



Navigating Pricing Structure Transitioned from Euro 4 to Euro 5 in Developing Countries: A Case Study of Thailand

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ABSTRACT

This study aimed to investigate the pricing structure of Thai oil refineries as they transitioned from Euro 4 to Euro 5 fuel standards, mainly focusing on compliance with regulatory requirements. The objectives comprised examining reference fuel types for pricing based on market conditions, evaluating quality adjustment costs to align with Euro 5 standards, analyzing additional premium costs within the pricing structure, and acknowledging the environmental benefits of transitioning to Euro 5. The rationale of this study generated a comprehensive framework to understand the economic implications of transitioning to Euro 5 standards and guide policymakers while supporting environmentally responsible practices. To achieve these objectives, qualitative research methods were employed, which consisted of surveys, interviews, and focus group consultations with important stakeholders in the oil refining industry, such as refinery operators and government agencies. Data were gathered to evaluate present pricing mechanisms and identify key cost components, including premiums for freight, insurance, and losses. The results indicated that Thai refineries faced substantial operational challenges, emphasized by increased costs associated with upgrading facilities, rising energy expenses, and escalating prices for catalysts and feedstock materials. The study found that recalibrating the pricing structure in line with real market conditions was essential for increasing regional competitiveness. Finally, the findings highlighted the significance of adapting fuel pricing policies to support the transition to Euro 5 standards successfully, ensuring a sustainable energy future and environmental improvement while nurturing economic growth for Thailand.

1. INTRODUCTION

Thailand is nowadays a net importer of energy, especially fuel oil, with imports accounting for up to 90% of its crude oil annually, leading to expenditures in the billions of baht every year. To reduce this reliance on foreign energy sources and boost energy security, the Thai government employed policies to promote biofuels, specifically ethanol and biodiesel, combined with conventional fuels. These initiatives aimed to reinforce the domestic agricultural sector by enhancing demand for local agricultural goods, thus nurturing a sustainable circular economy. Furthermore, adopting biofuels was proposed to address crucial environmental challenges, mainly the reduction of air pollution and diminutive particulate matter (PM 2.5) emissions from vehicles, contributing to enhanced national environmental standards.

Moreover, the Thai government established a goal to transition from Euro 4 to Euro 5 fuel standards by 2024 (Energy Policy Administrative Committee, 2023). This transiting period was to improve fuel quality and decrease engine emissions for environmental benefits, which inherently affected the fuel price structure due to higher production costs. The pricing mechanism at Thai refineries is activated within a free market, where prices can vary based on economic policies and social conditions. In the meantime, the concepts and policies adjacent to fuel pricing had evolved, driven by the growing adoption of electric vehicles, the extension of city mass transit systems, and international commitments to lessen greenhouse gas emissions. Subsequently, refinery prices played an essential role in shaping Thailand's fuel pricing guidelines, requiring alignment with Euro 5 standards while matching the interests of key stakeholders, including consumers, the oil industry, and the Thai government.

In light of these transits, this study proposed to examine the fuel price structure at Thai oil refineries and to assess implications for compliance with Euro 5 standards.

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2. OBJECTIVES

This study was to evaluate the fuel price structure at Thai oil refineries, with an accurate focus on assessing implications for compliance with Euro 5 standards. The objectives of this article were defined into four key sub-objectives:

- 1) To examine fuel types for reference pricing based on central market prices in the Asian region and incremental costs associated with Euro 5 standards;
- 2) To investigate quality adjustment costs for the pricing structure at Thai oil refineries associated with Euro 5 standards;
- 3) To measure and evaluate additional premium costs within the pricing structure at Thai oil refineries, in accordance with Euro 5 standards; and
- 4) To understand the environmental benefits of adopting Euro 5 standards in Thailand.

These sub-objectives were crucial for guiding upcoming decision-making in the fuel pricing structure. The first sub-objective, focusing on the examination of reference fuel types, established a fundamental understanding necessary for pricing strategies that accurately reflected actual and current market conditions in the Asian region. The second sub-objective involved analysing quality adjustment costs, which were relevant for aligning pricing structures with the new Euro 5 standards and addressing the significant variations required for compliance. The third sub-objective sought to evaluate extra premium costs associated with refining operations. Finally, the fourth sub-objective was to assess the environmental benefits of higher fuel standards in Thailand. Altogether, these sub-objectives provided a comprehensive framework to understand the economic implications of transitioning to Euro 5 standards and guide policymakers in matching key stakeholder interests while supporting environmentally responsible practices.

