the combustion chamber.

Slag, fly ash, and exhaust smoke are products of the powdered coal-burning process in the combustion chamber, which are discharged by the slag disposal system at the bottom of the boiler and the chimney. Slag is forced up the slag dump by a high-pressure water pump. The slag is sold to units with varying needs per the terms of the contract for selling slag. An electrostatic filter collects fly ash, which is then stored in silos. The fly ash is sold to units with various demands under the contract for selling fly ash. Fly ash and slag are the most common building materials. A part of the fire product as gas (SOx, NOx) is eliminated and retained by a desulphurization system (FGD) and by a NOx elimination system (SCR). The last remaining fire product is the exhaust that reaches environmental standards is pushed into the atmosphere.

In these plants, departments that manage materials are the Board of Directors, Board of Management, Planning Department, Technical Department, Fuel Department, and Boiler Department. They answered and supplied information about coal flows, management, and problems. In Quang Ninh thermal power joint stock Company, the accounting system is centralized in the Accounting Department. The company's accounting system is ERP, but this ERP only comprises finance and a few other modules. As a result, the MFCA application's IT situation is incomplete (Matthias Walz, 2020). TPPs have not been subjected to management accounting; instead, the accounting system has been focused on financial reporting. While the company's human resources can satisfy the demands for MFCA in plants, as well as innovation in accounting policy and IT skills. One of the drawbacks of MFCA application in TPPs comes from the structure of the plants. Quang Ninh TPPs and Pha Lai TPPs are under EVN Genco No.1 and EVN Genco No.2 and then under the Vietnam Electricity Corporation (EVN). All management decisions and production plans of TPPs are under the control of these corporations. Applying a new management tool should need to consider a lot of views.

According to the materials flow model (Figure 5); the manufacturing process of electricity in the coal-fired thermal power plant consists of four stages as follows:

Stage 1: Receiving charcoal from suppliers, then transferring charcoal to the coal bunker (raw coal).

Stage 2: Transfer raw coal from the coal bunker to the coal mill to produce powder coal.

Stage 3: Transferring powder coal to powder coal storage.

Stage 4: Moving charcoal in powder coal storage to the combustion chamber of a boiler. The powder coal is burned at this stage to generate electricity.

Materials flow like input fuel, output, and material efficiency are managed at each stage of the main production process. Therefore, each manufacturing stage of this system is selected and identified as a production center for data collection used in MFCA.

Material waste is found in two stages:

(i) Coal mill: Coal losses: due to coal spillage during coal milling and transportation; Waste: Coal dust and impurities in the coal.

(ii) Coal burning: Coal losses: due to burning coal; Waste: coal during combustion produces slag, fly ash, and gas losses.

5.2. Application of Material Flow Cost Accounting in Coal-Fired Thermal Power Plant

According to the data of TPPs, material and production costs are classified into material costs, energy costs, system costs, and waste management costs. According to data of Quang Ninh TPPs, MFCA was calculated and resulted in some figures on material and production costs as follows (Table 1).

Costs of raw materials of Quang Ninh TPPs (like Pha Lai TPP) include: coal, FO oil, DO oil, limestone, chemicals, grinding machine, and supplies for regular repairs. The cost of raw materials accounts for the largest proportion of the total cost (from 58% to 62%) according to the MFCA method. Among the cost of raw materials, the cost of coal accounts for 55% – 60% of the total cost, and the figure for fuel oil costs is 1.15% – 3.35%.

System costs of Quang Ninh TPPs (like Pha Lai TPPs) include labor costs, depreciation of fixed assets, interest expenses, other fixed costs, and maintenance and transportation costs. These costs account for from 37% to 41%, of the total cost according to the MFCA method. To save money on this system, it is necessary to take control of the purchase of input assets in the construction stage of the company.

Energy costs of Quang Ninh TPPs (like Pha Lai TPPs) such as electricity, and water account for a small proportion of 0.5% – 1.3% of the total cost according to the MFCA method. However, in number, the expenses represent relatively high costs.

The waste management cost of Quang Ninh TPPs (like Pha Lai TPPs) is the expense of "material wastage incurred in a volume center". Waste management includes the management of emissions, sewage, and solid waste. Waste management costs are the costs of carrying out activities within and outside the organization such as the refurbishment of unsatisfactory products, recycling, waste tracking, storage, treatment, or disposal. In TPPs, the cost of waste includes some main types such as oil spill responding costs, garbage collection, waste treatment, waste transportation, insecticide cost, ash removal costs, or environmental sanitation costs. Annually, the waste costs represent a negligible proportion of the total cost, only 0.04%.

In general, coal wastes are incurred in two principal stages: Coal mill and coal burning at TPPs. In TPPs, coal waste is raised in coal burning. According to the inquiry of Board of Management, seniors of Planning Department, Technical Department, Fuel Department, Boiler Department, Accounting Department, Environmental Supervisor. To reduce waste in Quang Ninh TPPs, unburned coal should be eliminated and the movement of coal should record carefully to help reclassification, calculation, and identify wastes.

