www.rericjournal.ait.ac.th

An Investigation of Internationally Transferred Mitigation Outcomes (ITMOs) on GHG Emissions Reduction in Thailand's NDC

Pornphimol Winyuchakrit*, Piti Pita*, Yod Sukamongkol^, and Bundit Limmeechokchai*, [1]

ARTICLE INFO

Article history:
Received 11 November 2025
Received in revised form
18 April 2025
Accepted 15 May 2025

Keywords:
AIM/EndUse
Joint credit mechanism (JCM)
International transferred mitigation outcomes (ITMOs)
Nationally determined contribution (NDC)
Paris agreement

ABSTRACT

Thailand commits to achieving Carbon Neutrality by 2050 and net-zero GHG emissions by 2065. Its Nationally Determined Contributions (NDC) also aims to reduce greenhouse gas (GHG) emissions by 30% by 2030 through domestic efforts, termed "Unconditional NDC," and up to 40% with international support, termed "Conditional NDC," compared to its 2030 Business-as-Usual (BAU) of 555 $MtCO_2eq$. This study explores the potential for reducing GHG emissions in Thailand's energy sector through international cooperation such as the Joint Credit Mechanism (JCM), in accordance with of the Paris Agreement (PA). It is essential that the results of international transfers are accurately accounted for and reported in the NDC tracking under Article 13 by both Parties to prevent double counting. The investigation utilizes the AIM/EndUse model, created by the National Institute for Environmental Studies in Japan. The results show that under the international cooperation framework, Thailand needs to reduce GHG emissions beyond the target specified in the conditional NDC. Finally, to enable the transfer of Internationally Transferred Mitigation Outcomes (ITMOs) under Article 6.2 of PA, Thailand's share of carbon credits should reasonably be capped at no more than 20%, with an additional emission reduction of 12.34 $MtCO_2$ beyond the conditional Nationally Determined Contribution (NDC) target of 49.34 $MtCO_2$.

1. BACKGROUND OF THAILAND'S ENGAGEMENT ON CLIMATE ACTIONS

The Paris Agreement aims to empower Parties in tackling climate change by ensuring the global temperature rise remains well below degrees Celsius above pre-industrial levels, while also striving to limit the increase to 1.5 degrees Celsius. Currently, many countries are expanding their greenhouse gas (GHG) reduction policies and activities not only within their own territories but also through international collaborations to combat climate change. Consequently, Article 6 of the Paris Agreement lays the groundwork for a framework of international cooperation.

In 2025, Thailand ranked as the 30th most affected country, showing a pronounced vulnerability to climate change [1]. Thailand is aware of these impacts and has actively engaged in efforts to address them alongside the global community. Without any mitigation implementation in Thailand, known as the Business-as-Usual (BAU) scenario, the emission level is projected to reach 555 $MtCO_2eq$ by 2030. However, according to its second generation of Nationally Determined Contributions (NDC), referred to as "NDC 2.0," Thailand has established a target to reduce GHG emissions by 30-40% from its BAU emission level in 2030. Through domestic efforts, the emission reduction achieved was 170 $MtCO_2eq$, or approximately 30% of its BAU emission level, referred to as the "Unconditional NDC." Additionally, an emission reduction target of an additional 52 $MtCO_2eq$, approximately 10% of its BAU emission level, is founded on international support for technology deployment and development, financing, and the strengthening of capacity-building initiatives, collectively known as the "Conditional NDC." [2]. Therefore, the emission level is projected to be 333 $MtCO_2eq$ by 2030 as shown in Figure 1. Furthermore, at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), Thailand pledged to achieve carbon neutrality by 2050 and net-zero greenhouse gas emissions by 2065 as part of its Long-Term Low Emission Development Strategy (LT-LEDS) [3].

To achieve the Nationally Determined Contribution (NDC) target, Thailand's NDC Action Plan on Mitigation for 2021-2030 was approved by the Cabinet in December 2024. This plan serves as an operational framework for relevant sectoral agencies to implement their mitigation strategies. Under the unconditional NDC, domestic efforts prioritize four key sectors:

* Sustainable Energy & Built Environment Research Unit, Faculty of Architecture and Planning, Thammasat University, 99 Moo 18, Klong Neung, Khlong Luang, Pathumthani, 12121, Thailand.

^ Technology of Information System Management Division, Faculty of Engineering, Mahidol University, 25/25 Phuttamonthon 4 Road, Salaya, Phuttamonthon, Nakhon Pathom, 73170, Thailand.

[1]Corresponding author:
Email: bundit.lim@gmail.com

energy and transportation, waste, industrial processes and product use (IPPU), and agriculture These sectors aim to reduce emissions by 184.8 $MtCO_2eq$, surpassing the pledged NDC target and representing 33.3% of the emissions forecast under the BAU scenario. The energy and transportation sectors are expected to contribute approximately 92% of the total domestic emission reduction. Conversely, with international support under the conditional NDC, additional reduction efforts amounting to 36.4 $MtCO_2eq$ or 6.5% of the BAU emission level are required. Most of this reduction, 34.5 $MtCO_2eq$, is anticipated to come from the energy and transportation sectors, while smaller reductions will be achieved through cooperation and implementation in the IPPU and agricultural sectors [5].

