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Impact Assessment from Enacting Cap-and-Trade Legislation in Thailand's Industrial Estates

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Industrial estates are designated areas of land allocated for industrial factories to operate together in proportion, resulting in significant energy consumption and greenhouse gas (GHG) emissions in Thailand. Presently, there are 61 operational industrial estates, dispersed across 17 provinces. These estates accommodate over 1,295 designated factories, which extensively utilize energy resources and emit considerable quantities of GHG annually. Cap-and-trade is one of the carbon pricing mechanisms widely employed across numerous countries. It stands as an effective policy instrument aimed at reducing GHG emissions through legislative mandates that enforce major emitters to decrease their GHG emissions. This study evaluated GHG emissions from energy consumption in designated factories within industrial estates. It assessed the potential applicability of cap-and-trade mechanisms based on the European Union Emissions Trading System (EU ETS) thresholds and other assumptions for different scenarios. Additionally, it estimated the factory's administrative burdens resulting from legislative mandates, employing the Standard Cost Model (SCM). The study identified the number of designated factories emitting GHG beyond the set threshold between 45 and 200. Their combined emissions amounted to 9.20–43.34 $MtCO_2e$/y. Moreover, the study revealed that factories incurred a time-related compliance cost of 4,365–19,400 h/y and a financial compliance cost of 8–36 million Baht per year. Findings can be utilized for subsequent regulatory impact assessment (RIA).

1. Introduction

Thailand is among the countries significantly impacted by climate change, facing persistent weather variability and alterations, such as floods and droughts. These phenomena severely affect the economy and ecosystems. According to the Global Climate Risk Index, Thailand is ranked 9th globally in terms of climate risk (Eckstein et al., 2021). The industrial sector has consistently played a crucial role in the economic development of Thailand, with its significance increasing over time. This is evidenced by the growing share of the industrial sector in the nation's Gross Domestic Product (GDP), which reached 30 % of the GDP in 2023, amounting to 5.37 trillion baht. Industrial estates are critical areas within the industrial sector, systematically organized to house factories and serve as mechanisms for the government's strategy to decentralize industrial development across various regions. As of 2023, Thailand has 61 operational industrial estates spread across 17 provinces, encompassing all regions of the country. These estates collectively house 4,898 industrial factories, which constitute 6.74 % of the nation's total of 72,699 factories (DIW, 2024). Consequently, these industrial estates exhibit high energy consumption rates and significant GHG emissions, particularly from designated factories classified as controlled under the law. Currently, there are 1,295 designated factories, representing 26.44 % of the factories within industrial estates (DEDE, 2021).

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Despite these challenges, Thailand remains committed to its shared responsibility in addressing climate change as a party to the United Nations Framework Convention on Climate Change (UNFCCC). The country has ratified the Paris Agreement and submitted its national targets for post-2020 climate action through its 2nd Updated Nationally Determined Contribution (NDC) to the UNFCCC Secretariat. The core of Thailand's commitment is to reduce greenhouse gas emissions by 30 % by 2030 from the business-as-usual (BAU) scenario, with the potential to increase this reduction to 40 % with international support (UNFCCC, 2022). However, the 2020 monitoring results indicate that the country has not yet met its targets, particularly in the energy and transportation sectors, achieving only 56.54 $MtCO_2e$ of the 216 $MtCO_2e$ target.
The design and implementation of appropriate measures to address energy reduction and greenhouse gas mitigation are of significant importance. Particularly, the use of mandatory measures, such as carbon pricing, plays a crucial role. The cap-and-trade system, widely adopted in many countries worldwide, is one such measure. At the national level, various studies have been conducted, including those by Dechezlepretre et al. (2023) for the European Union (EU), Cao et al. (2019) for China, and Wongsapai (2016) for Thailand. In the realm of urban-level studies, Lessmann and Kramer (2024) investigated the impact of California's cap-and-trade system, while Li et al. (2024) studied the application of this measure at the provincial level in China. Hashim et al. (2022) discussed a framework for the decarbonisation of industries using a carbon trading approach. Betz et al. (2010) proposed an alternative approach of "partial coverage" based on benefit-cost analysis, which can achieve the same emission reduction outcome at a lower social cost for the European Union. Parry et al. (2022) examined the efficacy of carbon taxes and emissions trading systems (ETS) in providing direct financial incentives contingent upon the quantity of GHG emissions. Their findings suggest that these mechanisms effectively mitigate GHG emissions, yielding enduring benefits for the economy, society, and the environment. This research aims to assess GHG emissions resulting from energy consumption in designated factories within industrial estates, to evaluate the potential implementation of cap-and-trade mechanisms, and to examine the possible future impacts of such enforcement.

