Assessment of Carbon Footprint Organization and Analysis of Appropriate Greenhouse Gas Mitigation Measures: Case Study PTA Factory in Thailand

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The Asian Conference on Sustainability, Energy and the Environment 2015
Official Conference Proceedings

Abstract
This research investigated carbon footprint organization and analyzed appropriate greenhouse gas mitigation measures of purified terephthalic acid (PTA) factory in Thailand. The factory has a production capacity about 40% of intermediate petrochemical products in Thailand. PTA is raw materials for producing textiles, plastic bottles, X-ray films and products in the automotive industry, and etc. Two PTA factories are used as case studies. The production capacities of PTA representative factories are around 1,347,000 ton per year.
The results indicated that the carbon footprint organization of PTA factory is average around 216,557 tCO_2e per year. The energy use on average is 1,606 TJ per year. The average carbon intensity of PTA product is 0.3878 CO_2e/ton product. Potential greenhouse gas mitigation measures are mainly energy conservation including using excess steam from steam turbine, replacing Hollow GRP to Hollow FRP, and installing vapor absorption chiller. Mitigation measure that can reduce relative largest greenhouse gas emissions is by renovating steam turbine. Based on a case study, it can reduce electricity appromately 5,100 MWh which is equal 2,958 tCO_2e reduction. Energy inspection and conservation measures should be implemented within the plant continuously for substantial greenhouse gas reduction.

Keywords: purified terephthalic acid, carbon footprint organization, greenhouse gas mitigation

Introduction

Nationally Appropriate Mitigation Actions (NAMAs) become a mandate for counties that ratified the Kyoto protocol. Mainly, each county has to identify and develop greenhouse gas mitigation in their countries. Thailand also prepares how to reduce greenhouse gas emission efficiently in the future. The petrochemical industry has high contribution of greenhouse gas emission and also has high capability to reduce greenhouse gas emissions effectively.

Intermediate petrochemical industry in Thailand produce 16 products and its production capacity average is around 7,003,000 ton (Table 1). Purified terephthalic acid (PTA) factories have a production capacity about 40% of intermediate petrochemical products in Thailand. PTA chemical formula is $C_8H_6O_4$. The appearance is white crystals or powder and solubility in organic solvents.

Table 1: Products of intermediate petrochemical factories in Thailand

No.	Products	Capacity (ton/year)	Percentage capacity
1	Purified Terephthalic Acid	2,787,000	39.80
2	Vinyl Chloride Monomer	900,000	12.85
3	Styrene Monomer	560,000	8.00
4	Bisphenol A	430,000	6.14
5	Propylene Oxide	390,000	5.57
6	Ethylene Glycol	325,000	4.64
7	Cumene	262,000	3.74
8	Methyl Methacrylate	245,000	3.50
9	Acrylonitrile	200,000	2.86
10	Crylohexane	200,000	2.86
11	Phenol	200,000	2.86
12	Caprolactam	130,000	1.86
13	Acetone	124,000	1.77
14	Epichlorohydrin	115,000	1.64
15	Ethylene Oxide	85,000	1.21
16	Pthalic Anhydride	50,000	0.71
		7,003,000	**100.00**

Source: The Petroleum Institute of Thailand (PTIT), 2013.

Process of PTA production include 2 processes (1) Oxidation and (2) Purification that have details of each process as follows Figure 1.

Oxidation starts from the paraxylene to react with oxygen. The reaction takes place under the acetic acid solution and a catalyst. The product of the process is crude terephthalic acid (CTA) in form of Slurry. Reaction is exothermic.

Purification The oxidation process will get rid of contaminants such as 4-carboxy benzaldehyde (4-CBA), which are required to make the amount of contaminants less.

The hydrogenation change the 4-CBA to para-toluic acid, which has the ability to dissolve in water better than CTA. Later, it will crystallize and separate out the impurities.