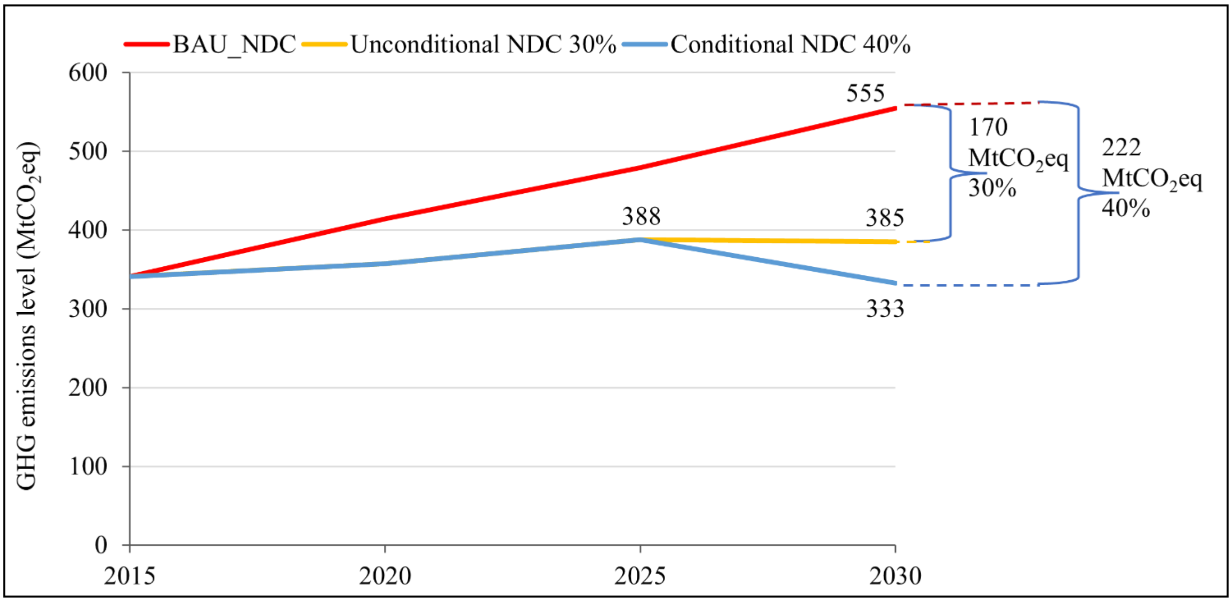

Fig. 1. Thailand's GHG reduction targets in NDC 2030 [4].

The national GHG inventory from Thailand's first Biennial Transparency Report (BTR1) reveals that the energy sector was the leading contributor to greenhouse gas emissions in 2022, comprising 65.89% of the country's total emissions. This was followed by agriculture (17.86%), IPPU (10.50%), and waste (5.75%) sectors as shown in Figure 2. Within the energy sector, energy industries accounted for 36.26% of emissions, followed by transport (30.29%) and manufacturing industries and construction (24.61%) as shown in Figure 3. Although seven gases are considered—Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur Hexafluoride (SF_6) and Nitrogen Trifluoride (NF_3), only CO_2, CH_4, and N_2O are emitted from the energy sector. In 2022, CO_2 alone contributed 94.89% of all GHGs emitted from this sector [6].

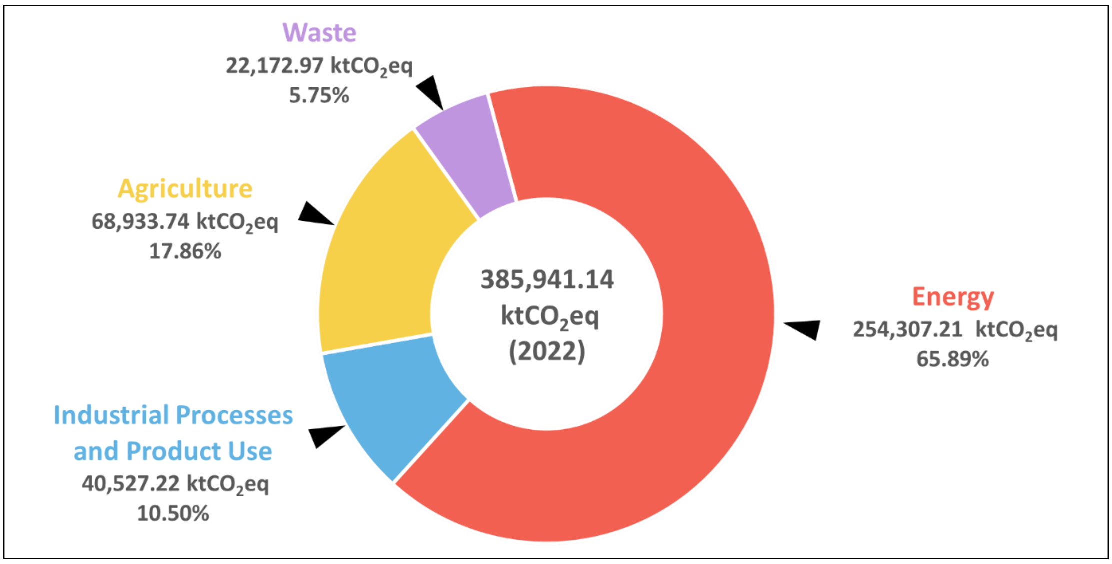

Fig. 2. Total National GHG emissions by sector (excluding LULUCF) in 2022 [6].

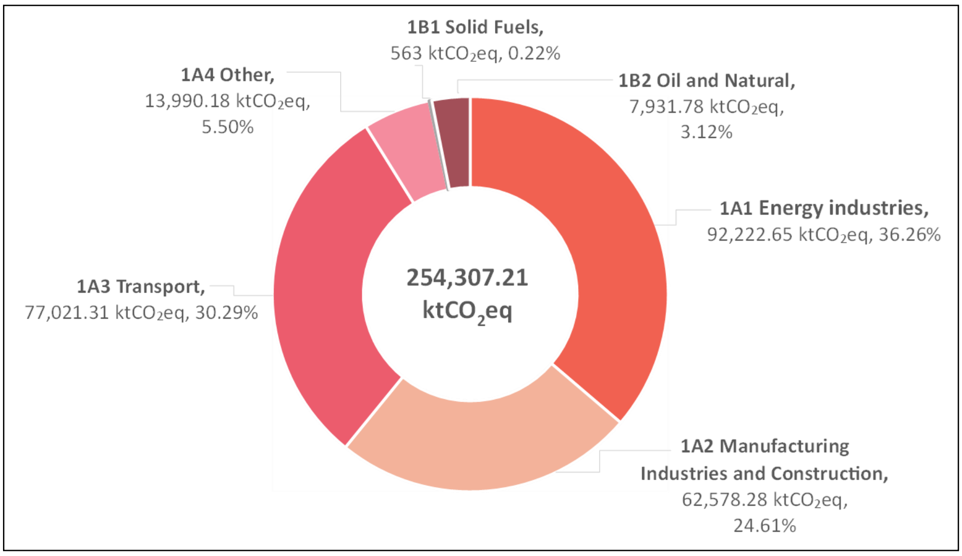

Fig. 3. GHG emissions in the energy sector in 2022 [6].

2. INTERNATIONALLY TRANSFERRED MITIGATION OUTCOMES UNDER THE JOINT CREDIT MECHANISM

Article 6 of the Paris Agreement enables countries to voluntarily collaborate in achieving their national greenhouse gas emission reduction targets through the transfer of emission reductions. Article 6.2 specifically authorizes Parties to transfer Internationally Transferred Mitigation Outcomes (ITMOs), quantified in tons of carbon dioxide equivalent (tCO_2eq), to assist other countries in achieving their emission reduction goals. This mechanism aims to support sustainable development and ensure environmental benefits while requiring rigorous accounting and reporting to prevent double counting. Measuring, Reporting, and Verifying (MRV) processes must adhere to international standards outlined by the Intergovernmental Panel on Climate Change (IPCC) and the UNFCCC.