2. Data and method

The data utilized in this study is divided into two categories: energy consumption data and greenhouse gas emissions data from industrial factories within industrial estates. This study specifically considers legally designated factories, as they exhibit significant energy consumption and have verifiable data available from government agencies. The details are as follows.

2.1 The overall energy consumption

Energy consumption data is crucial for evaluating the greenhouse gas emissions resulting from industrial operations. This data encompasses fuel usage for combustion and electricity consumption. In this study, the data is sourced from the energy management reports (EMR) that designated factories are legally required to submit annually to the Department of Alternative Energy Development and Efficiency (DEDE). The data covers a total of 1,295 designated factories between the years 2018 and 2020. The energy consumption details are categorized by industrial sectors in Table 1.

Table 1: The energy consumption data categorized by industrial sectors.

Industrial sectors	Annual energy consumption (TJ/y)				Share (%)
	2018	2019	2020	Average	
Food and beverages	5,423.72	6,291.53	5,845.24	5,853.50	0.78
Textiles	4,645.88	2,631.31	3,751.77	3,676.32	0.49
Wood	228.09	991.80	1,182.00	800.63	0.11
Paper	1,622.65	1,670.83	1,602.10	1,631.86	0.22
Chemical	247,404.73	235,174.17	242,321.49	241,633.46	32.27
Non-metallic	23,627.78	24,373.26	23,730.57	23,910.54	3.19
Basic metal	22,678.88	21,306.23	20,057.25	21,347.45	2.85
Fabricated metal	18,637.53	19,017.95	17,106.21	18,253.89	2.44
Gas	2,360.53	1,977.73	2,681.33	2,339.86	0.31
Electricity	420,879.71	469,758.21	343,203.33	411,280.42	54.92
Stone, sand and clay	190.04	171.32	150.59	170.65	0.02
Other (unclassified)	19,776.39	18,912.06	15,243.49	17,977.31	2.40
Total	767,475.93	802,276.39	676,875.37	748,875.90	100.00

2.2 The overall GHG emissions

The calculation of greenhouse gas emissions from energy consumption data, as described in Section 2.1, is performed by multiplying the energy usage activity data (AD) by the emission factors (EF) for each type of greenhouse gas. This product is then multiplied by the Global Warming Potential (GWP) values over a 100-year time horizon, as referenced in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) (Myhre et al., 2013). This calculation of GHG emissions is illustrated in Eq(1).

$$GHG\ Emissions = AD \times EF \times GWP_{100}AR5 \quad (1)$$

Where AD is the data on fuel consumption and electricity usage (units), EF is the emission factor of fuel and electricity consumption (kgGHG/units), and $GWP_{100}AR5$ is the global warming potential over a 100-year period, according to the fifth assessment report (AR5) ($kgCO_2e/kgGHG$).

The calculations in this study consider GHG emissions within two scopes, as defined by ISO 14064-1. Scope 1 covers direct GHG emissions, which in this research are limited to emissions from fuel combustion activities, following the calculation guidelines provided by the 2006 IPCC Guidelines (IPCC, 2006). Scope 2 encompasses indirect GHG emissions from imported energy consumption activities, specifically focusing on imported electricity in this study, based on the calculation guidelines from the Carbon Footprint for Organization (CFO) of the Thailand Greenhouse Gas Management Organization (TGO) (TGO, 2022). The GHG emissions data, categorized by these emission scopes, are presented in Table 2.

Table 2: GHG emissions categorized by industry sectors.

Industrial sectors	GHG emissions in Scope 1 only ($ktCO_2e/y$)		GHG emissions in Scope 1 and 2 ($ktCO_2e/y$)	
	Average year 2018-2020	Share (%)	Average year 2018-2020	Share (%)
Food and beverages	181.31	0.45	493.93	0.95
Textiles	149.81	0.37	302.68	0.58
Wood	0.84	0.00	30.79	0.06
Paper	27.83	0.07	196.10	0.38
Chemical	8,535.67	21.32	12,880.50	24.70
Non-metallic	560.33	1.40	2,086.30	4.00
Basic metal	607.85	1.52	2,038.88	3.91
Fabricated metal	228.41	0.57	2,229.10	4.28
Gas	57.31	0.14	243.09	0.47
Electricity	29,401.08	73.43	29,566.98	56.71
Stone, sand and clay	5.74	0.01	15.57	0.03
Other (unclassified)	285.96	0.71	2,057.55	3.95
Total	40,042.15	100.00	52,141.47	100.00