3. LITERATURE REVIEW

3.1 Pricing Structure at Thai Oil Refineries

The pricing structure at Thai oil refineries currently

employs the Import Parity approach, benchmarking against the import prices of refined petroleum products from Singapore, known as the central oil trading hub in the Asian market (Mean of Platts Singapore: MOPS). This framework incorporates various logistical costs, including transportation fees for shipping fuel from Singapore to Thailand (Freight: F), insurance premiums (Insurance: I), and losses incurred during transit (Loss: L) [1]. Furthermore, it covered quality and temperature adjustments and expenses associated with biofuel blending to conform with Thailand's gasoline specifications as specified by the Department of Energy Business (DOEB). Additionally, it comprised costs for maintaining strategic oil reserves and other additional services (such as storage and handling fees). This framework had undergone modifications to ensure it aligned with its role as a reference price for transactions between refineries and fuel distributors. The pricing strategy followed a model termed Applied Import Parity, which aimed to equate the existing ex-refinery prices of refined products with those of imports from Singapore while adapting certain elements to precisely reflect the real importation costs.

The pricing structure was divided into two main components: (1) A reference price resulting from the Asian regional market's central price index, MOPS, which must be cautiously selected to correspond with the specific type of fuel traded. Hence, appropriate authorities must set a reference price that is consistent with the prevailing trade practices. (2) Premiums, comprising quality adjustment costs (Quality Adjustment: QA) that should account for improvements compliant with Euro 5 standards. Freight: F, Insurance: I, and Loss: L components should reflect the actual operational expenditures. Finally, strategic oil reserve costs varied in line with suitable rate adjustments?

Table 1 provides a complete breakdown of costs and criteria related to different types of fuel at current Thai oil refineries, focusing on Gasoline Octane 95, Base Gasoline Types 1 and 2, and High-Speed Diesel. Each cost component played an essential part in defining the final price of the fuels sold, ensuring compliance with quality standards and the nuances of the supply chain [2].

Table 1. Current pricing structure at Thai oil refineries.

Principal Component	Item	Gasoline Octane 95	Base Gasoline Type 1	Base Gasoline Type 2	High-Speed Diesel
Price of reference oil	Criteria	[(MOPS + Premium costs) at 60°F x Exchange Rate] / 158.984			
	Type of reference oil	MOPS Gasoline 95	MOPS Gasoline 91 Non-Oxy	MOPS Gasoline 91 Non-Oxy	Average MOPS of ▪ Gasoil 10 ppm ≈ 91.84 % ▪ Gasoil 500 ppm ≈ 8.16 %
Premium	Quality adjustment costs	2.05 USD/barrel	-0.63 USD/barrel	1.57 USD/barrel	None
	Freight	Weighted average of crude oil tankers, VLCC: LR2 ratio 60:40, long term charter (Singapore to Sriracha)			
	Insurance costs	0.084% of C and F in crude oil			
	Loss costs	0.3% of CIF in crude oil			
	Oil reserve costs for security	\$0.68 per barrel (oil reserve at 6%)			

3.2 Fuel Quality and Price Structures in ASEAN Countries Compared to Thailand

The oil industry in Thailand functioned under a free trade system where retail prices were set by fuel retailers, with supervision by the Ministry of Energy through the Energy Policy and Planning Office (EPPO). The price structure comprised four key components: ex-refinery price, taxes, funds, and marketing margins, which changed according to economic and social conditions.

Table 2 compares fuel pricing mechanisms across Southeast Asian countries, demonstrating how each nation sets fuel prices and their components. The import parity model in Thailand referenced the MOPS and includes premium costs, transportation fees, quality adjustments, insurance, and losses. A petroleum fund was used to stabilize prices. Likewise, the Philippines employed import parity with MOPS as the reference

price but operated in a deregulated market without government controls on pricing, combining various CIF charges. Vietnam utilized a base price mechanism, calculating costs based on transportation specifics and import duties, supported by a price stability fund for gasoline price stabilization. Malaysia's Automatic Pricing Mechanism (APM) was also MOPS-based, including an alpha factor to shield price fluctuations and plans to present targeted diesel subsidies soon. Indonesia retained the import parity model with MOPS, adding adjustment factors and a ceiling price policy while depending on state budget actions rather than a stability fund. Singapore's pricing was based on MOPS transaction prices, with related policies funded by the state budget. Finally, Cambodia set a government-calculated price ceiling using average MOPS prices, regulating retail prices through tax-related policies.

