CHEMICAL ENGINEERING TRANSACTIONS
VOL. 106, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Peck Loo Kiew, Hon Huin Chin

ISBN 979-12-81206-05-2; **ISSN** 2283-9216
DOI: 10.3303/CET23106004

Tracking the Real-World Energy Efficiency Measures: Does Past Industrial Sector Performance Can Accelerate Thailand's NDC Target Achievement?

Sopit Daroon[a], Wongkot Wongsapai[b,c,*], Tassawan Jaitiang[c], Waranya Thepsaskul[a], Varoon Raksakulkarn[a], Phitsinee Muangjai[b,d], Chaichan Ritkrerkkrai[b,d]

[a]Program in Energy Engineering, Department of Mechanical Engineering, Chiang Mai University, 50200, Thailand
[b]Faculty of Engineering, Chiang Mai University, Chiang Mai, 50200, Thailand
[c]Multidisciplinary Research Institute, Chiangmai University, Chiang Mai, 50200, Thailand
[d]Office of Research Administration, Chiang Mai University, Chiang Mai, 50200, Thailand
wongkot@eng.cmu.ac.th

Since the enforcement of eight-step energy management system (EnMS) in 2010, the electricity and thermal energy in 6,161 designated factories have been conserved through electricity and thermal energy housekeeping, process improvement and machine change measures. As from Nationally Determined Contribution (NDC) target that aims to reduce greenhouse gas (GHG) emissions, energy efficiency has long been regarded as a key pathway for GHG mitigation, but the volume and diversity of efficiency options has resulted in an unclear understanding of their combined impacts. Past national energy conservation evaluations focused only on an annual calendar-based concept, without considering cumulative aspects. The challenge of reducing industrial GHG emissions has led to an increasing need for a more precise methodology that highlights how energy conservation can significantly contribute to achieving the target. This paper aims to track GHG mitigation through energy efficiency measures in the industrial sector to achieve the NDC target. It analyzes and validates the real-world meta-data from all designated factories database from the year 2010 to 2020. By using the cumulative energy savings from 2015, which is the NDC base year, with decay rate and equipment lifetime assumption taken from national labeling demand side management program. From three main conservation types which are housekeeping, process improvement and machine change, we found that the cumulative electricity and thermal energy saving were at 2,541 GWh and 17,933 TJ. While the GHG mitigation was 2.24 Mt CO_2 in the year 2020. This figure is far behind the mitigation target in NDC which require about 16.5 Mt CO_2. Additionally, policy recommendations have been thoroughly discussed to address this gap.

1. Introduction

Thailand, after joining the Paris Agreement in 2016 and submitting a letter of intent for her Nationally Determined Contribution (NDC), aims to achieve a 20-25 % greenhouse gas (GHG) mitigation target for the overall economy by 2030 (ONEP, 2020a), then cabinet approved the NDC Mitigation Roadmap (2021-2030) in 2017 This roadmap outlines measures in four key sectors: waste, industrial processes and product use (IPPU), and energy and transportation, which have the potential to reduce GHG emissions by 115.60 Mt CO_2-eq by 2030. As a result, Thailand is obligated to establish a GHG mitigation tracking system to ensure preparedness in achieving the NDC target. In this regards, the NDC has been updated into 30-40 % (ONEP, 2022b), and Thailand also set her sights on implementing the carbon neutrality plan.

1.1 GHG Mitigation Target

From the updated NDC, Thailand aims to achieve unconditionally 30 % reduction in GHG emissions by 2030 compared to the business as usual (BAU) while Thailand can improve another conditionally 10 % more from technology development and transfer, financial resources, and capacity building from international support. The total GHG mitigation potential in Thailand is estimated by sector, as shown in Figure 1 (ONEP, 2020c).

