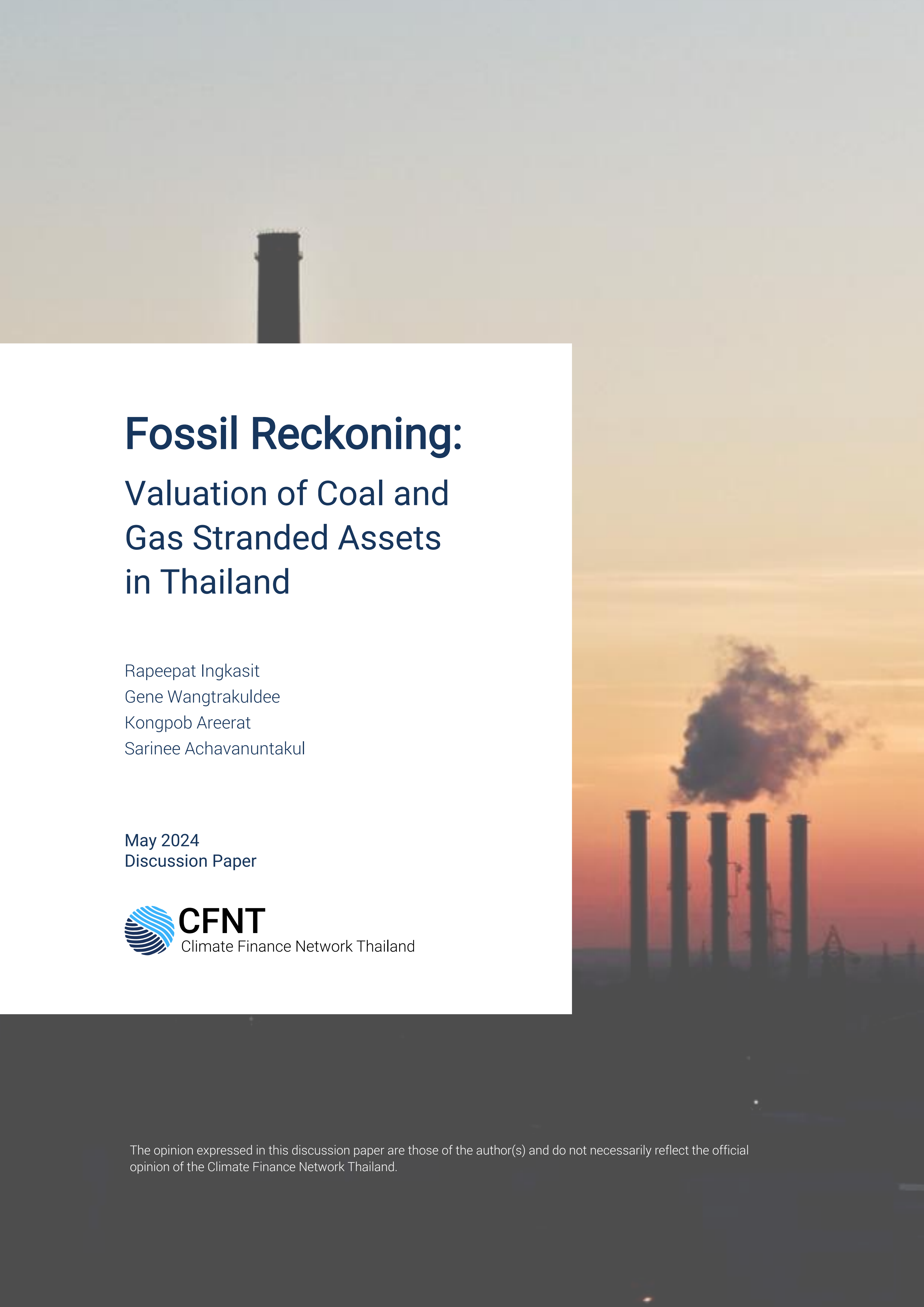

Fossil Reckoning:

Valuation of Coal and Gas Stranded Assets in Thailand

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May 2024
Discussion Paper

CFNT
Climate Finance Network Thailand

Table of Content

List of Tables

List of Figures

Abbreviations

AP	Availability Payment
BAU	Business-As-Usual
CAPEX	Capital Expenditure
CP	Capacity Payment
DCF	Discounted Cash Flow
DICE	Dynamic Integrated Climate-Economy
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
ECB	European Central Bank
EGAT	Electricity Generating Authority of Thailand
EMH	Efficient Market Hypothesis
EP	Energy Payment
ETR	Effective Tax Rate
FCF	Free Cash Flow
FS	Fuel Saving
Ft	Automatic tariff adjustment mechanism
GCAM	Global Change Assessment Model
GEM	Global Energy Monitor
GHG	Greenhouse gas
IAMs	Integrated Assessment Models
IEA	International Energy Agency
IPPs	Independent Power Producers
IUs	Industrial Users
JET-P	Just Energy Transition Partnership
LT-LEDS	Long-term Low Emissions Development Strategies
LULUCF	Land Use, Land Use Change, and Forestry
MCDA	Multi-Criteria Decision Analysis
MEA	Metropolitan Electricity Authority
MW	Megawatts
NDC	Nationally Determined Contributions
NEP	National Energy Plan
NEPC	National Energy Policy Council
NOPAT	Net Operating Profit After Tax
NPV	Net Present Value
O&M	Operations and Maintenance
PDP	Power Development Plan
PEA	Provincial Electricity Authority
PPAs	Power Purchase Agreements
SPPs	Small Power Producers
WACC	Weighted Average Cost of Capital

About Us

Climate Finance Network Thailand (CFNT) is a think tank and a network of like-minded individuals headquartered in Bangkok, devoted to propelling sustainable financial practices and assisting in Thailand's transition toward a low-carbon economy in line with 1.5°C climate target. CFNT's primary objective is to help catalyze impactful climate finance through solution-based research, stakeholder engagement, and network building. Our goal is to assist Thailand's financial sector to be more responsive to the challenges of climate change. By uniting forces with like-minded partners, CFNT endeavors to help shape a financial landscape that aligns with global sustainability goals and fosters a resilient, green, and inclusive economy.

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Acknowledgement

The authors would like to extend their sincere appreciation to Sunee Moungchareon, Cheunchom Greacen, and a multitude of other individuals whose invaluable support has contributed to the success of this research initiative.

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Suggested Citation

Ingkasit, R., Wangtrakuldee, G., Areerat, K., & Achavanuntakul, S. (2024). Fossil Reckoning: Valuation of Coal and Gas Stranded Assets in Thailand. Climate Finance Network Thailand. Bangkok.