Avoiding double counting is vital to prevent an increase in global net greenhouse gas emissions, as it can occur through double issuance, double claiming, double use, or double purpose. ITMOs and Corresponding Adjustments (CA) help prevent double counting of GHG reductions under the PA. ITMOs adjustments are made after their first transfer: the acquiring country counts the GHG emission reduction, while the host country's national inventory adjusts for the same amount of increased emissions, as shown in Figure 4.

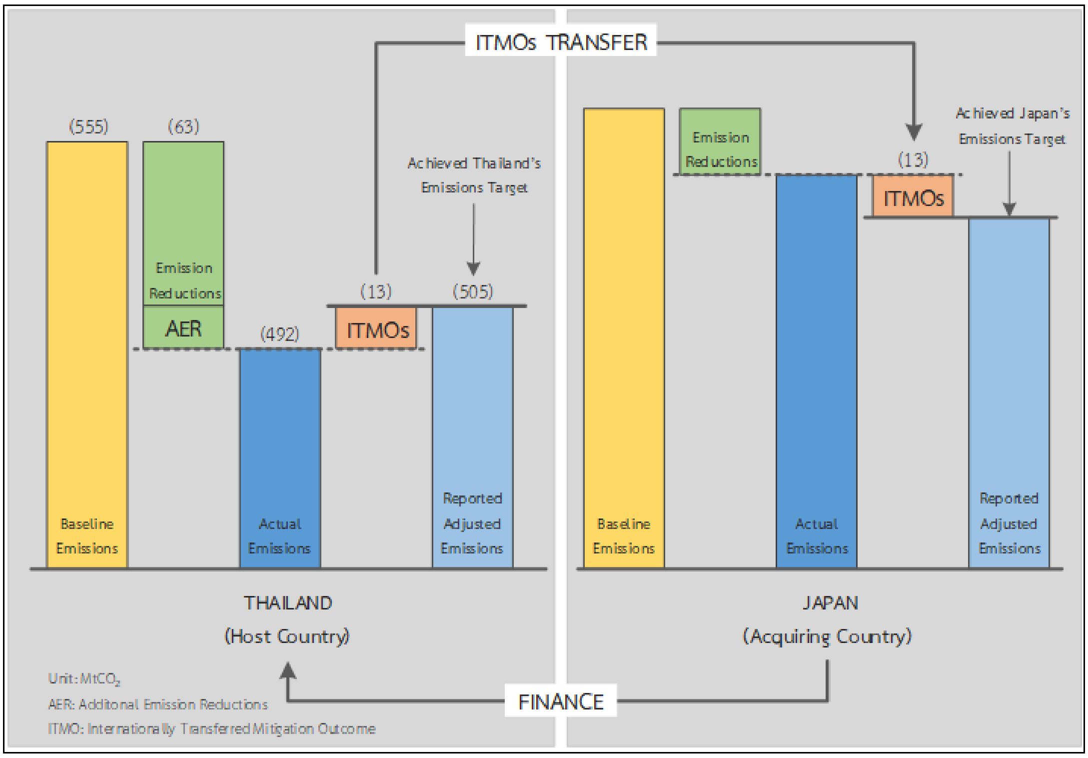

Fig. 4. Example of national inventory adjustments after ITMOs transferred [7].

For instance, the BTR1 of Thailand outlines that, under the agreement with the Swiss Confederation, the Kingdom of Thailand approved a pilot mitigation initiative known as the 'Bangkok e-bus program' as part of its cooperative approach. The first transfer of ITMOs under this program, amounting to 1,916 tCO_2eq during the crediting period from 1 October to 31 December 2022, was acknowledged by the Swiss Confederation on December 20, 2023. Figure 5 illustrates the impact of ITMOs on Thailand's National GHG inventory in the transferred year [6].

Additionally, Japan's Bilateral Joint Credit Mechanism (JCM) is a bilateral initiative developed by Japan to assist cooperating countries in utilizing low-carbon technologies for the implementation of greenhouse gas (GHG) emissions reduction projects with financial support from the Japanese government [8], [9]. This mechanism facilitates the transfer of GHG reduction outcomes. The country's efforts to reduce GHG emissions align with the objectives of the Paris Agreement. Projects executed through the JCM mechanism require the MRV process to ensure that GHG reduction results are accurate and transparent, as illustrated in Figure 6. The JCM is being developed and implemented in accordance with these stipulations.

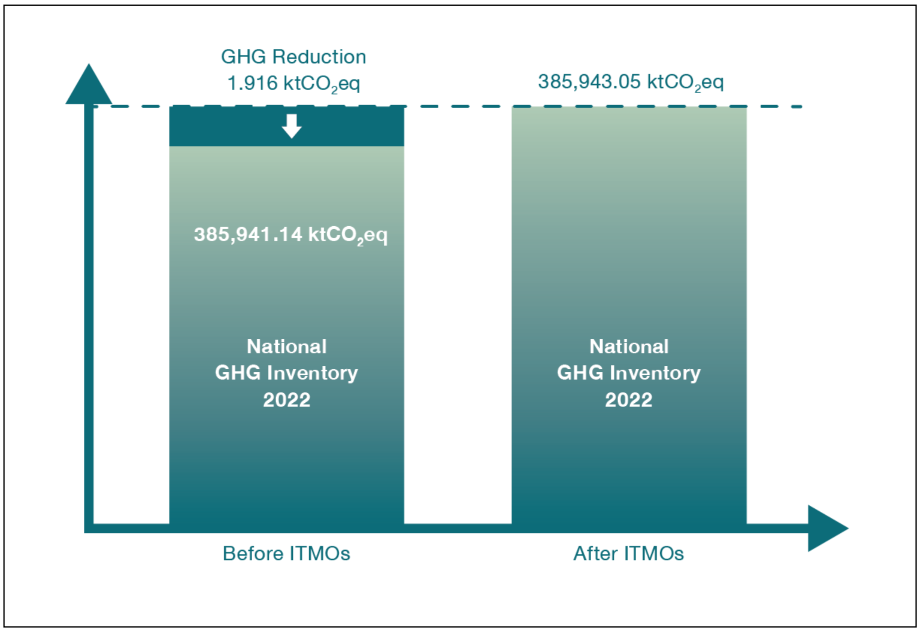

Fig. 5. Illustration of adjustment of Thailand's National GHG Inventory after ITMOs [6].