Paper Received: 31 May 2023; Revised: 2 September 2023; Accepted: 14 September 2023
Please cite this article as: Daroon S., Wongsapai W., Jaitiang T., Thepsaskul W., Raksakulkarn V., Muangjai P., Ritkrerkkrai C., 2023, Tracking the Real-World Energy Efficiency Measures: Does Past Industrial Sector Performance Can Accelerate Thailand's NDC Target Achievement?, Chemical Engineering Transactions, 106, 19-24 DOI:10.3303/CET23106004

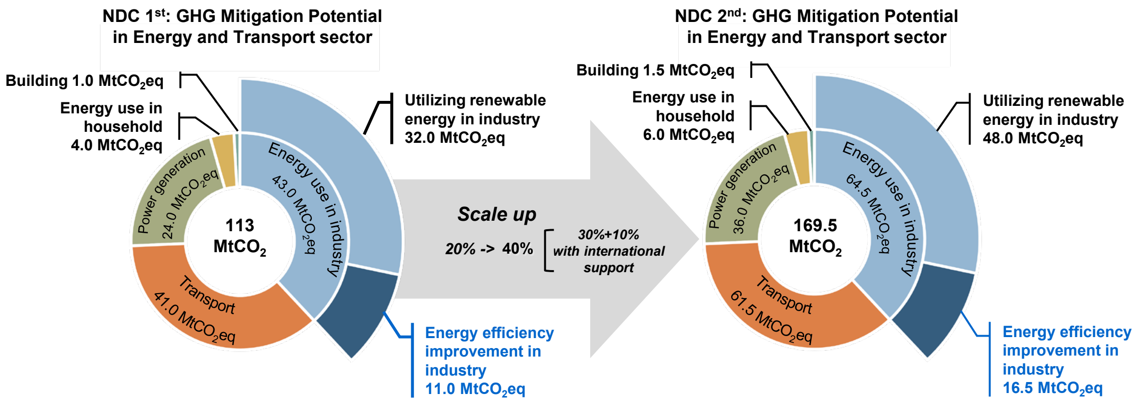

Figure 1: Thailand's Nationally Determined Contribution (NDC) (a) First NDC, and (b) Updated NDC.

The GHG mitigation potential in the energy and transport sector is projected at 64.5 Mt CO_2-eq by 2030. Renewable energy utilization in industry contributes 48.0 Mt CO_2-eq, and industry energy efficiency improvements account for 16.5 Mt CO_2-eq. Thailand will also strive to achieve carbon neutrality by 2050 and net-zero GHG emissions by 2065.

1.2 Energy Efficiency Plan and Energy Conservation Promotion Act in Thailand

Thailand has two main keys for deploy the energy efficiency; The first one is the Energy Efficiency Plan (EEP). The EEP for the years 2018 to 2037 aims to achieve 30 % reduction in energy intensity (EI) by 2037 compared to the 2010 BAU level (DEDE, 2018). Successful implementation of the energy efficiency plan will result in energy savings of 54,371 ktoe. The plan focuses on all key economic sectors, including industrial, commercial, household, agriculture, and transport (Wongsapai et al., 2016). Specifically, the industrial sector, which accounts for 36.4 % of energy consumption in Thailand in 2019, has a significant impact on energy utilization (Luknongbu et al., 2021). To achieve its energy-saving targets, the industry needs to implement measures to improve energy efficiency. The second key is the Energy Conservation Promotion Act (EPPO, 2007). This act, under B.E. 2535, Section 7, outlines seven characteristics of energy conservation activities. These include improving combustion efficiency, preventing energy loss, recovering waste heat, fuel switching, enhancing electricity usage efficiency, utilizing energy-efficient equipment and materials, and complying with additional energy conservation measures specified in Ministerial Regulations. In assessing energy conservation, this study excludes measures related to fuel switching and waste heat recovery, as these may involve renewable energy and are not directly relevant to estimating GHG mitigation through energy efficiency measures.

Previous research on performance tracking of Thailand's energy management system (Wongsapai et al., 2016) shown that Thailand's energy management system systematically collects data on energy consumption and conservation, enabling the estimation of energy savings in designated factories over time. However, the annual energy savings derived from energy efficiency measures, as reflected in energy conservation data, do not align with the GHG mitigation target set in the NDC for the industrial sector. To assess energy conservation more effectively, this study emphasizes cumulative tracking of energy savings through energy efficiency measures in designated factories, aiming to align with NDC targets. It also establishes guidelines for cumulative energy savings tracking and their correlation with GHG mitigation.

2. Methodology

The evaluation of GHG mitigation will be calculated using Eq(1) and Eq(2).

$$ER_{EC,y} = \sum EC_y \times EF_{EC,2015} \quad (1)$$

$$ER_{HC,y} = \sum HC_y \times EF_{thermal\ EE,2015} \quad (2)$$

Where the emission mitigation in electricity and thermal energy improvement are ER_{EC} and ER_{HC} while the sum of cumulative electricity and thermal energy saving in year y are EC_y and HC_y. The authors applied the emission factor as $EF_{EC,2015}$ and the thermal emission factor with the static 2015 value as base year (TGO, 2020).