Executive Summary

The 28th United Nations Climate Change Conference in December 2023 (COP28) marked a significant shift, signaling the start of a transition away from the fossil fuel industry (United Nations Climate Change , 2023). This transition is pivotal for decarbonizing the global economy, particularly within the energy sector, which was responsible for 73.2% of worldwide greenhouse gas (GHG) emissions in 2020 (Ritchie, 2020). To adhere to the 1.5°C goal of the Paris Agreement, it is essential to keep 60% of oil and gas and 90% of coal reserves unexploited (Welsby, Price, Pye, & Ekins, 2021)

This necessary transition suggests that fossil infrastructure such as pipelines and power plants could be 'stranded' if asset owners have to abandon them before the end of useful life. Globally, the value of these stranded assets could range from over half a billion to nearly 20 trillion USD, depending on sector scope and analysis duration. Specifically, coal assets face significant devaluation, with national estimates of stranded assets ranging from 2 billion to 1 trillion USD. The significant stranded value worldwide underscores the significant financial implications of transitioning from fossil fuels.

Thailand's energy transition goals are embedded in its Nationally Determined Contributions (NDCs), which include Long-term Low Emissions Development Strategies (LT-LEDS) and the 2022 National Energy Plan (NEP). These plans establish targets for achieving carbon neutrality by 2050, with a minimum requirement of 50% renewable energy in new power generation (Ministry of Natural Resources and Environment, 2022). However, to better address the issues of power overcapacity and transition risks, Thailand may need to consider retiring less efficient fossil fuel power plants and delaying new fossil fuel investments sooner than as stipulated in its NDC. We believe that this strategic adjustment is also essential for aligning with the Paris Agreement Goals.

According to 2023 data on Thailand's energy mix, natural gas held the largest share in power generation capacity, followed by coal and lignite (Statista, 2024). This paper employs a discounted cash flow model to calculate the potential 'stranded values' of coal and gas power plants that stem from potential decommissioning between 2024 to 2050 under two scenarios, compared against the 'base case' of Thailand's current Power Development Plan (PDP):

1. 'Base Case' or PDP2018 scenario: Power Development Plan (PDP) 2018 Revision 1 Pathway, reflecting a business-as-usual scenario.
2. 'Rapid Transformation' scenario: This scenario is published the National Energy Plan for the People Pathway (People NEP), which is aligned with the 2023 Nationally Determined Contributions (NDC) to achieve carbon neutrality by 2050 and net zero GHG emissions by 2065.
3. '100% Renewable' scenario: aiming for a transformative 100% renewable energy pathway which is consistent with the 1.5°C goal of the Paris Agreement.

Using comprehensive datasets from the Global Energy Monitor and various publicly available financial and operational parameters, we find a significant risk of stranded coal and gas assets emerging from 2025 onward. The Rapid Transformation and the 100% Renewable scenarios could necessitate the premature decommissioning of a considerable portion of coal and gas-fired power plants, with potential stranded losses reaching up to 360 and 530 billion THB, respectively. This presents a substantial overvaluation for Thailand's major energy utilities, with projected downside risks ranging from 6% to 61% compared to the companies' market capitalization in January 2024.

Acknowledging the volatility of the stock market, we propose a 'stranded EBITDA multiplier' as an alternative metric for assessing cash flow risks. This metric reflects the companies' dependency on net revenues from fossil power plants in Thailand, which are at risk of becoming stranded assets. We found that stranded EBITDA ranges from 1.61 to 7.84 times in the Rapid Transformation scenario, and from 3.10 to 8.18 times in the 100% Renewable Energy scenario.

The transition towards a low-carbon economy, while environmentally imperative, poses significant financial challenges for conventional energy companies. This analysis underscores the necessity for strategic adjustments and adaptive responses, including diversifying energy portfolios and increasing renewable energy investments. Additionally, it highlights the financial risks faced by lenders and bondholders from changes in energy policy directions. Our estimate of potential stranded assets also underscores the risks of long-term fossil fuel investments and the importance of a just and transparent transition plan.

In addition, our analysis suggests that Thailand's engagement in global initiatives, such as the Just Energy Transition Partnership (JET-P), could facilitate financing for a just and equitable energy transition, thereby enhancing Thailand's role in the global shift towards sustainable energy. Lastly, our analysis offers a numerical estimate of 'stranded value' which policymakers can utilize to design a just energy transition for Thailand, including a credible coal and gas phaseout plan.

1. Introduction

The December 2023 United Nations Climate Change Conference (COP28) marked a pivotal moment as it concluded with a clear signal of the beginning of the end for the fossil fuel industry (United Nations Climate Change , 2023). UN Climate Change Executive Secretary, Simon Stiell, emphasized the need for swift action to turn pledges into real-world outcomes. The central outcome of the historical deal is the 'global stocktake,' recognizing the imperative to reduce global greenhouse gas emissions by 43% from 2019 levels by 2030, aligning with the Paris Agreement's 1.5°C goal (United Nations Climate Change , 2023).This imperative underscores the necessity of decarbonizing the global economic system, especially the fossil-fuel-dependent energy sector which was responsible for 73.2% of global greenhouse gas emissions in 2020 (Ritchie, 2020). Achieving the 1.5°C limit requires leaving a significant portion of fossil fuel reserves untapped— 60% of oil and gas and 90% of coal reserves (Welsby, Price, Pye, & Ekins, 2021).This transition may lead to potential stranding of assets in the fossil fuel industry, including pipelines and power plants.

Thailand faces increased climate risks, including prolonged droughts and floods, with extensive coastlines and flood-prone lowlands. The 2011 flood, which caused 728 fatalities and economic losses of THB 1.43 trillion, exemplifies the country's vulnerability (Poaponsakorn, 2013). Despite ranking 81st for natural hazard risks, Thailand's coping capacity and social vulnerability levels contribute to a relatively favorable position on the INFORM risk index (European Commission , 2019). Thailand's revised Long-term low emissions development strategies (LT-LEDS) and 2022 National Energy Plan (NEP) signal positive strides toward clean energy transformation, aiming for carbon neutrality by 2050 with at least 50% renewable energy in new power generation (Ministry of Natural Resources and Environment, 2022). This transition implies the process of phaseout and associated potential write-downs of fossil-related assets, including power plants and pipelines, alongside the devaluation of related securities in the financial market.

This research aims to contribute to the stranded asset literature and institutional investors' climate change strategy by quantifying potential financial impact of publicly traded energy corporations associated with the decommissioning of coal-fired and gas-fired power plants in Thailand using a discounted cash flow model from 2024 to 2050, under three distinct scenarios:

1. Thailand's Power Development Plan (PDP) 2018 Revision 1 Pathway: This scenario is interpreted as a business-as-usual (BAU) scenario, adhering to current policy frameworks without significant shifts toward renewable energy.
2. Rapid Transformation Pathway: This scenario is published in Thailand's National Energy Plan for the People (People NEP) In this pathway, Thailand commits to phase-out of fossil fuel power plants, consistent with the targets set in the 2023 Nationally Determined Contributions (NDC).
3. 100% Renewable Energy Pathway: This scenario envisages a transformative approach in line with the objective of limiting global warming to 1.5°C. It adheres to the principles of equitable distribution and fairness as emphasized in the Paris Agreement.