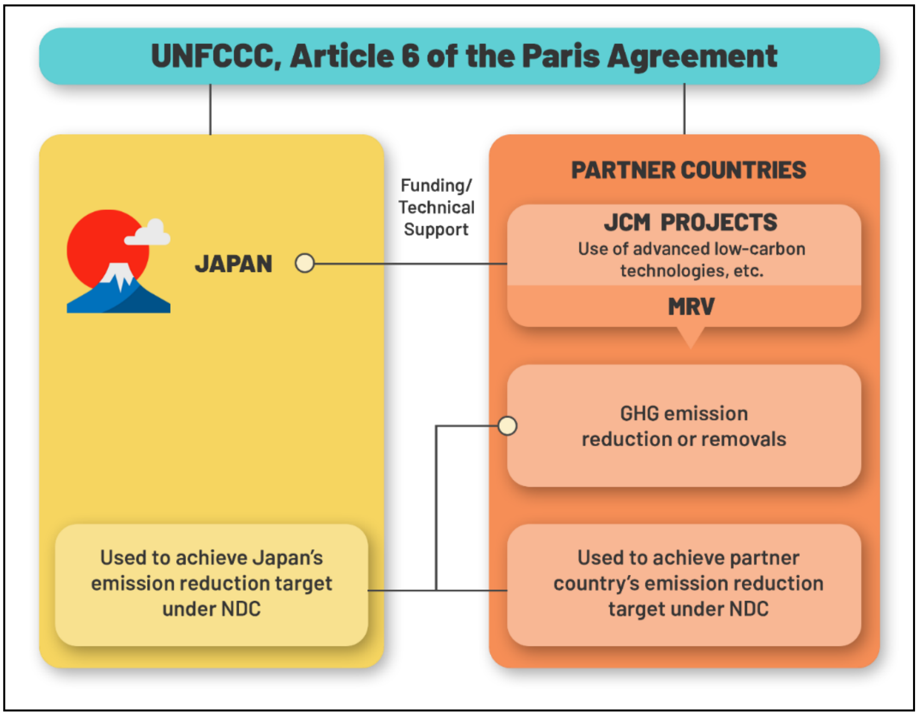

Fig. 6. Overview of the JCM mechanism [7].

Thailand needs support to achieve an additional 10% of its conditional NDC, focusing on areas lacking knowledge, personnel, and technologies. This includes high-cost GHG reduction measures, especially in the energy sector (see Table 1), which has significant potential for reducing emissions.

The initial framework for carbon credits sharing between Japan and Thailand is based on a proportional division of 50:50. This arrangement adheres to a cabinet resolution establishing a bilateral cooperation agreement between Thailand and Japan under the Joint Crediting Mechanism (JCM) in 2015 [10]. The agreement mandates an equitable distribution of benefits, stipulating that developers seeking investment support from the Japanese government for JCM pilot projects must commit to allocating at least 50% of carbon credits generated by the projects to Japan. This provision aims to proactively address potential issues related to carbon credits allocation following investment and project implementation.

Since 2021, the proportion of carbon credits for JCM projects in Thailand has been adjusted based on project funding. Japan can fund 30-50% of total investments, depending on technology usage and country-specific conditions. Figure 7 shows a project certified for 1,000 tCO_2 of carbon credits, with 43% funding from Japan. Thus, Japan receives 430 tCO_2 (43%), while 570 tCO_2 goes to the host country [11].

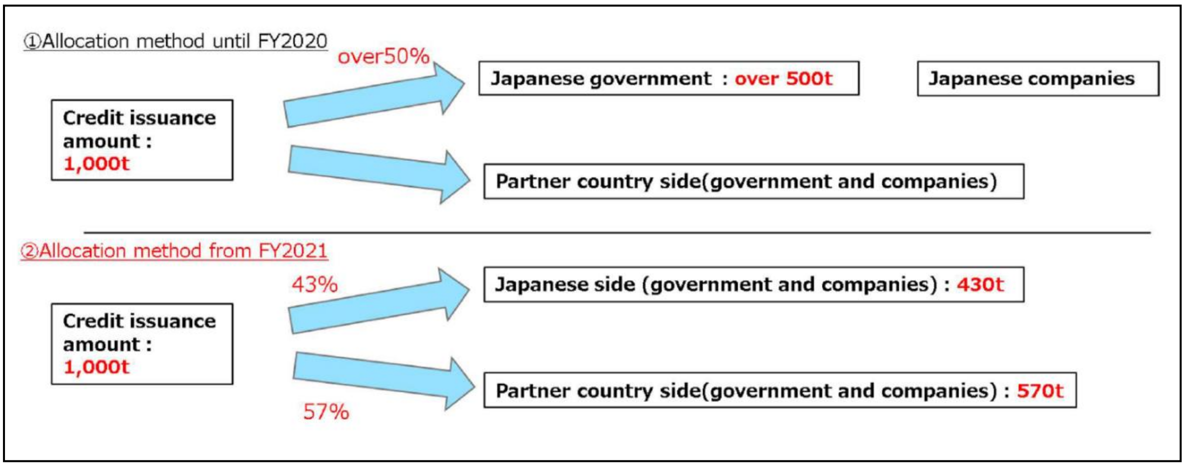

Fig. 7. Carbon credits sharing under JCM [11].

There are 49 pilot projects under the JCM between Japan and Thailand, with an expected GHG emission reduction of 262,357 tCO_2eq. However, only 11 projects have been registered, expecting a GHG emission reduction of 58,097 tCO_2eq. Five projects have shared carbon credits totaling 4,032 tCO_2eq, allocated to Japan (2,017 tCO_2eq) and Thailand (2,015 tCO_2eq) [12], [13]. The CERs from two solar panel installation projects classified as "Use of renewable energy (RE)" totaled 1,009 tCO_2eq. The remaining CERs from "Energy efficiency improvement" projects amounted to 3,023 tCO_2eq, as shown in Table 2.

Thailand should evaluate the implementation within the framework of international cooperation, especially concerning the Joint Crediting Mechanism (JCM). Accurate representation of ITMOs transferred from Thailand to Japan in national GHG inventories is of utmost importance.

This study aims to explore the potential for CO_2 emission reduction through cost optimization principles, with a focus on carbon credit sharing and adjustments in national GHG inventories, particularly in the energy sector, which holds the highest potential for emission reduction. The research will be conducted within the framework of international cooperation, including JCM, in alignment with Article 6.2 of the Paris Agreement. This approach supports Thailand's long-term climate change policies and the goal of achieving Carbon Neutrality by 2050.

Table 1. Thailand's enhanced mitigation measures in the energy sector.

Sectors	Supported Measures
Power generation	• Increasing share of RE in high-efficient power plants • Use of battery storage
Transportation	• Use of electric vehicles • Increasing share of biofuel blending such as B10 and B20
Manufacturing industries	• Use of high-efficient equipment such as motors and heating devices • Replacing of high-efficient electrical equipment to fossil fuel burning appliances such as furnaces and boilers
Residential and commercial buildings	• Use of RE technology such as solar rooftop

Table 2. List of certified projects under JCM [13].