2.1 Activity Data for energy efficiency improvement in industrial sector

Energy savings resulting can be classified into three distinct types: Housekeeping (HK), Process Improvement (PI), and Machine Change (MC). GHG mitigation tracking concept takes into account the accumulation of energy savings based on the specific energy conservation measure types. In the subsequent year, the cumulative energy saving effect is applied to PI and MC measures while HK measures do not have cumulative savings due to most of measures are based on practical measure which are not suit for long run monitoring, reporting, and verification process approved, as shown in Table 1.

Table 1: Criteria for evaluating cumulative energy savings.

Type of measure	Energy saving	Decay Rate	Machine lifetime
Housekeeping (HK)	Non-cumulative	-	-
Process Improvement (PI)	Cumulative	-	3 y
Machine Change (MC)	Cumulative	Applied	Equipment lifetime

Equation for cumulative energy savings from measure to improve the electricity efficiency in the industrial sector as Eq(3), while measure to improve thermal energy efficiency presents in Eq(4). It is important to note that the Machine Change measure, which involves equipment replacement, exhibits both cumulative energy savings and equipment decay rate, obtained from a statistical principle known as the "Weibull distribution" (Kohout, 2022), which accounts for the gradual decrease in energy savings over time.

$$\sum EC_y = \sum \left\{ EC_{HK,y} + EC_{PI,y} + \left(EC_{MC,FY} \times e^{-(t\times\lambda)^{\beta}} \right) \right\} \tag{3}$$

$$\sum HC_y = \sum \left\{ HC_{HK,y} + HC_{PI,y} + \left(HC_{MC,FY} \times e^{-(t\times\lambda)^{\beta}} \right) \right\} \tag{4}$$

Where $EC_{HK,y}$ is electricity saving from housekeeping measure in year y while $EC_{PI,y}$ is electricity saving from process improvement measure in year y and $EC_{MC,FY}$ is first year electricity saving in machine change measure (with decay rate). $HC_{HK\ and\ PI}$ are thermal saving consumption in housekeeping (HK) and process improvement (PI) measure in year y, respectively while $HC_{MC,FY}$ is first year thermal saving in machine change measure. t is number of observations, λ is decay rate, and β is shape parameter (assuming constant at 4).
The assumption of a decay rate is used to calculate the energy savings of equipment, as shown in Table 2. There is a lack of clear decay data specifically for thermal equipment. In this case, the age of the equipment is considered to be 10 years, and a decay rate of 1% per year will be assumed for the calculations in this study.

Table 2: Decay Rate of equipment.

System	Equipment	Age of equipment (y)	Decay Rate (%)
Motor	Automatic Water Pump	10	10.0
Air conditioner or chiller system	Air Conditioner	10	9.2
	Chiller (Eleftheriadis and Hamdy, 2017) (Bannai et al., 2008)	15	24.6
Lighting system	LED	5	10.0
	CFL	3	6.0
Fuel combustion	Industrial Furnace	10	10.0
Fuel combustion	Boiler (Griffith et al., 2008)	10	6.5

2.2 Emission factor for energy efficiency improvement in industrial sector

Electricity emission factor is obtained by dividing the emissions resulting from the combustion of fossil fuels to generate electricity by the total amount of electricity produced in Thailand and imported from abroad while thermal energy emission factor is derived from the combustion of fossil fuels to generate thermal energy, divided by the amount of heat produced. The data used for this calculation is sourced from the annual report of DEDE, along with default emission factors for relevant fuels provided by the IPCC (IPCC, 2006).

3. Data preparation

3.1 Activity Data

From the Energy Management Report, the authors estimate the energy saving measures annually (DEDE, 2020), as shown in Table 3.

Table 3: Annual energy saving in Thailand's industrial sector form the period of 2016 – 2020.