3. Threshold scenarios

3.1 Assumptions

This study simulates various potential scenarios that might arise from the future implementation of a cap-and-trade system. The analysis is divided into three scenarios:

- Scenario 1 (S1) considers only Scope 1 GHG emissions, including the electricity generation sector.
- Scenario 2 (S2) considers only Scope 1 GHG emissions, excluding the electricity generation sector.
- Scenario 3 (S3) considers GHG emissions in both Scope 1 and 2, excluding the electricity generation sector.

The rationale for isolating the electricity generation sector stems from Thailand's current electricity structure, known as the Enhanced Single Buyer (ESB) model. In this model, the government purchases electricity from private producers, who are not permitted to sell it directly to consumers. This arrangement imposes constraints associated with long-term power purchase agreements, which limits the capacity to decrease production or improve efficiency. These contracts include an available payment (AP), a readiness fee ensuring that the system can immediately supply electricity when demanded. Each scenario also sets different GHG emission thresholds for industrial factories—15,000, 20,000, and 25,000 t CO_2e—aligning with the current standards used by the EU ETS (Betz, 2010) and other countries. This approach facilitates the examination of the impacts on industrial factories under various conditions, as shown in Figures 1 to 3.

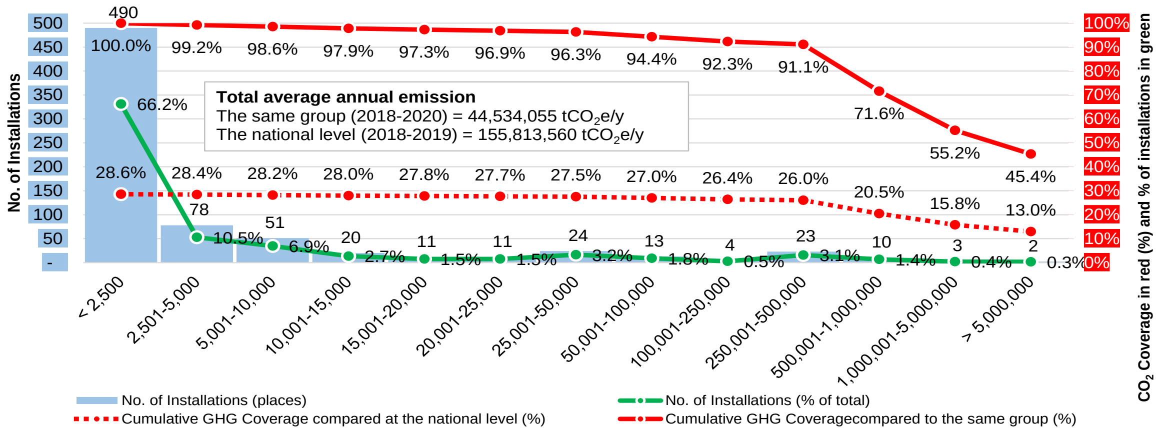

Figure 1: S1 considers GHG emissions in Scope 1 only, including the electricity generation sector.

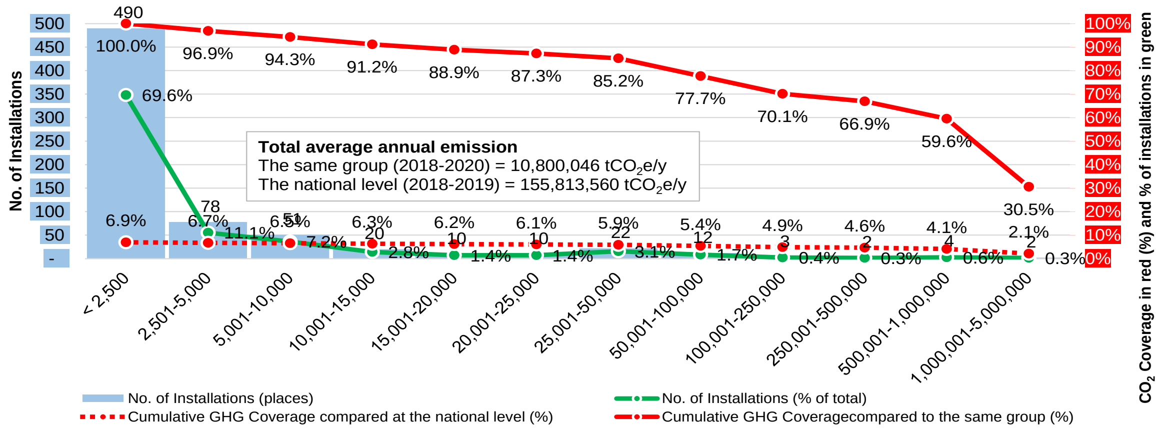

Figure 2: S2 considers GHG emissions in Scope 1 only, excluding the electricity generation sector.

