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Article

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Energy conservation tracking of Thailand's energy and GHG mitigation plan: A case of Thailand's textile industry

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Abstract

Thailand's textile industry is the traditional industrial sector which shows the continuous increase in energy consumption and Energy Intensity (EI) index, primarily on electrical and thermal energy. This paper aims to track the implementation of energy conservation measures through the textile industry to meet Thailand's target of Energy Efficiency Plan 2015- a=2036 (EEP2015), Alternative Energy Development Plan 2015–2036 (AEDP2015) and NDC Roadmap by absolute and intensity indicators. As the analyst indicates that energy consumption in this sector will grow while EI can be reduced. 4 Scenarios of energy conservation and the implementation of renewable energy in the sector are studied; (1) BAU, (2) switching to high-efficiency equipment and waste heat recovery, (3) solar PV utilization, and (4) the combination of the equipment switching, heat recovery, and Solar PV utilization. It is deduced that, in 2036, Energy consumption and EI of scenario 2 and 4 is approximately reduced for 16.63% in comparison with BAU which implies the reduction of 373.41 ktoe energy consumption. This is well over the EEP2015 target by 9.94% as solar PV utilization plays small influences. Solar PV systems alone cannot primarily help the textile industry to meet AEDP2015 target. It is recommended that textile industry should implement more renewable-related measures or the alteration of policy and technology is needed. In the case of the environment impacts, GHG emission and GHG mitigation show consistent results with the energy consumption. In 2036, scenario 1 suggests GHG emission of 13,482.58 Gg CO₂-eq and GHG Intensity (GHGI) of 29.54 Gg CO₂-eq/billion baht. Scenario 2, 3 and 4 possibly reduce GHG emission and GHGI in 2036 as 16.67%, 1.15% and 17.82% above the BAU, respectively. The target of NDC roadmap is to mitigate GHG within 2030. Scenario 4 can mitigate 53.75% over the target while scenario 2 can mitigate more than 41.11%.

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Keywords: Textile industry; Energy conservation; GHG mitigation; Energy efficiency; Organic Rankine Cycle

1. Introduction

The textile industry is the traditional industrial sector that has been one of the focal points of Thailand's economy for more than 60 years. It ranks 5th in a value-added per GHG in the country. NESDB [1], DEDE [2] and also

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ranks 5th in an export value [3]. There are six main stages in textile industry which are cultivating and harvesting, material preparatory, spinning, weaving, finishing, and marketing. The industry can be differentiated into 3 levels according to their productions and sizes: (i) upstream industry whereas they are usually the large factory with large production, high energy consumption on both electricity and thermal energy (ii) midstream industry, mostly these are factories with heavy machineries and (iii) downstream industry where simple processes from cultivating, harvesting, spinning to weaving are focused in the community and consumption is mainly on electricity. Most of them are usually the medium and small entrepreneurs [4]. While the processes of spinning, weaving and printing tentatively consume mainly on electricity, the finishing process which includes sub-processes as washing and dyeing requires both electricity and thermal energy [5] which subsequently generates the low-temperature waste heat and its temperature ranging from 40–96 °C [6]. Since 2010, the energy consumption of the industries has grown 3.4% while that of the country has grown only 2.95%. In 2017, the textile industry consumed the total energy of 958.62 ktoe which is comprised of 62.55% in electricity and 37.45% in thermal energy. 2017 Energy Intensity (EI) index for the industry is 3.12 ktoe/billion baht. This index may be not too high, but its growth rate has significantly increased by 50% since 2010 [2]. While economic prosperity is sought, sustainability has been weighted in such that energy consumption of textile industry is one of the focusing as part of national mitigation plan.

Thailand has proposed a plan to improve energy efficiency especially for the industrial sector. It consists of 2 parts, i.e. Energy Efficiency Plan 2015–2036 (EEP2015) and Alternative Energy Development Plan 2015–2036 (AEDP2015). The EEP2015 targets the 30% reduction of EI index within 2036 based on 2010 base data which is equivalent to 56,142 ktoe energy-consumption reduction. There are five-main measures among this plan for reducing the energy consumption, i.e. enforcement of energy conservation standards in designated factories (EE-1), promotion of energy labeling on machines and equipment that consume electricity and thermal energy (EE-3), enforcement of Energy Efficiency Resource Standard (EERS) for energy producer (EE-4), supporting financial tools to hasten the equipment improvement (EE-5) and promoting LED by pricing mechanism (EE-6) [7]. AEDP2015 also promotes renewable energy to the industries. These include the use of municipal solid waste as the alternate energy sources, the use of small hydropower, the use of biofuels to generate electricity, heat and biofuels. This plan points out three national strategies which are (i) harnessing the potential of renewable sources (ii) promoting the use of renewable energy and creating the market, and (iii) improving awareness and knowledges of renewable energy to the population. The target of this plan aims at 30% utilization of renewable energy within 2036 which is equivalent to 39,389 ktoe.