Energy efficiency measures	Energy saving (in Physical unit)				
	2016	2017	2018	2019	2020
Electricity saving (GWh)	763	773	721	733	781
Thermal energy saving (TJ)	4,390	5,337	6,900	7,682	5,763

Annual energy saving demonstrates fluctuations in electricity and thermal energy savings in 2018 and 2020. These variations are attributed to the annual energy-saving outcomes, which depend on the specific industrial energy conservation plans of each factory reported to the government (DEDE). This means that the energy-saving outcomes may not be the same across all sectors in each year. Kindly note here that in some year Thailand also setting up the subsidy programs for energy efficient replacement. This may boost up the investment in some specific year. However, there are various factors contribute to energy conservation results, e.g the government's tax incentive program, the new technology in that year, the pattern of energy conservation (i.e. Machine change (MC) measures typically yield greater savings than housekeeping (HK) measures).
The electrical energy saving measures comprise a proportion of electricity conservation achieved through various measures, including the replacement of label no.5 (national labeling system for electrical equipment in Thailand, ranging from energy-saving levels no.1 to no.5, with no.5 being the most energy-efficient level) equipment over a five-year period (2016-2020), as shown in Figure 2. Among these measures, the air conditioning or cooling system and ventilation (HVAC) demonstrate the highest proportion, followed by compressed air system, lighting, and motor, respectively. Similarly, the thermal energy-saving measure includes a proportion of thermal energy savings resulting from various implemented measures. Among these measures, energy leakage protection has the highest proportion, followed by waste heat recovery, and boiler combustion improvement, respectively.

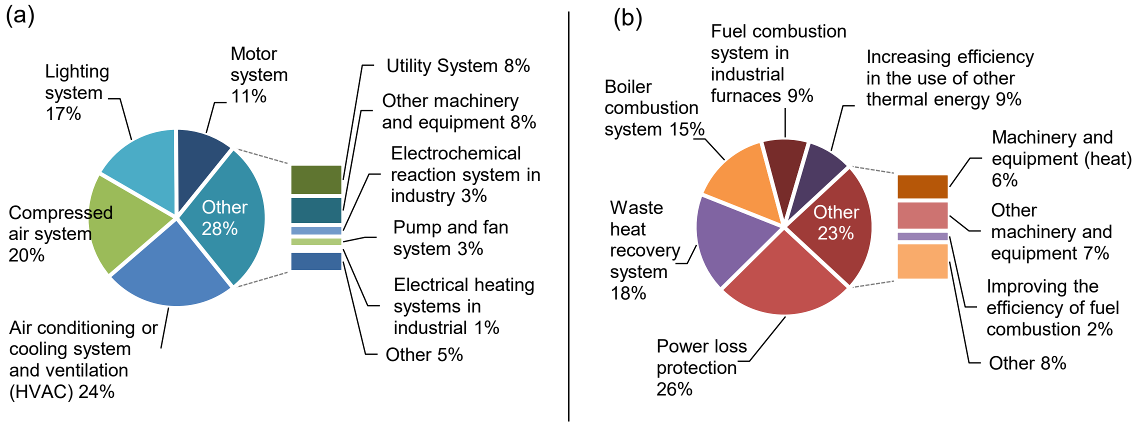

Figure 2: The proportion of energy saving from the type of measures in 2016 – 2020. (a) electricity saving, (b) thermal energy saving

3.2 Emission factor

It should be noted here that the static 2015 emission factor has been applied in this study due to two reasons. First, during the NDC development, the modelers applied the GHG mitigation potential from energy efficiency improvement by using the most recent emission factor at that period to forecast the potential from 2016 to 2030 which is so called static emission factor. Second, due to the limitation of energy efficiency improvement template which is not clearly identified on the fuel type especially in thermal insulation measure, the normalized thermal energy emission factor has to be applied in case of thermal energy efficiency improvement in this study.
The emission factors are documented in the summary report of GHG emission factor calculation are taken from the Climate Change Office of the Ministry of Energy (CCOME), following the guidelines provided in topic 2.2. The electricity emission factor is set at 0.5215 tCO_2/MWh while the thermal energy emission factor is determined to be 51.6663 tCO_2/TJ in 2015.

4. Results

Based on the activity data of cumulative energy conservation, GHG mitigation can be calculated into two measures: electricity and thermal energy efficiency improvement. The results are as follows.

4.1 Electricity efficiency improvement

The results of energy conservation and GHG mitigation achieved through electrical energy efficiency improvement are presented in Figure 3. In 2020, the cumulative figures reached 2,541 GWh, resulting in a cumulative GHG mitigation of 1.32 Mt CO_2.

