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Decarbonisation of the Industrial Sector Through Greenhouse Gas Mitigation, Offset, and Emission Trading Schemes

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Several nations have adopted a tax or market-based carbon pricing system, typically involving low price rates, inadequate emissions coverage, and price reductions for particular industries. The main driver of climate change and global warming is greenhouse gas (GHG) emissions, which include carbon dioxide. The drive to reduce carbon emissions and offset carbon is critical to industrial decarbonisation and achieving the net zero goal. This paper investigates two key actions to reduce carbon emissions: switching to low-carbon alternatives and carbon offset. The emission trading scheme (ETS) mechanism is a market-based pollution-control strategy that provides economic incentives to reduce emissions. This framework, also known as a cap and trade system or allowance trading, has the potential to reduce emissions by establishing a pollution limit and creating a market for each country. The use of the ETS in the waste-to-energy industry demonstrates the framework's applicability. It has been shown that a well-designed ETS can be both environmentally and economically sound as a driver of the low-carbon economy transition. It will be highly beneficial to the industry because it will provide precise emission monitoring, harsh penalties for violations, and high compliance.

1. Introduction

Heat and power generation in the energy sector results in a sizable share of fossil CO_2-eq emissions (Rajabloo et al., 2022). Countries worldwide have signed the Paris Agreement, which requires them to explore steps to mitigate global warming. Many countries have set a target of achieving net zero emissions by 2050. Japan, Korea, and Canada have all established policies to achieve net zero emissions by 2050 (Zhang et al., 2021). The world's net CO_2-eq emissions must drop by 45 % by 2030 compared to 2010 to attain the aim of net zero emissions by 2050. Companies and firms are the primary emitters; therefore, they must accept responsibility for reducing emissions generated by their organisations. Adopting only possible mitigation measures like renewable energy, water reclamation, and afforestation will not be enough to achieve the net zero goal (Fragkos et al., 2021). To achieve net zero, each firm in a country must achieve net zero in order for the country as a whole to meet the overall net zero goal. Implementing an emission trading system can assist industries in meeting their net zero goal (Narassimhan et al., 2018). Emission trading is a market-based pollution-control strategy that offers economic incentives to reduce emissions. This method is known as a cap and trade system or allowance trading (United States Environmental Protection Agency, 2022). Emission trading schemes have the potential to reduce emissions by establishing a pollution limit and creating a market for each company. A well-designed ETS is said to be both environmentally and economically successful. It could be highly beneficial to the industry because it can provide precise emission monitoring, harsh penalties for violations, and high compliance. In order to achieve climatic stability, the world economy must decarbonise, and by 2050–2070, net zero greenhouse gas emissions must be reached to keep global warming to 2 degrees Celsius (Rissman et al., 2020).

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The two primary components of an emissions trading system are a pollution limit (or cap) and tradable allowances equal to the limit that allow allowance holders to emit a specific quantity (Clarkson et al., 2015). A nationwide, or occasionally regional, cap on the overall quantity of pollution sources are permitted to emit into the environment serves as the foundation of emissions trading programmes. Typically, the government will establish a maximum pollution level and issue permits for each emission unit (Requate, 2005). Businesses must obtain and surrender a permit for each unit of emission. Permits are available from the government or at an auction with other businesses. The government could distribute the permits for free or auction them off. Companies that can reduce their emissions below the cap may be able to sell their permits. Companies that do not have enough permits or have exceeded the emission cap must buy more permits from other companies or reduce their emissions. The permit fee may change over time as the economy changes. When there is a high demand, the permit can be pretty expensive; when there is low demand, the permit can be very cheap. Implementing ETS has its advantages, such as establishing a specific total cap that is then divided into allowances, reducing pollution faster, encouraging more climate change goals, increasing government revenue, gradually lowering the overall cap in this system over time, and eliminating the need for another tax in the economy.

Numerous domestic and regional carbon trading projects are in the works, each with its design and state of development. The jurisdictions of these systems range from broad regional (European Union ETS, Regional Greenhouse Gas Initiative, Western Climate Initiative) to national (Australia, Republic of Korea, New Zealand), provincial (Alberta), or city level (European Union ETS, Regional Greenhouse Gas Initiative, Western Climate Initiative). The most extensive trading system for greenhouse gas emissions in the world is the European Union's (EU) Emissions Trading Scheme (ETS). The EU ETS is now the most extensive system in the world. It operates in all 28 EU nations, as well as Iceland, Liechtenstein, and Norway, regulating emissions from over 11,000 large consumers of energy, such as power plants and industrial plants, as well as airlines flying between ETS member countries. It covers around 45 % of the EU's greenhouse gas emissions (Clarkson et al., 2015). This paper assembles and evaluates a framework that can lead to net zero industrial emissions in the planned time. The development of the global climate framework to facilitate the shift to zero emissions is also discussed in this paper.