Our findings reveal significant risks of stranded assets from 2025 onwards. Under the Rapid Transformation and the 100% Renewable scenarios, a significant portion of coal and gas-fired power plants are likely to be decommissioned early. The value of total stranded losses for these plants could reach up to 530 billion THB, which suggest significant overvaluation for major publicly traded energy utilities in Thailand. We observe that the five major energy companies in the utilities sector face a downside risk ranging from 6% to 61%. Moreover, the stranded power plants could impact free cash flow, increasing default risks and potentially affecting lenders, bondholders, and the overall financial system.

This research contributes to the ongoing efforts worldwide to quantify stranded asset losses and financial risks associated with aligning the energy system with NDC commitments and the 1.5°C goals in an emerging market context. However, there are limitations to this analysis. Due to constraints in public data availability, we were unable to explore the infrastructure of the upstream gas and coal supply chain fully. Additionally, the specifics of power purchase agreements could not be examined in scenarios where the government decides to phase out contracts prematurely. Moreover, accurately quantifying risk within the banking sector would necessitate access to detailed bank portfolio data. These limitations highlight significant opportunities for future research in this area.

2. Literature Review

2.1. What are stranded assets?

The concept of stranded assets has varied definitions across contexts. In accounting, they are non-performing or obsolete assets leading to a loss of profit (Deloitte, 2016). Professionals use different terms for stranded assets, complicating communication; investors may call it a 'financial loss,' while regulators may term it an 'impairment.' In the 1990s, 'stranded costs' or 'stranded investment' referred to the declining value of electricity-generating assets amid industry restructuring in the U.S. and the U.K. (Davis, 2010). In economics, asset stranding aligns with 'creative destruction,' a concept by Joseph Schumpeter, where economic values are created and destroyed to fuel growth and innovation. For instance, the mass production of cars led to the decline of railways, illustrating the dynamic nature of economic development (Schumpeter, 1942). In summary, stranded assets, as per Schumpeter, are integral to the creative destruction process driven by commercialization and innovation.

Since the late 1980s, environmental groups and sustainability advocates recognized that stricter regulations might render fossil fuel companies unprofitable. Stranded assets in energy production, as defined by the International Energy Agency (IEA, 2013), refer to investments unable to yield economic returns before their assumed end. The Carbon Tracker Initiative concurs, citing economic losses from market and regulatory changes associated with transitioning to a low-carbon economy. The Generation Foundation broadens this definition, encompassing assets losing economic value due to legislative, regulatory, market, innovation, societal, or environmental shifts (Generation Foundation, 2013). In the early 2010s, 'stranded assets' became associated with 'unburnable carbon,' a concept highlighting the disconnect between fossil fuel producers' equity value and their potential under stricter carbon emission constraints. This concept led to debates about the risks of investing in fossil fuel assets and spurred the fossil fuel divestment campaign (Ansar, Caldecott, & Tilbury, 2013).

The concept of 'carbon bubble' also gained attention, suggesting that unburnable carbon might overvalue upstream fossil fuel assets, potentially leading to a financial bubble with global economic implications (Carbon Tracker Initiative, 2011) Reactions to this concept varied from qualified support to opposition. Though popularized in the early 2010s, the origins of the ideas of unburnable carbon and the carbon bubble date back to Krause et al. (1989). They were pioneers advocating for unburnable carbon, emphasizing the risk of early obsolescence for economic infrastructures reliant on fossil fuels due to limited global carbon emissions. Krause challenged industry assumptions, stating that climate stabilization demands leaving significant portions of conventional fossil resources untapped, contrary to conventional energy planning (Krause, Bach, & Koomey, 1989).

In the 2010s stranded assets discourse, the debate on risk types has evolved. Initially, some favored government-enforced carbon budgets (Carbon Tracker Initiative, 2011), while others were skeptical, suggesting indirect introduction through local policies, technology, and societal pressure (Caldecott, Tilbury, & Ma, 2013). The prevailing trend now leans toward the latter perspective (Hedegaard, 2015). Tension also exists on the emphasis between climate change and broader environmental concerns. While some focus on international climate policies (Carbon Tracker Initiative, 2011), others prioritize societal responses to climate impacts beyond unburnable carbon (Bank of England, 2015). The prevailing perspective now favors a comprehensive approach, including water risk and non-fossil fuel sectors like agriculture (Lamb, 2015).

In the aftermath of the Paris Agreement, recent developments in stranded assets highlight that environmental risks extending beyond unburnable carbon have a significant impact and are likely to increase as climate conditions worsen (Caldecott B., 2021). Evidence indicates that these risks, such as air pollution in China influencing coal demand, are more immediate and substantial in the short to medium term compared to the risks associated with unburnable carbon or the carbon bubble (Caldecott B., 2021). The shale gas revolution, for instance, resulted in lower coal prices in Europe, causing challenges for new and efficient gas plants (Caldecott & McDaniels, 2014). Furthermore, the fossil fuel divestment campaign has the potential to affect targeted companies' social standing and raise their capital costs (Ansar, Caldecott, & Tilbury, 2013).

2.2. Stranded assets and the financial market

Over the past decade, increased headlines on the financial implications of the climate emergency and uncertainties in climate policy have drawn attention to stranded asset risk (BNEF, 2014). Recognizing this risk, the Bank of England, through Governor Mark Carney, highlighted that 19% of the FTSE 100 Index is invested in fossil fuel-related sectors, with an additional 11% in sectors reliant on these resources (Carney, 2015). The IPCC expressed concerns about stranded asset risk in 2015 and recommended studying emissions' impact on the financial sector. Recent literature focuses on coal-fired power plants due to coal's environmental impact, projecting German coal industry stranded assets at EUR 2.6 billion by 2038, with an additional EUR 11.6 billion if the phase-out accelerates (Breitenstein, Anke, Nguyen, & Walther, 2021). Political decisions on fossil fuel phase-out pose variable risks for businesses relying on coal, leading to asset devaluation or stranding and subsequent decline in firms' valuation (Caldecott B. , 2011). The study also explores the economic challenges for hard coal and lignite power plants due to carbon pricing and renewable energy feed-in affecting the merit order.

