Professor Dr.Prasert Na Nagara Thesis Awards, Academic Year 2025

60th Anniversary The Graduate School Kasetsart University

Good Thesis Awards

Physical Science Section

Miss Prawdown Udol

Master Degree Program

Major in Chemical Engineering

Development of Emission Factors and Assessment of Greenhouse Gas Mitigation Pathways in Thailand's Economy Using an Environmentally Extended Input–Output Model

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Background

- Thailand has set a target to reduce greenhouse gas (GHG) emissions
  → Measuring and reporting GHG emissions is essential.
- Carbon Footprint of Organization (CFO)
  - Definition: Total GHG emissions generated directly and indirectly by an organization
  - Why important? → Support GHG reduction targets
    → Regulatory compliance
    → Meet global buyer requirements
    → Enhance competitiveness & green financing
  - Calculation framework: Based on GHG Protocol or ISO14064-1
  - Emission sources: Scope 1, Scope 2, Scope 3
  - Relies on two main data: 1. Activity data (Unit: kg, L etc.)
    2. Emission Factor (Unit: tonCO2eq/kg or L)

GHG protocol		ISO14064-1
Scope1	Direct GHG emissions and removals	Direct GHG emissions and removals
Scope2	Energy indirect GHG emissions	Indirect GHG emissions from imported energy
Scope3 – Other indirect GHG emissions	(4) Upstream transportation and distribution (6) Business travel (9) Downstream transportation and distribution (7) Employee commuting	Indirect GHG emissions from transportation
	(1) Purchased Goods and Services (2) Capital goods (3) Fuel-and-energy-related activities	Indirect GHG emissions from goods purchased by organization
	(5) Waste generated in operations (8) Upstream leased assets	Indirect GHG emissions from services used by organization
	(10) Processing of sold products (11) Use of sold products (12) End-of-life treatment of sold products (13) Downstream leased assets (15) Investments	Indirect GHG emissions associated with the use of products from the organization
	(14) Franchises	Indirect GHG emissions from other sources

Rationale

- Scope 3 categories with limited physical activity data require *Spend-based method* → EEIO EF (tonCOeq/฿) × Spend
- EEIO-Based EF Databases Examples → CEDA 3EID DEFRA
- Scope 3 Calculation in Thailand
  - Relies mainly on Thai National LCI Database (TIIS)
    → Physical-unit EFs
  - Lack of a country-specific EEIO EF database
  - *Research Gaps*: Previous Thai EEIO studies have limited applicability to spend-based Scope 3 accounting → Reliance on outdated IO tables
    → Incomplete coverage of emission sources
    → Lack of adjustment to purchaser prices

Objective

- To develop Thailand-specific GHG EFs for spend-based Scope 3 accounting using an EEIO approach.
- To evaluate the effects of purchaser price adjustments by comparing EFs before and after the adjustment.
- To analyze emission structures and key supply-chain sources embodied in the resulting EFs.
- To compare EFs between 2015 and 2021 to assess progress and identify potential mitigation pathways.

Method

1

Thailand IO table 180 x 180
Main Structure

Intermediate transaction	Intermediate transaction (2)				Final demand (y)	Total Output (x)	...	Margin cost		
	Sector 1	Sector 2	...	Sector j						
Sector 1	z_{11}	z_{12}	...	z_{1j}	y_1	x_1	...	Wholesale trade	Retail trade	Transport
Sector 2	z_{21}	z_{22}	...	z_{2j}	y_2	x_2	...			
⋮	...	...	...	...	⋮	⋮	...			
Sector i	z_{i1}	z_{i2}		z_{ij}	y_i	x_i	...			
Value Added (V)	V_1	V_2	...	V_j						

- Intermediate Transactions (Z)
- Total Output (x)

Total expenditure by all purchasers at Purchaser's price
- Total expenditure at Producer's price
- Margin costs

2 **Direct GHG emissions for each sector**
- Based on IPCC 2006 guidelines (Energy, IPPU, Agriculture and Waste)

3 **EEIO model** $B(I-A)^{-1}$ → **Producer's Price based EF** → 4 **Calculation to Purchaser's Price based EF + Margin emission calculation** → **GHG EFs for spend-based method calculation for 180 sectors in Thailand [ton CO2eq/ THB]**

1 Compilation of Thailand Input-Output (IO) table data

- The IO table represents the economic transactions and interdependencies among different sectors of an economy
- Thailand IO table published by the National Economic and Social Development Council (NESDC)
- The latest available 2021 and 2015 IO tables, each covering 180 sectors, used in this study

4 Add margin emissions and adjust to the purchaser's price

$$E_{n,j} = \frac{P_{i,j} + M_{n,j}}{Xm_j}$$

$$P_{i,j} = e_{i,j} x_j^p$$

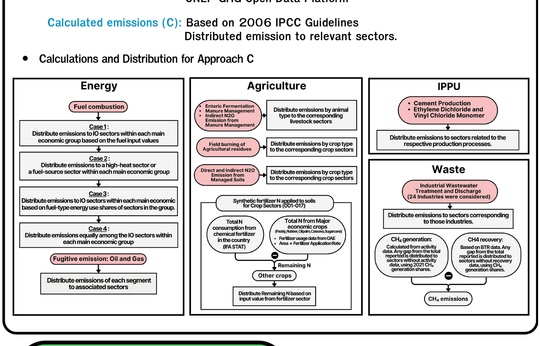
$$M_{n,j} = \sum_{m=1}^{n_{mgn}} e_{n,mgn} x_j^{mgn} + \sum_{m=1}^{n_{trn}} e_{n,trn} x_j^{trn}$$

$$Xm_j = x_j^p + \sum_{mgn=1}^{n_{mgn}} x_j^{mgn} + \sum_{trn=1}^{n_{trn}} x_j^{trn}$$