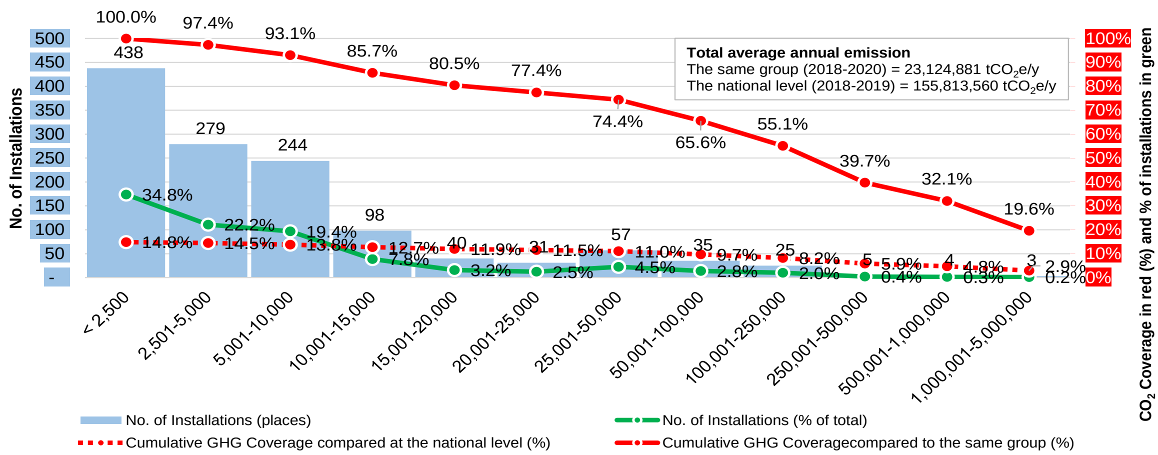

Figure 3: S3 considers GHG emissions in Scope 1 and 2, excluding the electricity generation sector.

3.2 Number of installations and sectors

The hypotheses established under different scenarios in Section 3.1 affect the number of industrial factories that will be included in the cap-and-trade system, as well as the overall annual GHG emissions. These impacts are illustrated in Table 3. This information is crucial for policy and planning, target setting, impact analysis, and estimating the potential reduction in greenhouse gas emissions resulting from the implementation of this mandatory measure in the future.

Table 3: The number of installations and GHG emissions covered under different scenarios.

Scenarios	No. of Installations (places)	No. of Installations (% of total)	Total annual emission ($ktCO_2e/y$)	Total annual emission (% of total)
Scenario 1 (S1)	740	100.00	44,534.05	100.00
S1-1: GHG emissions > 15,000 tCO_2e	101	13.65	43,337.18	97.31
S1-2: GHG emissions > 20,000 tCO_2e	90	12.16	43,146.59	96.88
S1-3: GHG emissions > 25,000 tCO_2e	79	10.68	42,901.22	96.33
Scenario 2 (S2)	704	100.00	10,800.05	100.00
S2-1: GHG emissions > 15,000 tCO_2e	65	9.23	9,603.17	88.92
S2-2: GHG emissions > 20,000 tCO_2e	55	7.81	9,429.98	87.31
S2-3: GHG emissions > 25,000 tCO_2e	45	6.39	9,205.23	85.23
Scenario 3 (S3)	1,259	100.00	23,124.88	100.00
S3-1: GHG emissions > 15,000 tCO_2e	200	15.89	18,613.10	80.49
S3-2: GHG emissions > 20,000 tCO_2e	160	12.71	17,909.65	77.45
S3-3: GHG emissions > 25,000 tCO_2e	129	10.25	17,210.76	74.43