Quantitative literature on financial assessments of stranded assets in the fossil industry due to climate change, which goes beyond physical assets, is still quite rare. This is partly due to inadequate disclosure in the financial sector and the intrinsic characteristics of climate change, which make its incorporation into financial risks difficult. However, since transitional climate risks are emerging in the long term, increasing numbers financial and research institutions are now trying to grasp the concept of transitional climate risk and translate it into numbers. The financial impacts of stranded assets have been theorized by Ansar et al. (2013), Silver (2017), UNEP Finance Initiative (2016), and the World Resources Institute (Breitenstein, Anke, Nguyen, & Walther, 2021). Both Ansar and Silver examined the effects of stranded assets on industries, companies, and individual financial assets using discounted cash flow (DCF) model and net present value (NPV) as metrics to their research outcome. The majority of research relies on case studies, primarily centered on fossil fuels, and frequently examines various levels, such as financial portfolio or industry, company, and asset. Integrated assessment models like the macroeconomic dynamic integrated climate–economy (DICE) model or E3ME-FTT-GENIE models specifically operate at the financial portfolio level (Breitenstein, Anke, Nguyen, & Walther, 2021).

Most identified studies focus on companies in the fossil fuel sector, particularly utilizing case studies and scenario analyses to predict potential values of stranded assets. These studies primarily address short to medium-term impacts related to impending policy, technology, and physical climate change hazards. However, many studies do not explicitly quantify the value of potential stranded assets in the considered scenarios. Macroeconomic studies, such as the one conducted by the Economist Intelligence Unit (2015), lack the capability to determine stranded asset magnitudes by industry, and only a few studies consider the financial impairment of stranded assets. Clapp et al. (2017) and Bender, Bridges, and Shah (2019) categorize transition risks for Center for International Climate Research (CICERO) and explore available metrics for climate-related investment considerations (Clapp, Lund, Aamaas, & Lannoo, 2017). While the latter proposes a framework for climate strategies in public equities, neither develops a transition risk model.

Notable progress in climate risk stress-tests is evident in the work of Battiston et al. (2017), who introduce a "climate stress-test" for equity portfolios (Battiston, Mandel, Monasterolo, Schütze, & Visentin, 2017). Their approach utilizes policy scenarios, a network analysis of financial dependencies, and a sector breakdown into "green" and "brown." This "green and brown" exposure approach is also adopted by several frameworks, including the one developed by Maria J. Nieto in his work on climate risk and financial stability (Nieto, 2019). Limited comprehensive risk assessment frameworks utilizing transition scenarios exist. Fang, Tan, and Wirjanto (2019) focus on managing climate change risks in equity investments, evaluating risk exposure based on carbon intensities and quantifying impacts using scenarios derived from Integrated Assessment Models (IAMs) (Kästner, 2020). Similarly, Bachner, Mayer, and Steininger (2019) model the economy-wide effects of the electricity sector's low carbon transition, considering policy scenarios and changes in the Weighted Average Cost of Capital (WACC) (Bachner, Mayer, & Steininger, 2019).

As Asia grapples with the slow adoption of clean energy, highlighted by the meager 14% share of renewable energy investments in the Asia Pacific region (excluding China) in 2022, concerns about stranded assets intensify the discourse on energy transition (Ernst & Young Global Limited, 2023). Reports from the Institute for Energy Economics and Financial Analysis and the Global Energy Monitor in 2021 cautioned against a reliance on gas in Asia (Global Energy Monitor, 2021). Projecting unfavorable factors, the former suggested potential obstacles to constructing 62% of LNG import terminal capacity and 61% of gas-fired power capacity in emerging Asian countries. The latter warned of jeopardizing Asia's economic and climate goals, citing $358 billion worth of planned gas projects at risk of becoming stranded assets amid the rising competitiveness of renewables and clean energy policies challenging fossil fuel power generation (Reynolds & Hauber, 2021).

In our review of previous studies on stranded assets valuation, we found that the majority of research in this area primarily consists of global level and country-based case studies. The analysis typically centers on power plants or upstream fossil fuel companies, with the discounted cash flow (DCF) model being a prevalent valuation method. Additionally, integrated assessment models (IAMs) such as the Global Change Assessment Model (GCAM), macroeconomic dynamic integrated climate-economy (DICE) model, or E3ME-FTT-GENIE models are commonly utilized for assessing financial portfolios. This is exemplified by the research conducted by Edwards et al. (2022) on the stranded asset risks associated with new coal power plants.

The majority of papers reviewed utilize Net Present Value (NPV) as the primary outcome metric. Globally, the calculated stranded assets vary widely, ranging from over half a billion to nearly 20 trillion USD, depending on the sector coverage and duration considered in the analysis. At the country level, coal emerges as a focal point, with estimates of stranded assets ranging from over 2 billion to one trillion USD. These findings underscore the significant financial implications associated with stranded assets in the energy sector.

Table 1 Review of studies and literature regarding the financial evaluation of stranded assets in the energy sector

Author	Type	Model	Sector	Geographic coverage	Unit of analysis	Outcome metrics	Outcome values	Duration
Edwards et al. (2022)	Academic publication	Integrated assessment models (IAMs)	Coal	Global	Power plants	Undiscounted overnight capital cost from early retirement	USD 573 bn – 1.4 trn	2016 – 2030
Kepler Cheuvreux (2014)	Lobby group report	DCF	Oil, gas, coal	Global	Upstream oil/gas/coal sector	NPV of revenues	Oil: USD 19.3trn Gas: USD 4trn Coal: USD 4.9trn	2013 - 2035
Semieniuk et al. (2022)	Academic publication	DCF	Oil, gas	Global	Upstream oil/gas sector	NPV of future profits or losses	USD 1.4trn	2018 - 2036
UBS (2016)	Lobby group report	DCF	Oil, gas	Global (focused on US and Canada)	Upstream oil / gas companies	NPV of cash flows as a percent of EV (Median) by peer group)	Approximately -16% to 140% (depend on peer group and fuel price)	2020 - 2035
Breitenstein et al. (2021)	Academic publication	DCF	Coal	Germany	Power plants	NPV of cash flows	€2.6 bn (~USD 2.8bn)	2019 - 2038
Caldecott et al. (2016)	Academic publication	DCF	Coal	Japan	Power plants / companies	NPV (total coal stranded plant value from installation, sunk cost, etc.)	USD 61.6 - 80.2bn	2016 - 2031
Caldecott et al. (2017)	Academic publication	DCF	Coal	China	Power plants / companies	NPV (total coal stranded plant value from installation, sunk cost, etc.)	USD 449 - 1,047bn	2016 - 2036
Zhang et al. (2021)	Academic publication	Annualized Expected Return	Coal	China	Power plants	Net value of fixed assets and expected return equity funds and bank loan.	USD 55 - 451bn	2019 - 2050

3. Thailand’s Energy Pathway

Thailand's power sector operates under an enhanced single buyer model, with the Electricity Generating Authority of Thailand (EGAT) at its core. EGAT plays a dual role as a major electricity generator and the sole purchaser of electricity in the country, also managing the national transmission system. It sources electricity from independent power producers (IPPs), small power producers (SPPs), and through regional integration agreements, further distributing it wholesale to the Metropolitan Electricity Authority (MEA) for urban areas and the Provincial Electricity Authority (PEA) for rural areas. Additionally, EGAT directly supplies electricity to industrial customers and neighboring countries' utilities.

