In defense of the old generation: the strategic options to sustain a vintage urea plant production

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Abstract. The Need for Urea Fertilizer supply is one of the essential factors for the development of the agricultural sector. However, due to the high energy usage and the increasing price of natural gas as the raw material, some of the old urea fertilizer industry was forced to shut down due to the inability to cover the high production cost. The purpose of this study is to analyze the alternative strategy for the urea industry to be more efficient and also produce good quality urea to remain sustainable. This paper will use descriptive analysis based on the Case Study compared to the literature and related references to find the appropriate and well-implemented alternative. Based on the study, several options can be purposed such as retrofitting in ammonia and urea plant mainly in syn-loop and high-pressure section, and by optimizing the feed ratio and process condition.

1 Introduction

Nowadays, the development in science and technology particularly in the industrial sector competes for each other to fulfill the population necessity, and the fertilizer industry is one of them [1]. Fertilizer industry itself has grown each year in many countries due to the rising needs of food production [2]. The global consumption of fertilizer in the last decade has focused on certain developing countries [3]. Urea has the highest nitrogen content among the similar fertilizer, making it considered as one of the essential chemical compounds that had been worldwide mass produced for agricultural intensification purpose [4]. The rapid growth of population accompanied by the significant demand for fertilizer in various developing countries [2], placed the fertilizer industry in a high concentration market with high sales rates [5].

The sustainable development concept for fulfilling human necessity that involves a harmonization between social, ecological, and economic aspects, requires to sustain the resource exploitation integrity, also the direction and orientation of the development including investment, technology, and institutional [30]. This is in line with the article 36 paragraph 2 of Indonesian Constitution Number 3 year 2014 about Industry states that development, escalation, and technology optimization in industry carried out to improve efficiency, productivity, added value, competitiveness and independence of the sector [6].

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The increasing amount of natural gas which is no longer seen as a by-product of petroleum manufacturing, causing significant increases in its prices throughout the world [7], causing some fertilizer factories losing the ability to compete competitively, as well as high consumption energy costs [8]. One of them is the case that occurs at the urea fertilizer plant X.

Urea Fertilizer Plant X is one of the biggest fertilizer factories in Indonesia located in South Sumatera regency. It consists of 4 plants, where two of the plants was built in 1977 and 1978 and still operating until now. Plant A (1977) and B (1978) operate using TRCI (Total Recycle C-Improved) process while Plant C (1991) and D (2016) have undergone a process change to ACES (Advanced Cost Energy Saving) which is more energy efficient than the previous ones. However, the urea product from Plant A and B has a lower concentration of biuret compared to plant C and D, making it a suitable product for the international market. Due to the recent increase of natural gas price as well as the higher energy consumption in plant A and B, making the urea fertilizer from plant X is less competitive compared to urea manufactured by Chinese plant using coal as the raw material. This has caused Plant B to shut down in May 2018 to save production cost temporarily. Currently, Plant X only relies upon their urea production from plant A, C, and D to fulfill the demand for fertilizer both domestic and international. However, urea fertilizer produced from plant D contains high levels of biuret, so it only used for plantations (not suitable for agriculture), while at the same time plant A and C experienced problems with their equipment in the urea section, making the production more obstructed. Plant C suffered the worst damage in the urea recovery section but forced to continue to balance the production, arising an environmental issue (because of the plant located near the river and human settlement).

Therefore, an alternative is needed at plant X so it can continue to be sustainable and able to be competitive in the markets that highly demanding a fertilizer. This paper aims to analyze alternatives that can be applied to reduce the energy consumption of the plant so it can be sustainable.

2 Methods

This paper presents a case of urea fertilizer plant “X” located in South Sumatera, Indonesia. The factory has been selected due to two of plants that built in 1976 and 1977. The plant still manufacturing up until 2018 even though having several issues (mainly energy consumption and raw material cost), due to the quality of urea that produced was better than the other two plant that uses the new technology. Quantitative approach with systematic reviews used to identify the problem based from the observational study and key informant interview, and to synthesize with related issues from previous studies to find the appropriate strategy.

3 Result and discussion

Responsibility for extracting natural resources for development purpose is one of the important aspects of sustainable development [9]. In the attachment of presidential regulation number 28 year 2008 about national industrial policies stated that the development of industry would be directed to the principle of sustainable industrial development based on several aspects including environmental and technological innovations. The long-term plan attached in this regulation particularly for the petrochemical industry is by increasing the petrochemical industry’s process technology and engineering product through integrated research and development; improving the technology in engineering design as well as domestic machinery equipment industry; increasing the productivity and efficiency of fertilizer products through restructuring old fertilizer plants with new plants using coal as raw material and fuel [10]. The coal prices are lower than natural gas [11], besides the urea product from coal (particularly Hybrid brown coal) able to retain the N compound in urea, enhancing its supply to crops and minimizing negative off-sites impacts [12]. However, the manufacturing process by using coal as the product requires at least 1.7x more energy compared to a natural gas-based plant with an efficient process [11]. Prices of energy as the raw materials (i.e., natural gas, petroleum) in the next few years predictably will continue to rise due to the scarcity for resources as well as the production cost [13]. Therefore, the efficiency of the use of raw material and energy is an effective way to countermeasure the rise of energy material consumption and insecure energy supplies [14]. Moreover, the rising price of energy and trend industry that leads to sustainability have exerted the new pressure on manufacturing enterprises to reduce energy consumption for both saving cost and environmentally friendly process [15].