Table 2. Review of regulatory guidelines for controlling fuel prices in the ASEAN countries.

Ref	Country	Pricing Mechanism	Referenced Price	Components Similar to the Thai Fuel Price at the Refinery Concept
[3]	Philippines	Import Parity	MOPS	The CIF rate, exchange rate, and total landed cost included the following expenses: Brokerage Fees, Bank Charges, costs associated with handling imported oil (Arrastre Charge), port service charges (Wharfage Charge), Import Processing Fees, Customs Documentary Stamps, Customs Duty, Special Duty, Excise Tax, and value-added tax (VAT) on importation.
[4]	Vietnam	Base Price	MOPS	The foreign component included the cost of transporting gasoline from a foreign country to Vietnam's port (Transportation Cost of gasoline from the foreign Country to Vietnam's port) plus the Import Duty multiplied by the Import Ratio: %. The domestic component consisted of the premium (Premium) plus the Transportation Cost of Gasoline from Domestic Refineries to Port multiplied by the Domestic Production Ratio: %.
[5]	Malaysia	Automatic Pricing Mechanism (APM)	MOPS	Alpha was the difference between the MOPS price and the actual price resulting from transactions between oil companies and refineries. The alpha acted as a buffer that helped offset fluctuations in global oil prices.
[6]	Indonesia	Import Parity	MOPS	Adjustment factor, exchange rate, constant, and margin.
[7]	Singapore	MOPS-Based Pricing	MOPS	Used the transaction prices directly from the MOPS reference prices.
[8]	Cambodia	Government-Calculated Price Ceiling	MOPS	Used the average reference price of MOPS directly.

3.3 Fuel Quality According to Euro 5 Standards and Euro 5 Engine Emission Standards

Thailand was transitioning to Euro 5 standards, effective January 1, 2024, which necessitated significant investments by domestic refineries to upgrade their facilities, resulting in extra processing and energy costs. The transition to Euro 5 standards involved rigorous requirements set by the European Committee for Standardization and obligatory by the European Parliament. These standards impacted fuel composition and engine emissions, improving the efficiency of

pollution control devices and reducing equipment damage. Detailed standards for Euro 4 and Euro 5 fuel quality and engine emissions were summarized below.

Table 3 presents a comparison of fuel quality standards between Euro 4 and Euro 5 for both gasoline (including gasohol) and diesel fuels, focusing on parameters such as aromatics, olefins, benzene, polycyclic aromatic hydrocarbons (PAHs), and sulfur. The Euro 5 standards enforce stricter limitations on sulfur content for both gasoline and diesel, decreasing the allowable level from 50 ppm to 10 ppm.

Furthermore, for diesel fuels, the permissible PAHs content was reduced from 11% to 8%. In contrast, the conditions for other parameters, including aromatics,

olefins, and benzene content, remain unchanged for gasoline and gasohol.

Table 3: The comparison between the Euro 4 and 5 fuel quality standards.

Type	Quality Standards	Aromatics (% vol)	Olefins (% vol)	Benzene (% vol)	PAHs (% wt)	Sulfur (ppm)
Gasoline/ Gasohol	Euro 4	35	18	1.0	-	50
	Euro 5	35	18	1.0	-	10
Diesel	Euro 4	-	-	-	11	50
	Euro 5	-	-	-	8	10

Table 4. The comparison between the Euro 4 and 5 engine emission standards.

Type	Quality Standards	CO	HC	HC+NOx	NMHC	NOx	PM	PN
		Gram/Kilometer						Quantity/ Kilometer
Gasoline/Gasohol	Euro 4	1.00	0.1	-	-	0.08	-	-
	Euro 5	1.00	0.1	-	0.068	0.06	0.0045	-
Diesel	Euro 4	0.50	-	0.30	-	0.25	0.25	-
	Euro 5	0.50	-	0.23	-	0.18	0.0045	6.0x10 ¹¹

Furthermore, Table 4 compares the engine emission standards between Euro 4 and Euro 5 for gasoline (including gasohol) and diesel engines. For gasoline and gasohol engines, Euro 5 set new limits for non-methane hydrocarbons (NMHC) and particulate matter (PM), while also dropping the allowable limit for nitrogen oxides (NOx) emissions. In the case of diesel engines, Euro 5 decreased the limits for hydrocarbon plus nitrogen oxides (HC+NOx), NOx, and PM emissions, and presented a new limit for particle number (PN) emissions. Notably, the limits for carbon monoxide (CO) continued to be the same for both gasoline and diesel engines when comparing Euro 5 to Euro 4 [9].