2. Problem Statement

The Emission Trading System is a developing topic, and there is an increasing need for additional clarification through research in this field. There are few research publications on using ETS to achieve the net zero target. This study looks at how successful ETS can be, how it can be applied in industries and the amount that can be traded through ETS to reduce emissions. Critics are worried that carbon trading programmes will not succeed in decreasing emissions as intended. Setting the rules of each carbon trading scheme is a political process in which lobbying organisations exert pressure on governments, resulting in overly liberal restrictions. Furthermore, this system necessitates the implementation of monitoring, reporting, and verification (MRV) criteria to ensure that a tonne of carbon emitted or reduced in one facility equals a tonne of carbon emitted or reduced in another. Due to a lack of administrative capacity and socio-economic imbalance, implementing ETS in a developing country may be difficult. Various procedures must be completed for the ETS to be implemented successfully. These include coordinating government action on the carbon tax and ETS policies to prevent "carbon leakage," which happens when carbon-intensive industries move to nations without carbon prices, educating the public about the significance of policy implementation to national and international climate agendas, enhancing public transportation, and outlining assistance options for the general public and wealthy citizens (Muhammad, 2021). Implementing ETS in industries does not encourage some industries, particularly fossil fuel use, to change their behaviour. It will encourage them to continue polluting because this system allows them to obtain carbon credits or low-cost offsets that are less expensive than switching away from fuels that emit greenhouse gases. Furthermore, monitoring or implementing monitoring equipment that measures greenhouse gas outputs from each company is challenging. This framework can improve compliance while also encouraging businesses to game the system. For this system to work, the government must be steadfast in enforcing a cap on emissions. There is no point in having this arrangement in place if major polluters are constantly granted extensions. Because no one knows what the final costs will be, agencies that require more resources due to greenhouse gas emissions cannot properly budget for the expense. To avoid dangerous climate change, every sector of the global economy must reduce greenhouse gas (GHG) emissions (Rissman et al., 2020).

3. Methodology

The product with the highest priority in the production model must be used as the main or reference product to calculate the comparable production in this process. At the end of the process, this is usually the one that consumes the most energy. Figure 1 depicts the methodology for establishing an energy baseline and Figure 2 presents the framework for implementing energy trading schemes (ETS).

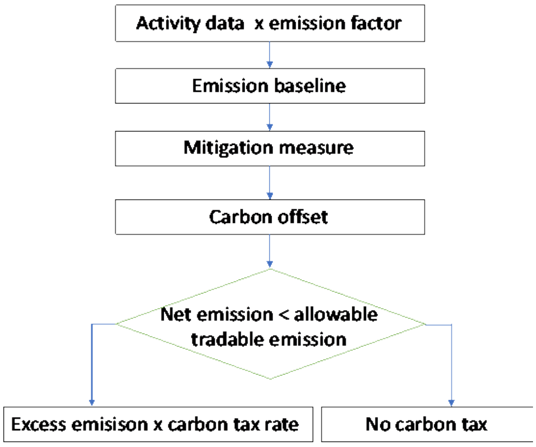

Figure 1: Flow diagram to establish the ETS framework

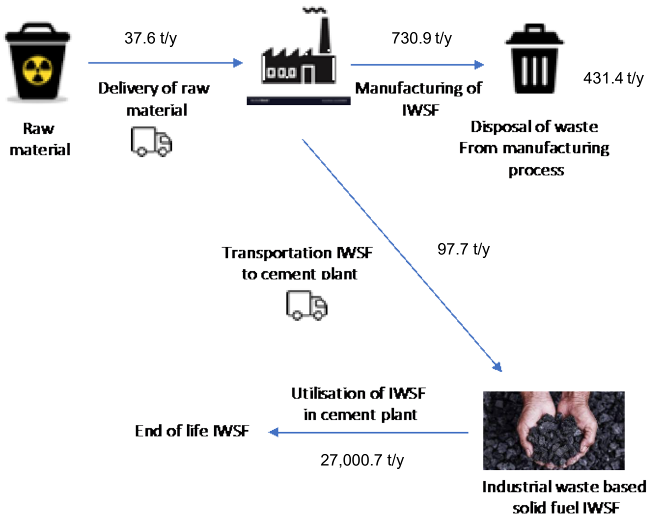

Figure 2: Baseline of carbon emission for hazardous waste based solid fuel: application in a cement kiln (Karpan et al., 2021)