(a) (b)

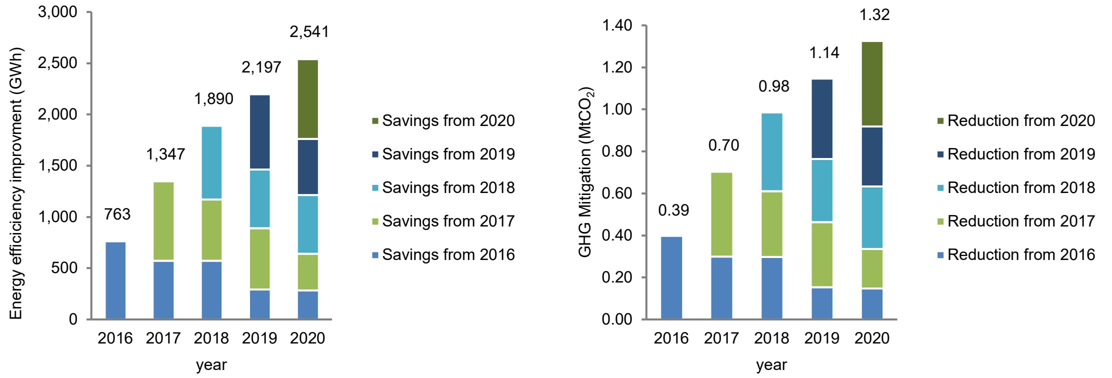

Figure 3: Cumulative electricity efficiency improvement. (a) in energy unit, (b) in GHG mitigation unit

4.2 Thermal energy efficiency improvement

The results of energy conservation and GHG mitigation obtained from thermal energy efficiency improvement are presented in Figure 4. In 2020, the cumulative thermal energy conservation reached 17,933 TJ, resulting in a cumulative GHG mitigation of 0.92 Mt CO_2. The cumulative GHG mitigation resulting from electrical and thermal energy efficiency improvement measures between 2016 and 2020 is summarized in Table 4.

(a) (b)

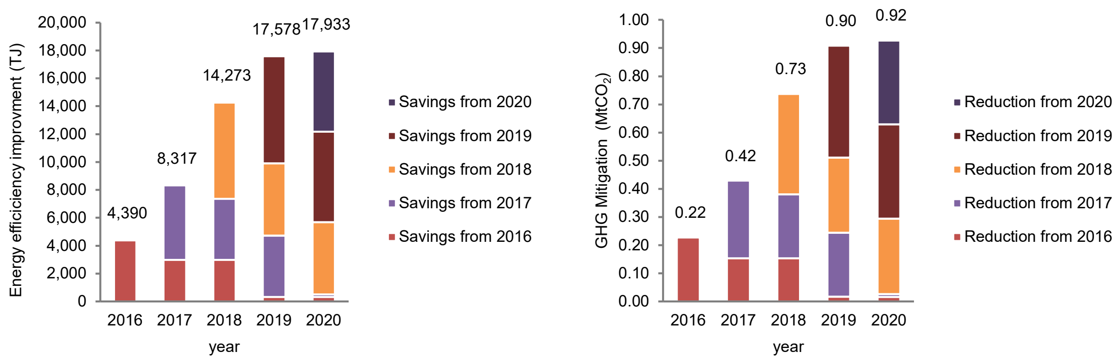

Figure 4: Cumulative thermal energy efficiency improvement. (a) in energy unit, (b) in GHG mitigation unit

Table 4: Cumulative GHG Mitigation from energy efficiency measures in the industrial sector (Mt CO_2)

Energy efficiency measures	GHG Mitigation (Mt CO_2)				
	2016	2017	2018	2019	2020
Improve the electricity efficiency	0.39	0.70	0.98	1.14	1.32
Improve thermal efficiency	0.22	0.42	0.73	0.90	0.92
Total	0.61	1.12	1.71	2.04	2.24

4.3 Analysis on past industrial sector performance to achieve NDC.

Cumulative GHG mitigation achievement was 2.24 Mt CO_2 in 2020 while the NDC target is 16.5 Mt CO_2 by 2030. This means that only 13.5 % have been well set and Thailand requires a minimum of 14.26 Mt CO_2 to achieve her NDC target. Consequently, an annual 22 % increase in efficiency improvement has to be set and deployed.