4. Standard Cost Model (SCM)

The Standard Cost Model (SCM) is a principle for calculating the administrative burdens on the public arising from the enactment of laws. The goal is for SCM to serve as a model for calculating the burdens resulting from legal compliance, which can then be used as a tool for improving the quality of government legislation. SCM can calculate the burdens of legal compliance in terms of both financial costs and time costs. The foundational structure of this calculation principle is illustrated in Eq(2).

$$\text{Administrative Burdens (AB)} = \text{Time Costs } (T \times Q) + \text{Financial Costs } (C \times Q) \quad (2)$$

Where T represents the time required to comply with the law, Q is the quantity or frequency of the compliance activity, and C stands for the financial cost of compliance. Thus, the total administrative burden is the sum of the time costs and financial costs, each multiplied by the quantity or frequency of the compliance activity. The details of the calculation steps can be summarized in the diagram shown in Figure 4.

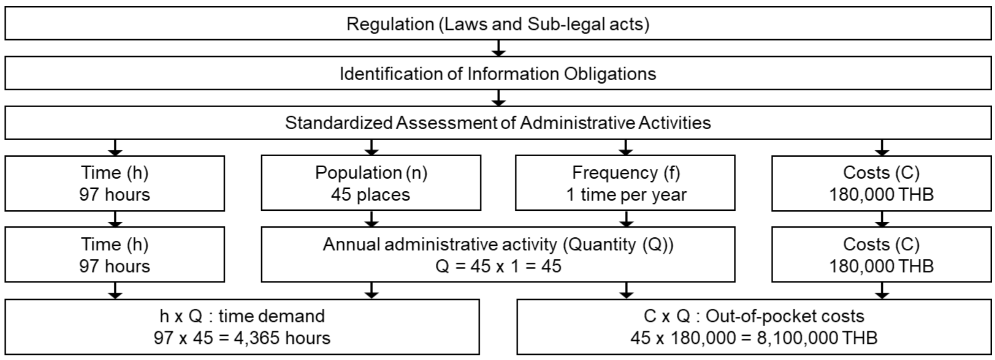

Figure 4: Example of calculation steps for the public burden from legislation in Scenario S2-3.

5. Results

The study's results indicate a varying number of designated factories when different scenarios and thresholds are applied within a cap-and-trade system, as shown in Table 3. In Scenario 1, there are 740 factories considered, collectively emitting 44,534.05 $ktCO_2e$ per year. Among these, 79 to 101 factories fall under the regulation, accounting for 96.33 % to 97.31 % of total GHG emissions. In Scenario 2, 704 factories are considered, with a total emission of 10,800.05 $ktCO_2e$ per year, excluding the group of power plants. Within this scenario, 45 to 65 factories are regulated, representing 85.23 % to 88.92 % of total GHG emissions. In Scenario 3, there are 1,259 factories considered, with total emissions of 23,124.88 $ktCO_2e$ per year, including additional factories that use only electricity. In this scenario, 129 to 200 factories are regulated, covering 74.43 % to 80.49 % of total GHG emissions. The data indicates that within a cap-and-trade system, it is not necessary to apply this measure to all factories. Regulating only a subset of factories still covers the majority of GHG emissions, reducing unnecessary administrative burdens in terms of both time and cost for regulators and the industrial sector. The administrative burdens associated with different scenarios are detailed in Table 5.

6. Conclusions

This research evaluates the impact of implementing cap-and-trade legislation within Thailand's industrial estates. The scope of the study focuses exclusively on designated factories due to their significant energy consumption and the availability of relevant data. The study commenced by collecting energy consumption data and estimating the GHG emissions of all designated factories. Subsequently, various feasible scenarios were simulated. The authors believe that Scenario 2 is the most feasible within the Thai context, considering only scope 1 (direct emissions) and excluding power plants due to the current structure of the electricity sector, which poses obstacles. This scenario encompasses 45 to 65 factories, covering approximately 9,200 to 9,600 ktCO_2e per year, accounting for 5.90 % to 6.16 % of the industrial sector's national GHG emissions. These factories are primarily in three industries: non-metal, basic metal, and chemical. Regarding administrative burdens, this scenario results in a time demand of 4,365 to 6,305 h and a financial cost of 8.10 to 11.70 million baht. The limitations of Scenario 1 involve the need to amend Thai laws governing the electricity sector to ensure power plants meet GHG mitigation standards. In contrast, Scenarios 2 and 3 can be implemented without altering the electricity sector, but their GHG reduction potential is significantly lower. These findings can be utilized as supporting information for planning and formulating national policies on GHG management.

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