There is a number of previous investigations reporting effort of the textile industry to reduce energy consumption and promote renewable energy within the industry. Dechasiri et al. [8] studied the potential on reducing energy consumption by means of the improvement on the electrical motor and boiler efficiency which are main equipment essential to textile processes. There are also an investigation on the energy saving in lightings by replacing the tradition light tubes with LED which not only decreases energy consumption but also decreases the cost and expands longevity [9]. Sonawane and Keste [6] supports the fact that plant efficiency can be improved by reclaiming the waste heat to generate the electrical power. Zhang et al. [10] reports a tremendous potential for the textile industry in Southeast Asia possibly to generate more than 1788 MW of WHP. Recently there has been a number of publications on the use of small-module Organic Rankine Cycle (ORC) engine which can be effective with low-temperature heat sources which include waste heat from the textile processes [11–13]. Recently, Thai government has promoted the use of solar PV on the rooftop of the plants with significant incentives and solar PV is simple to be installed and utilized. Moreover, once installed, it is simple to operate with low maintenance cost [14].

In 2015, Thailand has established Nationally Determined Contribution Road Map on Mitigation (NDC) aiming at reducing GHG emission by 20% within 2030. This is accounted for 113,000 Gg CO₂. The task of reducing 45,000 Gg CO₂ is put upon the industrial sector in Thailand. Textile industry is therefore targeted as a sector to participate in national scheme of efficiency improvement and the reduction of both energy consumption and GHG emission.

2. Conceptual framework

This paper's objective is to study the implementation of measures in the textile industry to meet national target set in EEP2015 and AEDP2015 in comparison with the BAU. Firstly, the current energy consumption and GHG emission is reported without any implementation on energy conservation or any supporting policies. Data archives

of 5,822 factories [15] is studied. It consists of 435 by-law designated factories [16] and the remaining small and medium entrepreneurs (SMEs) that voluntarily submitted the data.

The estimation the future demand from 2018–2036 is then performed by the energy consumption data from 2010–2017 available from the Department of Alternative Energy Development and Efficiency's Data [2] and from Chaichaloempreecha et al. [17] along with national figures on Gross Domestic Product (GDP) and annual number of population. Then the GDP forecast is achieved in accordance with the growth rate of Thailand Development Plan 2015 (PDP2015) by EGAT according to which average 3.94% growth rate per year is suggested [7]. The number of populations is also forecasted using the growth rate of the National Economic and Social Development Board (NESDB) database, i.e. average 0.03% growth rate per year [18]. The estimation of energy demand is then analyzed by linear regression method and used as BAU.

Secondly, the forecast estimation is then done again by including all possible implementation measures in accordance to EEP2015 and AEDP2015. A number of measures are selected based on the manufacturing processes of 380 textile designated factories in the DEDE database, i.e. the deployed measures in reference to EEP2015 and the deployed renewable energy initiatives in reference to AEDP2015. Relating GHG emission is also analyzed reported in corresponding to NDC. The absolute and intensity indicators in terms of energy and GHG emission are summarized accordingly. Estimation for each implementation measure has to be performed.