Historically reliant on natural gas for the bulk of its electricity generation, Thailand is shifting towards renewable energy to align with global energy transition trends. The country's Power Development Plan (PDP) emphasizes energy security, economic and environmental sustainability, aiming to increase renewable energy's share (excluding imported hydropower) to 29% by 2037. This goal is part of a broader strategy to enhance energy efficiency by 6% and expand renewable capacity to 29 GW, representing about 35% of Thailand's total energy capacity.

However, the Thai power sector is currently grappling with the challenge of generation overcapacity and an elevated reserve margin, typically hovering around 40%. This issue has been exacerbated by a growth in demand that has fallen short of projections, a trend that has become increasingly pronounced in the wake of the Covid-19 pandemic. As part of the broader energy transition, there is a growing recognition of the potential risk of stranded assets within the sector.

To address the overcapacity and transition risk, Thailand may need to consider retiring older and less efficient power plants and a strategic delay in new investments in large-scale fossil fuel power plants. Such measures are aimed not only at aligning with the global shift towards more sustainable energy sources but also at mitigating the financial and environmental costs associated with stranded assets.

In our study, we analyze three distinct pathways to forecast the evolution of Thailand's energy sector, aiming for sustainability and alignment with global climate goals. For full details, please see appendix A. The Energy Pathways.

- **Thailand's Power Development Plan 2018 Revision 1 (PDP 2018 Rev1)**

This plan serves as the government's roadmap for the power sector's development from 2018 to 2037, projecting an increase in generation capacity from 46,090 MW to 77,211 MW. Despite ambitions for carbon neutrality by 2065-2070 and a target for renewables to account for 50% of new power generation, our analysis suggests that the plan maintains or slightly increases the capacity of gas and coal power plants, categorizing it as a 'business-as-usual' (BAU) scenario with limited progress towards the 1.5°C Paris Agreement target.

Until 2037, it is anticipated that some fossil fuel power plants will be decommissioned as outlined in the 2018 Revision 1 of the PDP. From 2037 onwards, in the absence of specific directives, it is presumed that these plants will continue to operate until the end of their economic lifespan, typically ranging from 25 to 30 years after their commissioning date.

- **Rapid Transformation Pathway**

The Rapid Transformation Pathway, detailed within The National Energy Plan for The People is authored by The Institute of Industrial Energy and the Clean Energy for People Foundation, this plan presents a more aggressive shift towards sustainability, particularly under its Rapid Transformation Scenario Revision 1. It envisages eliminating CO_2 emissions in power generation by 2050, with significant milestones including the phase-out of coal by 2040, limiting gas-fired plants to under 10% of the energy mix, and achieving 100% electric vehicle usage by 2035. Carbon neutrality will be achieved partly through implementing a carbon offset mechanism, targeting 10 million tons of equivalent emissions from Land Use, Land Use Change, and Forestry (LULUCF) activities.

This scenario aims for a power generation capacity of 70,620 MW by 2050. It is noteworthy that while the pathway outlined by People NEP aligns with Thailand's second NDC, it deviates from the 1.5°C emission range analyzed for the country.

- **100% Renewable Energy Pathway**

Developed by Climate Analytics and based on studies from LUT University and the Energy Watch Group, this ambitious scenario requires Thailand to cut its GHG emissions by 78–83% below 2015 levels by 2050, excluding LULUCF. As of 2020, Thailand's energy composition heavily leaned towards fossil fuels, with natural gas and coal comprising 66% and 20% of the energy mix, respectively (IEA, 2021). It necessitates a drastic overhaul of the energy sector, increasing renewables' share from 16% in 2020 to 57–67% by 2030, and phasing out coal and fossil gas by 2034 and 2042, respectively.

This pathway aligns with the 1.5°C goal, emphasizing a significant ramp-up in renewable energy investments and a cross-sectoral, cost-effective transition to renewables, challenging yet ahead of current policy trajectories, as the government's revised Long-term Low Greenhouse Gas Emissions Development Strategy (LT-LEDS) targets a 74% share of renewable electricity generation by 2050, and the revised Power Development Plan only aims for renewables to constitute 37% of power generation by 2037.

