Cogeneration system for energy saving and CO$_2$ emission reduction: A case study of textile factory

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Abstract. Thailand has many textile factories of which the complete value chain consists of upstream, midstream and downstream sectors. It is well-known that textile manufacturing consumes considerable amount of energy. The textile factory in this case study is located at Bang Poo Industrial Estate in Samut Prakarn province, Thailand. It is categorized as a midstream sector and has been consuming final energy in terms of 87% thermal energy (steam) and 13% electrical energy. The factory had 6 fire-tube steam boilers having capacity of 40 tons steam per hour. The age of the existing boilers was longer than 20 years. Therefore, it was decided to install a cogeneration system to replace the existing boilers for energy saving, safety integrity and CO$_2$ emission reduction. The gas turbine topping cycle cogeneration system with waste heat recovery was selected due to several advantages such as low energy consumption, high boiler efficiency and high energy efficiency. Considering the energy and environmental issues, the results showed 92% overall efficiency, 19.5% primary energy or natural gas saving, and 38.6% reduction of CO$_2$ emission when compared to the separated heat and power system. In summary, the cogeneration system shows positive energy and environmental impacts.

1. Introduction

Based on the Thai Textile Statistics for the Year 2017/2018 by the Thailand Textile Institute (THTI), Ministry of Industry, it is reported that the value of textile exports increased from 226 billion Baht in 2012 to 306 billion Baht in 2017 [1]. The supply chain of textile industry can be divided to the upstream fibers; midstream spinning, weaving, knitting, dyeing and printing; and downstream clothing and retail. There are about 4,789 textile mills in Thailand, of which 38% is in the midstream sector (Figure 1). The textile industry consumes large amounts of both fuels (oils and natural gas) and electricity. The ratio of fuels and electricity within the total final energy consumption depends on the processing units or structure of the textile industry. Generally, the major energy source is fuels in the wet processing while electricity is the dominant energy source in spun yarn spinning. According to high concerns about energy consumption and environmental impacts, energy efficiency technology is becoming a cornerstone of the textile industry. The cogeneration system, known as a combined heat and power (CHP), has been recognized for its substantial benefits such as the roles in high energy efficiency and low environmental impacts [2].
Due to the limited life of fire-tube steam boilers, the corporate textile case study decided to replace 6 existing boilers with a cogeneration system to obtain energy saving, safety integrity and CO$_2$ emission reduction. However, the constraints in this case study are not much available data involving the amount of energy consumption records and environmental study. This project was therefore to investigate the impacts of cogeneration system installation on the energy saving and CO$_2$ emission.

2. **Methodology**

The textile factory in this case study is located at an Industrial Estate in Samut Prakarn province of Thailand. The scope of work can be explained as follows:

2.1 *Collect the relevant primary and secondary data*

The data including the textile industry structure (processing units) and cogeneration system were obtained from multiple sources such as interview and discussion with the experts, observations, on-site walkthroughs in the textile factory, and review the available records.

2.2 *Evaluate energy saving*

The energy saving was evaluated by using the overall efficiency ($\eta$) and primary energy savings (PES) [3]. The calculation methods are based on the Manual for Measuring Efficiency of the Combined Heat and Power System and Calculating the PES Ratio of Cogeneration VSPP [4,5]. The whole data analysis for energy saving can be divided into 3 major steps, respectively: (i) determine system boundaries and calculate the overall efficiency of the cogeneration system; (ii) distinguish the natural gas used for generating cogeneration products (i.e., thermal energy and electricity) from the total natural gas input; and (iii) calculate the percentage of primary energy savings (PES).

2.3 *Assess CO$_2$ emission*

The CO$_2$ emission was assessed based on the Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems [6]. The natural gas savings and CO$_2$ emission associated with the operation of a cogeneration system can be evaluated by: (i) calculate the natural gas use and the CO$_2$ emission from displaced separated heat and power in terms of grid-supplied electricity and on-site thermal energy generation from 6 existing boilers; (ii) calculate the natural gas use and the CO$_2$ emission from the new cogeneration system; and (iii) subtract (ii) from (i).

3. **Results and Discussion**

3.1 *Textile manufacturing processes and energy profile*

The textile factory in this case study is characterized as a midstream sector comprising of spinning, weaving, knitting, dyeing and printing processes. The final energy consumption mainly includes 87% thermal energy (steam) and 13% electrical energy. Natural gas is exploited as fuel for the existing...
6 fire-tube steam boilers which generates 40 tons steam per hour to use in textile manufacturing processes, while the electricity is used for machines, heating, cooling and lighting systems and office.

3.2 Cogeneration system
Since the age of the existing 6 fire-tube steam boilers was longer than 20 years, the corporate textile case study decided to install the new cogeneration system with waste heat recovery unit for energy saving, high energy efficiency and less environmental impacts. The gas turbine topping cycle cogeneration system is shown in Figure 2.

![Gas turbine topping cycle cogeneration system](image)

**Figure 2.** Gas turbine topping cycle cogeneration system.

3.3 Energy saving and CO₂ emission reduction
After installation of cogeneration system, the overall efficiency increases from about 60% to 92% (Table 1). The new cogeneration system provides 19.5% PES and 38.6% CO₂ emission reduction compared with the references, namely the separated heat and power system.

| Category                  | Separated Heat and Power System | Cogeneration System |
|---------------------------|---------------------------------|---------------------|
|                           | Thermal System                  | Power System        |                         |
|                           | MWh/y                           | ktoe/y              | MWh/y                   | ktoe/y                   | MWh/y | ktoe/y |
| 1. Energy                 |                                 |                     |                          |                          |       |
| - Natural gas consumption | 331,920                         | 28.54               | 126,720                 | 10.90                    | 301,032 | 25.88 |
| - Energy production       | 226,800                         | 19.50               | 48,168                  | 4.14                     | 274,968 | 23.64 |
| - Overall efficiency      | -                               | 60%                 | -                       | 92%                      |        |       |
| - PES                     | -                               | -                   | 19.5%                   |                         |        |       |
| 2. Environment            | t CO₂/y                         | t CO₂/y             | t CO₂/y                 |                          |        |       |
| - CO₂ emission            | 59,760                          | 28,368              | 54,114                  |                          |        |       |
| - CO₂ emission reduction  | -                               | -                   | 34,014 (38.6%)          |                          |        |       |
Figure 3 shows the schematic diagram of energy production systems: (a) separated heat and power system and (b) new cogeneration system. It is clearly that by using the new cogeneration system in the textile factory case study, the energy efficiency increases and CO₂ emission decreases.

**Figure 3.** Schematic diagram of energy production systems: (a) separated heat and power system and (b) cogeneration system.

4. **Conclusions**

The cogeneration system can obviously increase energy efficiency greater than 32% thereby decrease CO₂ emission about 40%. Therefore, the cogeneration system is one of the opportunities of the textile industry to improve energy efficiency. Since energy is the significant cost of the energy-consuming
plant like textile industry, high energy efficiency of the energy production system is the key competitive factor of the textile industry when energy price is abruptly high.

References
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