For EE-1 (the implementation of energy conservation activities in designated factories), data from the sampling group is retrieved with the data from implemented measures with unit of electricity and thermal energy spent, resulting energy conservation of each measures, main infrastructure data, amount of waste heat, and other related figures. Then, total number of implemented measures and their corresponding energy consumption are then determined by linear regression method for the whole group of factories. The estimation then expands to all textile designated factories by the proportion of energy consumption and comparison with BAU for the reduction analysis. The second and third measures are the implementation of high-efficiency air-conditioning systems (EE-3) and replacing the traditional light tube with high efficiency lighting fixture (EE-6), respectively. This is in accordance to the EEP2015's replacement plan. The analysis repeats as the relevant energy usage data from previous years is collected and the calculation of the energy reduction ratio from the equipment replacement is achieved for the sampling group. The results are then expanded to determine the potential to all recorded factories. For the waste heat recovery measure, it is assumed that the recovery of waste heat is to be used for preheating feedwater for the boiler or water heater which are normally used in the textile industries. The analysis starts with evaluation the waste heat generation potential. This is done by the primary data from survey questionnaires. The data includes waste heat volume, temperature, pressure of waste heat and other related data essential to the estimation. Then, the waste heat utilization is calculated against of thermal energy usage reduction. The results are then expanded to cover all textile factories based on their thermal energy usage proportion. Waste heat utilization by electricity generation from ORC technology is also estimated. ORC is beneficial to not only EEP2015 and AEDP2015 but also to NDC as well because of its environmental-friendly features and its ability to operate at the temperature range of waste heat in textile industry. Collected data by survey is also sought and the simulation of the electricity generation is determined. The percentage of grid electrical power replaced by ORC is reported and the estimation is expanded to cover the potential of all textile factories based on waste heat generation proportion of each factory. In addition to the efficiency enhancement of the electrical equipment and the use of ORC for waste heat recovery system, this study also considers the potential of renewable energy usage e.g., the implementation of solar rooftop for electricity generation in order to reduce the electricity from the national grid for the textile industry. To estimate of GHG emission and mitigation, energy consumption data of each measure is calculated and relevant GHG emission and mitigation (Gg CO₂-eq) are determined. Only CO₂, CH₄ and N₂O are focused as it is based on 2006 IPCC Guideline for National Greenhouse Gas Inventories [19]. Using the energy consumption and GHG emission of the BAU and of those with all measures implemented leads to the determination of Energy Intensity (EI) and GHG Intensity (GHGI). The concept of the work is given as shown in Fig. 1.

Thirdly, the relation and trend between energy consumption or GHG emission and economic value (GDP) through the end of EEP2015, AEDP2015, and NDC is then suggested with 4 scenarios as the followings:

Scenario 1: Business-as-usual

Scenario 2: Only EEP2015 measures are implemented

Scenario 3: Only AEDP2015 measures are implemented

Scenario 4: Both EEP2015 and AEDP2015 measures are implemented

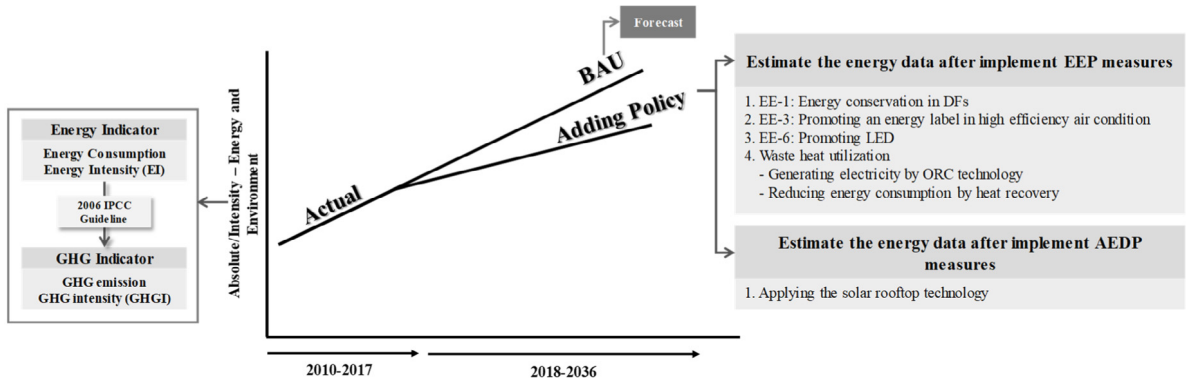


Fig. 1. Concept of the methodology used.

3. Energy conservation measures in textile industry

3.1. Energy conservation by EEP2015

The target of EE-1 measure is all designated textile factories. During the past seven years (2010–2017), some designated textile factories have already implemented EE-1 measures under EEP2015. 1766 replacement activities have been carried out on both electricity and thermal energy measures. It is also shown that a number factory undergoes more than one replacement activities. The ratio of implemented efficiency-improvement measures in electrical system is 1.54 measures/factory and that in thermal system is 1.18 measures/factory. To estimate a number of factories to implement the measures can be calculated by Eq. (1) and implemented measures is calculated by Eq. (2). and then, energy reduction of each measures is reported as shown in Eq. (3).

Implemented factories

$$\text{Total of implemented factories} = \text{Implemented factories ratio on base year} \times \text{Total of factories in year } i \quad (1)$$

Implemented measures

$$\text{Total of implemented measures} = \text{Implemented factories in year } i \times \text{Implemented measure ratio} \quad (2)$$

Energy saving

$$\begin{aligned} &\text{Energy saving of measure } j \\ &= (\text{implemented factories of measure } j \text{ in year } i \times \text{energy consumption per factory}) \\ &\quad \times \% \text{ saving of measure } j \end{aligned} \quad (3)$$

The reduction of energy consumption when measure j is implemented is calculated and reported as shown in Table 1.