5. RESEARCH METHODOLOGY

The authors employed qualitative methodology to thoroughly investigate Thai oil refineries' pricing structure and evaluated the incremental costs related to these facilities. This research methodology required systematic data collection and analysis, focusing on two primary sources:

5.1 Primary Data Collection

Data were gathered through offline channels, together with structured and unstructured in-depth interviews and focus group consultations. The structured interviews adhered to a set questionnaire alongside the survey, providing consistency, whereas unstructured interviews facilitated the exploration of emerging topics during discussions. The informants were senior executives from businesses or agencies with the authority to make decisions regarding activities related to this research study. They were categorized into three main groups:

Business Sector Representatives: This group included operators from the oil trading industry across the value chain, especially refinery operators represented by the Federation of Thai Industries-Oil

Refining Industry Group, as well as Section 7 oil traders in Thailand. A purposive sampling approach was used to choose six representatives from the major fuel dealers under Section 7 with substantial market shares, ensuring coverage across various regions. This approach aimed to yield a complete overview of the current fuel retail market. Fruitful data collection depended mainly on cooperation from each fuel dealer.

Fuel Users Representatives: This cohort comprised public vehicle users and representatives from the Thai Automotive Industry Association, the Federation of Thai Industries (automotive group), and manufacturers of vehicles that utilize fuel. Their insights provided a critical perspective on fuel consumption and user experiences.

Government Agency Representatives: This group was composed of officials from the Energy Policy and Planning Office (EPPO), the Department of Energy Business (DOEB), and the Department of Alternative Energy Development and Efficiency (DEDE). Their contribution confirmed that regulatory and policy-related factors were adequately represented and addressed.

5.2 Secondary Data Collection

Secondary data were collected from a wide range of sources, including academic articles, news reports, published documents, conference proceedings, annual reports, and relevant projects both domestically and internationally.

To guarantee data reliability and minimize discrepancies, the authors accurately cross-referenced information from multiple stakeholder groups. Besides, they verified the investment values of Thai refineries by reviewing publicly available databases, such as annual reports submitted to the Stock Exchange of Thailand, and other relevant reference documents associated with

the study's objectives.

Upon completion of the data analysis, the research findings were presented in focus group seminars with two sessions involving 63 and 59 representatives from all three stakeholder groups, to collect feedback and insights. Following the incorporation of this feedback, the authors conducted a public hearing seminar involving 109 participants, ensuring broad acceptance and validation of the findings among stakeholders.

6. STUDY RESULTS

6.1 Examination of Fuel Types for Reference Pricing based on the Central Market Prices in the Asian Region and Incremental Costs according to Euro 5 Standards

Thailand was currently transitioning from Euro 4 to Euro 5 standards. This transition required a reassessment of the reference oil types used for pricing and quality determination to reflect real market trading and quality benchmarking. Formerly, stakeholders in the oil industry noted the inadequacy of the former reference oil type, which lacked liquidity and did not relate to actual market transactions, mainly for gasoline and base gasoline types referenced from MOPS Unleaded Gasoline (ULG) 91 Non-Oxy. This inadequacy made these prices ineffective as true market indicators, and they were not taken into account in transactions. To address this, the authors established the following criteria for selecting an appropriate reference oil type:

1. The reference oil type must reflect market-driven prices in the Asian region, primarily based on MOPS ULG 95.
2. It must be recognized by Thai oil traders, using MOPS ULG 95 as the basis for domestic market transactions, basic gasoline imports, and exports.

3. The reference oil must meet fuel quality standards equivalent to Thailand's Euro 5 standards.

Regarding the interviewing analysis with key stakeholders, including fuel producers and traders, along with secondary document analysis, it was concluded that MOPS ULG 95 was the most appropriate reference oil for gasoline (ULG95) and base gasoline (G-Base).

For diesel, earlier referenced from MOPS Gasoil 10 ppm and MOPS Gasoil 500 ppm, the new quality standards required a single reference oil type, MOPS Gasoil 10 ppm, due to its alignment with new quality standards.