Project Type/Name	Expected GHG Emission Reductions (tCO_2eq)	Certified GHG Emission Reductions (tCO_2eq)		
		Thailand	Japan	Total
Use of renewable energy				
- Solar rooftops in factory and office buildings	440	149	151	300
- 3.4 MW of solar rooftop providing for air-conditioner in factories	1,071	355	354	709
Sub-Total	1,551	504	505	1,009
Energy efficiency improvement				
- Energy efficiency in semiconductor factories using high-efficiency centrifugal chillers and compressors.	324	57	58	115
- Implementing high-efficiency air conditioning systems and chillers in semiconductor factories for enhanced energy savings and operational efficiency.	3,327	1,202	1,202	2,404
- Minimizing greenhouse gas (GHG) emissions at the textile factory, Luckytex (Thailand) Public Co., Ltd., using upgraded air-saving looms.	253	252	252	504
Sub-Total	3,904	1,511	1,512	3,023
Total	5,455	2,015	2,017	4,032

3. METHODOLOGY

The Asia-Pacific Integrated Model (AIM), specifically its AIM/Enduse variant developed by Japan's National Institute for Environmental Studies (NIES), serves as a bottom-up technology model in this study to identify the optimal technology systems within an economy. The system cost, measured in units like 1,000 USD/toe, encompasses fixed costs, operational and maintenance expenses, fuel costs, and additional charges such as energy or carbon taxes and subsidies. These costs are evaluated within constraints that include meeting demand, ensuring accessibility, and maintaining supply availability. The AIM/Enduse model is functional to calculate sets of technologies with minimized cost based on the exogenously given energy price to serve required energy demand [14]. Generally, the model is employed to investigate technology selection of country-level policies related to GHG emissions reduction under the given constraints [15], by which it operates on the principal of optimization techniques based on economic, energy, and environmental criteria.

In addition, the structure of AIM/Enduse model is presented in Figure 8, comprising three main components: types of energy or fuels, technology and energy demand, used to investigate changes in energy-related to environment issue. Inside the model, it is categorized into 5 sub-sectors: (1) power generation, (2) manufacturing industries, (3) transportation, (4) residential, and (5) commercial buildings.

In the power generation sector, information of primary energy supply during the period of 2016-2020 was referred from [16], which indicated that more than 70% of fuel used in electricity generation of Thailand was fossil fuels, including natural gas (58%), coal (16%) and petroleum products (less than 1%). The remaining shares were in renewable energy, *i.e.*, biomass, solar, biogas, hydro, wind, municipal waste, and geothermal. The energy conversion technologies are comprised of 4 groups: (1) existing, (2) efficient, (3) renewable energy (RE) and (4) biofuels and innovative technologies. Specific information on power generation, including lifetime, efficiency, initial or investment cost, operating and maintenance (O&M) cost and fuel cost can be summarized as Table 3.

The manufacturing industries sector is divided into 9 sub-sectors: (i) food and beverages, (ii) textiles, (iii) wood and wood products, (iv) pulp and paper, (v) chemical, (vi) non-metallic, (vii) basic metal, (viii) fabricated metal, and (ix) others (unclassified). Additionally, the end-use technologies in each industry are categorized into 5 equipment systems: lighting, motor, cooling, heating, and others. This sector utilizes three types of final energy conversion: fossil fuels, renewable energy (RE), and electricity, depending on the specific equipment in use.

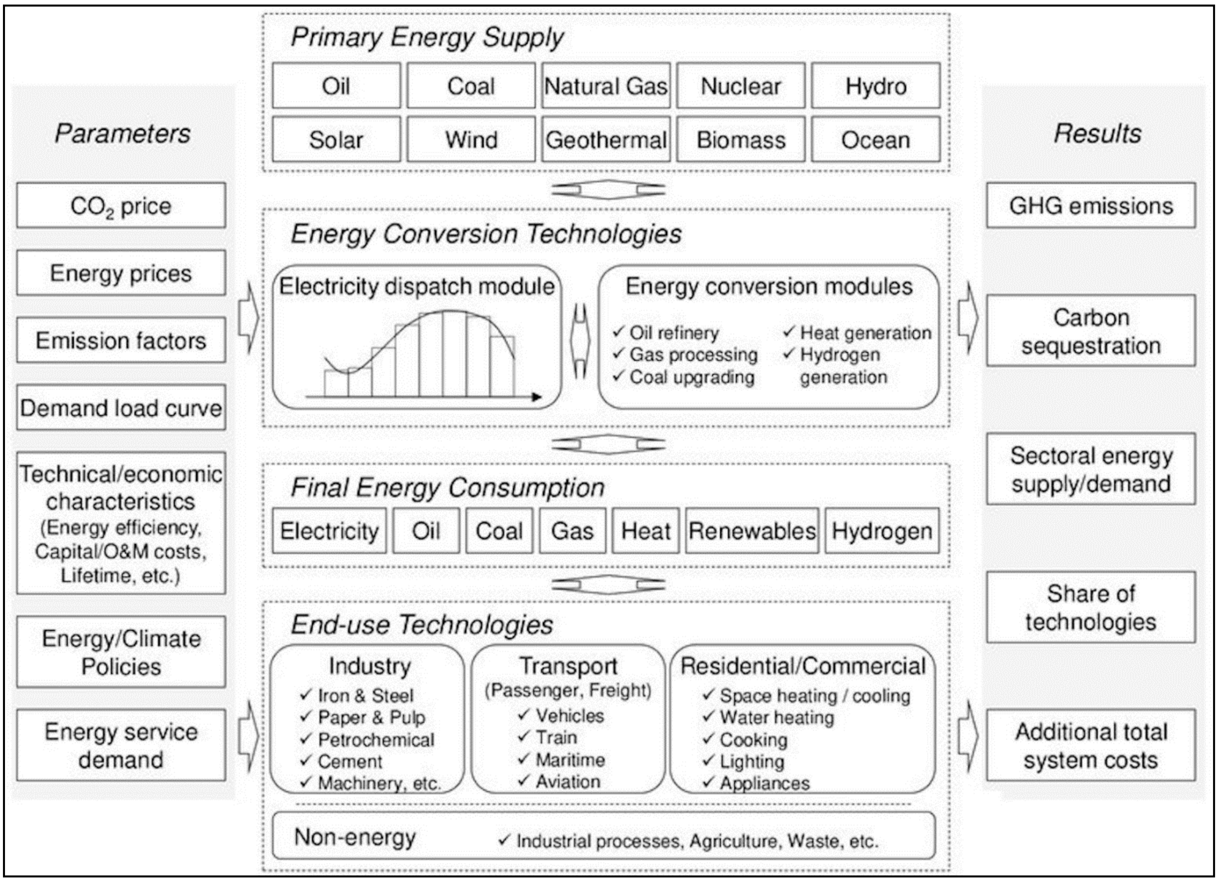

Fig. 8. The framework of the AIM/Enduse model [15].