In this case study, a cement manufacturing company replaces coal with about 12,000 t of produced industrial waste-based solid fuel (IWSF) each year. Compared to Indonesian bituminous coal, which has an average calorific value of 4,500 kcal/kg, the IWSF has a stable calorific value of 3,200 kcal/kg, making it a more usable alternative fuel. The methodology is outlined below:

3.1 Step 1 - Calculation of Emission Baseline

The emissions are calculated for the entire supply chain, which includes various activities such as energy consumption, electricity consumption, water consumption, waste generation, and transportation. The GHG emission is calculated using Eq(1):

$$\text{Emissions GHG} = \text{Activity data} * \text{Emission Factor} \quad (1)$$

3.2 Step 2 – Propose mitigation measure

Mitigation measures to reduce emissions, such as renewable energy implementation, water savings, and turning waste into wealth, are proposed.

3.3 Step 3 – Propose carbon offset

Mangroves are one of the most promising carbon-offsetting strategies. Each mangrove tree planted will remove over 0.018 t CO_2-eq per tree.

3.4 Step 4 Cap and trade mechanism

Cap and trade is a tactic that employs the forces of the market to reduce emissions effectively and economically. The government sets an emissions ceiling in a cap-and-trade system and allots a predefined number of emission allowances. For each tonne of greenhouse gas emitted, emitters are required to have allowances. Companies may purchase and sell allowances, and this market sets the price of emissions. Any extra allowances can be sold to businesses that will pay more to buy them if they can cut their emissions at a cheaper cost.

4. Results and discussion - Economy-wide carbon pricing

The average price and price gap criterion findings show that the current carbon pricing in effect worldwide is not very reliable (Finch and van den Bergh, 2022). The adoption of solar power can help to mitigate carbon emissions by placing more carbon-intensive sources of heat and power. Table 1 shows the parameter for solar technology, and Table 2 shows the emission baseline for the case study and CO_2-eq absorption rate based on Biennial update report (BUR 3) and in-situ measurement. It was found that solar installation can reduce about 2,073.20 t of CO_2-eq /y.

Table 1: Parameter of solar installation and emission reduction

Parameters	Value	Unit
Inverter efficiency (TNBR)	0.96	
Emission factor for grid (MYRER, 2021)	0.71	t/MWh
Operational time	4	h/d
Solar panel capacity	2	MW_{ac}
Energy	10.512	GJ
Emission reduction	2073.2	t CO_2-eq /GJ

Table 2: Baseline emission and absorption rate

Item	Value	Unit
Baseline emission for hazardous waste company (2020)	28,636.80	t CO_2-eq /yr
Absorption rate (KASA)	0.0180	t CO_2-eq /tree
Absorption rate (In situ measurement)	0.0205	t CO_2-eq /tree
Mangrove survival rate	90	%

In this case study, it was assumed that about 50,000 trees of mangrove were planted for the carbon offset, which would lead to 27,611 t CO_2-eq/y carbon offset. Table 4 shows the carbon pricing for this case study. It was found that about 3,636 t CO_2-eq/y will be taxable, and about 26,046 t CO_2-eq/y excess may be sold to other companies facing higher costs to reduce emissions. Figure 3 illustrated the total CO_2-eq emission reduction by solar installation in Malaysia, average price rate and price-gap performance of economy-wide carbon prices.

