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Assessment of energy efficiency measures in the petrochemical industry in Thailand

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ABSTRACT

Petrochemical industry is one of the most important industries that contribute to Thailand's economic growth. Its energy consumption and greenhouse gas emission were approximately 170,000 TJ and 8300 $ktCO_{2e}$/year in 2010. This research assessed 35 energy conservation measures implemented in the Thailand's petrochemical industry, categorized into the six following categories: 1) steam saving and steam loss reduction, 2) steam optimization, 3) cogeneration, 4) power saving by efficient chillers, 5) energy efficiency, and 6) waste energy recovery. The analyses were performed in energy, environmental, and economic perspectives using five indicators: 1) reduction in energy intensity, 2) reduction in carbon intensity, 3) energy consumption reduction on investment,4) greenhouse gas emission reduction on investment, and 5) abatement cost. The results show that, from energy and environmental perspectives, the cogeneration is the most capable of reducing energy consumption and greenhouse gas emission which accounted for 82% of the total reduction, followed by the waste energy recovery and energy efficiency categories. From economic point of view, the most cost effective measure category was steam saving and steam loss reduction, followed by waste energy recovery and energy efficiency categories. The cogeneration category is found to have the low cost effectiveness due to its high investment required. The abatement costs of the energy conservation measures was calculated to assess the economic feasibility. Almost all measures were economically feasible, except for some measures under the energy efficiency category. To encourage non-cost-effective measures, carbon credits should be promoted to cover the implementation cost of the measure. The results in this research will be useful for industrial sector, petrochemical companies, and other interested parties for transformation towards industrial sustainability.

1. Introduction

An increase in greenhouse gas (GHG) emissions could lead to greater warming, which, in turn, could have an impact on the world's climate, leading to the phenomenon known as climate change (VijayaV.S. et al., 2012). Thailand was ranked 23rd in the world in GHG emissions in 2009 (IEA, 2009a) and as a Non-annex I party (developing country) has fulfilled its obligations and commitments under the United Nations Framework Convention on Climate Change (UNFCCC) to address climate change. The 11thNational Economic and Social Development Plan (2012–2016) includes “management of natural resources and the environment toward sustainability” as one of the important development topics, under which various issues will be addressed, including creating a low-carbon society, energy awareness and preparing for climate change and natural disasters (NESDB, 2011). The supported key policies that have greatly contributed to GHG mitigation include energy efficiency, energy switching from fossil fuels and coal to natural gas, improvements in the public transportation network, and promotion of energy saving practices and renewable energy use (Chollacoop et al., 2013).

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Nomenclature

ECM	energy conservation measure
EnR	energy consumption reduction
ER	greenhouse gas emission reduction
EnRI	reduction in energy intensity
ERI	reduction in carbon intensity
EnROI	energy consumption reduction on investment
EROI	energy consumption reduction on investment
EAC	equivalent annual investment cost
SS	steam saving and steam loss reduction
SO	steam optimization
CO	cogeneration
EE	energy efficiency
EC	power saving by efficient chillers
WE	waste energy recovery

The increasing GHG emissions and climate change are mainly caused by energy consumption. The industrial sector uses more energy than any other end-use sector, and this sector is consuming approximately 37% of the world's total delivered energy (Abdelaziz et al., 2011). The industrial sector in Thailand also contributes the largest share of the total final energy consumption, followed closely by the transportation sector (Phdungsilp and Wuttipornpun, 2013). In 2011, the share of final energy consumption in industry by economic sectors was 25,366 ktoe (36.0%) (DEDE, 2011). The pattern of sectoral energy consumption in Thailand is similar to those of Taiwan and Jordan. In Taiwan, the industrial sector, i.e., the largest final energy use sector, accounted for 53.8% of the total energy use (Lu et al., 2013). In Jordan, the industrial sector accounted for 22% of the final energy consumption in 2009 (Abdelaziz et al., 2011). The GHG emissions from energy consumption can be divided into 2 categories: direct emissions (e.g., fuel combustion) and indirect emissions (e.g., steam and electricity) (IEA, 2009b). To reduce GHG emissions, many countries have continuously implemented measures to accelerate the use of alternative fuels (Shyi-Min Lu, 2015) and promoted energy conservation in many industries (Lu et al., 2013) such as cement (Brunke and Blesl, 2014), petrochemical (Mohammadi et al., 2013), chemical fiber (Lin and Zhao, 2015), pulp and paper (Kong et al., 2016), and automotive (Zhai et al., 2014) industries. There also be an effort to improve energy efficiency of specific equipments such as motor, which is a widely used in various industrial processes, in order to reduce energy consumption (Shyi-Min Lu, 2016). To achieve the target concerning greenhouse gas mitigation, the Clean Development Mechanism (CDM) was used as an important tool that can help developed countries meet their quantified emission reduction obligations at lower cost while helping developing countries in achieving sustainable development (Maraseni, 2013). The CDM offers an important opportunity to assist developing countries in making progress while simultaneously managing climate change, development, and local environmental issues; otherwise, developing countries would be preoccupied with immediate economic and social needs (UNEP, 2010). As with Thailand industries, other countries used CDM in many industries, such as the glass, cement, and steel industries. For example, in Morocco, CDM was implemented as a potential tool for energy efficiency in the cement industrial sector and other industrial sectors that are estimated at 20% of the current consumption, for an annual economic potential of approximately 300 ktoe (Karakosta and Psarras, 2013).