The shift to Euro 5 standards imposed compliance necessities on fuel producers and refiners. Incremental cost data from local refineries were gathered, averaged, and weighted based on annual sales volumes for different fuel types. Table 5 demonstrates the incremental costs related to meeting Euro 5 compliance for oil refineries in Thailand, focusing on two product groups: the Gasoline and Basic Gasoline Group, and the High-Speed Diesel Group. The data disclosed that the extra refining cost for diesel was substantially higher, at 3.14 USD per barrel, compared to 0.64 USD per barrel for gasoline. The allocation of investment showed that 20% was directed towards gasoline production, though 40% was contributed to diesel, representing a more solid emphasis on diesel production. Breaking down the cost components, hydrogen costs made up 26% of gasoline costs and 34% of diesel, while energy costs were 33% for gasoline and only 8% for diesel. Catalyst costs comprised 21% of gasoline production and 18% of diesel. Overall, the table underscored that gasoline refining requires more energy, whereas diesel production was characterized by higher hydrogen costs and a greater investment focus.

Table 5. Incremental costs of oil refineries in Thailand.

Item	Gasoline and Basic Gasoline Group	High-Speed Diesel Group
Incremental cost value of refineries	0.64 USD/barrel	3.14 USD/barrel
Investment cost ratio	20:80	40:60
Hydrogen cost	26%	34%
Energy cost	33%	8%
Catalyst cost	21%	18%

Note: The exchange rate of 35 Baht/USD

6.2 Analysis of Quality Adjustment Costs for the Pricing Structure at Thai Oil Refineries according to Euro 5 Standards

The transition from Euro 4 to Euro 5 standards in Thailand demonstrated two main quality differences: 1) between the reference oil quality (MOPS) and Thailand's Euro 4 standard (TH Euro 4), and 2) between

Thailand's Euro 4 standard (TH Euro 4) and Euro 5 standard (TH Euro 5). To confirm that reference prices accurately aligned with Thailand's fuel quality standards, establishing quality adjustment (QA) values was crucial to reflect these differences. The approach to determining QA values varied by fuel types as shown in Figure 1.

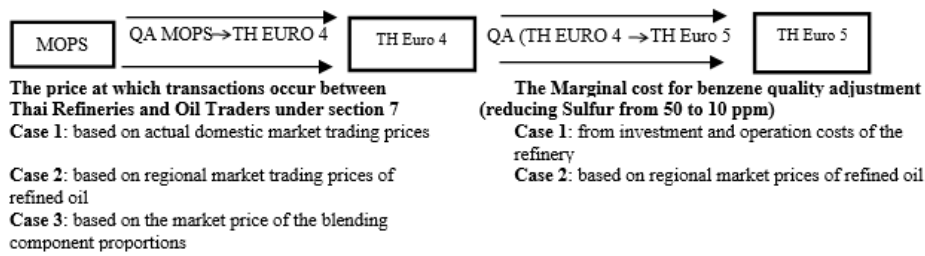


Fig. 1. Guideline to analyze the quality adjustment cost of benzene and base benzene.

6.2.1 Quality adjustment for benzene and base benzene groups

Based on the previous analysis, a critical concern for the gasoline and base gasoline sector lay in the disparity between the MOPS reference oil quality standard and TH Euro 4, as well as the differential between TH Euro 4 and TH Euro 5 standards. Six distinct research pathways arose when these issues were integrated into the study framework. Each case described the specific variations and the results of the quality adjustment studies for each scenario, as outlined in Table 6 below.

The authors recommended using QA values derived from actual transactions between refineries and traders for QA to TH Euro 4 and from investment and operating costs for QA to TH Euro 5. These adjustments reflected the cost differences between MOPS reference

standards and TH Euro 4/Euro 5 standards, confirming price structures at refineries align with import prices from Singapore. The proposed QA values were:

Base Gasoline Type 1 (G-Base 1): -0.04 USD/barrel

Base Gasoline Type 2 (G-Base 2): 2.16 USD/barrel

Gasoline Octane 95 (ULG 95): 2.69 USD/barrel

6.2.2 Quality adjustment for basic diesel group

The primary difference between gasoline and diesel lay in the reference oil quality (MOPS) and TH Euro 5, divided into three approaches (Table 7).

The authors selected the third approach, which entailed no quality adjustment, since the comparison between TH Euro 5 diesel and MOPS Gasoil 10 ppm presented no significant impact on costs and prices.

Table 6. Summary of quality adjustments for benzene and base benzene according to TH Euro 5.