$P_{i,j}$ Emissions associated with production activities
$M_{n,j}$ Emissions associated with margin-related activities
Xm_j Total expenditure at purchaser prices

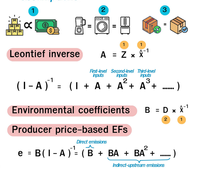
2 Compilation of direct GHG emission data by sector

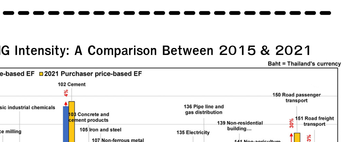
- Emission Data Sources and Compilation Approaches
  - Reported emissions (R): Thailand's First Biennial Transparency Report (BTR)
    ONEP GHG Open Data Platform
  - Calculated emissions (C): Based on 2006 IPCC Guidelines
    Distributed emission to relevant sectors.
- Calculations and Distribution for Approach C



3 Environmentally extended input-output (EEIO) model

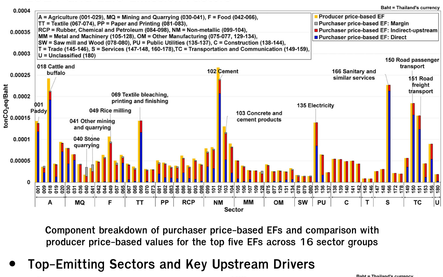
- An analytical tool used to quantify the environmental impacts of goods and services by accounting for both direct impacts from production and indirect impacts across the entire upstream supply chain.
- The model relies on IO table to calculate total upstream input required to produce one monetary unit of output for each product across sectors using *Leontief inverse*
- By multiplying *Leontief inverse* with *Environmental coefficients* (e.g. direct emissions per one monetary unit of output), *Producer price-based EFs* can be derived.
- The model relies on *three main assumptions*:





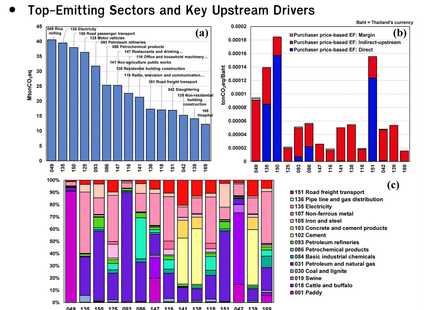
Results and Conclusion

- 2021 GHG EEIO Emission Factors



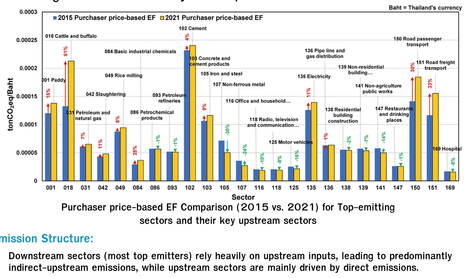
Component breakdown of purchaser price-based EFs and comparison with producer price-based values for the top five EFs across 16 sector groups

- Top-Emitting Sectors and Key Upstream Drivers



Top 15 emitting sectors: (a) GHG emissions based on final demand, (b) purchaser price-based EFs, and (c) shares of indirect-upstream EFs by supply chain source.

- Progress of GHG Intensity: A Comparison Between 2015 & 2021



Purchaser price-based EF Comparison (2015 vs. 2021) for Top-emitting sectors and their key upstream sources

Emission Structure:
- Downstream sectors (most top emitters) rely heavily on upstream inputs, leading to predominantly indirect-upstream emissions, while upstream sectors are mainly driven by direct emissions.
- Margin emissions are relatively minor overall, but significant for heavy, low-value goods with fragmented distribution.
- Purchaser price–based EFs are typically lower than Producer price–based EFs

Key Upstream Emission Drivers:
- Most influential upstream sectors are energy-related (Electricity; Petroleum & Natural Gas). A 10% reduction in electricity emissions leads to ~2% decrease in the economy-wide average EFs.

Progress between (2015 & 2021) and Mitigation Strategies:
- Downstream sectors (most top emitters), particularly Metals & Machinery, Construction, and Services show improving emission trends, while key upstream and primary food processing sectors worsen
- Prioritize key upstream sectors to achieve economy-wide emission reductions

Nationwide application:
- EF values published in TGO's "*Scope 3 GHG Emissions Reporting Guidance for Businesses.*"

Benefits:
- Thailand has its first national EEIO EF database for Scope 3 calculation.
- Helps organizations estimate Scope 3 emissions when physical data are unavailable
- Helps organizations screen Scope 3 emission sources and prioritize data collection, reducing GHG accounting time and costs.
- Supports green procurement and sustainable business opportunities.
- Supports GHG reduction research, strategies, and policies toward a low-carbon Thailand.

Thesis Book File