Table 4: Carbon pricing analysis for the case study

Item	Value	Unit
Carbon rate (SGD 5/tonne CO_2-eq)	20	MYR/t CO_2-eq
Carbon cap	25,000	t CO_2-eq /yr
Amount of CO_2-eq that will be tax	3,636.80	t CO_2-eq /y
Carbon tax	69,099.20	MYR/t CO_2-eq /y
Total CO_2-eq emission reduction (solar + mangrove)	29,685.00	t CO_2-eq /y
Tradable amount of CO_2-eq emission (can be sold)	26,048.20	t CO_2-eq /y
Tradable amount of CO_2-eq emission (can be sold)	494,915.80	MYR

Table 5 describes the Singapore carbon tax road map for 2019-2030, a guideline for this study. Several nations have adopted a tax or market-based carbon pricing system, typically involving low price rates, inadequate emissions coverage, and price reductions for particular industries (Finch et al., 2022). The average carbon price among nations is 7.90 EUR/t CO_2-eq, with a 57.7% price difference. The highest stated price for Sweden, in particular, needs to be considered because it deviates by almost EUR 100 from the average price. Furthermore, there are noticeable price differences between Switzerland and Finland.

Table 5: Singapore Carbon Tax Guideline

Guideline	Singapore's Carbon Tax Rates
Carbon Pricing Act: The Singaporean government began the implementation of its carbon tax on 1st January 2019.	2019-2023: 5 SGD/t CO_2-eq
The carbon tax applies to all facilities with annual GHG emissions of 25,000 t CO_2-eq or more, with no exemptions.	2024-2025: 25 SGD/t CO_2-eq
Singapore plans to progressively raise its carbon tax to achieve its climate ambition.	2026-2027: 45 SGD /t CO_2-eq
Companies may utilise high-quality international carbon credits to offset up to 5 % of their taxable emissions from 2024.	2030: 50-80 SGD/t CO_2-eq

Notes: Adopted from STRAITS TIMES news, Budget 2022: Singapore's carbon tax could increase to 80 SGD/t CO_2-eq by 2030.

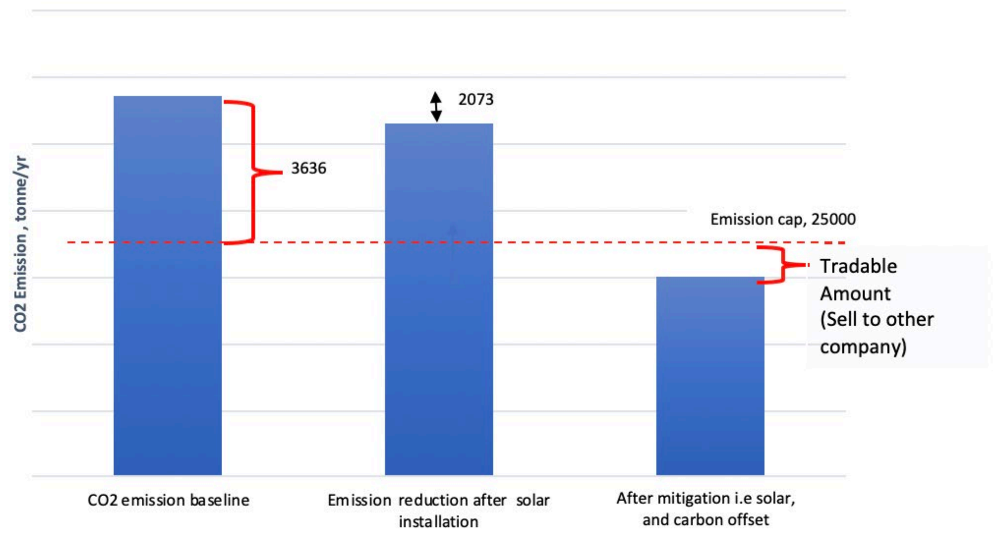

Figure 3: Total CO_2-eq emission reduction by solar installation in Malaysia and average price rate and price-gap performance of economy-wide carbon prices

5. Conclusions

Industries stand out as the primary contributors to emissions and must fully commit to reducing them. Adoption of possible mitigation measures such as renewable energy, water reclamation, and afforestation will not be sufficient to accomplish the net zero aim. Emission trading is a market-based strategy to control pollution that provides economic incentives to reduce emissions and reach net zero. This paper discusses a framework for the decarbonisation of industries using a carbon trading approach. The carbon tax applies to all industries with annual GHG emissions of 25,000 t CO_2-eq or more, with no exemption. By installing solar systems and planting 50,000 mangrove trees, industries can obtain about 26,048.20 t of CO_2-eq /yr that is tradable to other industries and worth approximately MYR 494,915.80. In future work, scenario analysis will be performed to perform cost benefit analysis and identify the tradeoff between the implementation of selection mitigation measures and tradable carbon offset to be sell to other companies.

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