The urea fertilizer manufacturing process commercially is obtained by reacting *ammonia* (NH_3) and carbon dioxide (CO_2) at high pressure, creating *ammonium carbamate* (NH_4CONH_4), and dehydrated by using heat to create urea solution ($NH_4CONH_{2(l)}$) [16]. Several factors cause high energy consumption, i.e., the process carried out on elevated temperature and pressure, and the higher difference of temperature and pressure inlet and outlet streams than the standard condition [8]. In general, the different technology of urea manufacturing somewhat requires different methods to maximize the product yield and to increase its efficiency [17]. Therefore, in this case, to reduce the energy consumption in the urea plant (particularly in urea synthesize section), several methods can be used, such as:

3.1 Optimization in ammonia plant

Natural gas frequently used in ammonia plant to extract its hydrogen compound as the primary material for synthesizing ammonia using the steam reforming process [18]. Based on U.S. Department of Energy, several options that can be used for efficiency in the ammonia plant including [19]:

a. Modifying in the synthesis loop

Synthesis loop section process aims to produce ammonia from hydrogen and nitrogen with a reversible reaction and its equilibrium condition determined by the design temperature and pressure. In one pass, high pressure (preferably more than 21 bar) required to achieve sufficient conversion, mainly 30% or less is converted to the product, so the remaining unreacted gas keeps recycling and involves a lot of energy [20]. Therefore, an addition of the second converter would be a preferable option for increasing the conversion while reducing the energy consumption [21]. The second converter will be installed downstream of the current converter so the increase in ammonia concentration in output resulting in a decrease in pressure and lower circulation rate, which give an energy saving on the synthesis gas compressor and refrigeration compressor approximately 0.18 Gcal/ MT NH_3 [22]. It also can be achieved by modifying a loop with revamping the first converter by replacing the cartridge with two radial- flow catalyst beds and an interbed heat exchanger, while the second converter comprises one catalyst bed enclosed in flow panels on the inside wall directly [23].

b. Enhancing the heat and cold utility section in Ammonia Plants

 https://doi.org/10.1051/e3sconf/20187405004

Ammonia plant can be divided in two section, the hot section (every process that involves feed preparation before entering the syn-loop) and the cold section (mainly ammonia synthesis and refrigeration cycles) [24]. For the hot section, there are two options: first is to cover the energy integration from each process, and second is modify the convection section in primary reformer through a new arrangement of heating coils [25]. For the cold section, energy reduction can be achieved by changing the chiller's operating pressure in the outlet valve before and after chiller was set rather than changing the chiller design because there are no significant changes [25].

c. Building a high-pressure natural gas pipeline

Due to the high-pressure condition required in natural gas purification at ammonia plant (mainly at 550 psig), it needs to elevate the natural gas pressure by using compressors [19]. Therefore, it is preferable to build a high-pressure gas pipeline from the supplier and to connect it directly to the plant to eliminate the compressor, that estimated to save approximately 851,000 MMBtu energy per year [19].

3.2 Optimization in urea plant

The process in the urea plant mainly divided into high pressure and low-pressure process. In this case, to make the plant more efficient, some of the options will be focused on the high-pressure process section. The high-pressure section mainly consists of urea reactor, CO_2 stripper, high-pressure scrubber, condenser, and ejector [26]. Several options that can be implemented such as:

a. Retrofitting the urea reactor

A modification can be done in urea reactor for efficiency, for example installing High-Efficiency Trays (e.g., HET developed by NIIK or Siphon jet HET developed by M/S) and vortex mixture with conversion booster in the bottom part of urea reactor [27]. HET installation purpose is to improve the unreacted carbon dioxide distribution inside the rich ammonia solution and reduce the back mixing from the bottom to the top reactor, so it increases the urea production up to 5% while saving the energy approximately 0.002 G.Cal/ ton of Urea [28].