EE-3 is the measure that replaces existing air-condition units with high-efficiency air condition units while EE-6 is the measure that replaces existing T8 (or older) fluorescent lighting fixtures with LED lighting fixtures. These measures were implemented nationwide. 2016 data of air condition units and T8 lighting fixtures is available in Table 2 and the estimation of the electricity-consumption reduction can be calculated using Eqs. (4) and (5). It is reported that the replacement yields higher improvement as the air-conditioning systems and lighting fixtures consume 11–18 BTU/Watt and 20 Watt, respectively.

Air-conditioning Unit

$$\text{Energy consumption} = \left[\frac{\text{Capacity (BTU)}}{\text{Efficiency (BTU/kWh)}} \right] \times \text{Working hour (h)} \times \text{No. of equipment} \quad (4)$$

Lighting Unit

$$\text{Energy consumption} = \text{Capacity (kW)} \times \text{Working hour (h)} \times \text{No. of equipment} \quad (5)$$

Table 1. EE-1’s energy saving from previous data.

Measure grouping	No. of sub-measures	%Energy reduction	Measure grouping	No. of sub-measures	%Energy reduction
Fuel type: Thermal			Fuel type: Electrical		
Switching fuel type	3	16.3%	Management	8	9.76%
Management	12	5.2%	Chemical process	7	3.85%
Boiler improvement	28	3.6%	Chiller/Air condition	44	3.67%
Process improvement	4	3.3%	Lighting system	45	2.60%
			Motor	30	2.11%
			Transformer	6	2.05%

Table 2. Data of replacing Air-conditioning Systems and Lighting fixtures from previous years.

Parameter	Equipment	
	Air-conditioning (Unit)	T8 light tube (Unit)
No. of equipment	3,245	115,166
Average lifetime	5.99Years	9.47Years
Average of efficiency indicator	8.90 BTU/Watt	36 Watt
%Electricity consumption of system	17.60%	9.79%

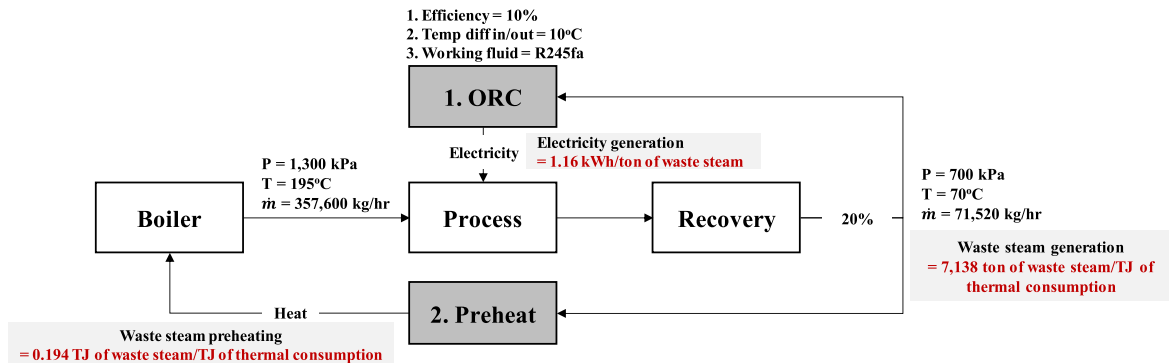


Fig. 2. Methodology to determine waste heat utilization in textile factory.

From the survey, the potential of waste heat recovering in process in textile factories is determined. Relevant methodology is shown in Fig. 2 with example of data from one particular factory. As the waste heat from the process is recovered to preheat the feed water for heating process, this will help to reduce fuel consumption in the boiler or water heater. As waste heat in textile factory is low-grade in temperature, the possible use of ORC to generate heat is also introduced in Fig. 2 by introducing 10-20kW ORC system from the previous work of Deethayat [20] to which system characteristics and performances are referenced and displayed in Fig. 2. In total, the data reveals 19.40% of waste heat can be reclaimed and it can be approximated that the ratio of waste heat recovery to the thermal consumption is 0.194 TJ from the waste steam per TJ of all thermal consumption. ORC simulation is done on REFPROP version 9.1 [21]. It is also reminding that the ORC used in this work is for rough estimation only. The potential of heat reclaims might be larger than the current estimation if other sizes or other heat recovery systems are used. Nevertheless, the results show that the ORC used in this investigation can generate the electricity as high as 1.16 kWh/ton of waste heat.

3.2. Energy conservation by AEDP2015

The data of already-installed capacity of solar PV system of the rooftop of the textile factory and available installation areas to be installed in the future is collected to evaluate the generating electrical power from the textile

industry in 2015. Using the 3% growth rate of the installation area, the reduction of electricity usage from national grid and GHG emission can be estimated.