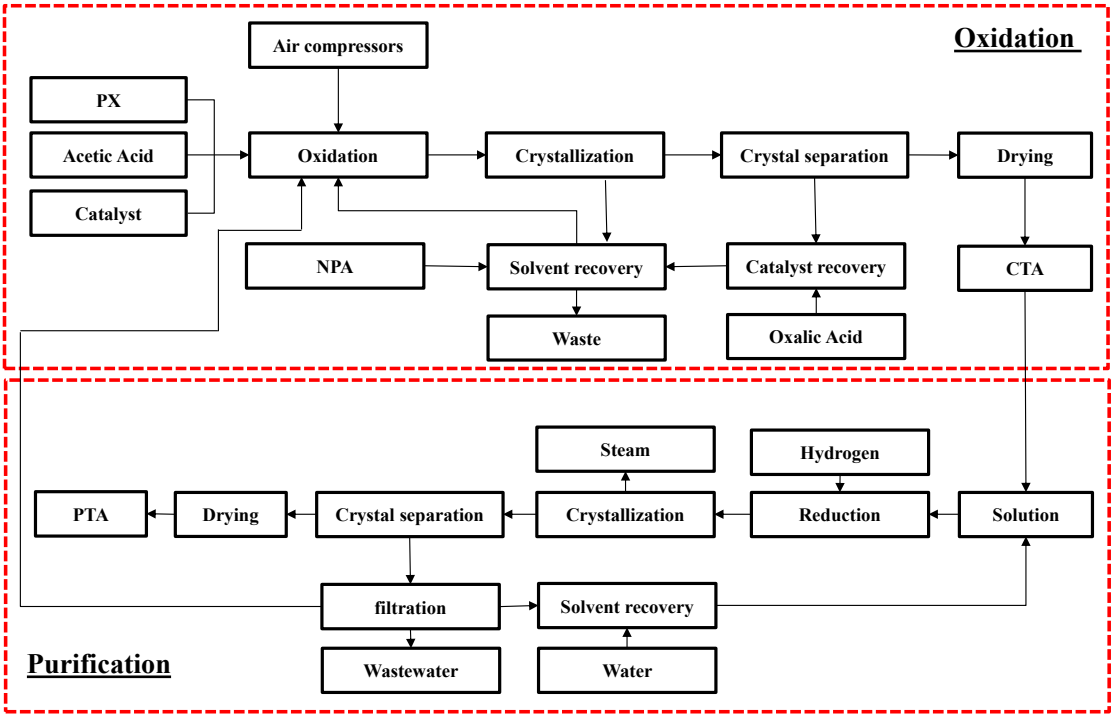


Figure 1: Process of purified terephthalic acid (PTA)

Methodology

Evaluation of greenhouse gas emissions as carbon dioxide equivalent (CO_2e) include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and Sulfur Hexafluoride (SF_6). Sources of greenhouse gas emission are classified into 2 types which are (1) direct greenhouse gas emission (combustion, vent, wastewater treatment, refrigerants, extinguishing and flare) and (2) indirect greenhouse gas emission (purchased electricity and steam). Period for data evaluation was 3 years during year 2011 to 2013.

Two PTA factories are used for carbon footprint organization assessment. Organization boundaries or compilation of resources and absorb emissions of greenhouse gases is defined based on the Operational Control including 2 scopes.

Scope 1: Direct greenhouse gas emissions include activities that contribute to the greenhouse gas emissions from operations, including the production of electricity, heat and steam for internal use or for distribution to external organizations. The combustion of fuel used in equipment and machine owned enterprise control.

Scope 2: Indirect greenhouse gas emissions are activities that contribute to the greenhouse gas emissions from energy import from outside to use in the factory, including the purchase of electricity, heat and steam.

Assessment of carbon footprint organization use basic equation as shown in equation 1.

$$\textbf{Emission = AD x EF} \quad \textbf{(1)}$$

Emission = Emissions of greenhouse gas (t CO_2e)
AD = Activity Data (Unit)
EF = Emission Factor (t CO_2e/Unit)

Emission factor will primary use domestic EF. If there is not EF within the country, emission factor from the IPCC (Default value) will be used for evaluation. Non CO_2 greenhouse gases will calculate by using equation 2.

$$\textbf{Emission} = \textbf{Emission}_{\textbf{GHG}} \times \textbf{GWP} \quad \textbf{(2)}$$

Emission_{GHG} = Emissions of greenhouse gas non CO_2 (t GHG)
GWP = Global Warming Potential (t CO_2e/t GHG)

Assessment of reduction the greenhouse gas and energy consumption from energy conservation measures is done from interviewing about the projects and collecting data from factory that were implemented reduce energy consumption and costs in production. Energy conservation measures can classified 2 groups:

1. Development and improvement of production technology.
2. Management and improvement energy efficiency of equipment used in the production process.