Figure 1 Energy pathways - Natural gas

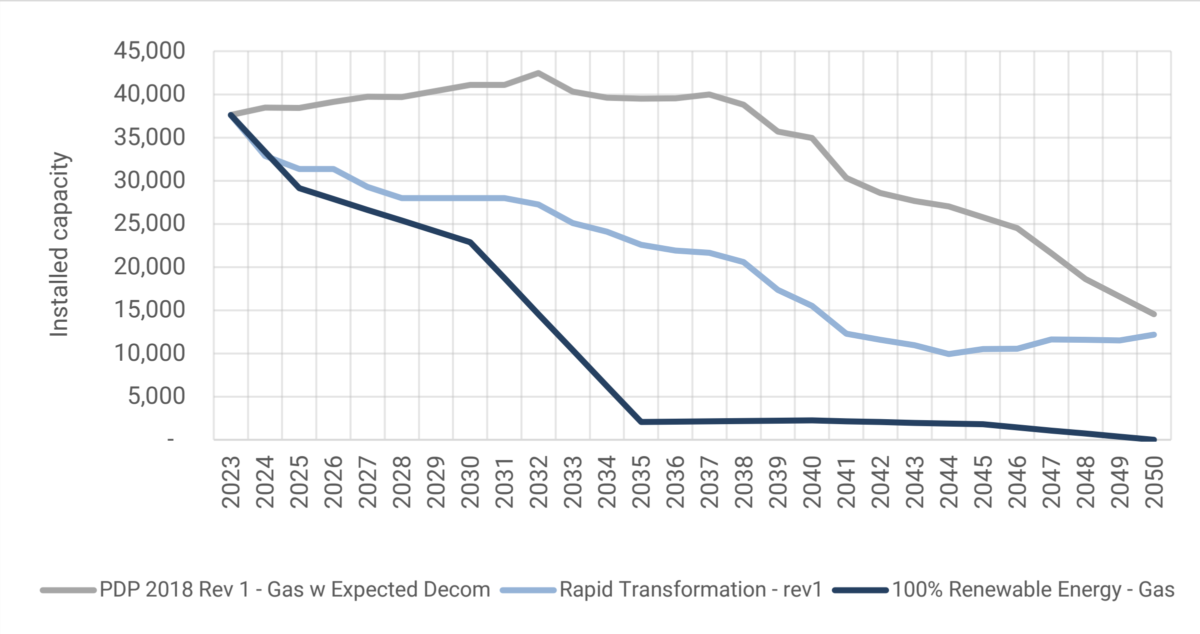
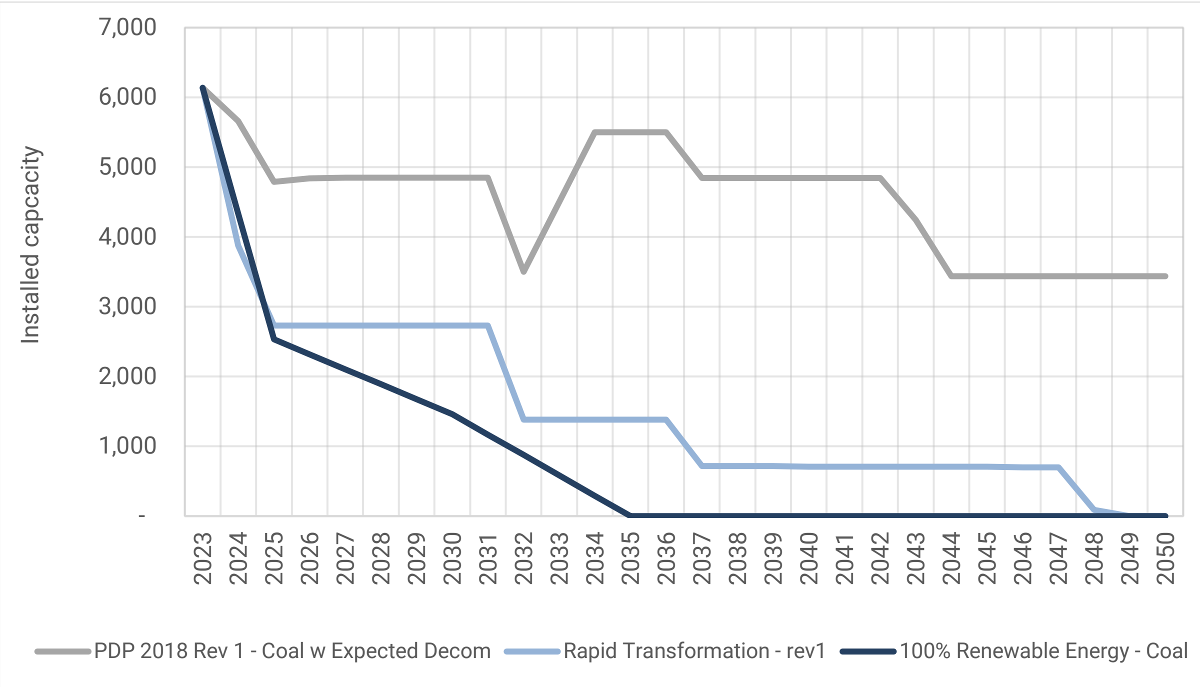


Figure 2 Energy pathways - Coal



4. Data & Methodology

In our study, we leverage a wide-ranging dataset that includes information on power plant operations, financial data and shareholder details to calculate potential financial losses from stranded assets in Thailand's coal and gas production sectors, employing the discounted cash flow method. Our primary sources of data are the Global Energy Monitor (GEM)'s reports for gas and coal power plants as of August and July 2023, respectively. To ensure the accuracy and reliability of this dataset, we conducted a comprehensive reconciliation process in December 2023, cross-referencing the GEM data with official sources in Thai language.

Revenue projections for the power plants draw on publicly available data from EGAT, segmented by Power Purchase Agreements (PPAs) types such as Independent Power Producer (IPP) and Small Power Producer (SPP), as well as wholesale price to industrial users. To mitigate the impact of recent fuel price volatility, we adopt an average price based on electricity prices from 2018 to 2020, deemed reflective of long-term pricing trends.

Our financial analysis assumes constant electricity prices through 2050, an approach to prevent overestimating power plant revenues and stranded asset valuations. We categorize power plants into Subcritical Coal and Natural Gas Combined Cycle, applying cost parameters from Handayani et al. (2022) and Lazard (2023), for operational and construction expenses.

Table 2 Summary of cost parameters

	Unit	Subcritical Coal	Natural Gas Combined Cycle
Facility lifetime	Years	30	30
Capital costs (New build)	USD/MW	1,520 - 1,900	690 - 1,200
Fixed O&M	USD/kW-Yr	56.6	23.5
Variable O&M	USD/MWh	0.11	2.3
Heat rate	BTU/kWh	10,075 - 11,075	6,925 - 7,450
Fuel price	USD/MMBTU	2 – 4	7 - 11.7

We also employ financial and shareholder data from the Corpus X database and SETSMART (2019-2023) to calculate of the Weighted Average Cost of Capital (WACC) for five major Thai energy utilities, resulting in an average WACC of 8.11%. This WACC has already incorporated adjustments for recent market conditions. Additionally, we calculated the effective tax rate (ETR) from firms' financial statements revealing a 5-year average ETR of 6.11% for gas companies and 9.74% for coal companies.

To determine a reasonable sequence of potential stranding among Thailand's natural gas and coal-fired power units, our study adopts a weighted multi-criteria decision analysis (MCDA). This approach considers various factors that influence the decommissioning decisions for power plants, incorporating economic, environmental, and technical criteria (Zhang, et al., 2021; Zhang, Ren, Kang, Zhou, & Yuan, 2022). Due to the specificities of the Thai energy sector and data availability, we selected four critical indicators, assigning equal weight to each to maintain a balanced evaluation across different dimensions. These indicators are unit capacity size, plant capacity size, unit status, and commission date. While recognizing the significance of additional variables, such as the marginal cost and the specifics of Power Purchase Agreements of each power plant, our inability to access such data represents a limitation of our study.

Subsequently, we align the future installed capacity with its corresponding energy pathway. Then, we employ the Discounted Cash Flow (DCF) model to calculate stranded values. The DCF model, a forward-looking valuation method, calculates the present value of anticipated future cash flows, adjusting specifically to each scenario. This calculation is performed at both the powerplants and major owner's levels.

For each power plant, we determine free cash flow (FCF) and then apply the Weighted Average Cost of Capital (WACC) to discount these cash flows to derive the net present value (NPV). Stranded losses are assessed by focusing on the FCF generated during the years when a plant is considered stranded. In scenarios where early decommissioning leads to a negative NPV, it is inferred that the construction of the power plant would not be a viable option. This assumes that firms will logically choose not to pursue projects if they are projected to result in financial losses. Therefore, in such cases, we conservatively estimate the stranded loss as zero due to the unlikelihood of these projects advancing to the construction stage. For more details, please see appendix B. Input Parameters and Data Collection and appendix C. Detailed Methodology.