Table 3. Specific information on power generation input into the AIM/EndUse model [17] – [19].

Power generation technologies	Lifetime (yr)	Energy Ratio (%)	Initial cost (MUSD/GW)	O&M cost (MUSD/GW)	Fuel cost (MUSD/ktoe)
Existing	30 – 40	22 – 43	430 – 1,050	7 – 39	0.03 – 1.40
Efficient	30 – 40	42 – 46	648 – 4,157	33 – 66	0.03 – 1.40
Renewable energy	20 – 30	30 – 100	964 – 5,601	8 – 168	0.00 – 0.16
Biofuels and innovative	20 – 40	35 – 60	1,200 – 4,500	19 – 121	0.03 – 0.58

In the construction of transport models, four modes of transportation are considered: road, rail, marine, and air. Each mode is subdivided into passenger and freight categories, encompassing a variety of vehicles and fuels. For instance, within road passenger transport services, there are six types of vehicles: sedan, van, tricycles, taxi, motorcycles, and bus. Four types of fuel are currently utilized in sedans: gasoline, diesel, LPG (Liquefied Petroleum Gas), and CNG (Compressed Natural Gas). In road freight transport, two types of vehicles are identified: truck and pick-up.

In both the residential and commercial building sectors, the model structure is similar due to the compatibility of end-use technologies. These technologies are categorized into five systems: lighting, cooling, cooking, entertainment, and miscellaneous uses. The primary sources of energy utilized in these sectors include LPG, electricity, solar and other renewable energies (REs), charcoal, fuel wood, and paddy husk, with the latter being used exclusively in the residential sector. Detailed information on manufacturing industries, residential and commercial building sectors, and transportation inputs for the AIM/EndUse model is provided in Tables 4 and 5, respectively.

To facilitate sub-sectoral assessment, the measures evaluated in this study are categorized into five main groups based on types of low-carbon technologies that align with Thailand's NDC implementation as described below:

- Measures (1) “Energy efficiency improvement”
- Measures (2) “Renewable energy and biofuels”
- Measures (3) “High-efficient electrical equipment”
- Measures (4) “High-efficient heating equipment”
- Measures (5) “Biofuels and innovative technologies”

Table 4. Specific information on manufacturing industries, residential and commercial buildings sectors input into the AIM/EndUse model [19], [20].

	Technologies	Lifetime (yr)	Efficiency compared to Existing (%)	Initial cost (MUSD/ktoe)	O&M cost (MUSD/ktoe)	Fuel cost (MUSD/ktoe)
Industries	Existing	10 – 20	100	0.05 – 8.03	0.01 – 0.80	0.11 – 1.18
	Efficient	10 – 20	110 – 120	0.09 – 17.28	0.01 – 1.73	0.11 – 1.18
	High-efficient electrical	20	125	1.22 – 5.50	0.12 – 0.55	0.11 – 1.18
	High-efficient heating	20	125	0.13 – 28.80	0.01 – 2.88	0.11 – 1.52
Residential	Existing	3 – 10	100	0.02 – 49.70	0.00 – 4.97	1.23 – 1.38
	Efficient	5 – 14	104 – 435	0.00 – 15.78	0.00 – 1.58	1.23 – 1.38
	RE	25	100	6.77	0.68	0.00
	High-efficient electrical	10	769	1.29	0.02	1.23
	High-efficient heating	10	122 – 139	0.27 – 1.43	0.03 – 0.14	1.38
Commercial	Existing	3 – 10	100	0.20 – 2.43	0.00 – 0.24	1.23 – 1.38
	Efficient	5 – 14	104 – 156	0.24 – 5.20	0.00 – 0.52	1.23 – 1.38
	RE	25	100	0.64 – 6.77	0.06 – 0.68	0.00
	High-efficient electrical	10	196	6.42	0.64	1.23
	High-efficient heating	10	122–139	0.14 – 2.22	0.01 – 0.22	1.38

Table 5. Specific information on transportation sector input into the AIM/EndUse model [19], [20].

Technologies	Lifetime (yr)	Fuel economy (km/liter or kWh)	Initial cost (USD/vehicle)	O&M cost (USD/vehicle/yr)	Fuel cost (MUSD/ktoe)
Existing	8 – 12	2.50 – 16.23	1,486 – 210,000	96 – 13,140	0.27 – 0.68
Efficient					
- Internal Combustion Engine (ICE)	10	11.00 – 32.20	28,872 – 540,000	866 – 13,140	0.27 – 0.68
- EV	6 – 15	0.77 – 22.20	240 – 369,458	2.40 – 11,826	1.27
Biofuels	10	7.59 – 14.34	28,872 – 38,700	866 – 1,161	0.52 – 1.33
Innovative	10	7.30 – 12.90	33,780 – 550,000	1,013 – 19,274	1.27 – 1.33

Measures (1) and (2) include low carbon technologies that are available in Thailand's market and widely used domestically, such as solar PV, efficient motors, efficient air-conditioners, gasoline blended with 10% ethanol (E10 or E20), diesel blended with 7% bio-fuel (B7 or B10), battery EVs (BEV), plug-in hybrid EVs (PHEV), and hybrid vehicles (HEV). Measures (3) and (4) consist of low-carbon technologies with higher potential for GHG reduction compared to current technologies used inland. These technologies are widely utilized abroad but have not been adopted in Thailand yet. Measure (5) includes new types of low-carbon technologies that are being piloted internationally but are not yet widespread, as well as technologies that are under development towards commercial use, such as the third generation biofuels, battery energy storage systems (BESS), fuel cells, green hydrogen, carbon capture, utilization and storage (CCUS), bio-energy with CCS (BECCS), and direct air capture (DAC), *etc.*

For assessment purposes, the potential for reducing CO_2 emissions from the group of low-carbon measures and technologies is aligned with the target of an additional 10% NDC and Thailand's target of achieving Carbon Neutrality by 2050 within the energy sector. The carbon credit sharing condition is divided into five cases, starting at 10% and increasing by 10% each time, up to 50%. Each increase in sharing requires an "additional amount of emission reductions," which must exceed the target specified in the conditional NDC to ensure the achievement of NDC goals.

According to the target of Thailand’s conditional NDC at 52 $MtCO_2eq$, along with a share of CO_2 among GHG emissions in the energy sector at 94.89%, the target for CO_2 reduction from the energy sector aligning with the conditional NDC is 49.34 $MtCO_2$. The additional CO_2 reduction consistent with carbon credit sharing within the framework of Article 6.2 is shown in Table 6.