The greenhouse gas reduction from case studies from different measures are analyzed compared the reduction ratio of each measure to analyze efficiency of energy conservation measures and provide recommendations as guidelines for further reduction.

Results and discussion

Sources of greenhouse gas emissions from 2 case studies are shown in Figure 2. Factory A has the largest contribution of greenhouse gas from stationary source (Scope 1: direct greenhouse gas emissions), which is natural gas used as fuel to generate steam. However, factory B has the largest contribution of greenhouse gas from purchased steam (Scope 2: Indirect greenhouse gas emissions), used in operating reactor of CTA and PTA process.

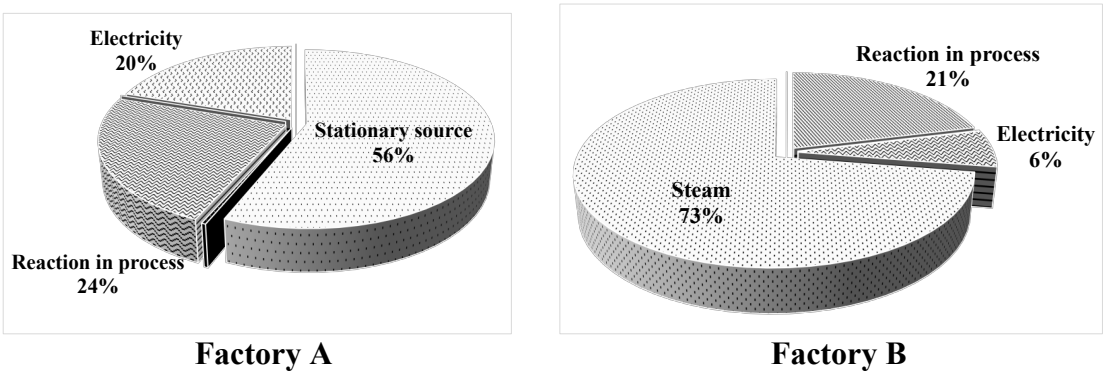


Figure 2: Assessment sources of greenhouse gas emissions.

The results indicated that the carbon footprint organization of PTA factory is average around 216,557 tCO_2e per year. The energy use on average is 1,606 TJ per year. (Figure 3)