Case	QA Euro 5 Case 1 from the investment and operation costs of the refinery			QA Euro 5 Case 2 based on regional market prices of refined oil		
	G-Base 1	G-Base 2	ULG 95	G-Base 1	G-Base 2	ULG 95
QA Euro 4 based on actual domestic market trading prices	-0.04	2.16	2.69	0.52	2.72	3.75
QA Euro 4 based on regional market trading prices of refined oil	6.44	6.44	2.14	7.00	7.00	2.70
QA Euro 4 based on the market price of blending component proportions	10.64	12.64	12.64	11.20	13.20	13.70

Note: The exchange rate of 35 Baht/USD

Unit: USD/barrel

Table 7. Summary of quality adjustments for basic diesel according to TH Euro 5.

Approach 1 (Investment and Operating Costs)	Approach 2 (Market Prices)	Approach 3 (No Quality Adjustment)
Based on Investment and Operating Costs	Based on Regional Market Prices	No Quality Adjustment
Referencing MOPS Gasoil 50 ppm	Referencing MOPS Gasoil 50 ppm	Referencing MOPS Gasoil 10 ppm
TH Euro 5 Diesel	3.14 USD/barrel (0.69 USD/liter)	0.52 USD/barrel (0.12 USD/liter)

Note: The exchange rate of 35 Baht/USD

6.3 Environmental Benefits from Adopting Euro 5 Standards

The transition from Euro 4 to Euro 5 vehicle emission standards resulted in substantial environmental improvement, particularly in urban areas, as shown in Table 8. Empirical data from European assessments indicated that particulate matter (PM) emissions from

passenger cars and light commercial vehicles decreased by approximately 80% with the adoption of Euro 5 standards. This reduction was primarily attributed to the mandatory implementation of diesel particulate filters (DPFs) and improvements in fuel quality.

Nitrogen Oxide (NO_x) emissions from new diesel and light-duty vehicles were also reduced by

approximately 20%. Correspondingly, the contribution of vehicular emissions to ambient PM concentrations in European cities was estimated to decline by 40-50%, thereby mitigating PM_{2.5} exceedances and associated health risks. Furthermore, Euro 5 standards were shown to reduce NO₂ levels in urban environments, particularly in areas with high diesel vehicle density [10].

The adoption of Euro 5 fuel standards in Thailand was economically justifiable. Implementation of Euro 5 gasoline and diesel standards was projected to yield benefits of USD 202 million and USD 540 million, respectively, compared to costs of USD 54 million and USD 201 million. These figures indicated substantial net gains supporting the advancement to Euro 5 as a cost-effective measure for improving air quality [11].

Table 8. Types of pollutant reduction.

Pollution Category	Reduction from Euro 5
Particulate matter (PM)	~80% reduction in passenger cars and light commercial vehicles (Europe)
Nitrogen oxides (NO _x)	~20% reduction for new diesel/light vehicles
Urban air quality / PM exposure	Significant improvement; ~40–50% reduction in PM contributions from vehicles
Local air pollutants (NO ₂)	Helps reduce NO ₂ exceedances in urban areas

6.4 Investigation and Assessment of Other Premium Costs within the Pricing Structure at Thai Oil Refineries, following TH Euro 5 Standards

Along with quality adjustments, the refinery price structure included extra costs for freight (F), insurance (I), losses (L), and maintaining oil reserves for security. These premiums needed to be recalibrated to accurately represent the actual costs under the new pricing framework established by the National Energy Policy Council (NEPC). Here were some key things to keep in mind as we recalibrated these figures:

Freight (F): The authors proposed a new approach for calculating maritime freight costs that integrated a composite usage model for both refined oil and crude oil tankers. Insights from Thai oil traders during the research interviews indicated a trend toward using smaller tankers for fuel imports. Furthermore, in situations where domestic production of base gasoline type 2 was insufficient, there was a need for increased imports of refined oil. To accommodate the use of smaller tankers in the calculation, the methodology employed the Average Freight Rate Assessment (AFRA), which weighed last year's import volumes against domestic production and included the ratio of refined to crude oil tankers. Freight rates were then determined using a long-term charter model based on the shipping route from Singapore to Sriracha.

Calculation Approach: The weighted average of

freight costs for crude oil and refined oil, based on long-term charter rates (Singapore to Sriracha), was employed.

Crude oil freight costs referenced AFRA rates for crude oil tankers (with a Very Large Crude Carrier (VLCC) to Long Range (LR2) ratio of 60:40) based on prevailing criteria.

Refined oil freight costs referenced AFRA rates for medium-range (MR) refined oil tankers, in alignment with the current import practices of oil traders.