6. Conclusion and Recommendations

The MFCA is implemented based on the system theory. It is a management tool that has clear elements, steps, and conditions. In the thermal power industry, MFCA helps to reduce waste and eliminate negative impacts on the environment. However, the case study in Quang Ninh TPPs and Pha Lai TPPs showed that MFCA application has just been suggested because of limitations of data recognition or IT condition (Tran & Herzig, 2020; Matthias Walz, 2020).

In the previous analysis, the following steps applied MFCA in coal-fired thermal power plants are recommended:

1. Incorporating management into the process and assigning responsibilities: Assign some staff with knowledge and experience in respective departments, such as top management, senior financial, procurement, and technical department personnel.
2. Determining the scope and limits of the production process, as well as the quantity center.
3. Costs are totaled and allocated using the MFCA technique, which is separated into four categories: material costs, energy expenses, system costs, and waste management costs.
4. Using the quantity center's material matrix, the quantity center's input-output material, the quantity center's material summary, the system cost, energy

Table 1: The Summary Costs of Quang Ninh TPP from 2015 to 2017

No	Contents	Unit	2015		2016		2017	
			Cost	(%)	Cost	(%)	Cost	(%)
I	**Actual Sales**	Million kWh	**5,692**		**6,458**		**5,282**	
II	**Costs**	Million vnd	**6,675,203**	**100.00**	**7,332,418**	**100.00**	**6,814,773**	**100.00**
II.1	**Material costs**	Million vnd	**4,402,693**	**65.96**	**5,017,120**	**68.42**	**4,334,069**	**63.60**
1	Coal (Consumption + Starting)	Million vnd	4,217,618	63.18	4,796,313	65.41	4,093,589	60.07
2	Limestone	Million vnd	489	0.01	411	0.01	177	0.00
3	Bi grinding machine	Million vnd	17,777	0.27	18,951	0.26	12,378	0.18
4	Chemicals	Million vnd	7,897	0.12	4,766	0.06	4,846	0.07
5	Lubricants	Million vnd	6,632	0.10	5,636	0.08	5,072	0.07
6	FO oil (incineration + starter)	Million vnd	114,767	1.72	93,332	1.27	131,721	1.93
7	DO oil	Million vnd	104	0.00	12	0.00	108	0.00
8	Supplies for regular repairs	Million vnd	37,409	0.56	97,699	1.33	86,178	1.26
II.2	**Energy Costs**	Million vnd	**96,247**	**1.44**	**42,125**	**0.57**	**82,849**	**1.22**
1	Industrial water	Million vnd	2,697	0.04	2,975	0.04	2,722	0.04
2	Self-produced electricity for production (included technical electricity)	Million vnd	93,550	1.40	39,150	0.53	80,127	1.18
II.3	**System Costs**	Million vnd	**2,173,362**	**32.56**	**2,270,221**	**30.96**	**2,395,192**	**35.15**
1	Salary costs	Million vnd	162,739	2.44	222,040	3.03	230,410	3.38
2	Depreciation of fixed assets	Million vnd	1,950,838	29.23	1,954,219	26.65	1,956,428	28.71
3	Other fixed costs	Million vnd	59,785	0.90	93,962	1.28	208,354	3.06
II.4	**Financial Costs**	Million vnd	**2,901**	**0.04**	**2,952**	**0.04**	**2,663**	**0.04**
1	Waste treatment costs	Million vnd	573	0.01	569	0.01	547	0.01
2	Responding to oil spills	Million vnd	742	0.01	602	0.01	637	0.01
3	Garbage collection, waste treatment	Million and		–	360	0.00	–	–
4	Environmental sanitation Fine	Million vnd	342	0.01	274	0.00	310	0.00
5	Transportation of waste	Million vnd	398	0.01	383	0.01	374	0.01
6	Insecticide	Million vnd	846	0.01	764	0.01	795	0.01

Source: Quang Ninh TPPs' books and reclassification.

cost, and waste management cost of the MFCA summary, interpret and communicate MFCA results.

5. Using the MFCA results to identify wastes and material losses in detail for each quantity center, improve production and reduce material waste.

The MFCA is also a management tool to reduce waste in usage material and eliminate environmental impact. A coal-fired thermal power plant should apply MFCA to calculate fully waste, electricity cost, and material losses. Costs in producing process-based MFCA are included material cost, energy cost, system cost, and waste management cost and they are illustrated. By using the exploratory case study in the Quang Ninh TPPs, the paper summarizes the stages and the generating costs to quantify the impact of material flow. Some causes of waste are identified to require some adjustments in the management of material flow that focused on coal.

In conclusion, this study is an exploratory of the application of MFCA in a typical coal-fired thermal power plant in an emerging country. It is recommended that MFCA be used to reduce waste and improve environmental indicators that contribute to long-term sustainability. Although coal-fired thermal power is rapidly being phased out in emerging countries, its setup and operation costs are low. One scenario of internal coal used in a thermal power plant is excluded from the study. More cases and more in-depth investigations of MFCA connected to environmental management accounting are suggested as future study topics.

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