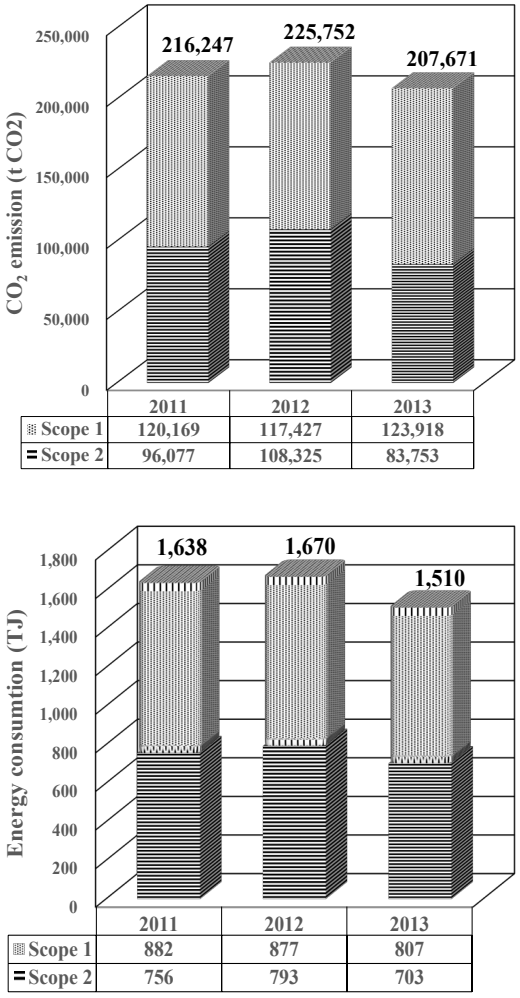
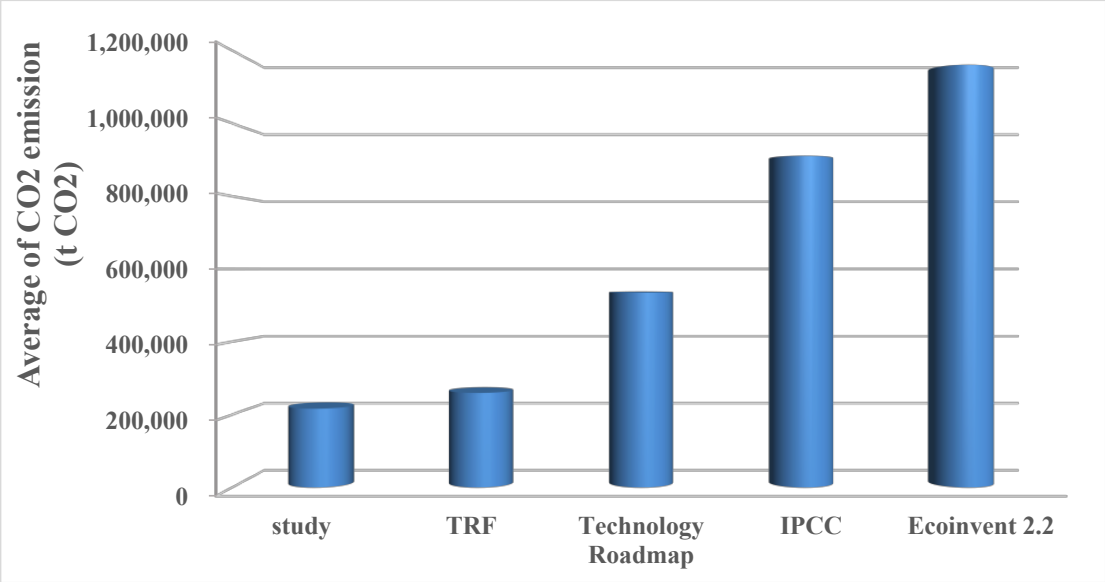


Figure 3: The results of average greenhouse gas emissions and energy consumption.

In addition, to the results from this study when compared with results from other studies (Figure 4) found that greenhouse gas emission of PTA factory in case studies (from Thailand) are less than other studies. However, this comparison does not take into account of the production capacity of each factory. Therefore, the carbon intensity (CO_2/ton PTA) should be used for comparison in the future.

Energy conservation measures implemented in the PTA representative factories were assessed for amount of greenhouse gas reduction and energy consumption each year, as shown in Table 2. Mitigation measures that can reduce relative largest greenhouse gas emissions is by renovating steam turbine. It can reduce electricity appromately 5,100 MWh per project which is equal to reduce 2,958 tCO_2e per project.



Source: TRF (Thailand Research Fund, 2011), Technology Roadmap (International Energy Agency, The International Council of Chemical Associations (ICCA) and Society for Chemical Engineering and Biotechnology (DECHEMA), 2013), IPCC (Intergovernmental Panel on Climate Change, 2006) and Ecoinvent 2.2 (LCA software, IPCC 2007. GWP 100a.)

Figure 4: Comparison of greenhouse gas emissions with other studies.

Table 2: Amount of energy saving and CO_2 equivalent reduction from energy saving measure of PTA factory in Thailand.

Saving	2011	2012	2013
Energy (GJ)	44,970	24,970	3,719
CO2 (t CO2e)	3,169	4,023	513

Conclusion

Carbon footprint organization of PTA representative factories have average greenhouse gas emission 216,557 tCO_2e/year and energy use on average is 1,606 TJ per year. The average carbon intensity of PTA product is 0.3878 CO_2e/ton product. Main source of greenhouse gas are from energy production and utilization which depend on energy sources (own generation or purchase). Energy conservation is recommended measure to effectively reduce greenhouse gas emission. High potential mitigation measures that can reduce relative largest greenhouse gas emissions are by renovating steam turbine which can be implemented practically. However, to increase amount of greenhouse gas reduction, best practice technology (BPT), new technologies or emerging technology should be considered and implemented in the future.

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