5. Valuation Results

We present our calculations of the undiscounted net operating profit after tax (NOPAT) for three scenarios in Figure 3: the PDP 2018 Revision 1, representing our business-as-usual pathway; the Rapid Transformation Pathway, aligning with Thailand's updated Nationally Determined Contribution (NDC); and the 100% Renewable Energy Pathway, illustrating the pathway toward achieving the 1.5°C climate goal.

According to our analysis, the stranding of coal-fired and gas-fired power plants begins from 2025 onwards. The variations in NOPAT reflect the early decommissioning of power plants to align with Thailand's recent NDC (Rapid Transformation) and the 1.5°C climate goals (100% Renewable Energy). The total stranded installed capacity, measured in megawatts (MW), for both energy pathways is presented in Figure 3 and Figure 6. The significant disparity in NOPAT and the substantial number of stranded megawatts underscore the misalignment of the current PDP 2018 Revision 1, which has been criticized for overestimating energy demand and lacking ambition in achieving net-zero goals.

Figure 3 Net operating profit after tax (million THB)

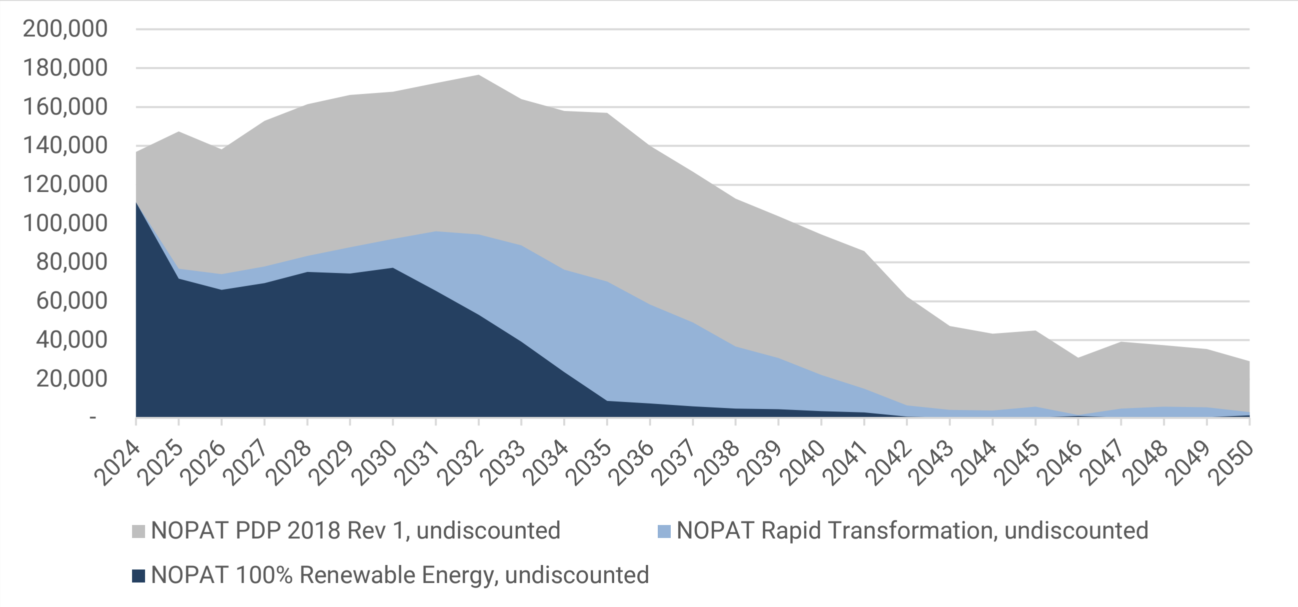


Figure 4 Stranded power plants – Rapid Transformation (MW)

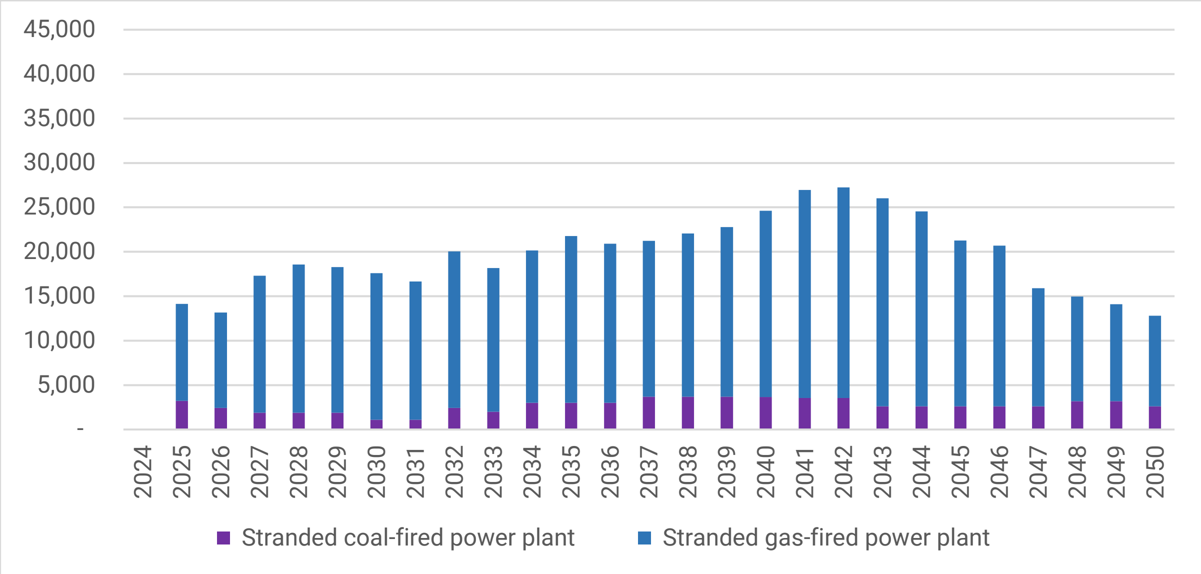
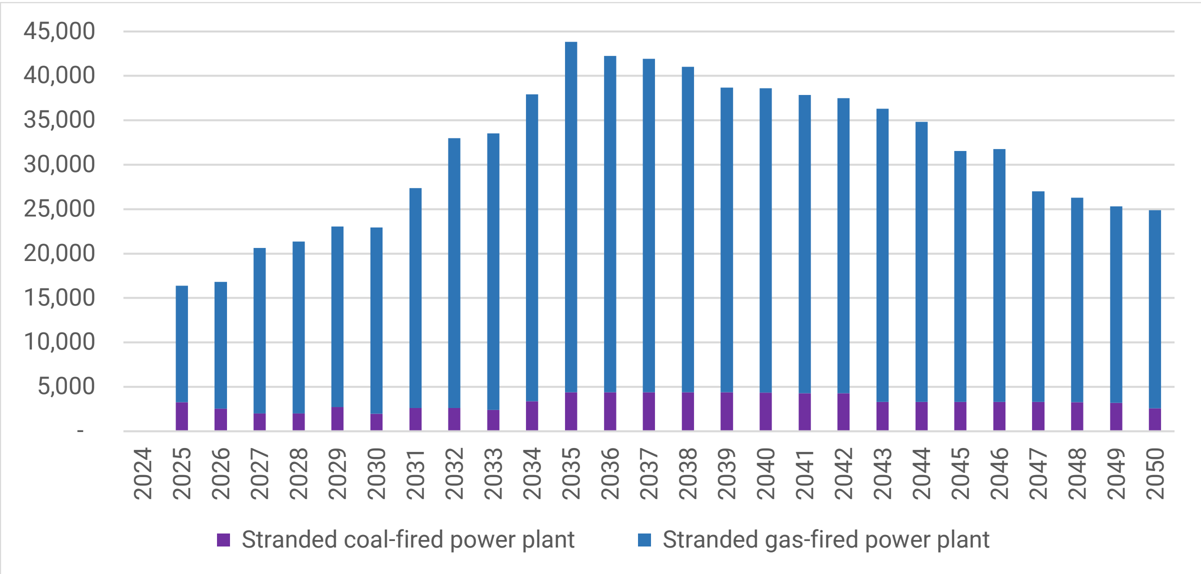