Insurance (I): The authors proposed a revised structure for insurance cost calculation, including a blend of refined oil and crude oil imports. In cases where domestic production of base gasoline type 2 was shortened, Thai oil traders must import refined oil. The proposed insurance rate was 0.084% of the weighted average C and F (Cost and Freight) value of crude oil and refined oil imports.

Loss (L): The authors suggested a revised structure for calculating loss, integrating refined oil and crude oil imports. When domestic production of base gasoline type 2 was lacking, refined oil imports became necessary. The loss rate was set at 0.3% of the CIF (Cost, Insurance, and Freight) value of crude oil and refined oil, weighted by the import ratio.

Oil Reserve for Security: The authors recommended a proper rate for the oil reserve for security. The current reserve rate was set at 6%, equating to \$0.68 per barrel. The relationship between the reserve cost and the reserve rate was linear for changes up to 6%, with each 1% change in the reserve rate equivalent to a \$0.11 per barrel change in reserve cost. For reserve rates above 6%, the impact was \$0.13 per barrel per 1% change.

7. CONCLUSION AND DISCUSSION OF THE RESULTS

In summary, the recalibration of Thailand's oil pricing structure was crucial for successfully transitioning to Euro 5 standards, with a specific focus on refining freight costs, insurance, losses, and oil reserves. The results specified that Thai refineries were facing substantial operational challenges, primarily driven by the rising costs of facility upgrades, increasing energy expenses, and swelling prices for catalysts and feedstock materials. This study emphasized the urgent need to restructure pricing to precisely reflect market conditions, which was crucial for enhancing national competitiveness.

In the broader ASEAN context, Thailand's initiatives should learn from the light of the diverse strategies employed by neighboring countries. For instance, Vietnam's emphasis on market stabilization through price ceilings offered a potential model for Thailand to effectively manage consumer expectations during its transition (Government of Vietnam, 2021). Cambodia's approach to maintaining affordability amidst global price variations provided valuable insights into an alternative approach for Thailand on fuel pricing strategies (Ministry of Commerce, Cambodia, 2016).

Table 9. Summary of pricing structure at oil refineries for base oil group according to TH Euro 5 standards.

Item	Description	Gasoline Octane 95	Base Gasoline Type 1	Base Gasoline Type 2	High-Speed Diesel
Criteria Insurance Costs	Previous Study	[(MOPS + Premium costs) at 60°F x Exchange Rate] / 158.984			
Loss Costs	Study Result	Maintained the existing criteria because it aligned closely with the actual trading practices between refineries and Section 7 oil traders.			
	Reason	Since it aligned closely with the actual trading practices between refineries and Section 7 oil traders.			
Type of Reference Oil	Previous Study	MOPS ULG 95	MOPS ULG 91 Non-Oxy	MOPS ULG 91 Non-Oxy	Average MOPS of ▪ Gasoil 10 ppm $\approx$ 91.84 % ▪ Gasoil 500 ppm $\approx$ 8.16 %
	Study Result	MOPS ULG 95	MOPS ULG 95	MOPS ULG 95	Gasoil 10 ppm
	Reason	Gasoline and Base Gasoline Group - Adjustments were made to ensure that the reference oil types reflected trading prices following the mechanisms of the Asian regional market and the actual trading references of the domestic market. The reference oil types were utilized in calculating the import prices of oil into the country and were accepted by Thai oil traders. Base Diesel Group - The reference oil types must meet fuel quality standards that were close to TH Euro 5 fuel quality standards.			
Quality Adjustment Cost	Previous	2.05 USD/barrel	-0.63 USD/barrel	1.57 USD/barrel	None
	Study Result	2.69 USD/barrel	-0.04 USD/barrel	2.16 USD/barrel	None
	Reason	Reflected the differences between TH Euro 4 and TH Euro 5 standards			
Freight	Previous	Weighted Average of Crude Oil Tankers, VLCC: LR2 Ratio 60:40, Long Term Charter (Singapore to Sriracha)			
	Study Result	Average Freight of Crude Oil and Refined Oil via Long Term Charter (Singapore to Sriracha), Weighted by Import Proportion Crude Oil Freight: Referenced by AFRA rates, using a weighted average of crude oil tankers of size VLCC (60%:40% ratio). Refined Oil Freight: Referenced by AFRA rates for MR-sized refined oil tankers.			
	Reason	Adjustments were made to reflect the current situation where oil traders use smaller oil tankers for importing fuel. This was appropriate for the scenario where the production of Base Gasoline Type 2 was insufficient to meet domestic demand, necessitating additional imports of refined oil products besides crude oil. The size of tankers used for transporting refined oil products was smaller.			
Insurance	Previous	0.084% of C&F in crude oil			
	Study Result	0.084% of the average C&F for crude oil and refined oil, weighted by the proportion of imports			
	Reason	Adjusted to reflect the current situation appropriately, considering the insufficient production of Base Gasoline Type 2 to meet domestic demand, leading to additional imports of refined oil products besides crude oil.			
Loss Costs	Previous	0.3% of CIF in crude oil			
	Study Result	0.3% of the average CIF for crude oil and refined oil, weighted by the proportion of imports			
	Reason	Adjusted to reflect the current situation appropriately, considering the insufficient production of Base Gasoline Type 2 to meet domestic demand, leading to additional imports of refined oil products besides crude oil.			
Oil Reserve Costs for Security	Previous	\$0.68 per barrel (oil reserve at 6%)			
	Study Result	- \$0.11 per barrel per 1% of oil stockpiling for security, for total reserves not exceeding 6%. - \$0.13 per barrel per 1% of oil stockpiling for security, for total reserves exceeding 6%.			
	Reason	The study results provided guidelines for future adjustments in oil stockpiling costs for security if a new policy on stockpiling rates was set. It was still recommended to maintain the current rate as announced by the relevant agencies.			