Vortex mixture installation able to improve the percentage of CO_2 conversion in reactor by 1.2% (from 64.10% to 65.30%), Efficiency in stripper by 0.35% (from 57.15% to 57.54%), Medium Pressure Decomposer by 2% (from 74.30% to 76.30%), and Low Pressure Decomposer by 2.30% (from 37.30% to 39.60%) [27]. However, if the material of construction in the urea reactor were using titanium, it would be having some problem with the installation (the welding on a titanium based material is very difficult).

b. Optimize N/C and H/C ratio

Mane et al. study stated that in achieving energy efficiency and conversion, excellent reaction condition should be met along with increasing the N/C and H/C ratio in urea reactor [29]. The study later calculate that in the condition of pressure 100 atm, temperature 150ºC, and 20 minutes longer to attain the equilibrium, raising the N:C ratio between 3:1 and 3:4 would be preferable to increase the efficiency of the reactor by 10.36% (from 49.68% to 60.04%) [29]. Based on the field observation, here is the summary for the possibility of the options above to be implemented in Plant A and B.

Table 1. Summary of the Strategic Options to Increase the Plant Efficiency

No	Options	Probability
1.	Optimization in Ammonia Plant	
	a. Install the second ammonia converter to increase conversion	This will be possible to be implemented, but the right design calculation will be necessary to achieve the desired conversion and energy saving.
	b. Revamp the first converter with replacing the catalyst bed	It would be hard to replace the bed or the cartridge because it is welded to the vessel in Plant A and Plant B.
	c. Modify the Heating coil in the Primary Reformer	Modify by re-arrange the reformer would be hard because of the reformer design.
	d. Change the temperature and pressure condition in a chiller	This will be possible but must pay attention because chiller is on the purification unit to separate the ammonia and purge gas; this might be affected in the product's purity.
	e. Install High-Pressure Natural Gas Pipeline from the source to the Plant	This is already considered by the factory and under the fabrication process.
2.	Optimization in Urea Plant	
	a. Install the High-Efficiency Tray and Vortex mixture in the bottom or Urea Reactor	It would be impossible to implement in Plant B because they used titanium as the material in their urea reactor, but possible in Plant A because it used stainless steel as the material.
	b. Increase the N/C or H/C ratio in the Urea Reactor	This will be possible to be implemented in both Plant if the calculation for temperature, pressure and residence time is appropriate. If it is not on the right condition will form by-product called "biuret" that will lower the urea quality.

Based on the table above, it can be inferred that two general options could be suggested as the alternative, i.e., altered the process condition and addition of the equipment, while at the same time both of the options have weaknesses that should be concerned. Based on the discussion with the urea plant X supervisor and operator, altering the process may be preferable particularly in switching over the temperature and pressure of the process, also the feed ratio. However, in forming a good quality of urea requires a right temperature and pressure, or else it may convert into biuret, an unwanted by-product that can degrade the urea quality. Therefore, should the first option apply, they must find a precise condition to avoid unwanted consequences. Addition of new equipment to reduce the burden of the old one while increasing the conversion can be preferable in this case. But then again, based on the discussion, some weakness such as the cost of the new material and the length of time needed for fabricating, transporting, and installing the equipment will be a significant consideration. As an example, it requires 1-2 months for the supervisor to get approval from the management to buy some material, 3-4 months of equipment shipping, and approximately 1-2 months to install the instrument, while at the same time it needs to manufacture urea for fulfilling the demand. Material purchase approval is also considered as the business decision based from one of the points stated in the Business Judgement Law, mainly standard of care where the decision is based on proper information and condition as well as rationally believe that the right decision in order to sustain the company [31]. Therefore, although the second option is safer for sustaining the plant, it is hard to be implemented due to the high budget and long period of approval and application.

4 Conclusion

In the development of industries that utilize natural resources, technology advancement is essential with the aim of reducing production costs without reducing company revenues. With the current rapid technological growth (particularly in engineering and manufacturing) that emphasize an environmentally friendly process, also required low energy and material consumption. Hence, in the case of the vintage factory, several alternatives must be maintained so the plant would be able to keep manufacturing while competing with the new plant concerning product price and energy consumption. From the study above, it can be inferred that the possible option to be implemented in Factory X including optimization in ammonia plant and urea plant. Modification in ammonia plant is necessary due to 78 – 80% of energy in urea plant depends upon the ammonia process. The possible option in ammonia plant including modification in synthesis loop with second ammonia converter installation to improve the ammonia conversion, changing the tray design inside the converter, changing the coil inside the reformer, and install a high-pressure pipe to transfer natural gas to the plant. While optimization in urea plant including the installation of high-efficiency tray and vortex mixture in the bottom reactor to increase the conversion approximately 0.35 – 5%, also optimizing the N/C and H/C ratio between 3:1 to 3:4 to improve the efficiency by 10.36%.

Acknowledgements

The author would like to thank Mr. Prem Baboo from National Fertilizer Ltd. India for giving knowledge and support to guide in constructing the paper.

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