Table 6. Amount of CO_2 reduction target in responding to Article 6.2 of the PA.

Carbon credit sharing (%)	CO_2 reduction ($MtCO_2$)	Add. reduction ($MtCO_2$)
0	49.34	-
10	54.82	5.48
20	61.68	12.34
30	70.49	21.15
40	82.23	32.89
50	98.68	49.34

4. RESULTS AND DISCUSSION

This study aims to examine the potential for CO_2 reduction through international cooperation frameworks, supporting Thailand's Carbon Neutrality objectives as stated in its Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS). Achieving "additional emission reductions" is essential. Table 6 indicates that increasing carbon credit sharing requires more effort, although this effort is not directly proportional.

According to the principle of cost-optimization, the results indicate that measures (1) and (2), which involve technologies available in the Thai market, should be adopted under the “Unconditional NDC.” The remaining measures should be implemented under the “Conditional NDC” due to the infeasibility of technology costs.

As shown in Table 7, measure (4) "high-efficient heating equipment" offers the highest potential for CO_2 reduction, followed by measure (5) "biofuels and innovative technologies." Measure (3) "high-efficient electrical equipment" has the lowest potential for CO_2 reduction.

Table 7. CO_2 reduction potential by measures.

Carbon credit sharing	CO_2 reduction potential by measures ($MtCO_2$)			
	(3)	(4)	(5)	Total
0	1.58	34.16	13.60	49.34
10	2.20	36.08	16.54	54.82
20	2.26	41.24	18.18	61.68
30	2.40	48.96	19.13	70.49
40	3.65	55.28	23.30	82.23
50	6.07	66.43	26.18	98.68

Many electrical systems employed across various sectors including industrial, residential, and commercial settings consume substantial amounts of energy and emit GHG emissions. These systems are primarily cooling devices such as chillers, air conditioners, and refrigerators. Since 2006, Thailand's Ministry of Energy has implemented energy efficiency standards for electrical equipment and appliances under the Label No. 5 program. It has ensured that high-quality equipment and appliances prevail in the Thai niche market.

The marginal abatement cost (MAC) for reducing one additional unit of emission through measures (3) is approximately 128 – 478 USD/tCO_2, based on the investigation. This indicates that replacing current technology with new technology would be costly. Consequently, the CO_2 reduction potential from measures (3) ranges from 2.20 – 6.07 $MtCO_2$, depending on carbon credit sharing, and is relatively small compared to other measures.

A large quantity of not only energy consumption but also CO_2 emissions of heating systems have originated from burning fossil fuels, i.e. coal, oil, liquefied petroleum gas, natural gas, in boilers, furnaces, especially in the industrial sector. Due to variety of heating technologies, the MAC results for measures (4) show in wide-ranging from 64 to 474 USD/tCO_2. Scoping to narrowing range of MAC between 64 and 225 USD/tCO_2 is the results of replacement by high-efficient with using unchanged fuels for the conventional. On the other hand, high MAC above 225 USD/tCO_2 is the results of high-efficient heating application, i.e. combined heat and power (CHP) technology; however, inconstant cost of technology depends on type of fuels. Therefore, because of its significant emission source, the reduction potential is also great, increasing from 34.16 – 66.43 $MtCO_2$, depending on share of carbon credit.

Emission reduction from the measures (5) “biofuels and innovative technologies” is the second highest potential with 16.54 – 26.18 $MtCO_2$, depending on carbon credit sharing. MAC length of this measures is 54 – 260 USD/tCO_2. The lowest MAC at 54 USD/tCO_2 occurs from using BESS technology in the power sector; however, even though its cost-effectiveness is remarkable, the capacity is limited relying on electricity demand as well as size of power plant. Alternatively, MAC values of more advanced technologies such as CCS and BECCS are higher than 180 USD/tCO_2. Nevertheless, since these technologies are primarily implemented in the hard abate sector, that are power generation and cement and petrochemical industries, the reduction potential is restricted.

The investigation results regarding additional CO_2 reduction by measures, as compared to the credit sharing in Table 8, indicate that measures (5) achieve higher additional reduction than measures (4) when carbon credit sharing is at 10%, despite the largest investment being in measures (4) (see Figure 9). Conversely, the additional reduction potential in measures (4) exceeds that of measures (5) when carbon credit sharing exceeds 10%.

The principle of price elasticity of demand is utilized to examine the impact of changes in total reduction costs on reduction potential. This analysis is crucial for policy decisions regarding appropriate carbon sharing with reasonable investment cost and emission reduction outcomes. The findings in Table 9 suggest that to create a robust framework for international cooperation under Article 6.2 of the Paris Agreement, and to meet Thailand's Nationally Determined Contributions (NDCs) while supporting the goal of Carbon Neutrality by 2050, a prudent carbon credit allocation should be capped at no more than 20%.

Table 8. Additional CO_2 reduction, compared to credit sharing.

Carbon credit sharing (%)	Add. reduction ($MtCO_2$)			
	(3)	(4)	(5)	Total
0	-	-	-	-
10	0.62	1.92	2.94	5.48
20	0.68	7.08	4.58	12.34
30	0.82	14.80	5.53	21.15
40	2.07	21.12	9.70	32.89
50	4.49	32.27	12.58	49.34

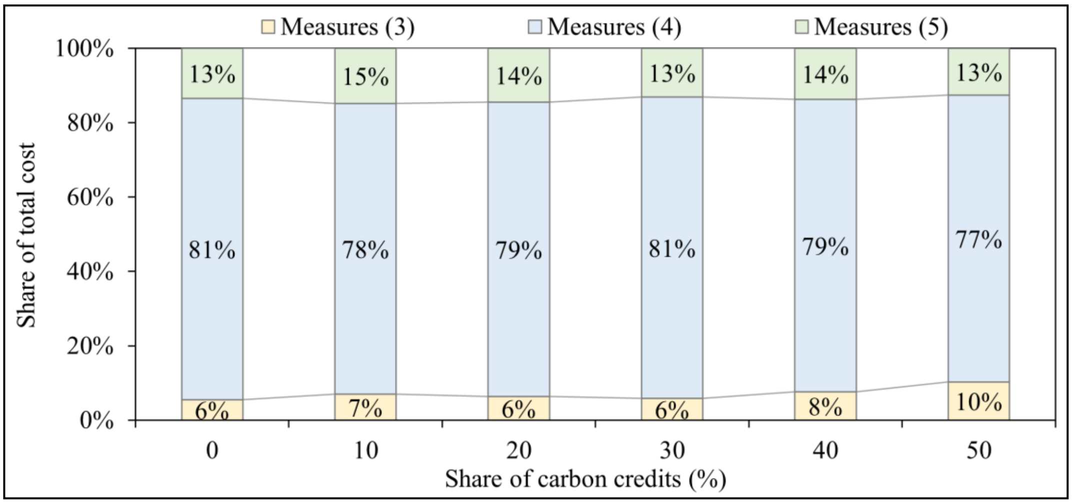

Fig. 9. Shares of total cost by measures.