Moreover, Singapore's responsive pricing strategies, which were meticulously aligned with international crude oil prices, highlighted the significance of adaptability in fuel pricing mechanisms (Ministry of Trade and Industry, Singapore, 2016). This adaptability was vital as Thailand sought to ensure its pricing strategies aligned with broader regional market conditions, maintaining a balance between consumer interests and industry sustainability.

The challenges discussed in this study echoed the observations made by Masami K. (2009) and Federico G. *et al.* (2003) [12]-[13], who stressed the critical importance of understanding oil price volatility and its considerable impact on the economies of developing countries. Their insights reinforced the need for strategic pricing mechanisms capable of cushioning against international fluctuations, further prompting Thailand to adopt refined pricing strategies responsive to dynamic market conditions.

To effectively facilitate this transition and improve energy security, policymakers should prioritize investments in refining technologies that enable cost-effective compliance with advanced environmental standards. A critical step in this process involves implementing a revised pricing structure for oil refineries that reflects the new standards while aligning with contemporary economic conditions. The adoption of established reference oil types—primarily MOPS ULG 95 for gasoline and MOPS Gasoil 10 ppm for diesel—is essential for creating market-driven pricing that can adapt to changes rapidly.

Likewise, the results exemplify that Thai refineries face substantial operational pressures arising from swelling costs related to facility upgrades, catalysts, and feedstock materials. This reality emphasizes the instantaneous urge for a recalibrated pricing mechanism that addresses these challenges. Policymakers should also consider incentives for refinery enhancements and financial assistance for innovative biofuel blending techniques that are related to national sustainability products [14].

To bridge the gap between Euro 4 and Euro 5 standards, it is necessary to employ quality adjustment values while recalibrating premiums associated with freight, insurance, loss, and oil reserves to accurately reflect actual costs. Eventually, establishing a transparent pricing mechanism that integrates stakeholder feedback is crucial for fostering trust and stability within the fuel market. This trust is vital for promoting resilience in the oil industry and nurturing long-term sustainability objectives.

Collectively, the adoption of Euro 5 standards represents a significant advancement in mitigating transport-related air pollution, demonstrating clear benefits in reducing particulate and nitrogen oxide emissions, improving urban air quality, and supporting public health objectives. The capacity of developing countries, such as Thailand, to implement higher fuel standards in particular Euro 5, and to realize their associated environmental benefits, provides a compelling rationale for the continuation and

strengthening of related policy measures across other developing countries.

Future research should prioritize exploring the long-term economic impacts of integrating biofuels into local markets, as well as evaluating the effectiveness of various biofuel blending ratios on emissions across different vehicle types. Understanding consumer acceptance and behavior regarding biofuel-blended fuels will deliver invaluable insights for policymakers aiming to encourage the adoption of these sustainable alternatives. Furthermore, comparative studies among ASEAN nations could underline best practices and innovative approaches to refining processes and fuel pricing, offering lessons learned from other countries that are navigating similar transitions in fuel standards.

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