The petrochemical industry is one of the highest energy consumers in the world and is closely related to GHG emissions. Therefore, energy conservation measures (ECMs) need to be applied to improve energy efficiency, taking into account environmental impacts and energy security. Saygin et al. (2011) analysed the energy efficiency potential on a country level if Best Practice Technologies (BPT) were implemented in chemical and petrochemical sector and suggested a global energy efficiency potential of 16% for this sector. Neelis et al. (2007) performed energy analysis for 68 petrochemical processes and showed that the theoretical energy-saving potential of the processes for the world was 10,092 PJ. Mohammadi et al. (2013) investigated energy efficiency potential in the petrochemical industries of Iran and indicated over 2.53 million tCO_{2eq}/year potential reduction in GHGs emission. Thorat et al. (2014) presented the opportunities to save energy in petrochemical plants by improving the insulation system, considering power distribution alternatives, utilizing an appropriate control and monitoring strategy, and selecting appropriate trace heating technology. Recently, computer-integrated production process has been introduced in petrochemical industry to manage and control the whole industrial chain to reduces loss and save energy (Li, 2016). Han et al. (2016) applied an artificial neural network to optimize the energy usage of petrochemical (ethylene) production plants and achieved the optimal production situation improving energy efficiency ratio of approximately 2%. In Thailand, petrochemical industry is one of the most important industry that contributes to Thailand's economic growth and is currently in a state of expansion. Its energy consumption and greenhouse gas emission were approximately 170,000 TJ and 12,000 $ktCO_{2e}$/year in 2010 (Kanchanapiya et al., 2014). Therefore, energy saving in this industry will provide a great contribution to low carbon development of the industrial sector.

The aims of this study are to evaluate the energy saving and greenhouse gas mitigation from ECMs implemented in the Thailand petrochemical industry based on CDM methodologies as well as identify the cost-effectiveness of the measures. This study provides a beneficial information for sustainable industrial development for industrial sector, petrochemical companies, researchers, engineers, decision makers, investor, and other interested parties.

2. Methodology

2.1. System and energy conservation measure scope

There is a total of fifty-three petrochemical plants in Thailand, covering thirty-two products. For this research, data were obtained from seven case study factories of six products, including two product of upstream petrochemicals (U1 and U2), a chemical product (M1) and three products of synthetic resin (D1-D3) which covers the products in upstream, intermediate, and downstream in Thai petrochemical plants as shown in Table 1.

The data of the ECMs occurring during 2010–2012 for each sample plant were gathered and summarized from the energy management reports. The ECMs could be grouped and categorized into the following six categories: 1) steam saving and steam loss reduction (SS), 2) steam optimization (SO), 3) cogeneration (CO), 4) power saving by efficient chillers (PC), 5) energy efficiency (EE), and 6) waste energy recovery (WE). The GHG emission reductions resulting from the ECMs were calculated using the CDM methodologies. According to the CDM methodologies, the CDM methodologies applicable for the categories of the measures described above are AM0017, AM0018, AM0048, AM0060, AMS.II.C, and AMS. III.Q, respectively, as shown in Table 2.