4. Result

As the result of study, the EI index of textile industry increased by an average of 0.86% annually. For scenario 1 as BAU, EI index is at 4.91 ktoe/billion baht in 2036 which results from the total energy consumption of 2,245.43 ktoe. 99.64% is from fossil fuel and only 0.36% is from renewable fuel. When scenario 2 is in consideration, the measures can reduce the usage as much as 16.63% compared with BAU. The EI index decreases to 4.09 ktoe/billion baht. However, scenario 3 still does not play a significant role in reducing energy consumption; therefore, the resulting energy reduction is similar between scenario 2 and 4.

For GHG emission and mitigation, BAU scenario 1 depicts GHGI index of 29.46 GgCO₂-eq/billion baht in 2036 and GHG emission of 13,482.58 GgCO₂-eq. With implementation of EEP2015 measures, this industry could mitigate GHGI index by 24.55 GgCO₂-eq/billion baht which is 16.67% reduction compared with BAU. When scenario 3 is considered as AEDP2015 measures are deployed, the result showed that GHGI index is 29.12 Gg CO₂-eq/billion baht which is 1.15% decreasing from BAU. If the textile industry implements both EEP2015 and AEDP2015 measures, the GHGI would mitigate more as much as 17.82% compared with BAU. This is equivalent to 24.21 Gg CO₂-eq.

The results are then compared with the target of Thailand's Energy and GHG plan (EEP2015, AEDP2015 and NDC roadmap). All results of comparison are shown in Table 3. The target of EEP2015 in all industrial sectors wants to reduce energy consumption as 14,515 ktoe with 2036. As the textile industry is only one part of the sector, the target is proportionally anticipated as 339.65 ktoe since the textile industry's average energy consumption is only 2.34% of total energy consumption of industrial sector. As seen from Table 3, scenario 2 and scenario 4 achieve 9.94% more than the target.

Table 3. Comparison of results.

Nation plan	EEP2015		AEDP2015		NDC Roadmap	
Unit	ktoe		ktoe		GgCO ₂ -eq	
Target for Textile Industry	339.65		287.54		1,053.00	
Result	Reduction	Ratio of target	Reduction	Ratio of target	Reduction	Ratio of target
Scenario 1: BAU	–	–	8.02	2.79%	–	–
Scenario 2: EEP	373.41	>target 9.94%	24.92	8.67%	1,485.87	>target 41.11%
Scenario 3: AEDP	–	–	30.75	10.69%	133.08	12.64%
Scenario 4: EEP&AEDP	373.41	>target 9.94%	47.66	16.57%	1,618.96	>target 53.75%

AEDP2015 is to increase the proportion of renewable energy in all economic sector within 2036 by 39,388.67 ktoe. If part of target is allocated to each industry by the proportion of energy consumption, as the textile industry has consumed 0.73% of total energy consumption, the target for the textile industry should be at 287.54 ktoe. The result shows that all scenarios are not able to meet the target. While scenario 4 yields highest conservation, it can only switch 47.66 ktoe into renewable sources which is far from the setting target.

According to NDC Roadmap of Thailand, the GHG mitigation plans to reduce GHG emission in all sectors within 2030. If the proportion of the target is cascaded to the textile industry due to its previous energy consumption, the reduction of 1,053.00 Gg CO₂-eq (2.34% of industrial sector) is set as a goal. The result of this study shows that the implementation of scenario 2 could mitigate 41.11% more than what is set as the target. Scenario 3 can mitigate GHG emission only 12.64% of the target. If the textile industry implements both plans as scenario 4, the textile industry could mitigate much more than what is expected as the target by 53.75%.

5. Conclusion

This study aims to evaluate the potential of the existing energy conservation measures which can reduce both energy consumption and enhance related GHG mitigation. For textile industry, this work suggests that with existing implemented measures, mainly switching to higher efficiency equipment (air-conditioning units and lighting fixtures), the target of energy usage reduction can be met without any additional extra measures. This results to

lower GHG mitigation beyond the target set in NDC Roadmap. Textile industry, therefore, becomes one of the industries that pay large contribution in national EEP plan. However, with existing renewable technology, textile industry yields less impact on renewable usage's target of national AEDP. Adjustment is needed to be done on AEDP strategy for textile industry. Supportive incentives or new innovative technology should be considered. GHG emission is achieved via energy-efficiency-improvement measures such that NDC's goal can be met. However, this work has not included other necessary factors such as economic perspectives since the study is only done from the tracking perspective. This might affect the results as investment always influences the decision of the industry. This can be a subject into a future work

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