5. Conclusions

In 2020, the cumulative energy savings data were compared to the 2015 NDC base year, considering decay rate and equipment lifetime assumptions from the energy labeling program. The cumulative electricity and thermal energy savings reached 2,541 GWh and 17,933 TJ, respectively which reflects to the 2.24 Mt CO_2 GHG mitigation. The major measures were air conditioning or cooling and ventilation (HVAC) improvements, along with heat loss protection. Despite these achievements, they fall short of the NDC mitigation target of 16.5 Mt CO_2. To achieve this target, the energy efficiency improvement measures in the industry must grow at a rate of 22 % per year.

Acknowledgments

The authors would like to thank Department of Alternative Energy Development and Efficiency (DEDE) for data support. This study is also funded by Thailand Greenhouse Gas Management Organization and Chiang Mai University, Thailand. We remain culpable for any remaining errors.

References

Bannai M., Yoshida T., Kimura Y., Fujii T., Sekiguchi K., Sawa T., 2008, Energy Solution in the Industrial and Commercial Sectors, Hitachi Review, 57(5), 220-225.

Department of Alternative Energy Development and Efficiency (DEDE), 2018, Energy Efficiency Plan 2018-2037 (EEP2018), Ministry of Energy, Thailand <https://www.dede.go.th/ewt_w3c/ewt_dl_link.php?filename=index&nid=54495> accessed 05.05.2023.

Department of Alternative Energy Development and Efficiency (DEDE), 2020, The energy management report, Ministry of Energy, Thailand, Not publicly published.

Eleftheriadis G., Hamdy M., 2017, Impact of building envelope and mechanical component degradation on the whole building performance: a review paper. Energy Procedia, 132, 321-326.

Energy Policy and Planning office (EPPO), 2007, Energy Conservation and Promotion Act, Ministry of Energy, Thailand, <http://www.eppo.go.th/images/law/ENG/nation2-1-E.pdf> accessed 01.05.2023.

Griffith B., Long N., Torcellini P., Judkoff R., Crawley D., Ryan J., 2008, Methodology for modeling building energy performance across the commercial sector, National Renewable Energy Lab (NREL), A national laboratory of the US Department of Energy, Office of Energy Efficiency and Renewable Energy <https://www.nrel.gov/docs/fy08osti/41956.pdf> accessed 01.09.2023.

IPCC Guidelines for National Greenhouse Gas Inventories, 2006, National Greenhouse Gas Inventories Programme, IGES, Japan.

Kohout J., 2022, Three-parameter Weibull distribution with upper limit applicable in reliability studies and materials testing. Microelectronics Reliability, 137, 114769.

Luknongbu W., Assawamartbunlue K., 2021, Specific Energy Consumption of Container and Tableware Glass Manufacture Industry, Chemical Engineering Transactions, 88, 991-996.

Office of Natural Resources and Environmental Policy and Planning (ONEP), 2020a, Thailand’s Updated Nationally Determined Contribution (NDC), Ministry of Natural Resources and Environment, Thailand, <https://policy.asiapacificenergy.org/sites/default/iles/Thailand%E2%80%99s%20Updated%20Nationally%20Determined%20Contribution%20%28NDC%29.pdf> accessed 01.05.2023.

Office of Natural Resources and Environmental Policy and Planning (ONEP), 2022b, Thailand 2nd Updated NDC, Nationally Determined Contributions (NDCs), Ministry of Natural Resources and Environment, Thailand, <https://climate.onep.go.th/wp-content/uploads/2023/05/Thailand_2nd_Updated_NDC.pdf> accessed 01.05.2023.

Office of Natural Resources and Environmental Policy and Planning (ONEP), 2020c, Thailand's Third National Communication (TNC). Ministry of Natural Resources and Environment, Thailand, <https://unfccc.int/sites/default/files/resource/Thailand%20TNC.pdf> accessed 01.05.2023.

Thailand GHG Management Organization (Public Organization) (TGO), 2020, Guidelines for Monitoring and Evaluation of GHG Reduction from Energy Sector Measures, Ministry of Natural Resources and Environment, Thailand, <http://www.tgo.or.th/2020/file_managers/uploads/file_managers/source/PUBLICATION/pdf/NDC_energy.pdf> accessed 01.05.2023.

Wongsapai W., 2016, Performance Tracking of Thailand's Energy Management System under Energy Conservation Promotion Act, Energy Procedia, 100, 448-451.

Wongsapai W., Ritkrerkkrai C., Pongthanaisawan J., 2016, Integrated Model for Energy and CO2 Emissions Analysis from Thailand's Long-term Low Carbon Energy Efficiency and Renewable Energy Plan, Energy Procedia, 100, 492-495.