Table 9. Total cost and price elasticity of CO_2 reduction.

Carbon credit sharing (%)	Total cost of CO_2 reduction (MUSD)	Price elasticity of CO_2 reduction
0	5,416	-
10	5,991	1.04
20	6,721	1.02
30	7,792	0.91
40	9,153	0.96
50	11,118	0.94

5. CONCLUSIONS AND POLICY IMPLICATION

Under this study, carbon credit sharing is set and divided into 5 cases, starting from 10%, and increasing by 10% each time, up to 50%. However, under Article 6.2 of the PA to support the Carbon Neutrality goal in accordance with LT-LEDS of Thailand, every carbon credit sharing increased requires "additional amount of emission reductions", which is more than the target specified in the conditional NDC to avoid failure of NDC achievement.

According to the cost optimization principle, the measure (4) "high-efficient heating equipment" possesses the highest potential for CO_2 reduction, alongside measures (5) "biofuels and innovative technologies." Measures (5) provide greater additional reduction potential than measure (4) under a carbon credit sharing scenario of 10%. However, when carbon credit share exceeds 10%, the opposite is true. In conclusion, for the transfer of ITMOs, it is recommended that Thailand's carbon credit sharing should not exceed 20%. This would allow for an additional emission reduction amounting to 12.34 $MtCO_2$, supplementing the conditional NDC target of 49.34 $MtCO_2$.

Furthermore, many nations are currently prioritizing the fight against climate change, leading to the rapid development and decreasing costs of low-carbon technologies. The technologies outlined in the plan will emerge before or within the specified timeframe. Consequently, policymakers should avoid long-term reliance on these results and instead conduct periodic analyses, such as every five years, in alignment with the NDC submission cycle mandated by the UNFCCC. In addition to considering the cost or cost-effectiveness of these technologies, it is essential to study their impacts or co-benefits on socio-economic aspects, such as health, employment, import-export values, and other environmental issues. Finally, an important matter that Thai policymakers and relevant agencies must reconsider is identifying any legal or regulatory obstacles to the adoption of innovative technologies, such as pipelines and storage facilities for CCUS or green hydrogen technology implementation and determining how to manage these challenges.

ACKNOWLEDGEMENT

The authors extend their gratitude to the Thailand Greenhouse Gas Management Organization (TGO) for their insightful comments and to the National Institute for Environmental Studies (NIES) Japan for providing support with the AIM model. The perspectives and opinions expressed in this article are solely those of the authors.

REFERENCES

[1] UNEP/GRID-Geneva. 2023. *Climate Change*, Retrieved January 29, 2025, from the World Wide Web: https://dicf.unepgrid.ch/thailand/climate-change

[2] UNFCCC. 2022. *Thailand's 2nd Updated Nationally Determined Contribution*, Retrieved January 29, 2025 from the World Wide Web: https://unfccc.int/sites/default/files/NDC/2022-11/Thailand%202nd%20Updated%20NDC.pdf

[3] ONEP. 2022. *Thailand's Long-Term Low Greenhouse Gas Emission Development Strategy (Revised version)*, Retrieved January 29, 2025 from the World Wide Web: https://unfccc.int/documents/622276

[4] GIZ., 2022. Technical Results from Tasks 1 – 3: The revision and update of Thailand's Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) and Thailand's National Determined Contribution (NDC).

[5] DCCE., 2024. NDC Action Plan on Mitigation 2021 - 2030. Department of Climate Change and Environment, Ministry of Natural Resources and Environment.

[6] DCCE. 2024. *Thailand. 2024 Biennial Transparency Report (BTR). BTR1*. Retrieved January 29, 2025, from the World Wide Web: https://unfccc.int/documents/645098

[7] TGO., 2023. The Study of GHG Mitigation Potential and Technology Selection Criteria According to JCM Cooperation Framework to Support Carbon Neutrality.

[8] TGO. 2016. *What is JCM?*, Retrieved June 16, 2016 from the World Wide Web: https://ghgreduction.tgo.or.th/th/about-jcm.html.

[9] GEC. 2022. *Overview of the Joint Crediting Mechanism (JCM)*. Retrieved 2022 from World Wide Web: https://gec.jp/jcm/about/

[10] Jansa P., Pita P., Misila P., Winyuchakrit P. and Limmeechokchai B., 2024. A Multicriteria Decision Analysis to Selection of Low-carbon Emitting Technologies under Joint Crediting Mechanism for Thailand's Carbon Neutrality 2050. *2024 International Conference on Sustainable Energy: Energy Transition and Net-Zero Climate Future (ICUE 2024)*. Pattaya City, Thailand.

[11] Ministry of the Environment, Japan. 2021. Credit Allocation Adjustment for the JCM Model Projects Starting from FY2021.

[12] TGO. 2022. *Project of Thailand that has been funded*. Retrieved 2022 from the World Wide Web: https://ghgreduction.tgo.or.th/th/statistics-jcm/jcm-model-project.html

[13] TGO. 2022. *Projects that have been registered/certified for carbon credits*. Retrieved 2022 from the World Wide Web: https://ghgreduction.tgo.or.th/th/statistics-jcm/jcm-registered-project.html

[14] Aruga K., 2010. *Report on AIM/Enduse Model*. Tsukuba, Japan: Economy and Environment Group, Institute for Global Environmental Strategies (IGES).

[15] Oshiro K., Masui T. and Kainuma M., 2017. *Quantitative Analysis of Japan's 2030 Target Based on AIM/CGE and AIM/Enduse.* In Post-2020 Climate Action (pp. 143-156).

[16] DEDE., 2020. Thailand Energy Balance 2020. Bangkok, Thailand: Department of Alternative Energy Development and Efficiency, Ministry of Energy.

[17] IEA. 2020. *Projected Costs of Generating Electricity 2020*. Retrieved 2020 from the World Wide Web: https://www.iea.org/reports/projected-costs-of-generating-electricity-2020

[18] IRENA., 2020. Renewable Power Generation Costs in 2019. Abu Dhabi: International Renewable Energy Agency.

[19] IEA. 2022. *World Energy Outlook 2022*. Retrieved 2022 from the World Wide Web: https://www.iea.org/reports/world-energy-outlook-2022

[20] IEA. 2021. *World Energy Outlook 2021*. Retrieved 2021 from the World Wide Web: https://www.iea.org/reports/world-energy-outlook-2021.