Figure 5 Stranded power plants - 100% Renewable Energy (MW)



Regarding Thailand's commitments to the NDC, the Rapid Transformation scenario suggests that gas-fired power plants will continue to play a significant role even in 2050. The scenario suggests compensating for these carbon emissions through Land Use, Land-Use Change, and Forestry (LULUCF). In contrast, the 100% Renewable Energy scenario, representing the most substantial loss in net operating profit in the energy sector from 2030 onwards, implies that achieving this in Thailand would require an aggressive phase-out of gas-fired power plants. Consequently, these plants are considered stranded assets in this context.

To calculate the net present value (NPV) of stranded losses, we discounted the stranded free cash flow in the Rapid Transformation and 100% Renewable Energy scenarios relative to PDP 2018 Revision 1, using the Weighted Average Cost of Capital (WACC) as detailed in " B.5 Weighted

Average Cost of Capital". We found that the total stranded losses for coal-fired and gas-fired power plants amount to 360 billion THB in the Rapid Transformation scenario and 530 billion THB in the 100% Renewable Energy scenario. Notably, a significant portion of these losses are attributable to gas-fired power plants, accounting for 83% and 87% of the total stranded loss in each scenario, respectively. The detailed breakdown is presented in Table 3.

Table 3 Net present value of stranded gas-fired and coal-fired power plants for the Rapid Transformation and 100% Renewable Energy Scenarios (Million THB)

Type	Rapid Transformation			100% Renewable Energy		
	Coal	Gas	Total	Coal	Gas	Total
IPP	1,171	109,910	**111,081**	6,784	201,514	**208,298**
Government-owned	5,134	37,144	**42,279**	5,543	104,178	**109,720**
Captive	5,676	14,848	**20,524**	5,676	16,264	**21,940**
SPP	48,920	137,642	**186,562**	48,920	141,663	**190,583**
Grand Total	**60,901**	**299,545**	**360,446**	**66,922**	**463,619**	**530,541**

A critical observation from the comparison between the Rapid Transformation and the 100% Renewable Energy scenarios is the notable increase in stranded losses, especially for IPPs and government-owned power plants. This additional loss, nearly doubling in some instances, is largely attributed to the aggressive phase-out of gas-fired power plants in which more than 12,000 MW of these plants are scheduled for commissioning from 2024 onwards. These findings highlight significant transition risks within Thailand's energy sector, particularly if the country more genuinely commits to the ambitious 1.5°C climate goal of the Paris Agreement.

Importantly, the projected stranded losses suggest that Thailand may experience a lock-in effect from its investments in fossil gas infrastructure, which extend beyond power plants. As the country's energy policies and market preferences shift towards renewable sources, these investments in coal and gas infrastructure risk becoming obsolete and unprofitable. This lock-in effect presents a considerable challenge for Thailand's transition to a sustainable energy model, as it could lead to sunk costs and may hinder the adoption of cleaner, more sustainable technologies.

6. Sensitivity Analysis

As noted earlier, we recognize the limitations inherent in using static fuel prices for our analysis. Our calculations are based on the average expected prices of coal and gas, at 3 USD/MMBTU and 9.35 USD/MMBTU respectively, as detailed in Table 2. For the sensitivity analysis, we will adjust the fuel prices to high and low boundaries: 2 and 4 USD/MMBTU for coal, and 7 and 11.70 USD/MMBTU for gas. The results of these adjustments are presented in Table 4.

Table 4 Sensitivity Analysis – Low and High fuel prices for Rapid Transformation and 100% Renewable Energy Scenarios (Million THB)

	Rapid Transformation			100% Renewable Energy		
	Low Fuel Price	Base case	High Fuel Price	Low Fuel Price	Base case	High Fuel Price
IPP	193,362	**111,081**	31,158	367,002	**208,298**	53,940
Government-owned	77,518	**42,279**	9,384	192,281	**109,720**	28,736
Captive	31,260	**20,524**	9,788	33,639	**21,940**	10,241
SPP	339,345	**186,562**	43,387	347,381	**190,583**	43,618
Total	**641,485**	**360,446**	**93,718**	**940,303**	**530,541**	**136,535**

In scenarios with high fuel prices, we observed a significant reduction, approximately 74%, in the stranded value of power plants, particularly coal power plants. This decrease is attributed to coal power plants becoming unprofitable and ceasing operations due to high fuel costs. However, this scenario might not heavily impact power plants, as Thailand's energy system can pass higher fuel costs to consumers, for instance, through energy payments and the automatic tariff adjustment mechanism (Ft). Therefore, even in high fuel price scenarios, power plants may remain operational by transferring all incremental costs to consumers.

Conversely, we found that low fuel prices lead to an approximate 78% increase in total stranded assets value, indicating that net operating profit after tax is highly sensitive to fuel price fluctuations. It's important to note that lower fuel prices may reduce their income due to decreased energy payments and Ft. Nevertheless, IPPs and SPPs still receive a fixed income through availability payments and capacity payments. Therefore, Thailand's energy sector faces limited downturn risk during high fuel cost periods but can benefit from a downward trend in fuel prices.

Given the extended period of our analysis, another factor that has recently shown high volatility and may impact future cash flows is the WACC. Therefore, to provide a comprehensive view, we will present the values of stranded assets using WACC rates adjusted by +/- 2%. These figures can be found in Table 5.

Table 5 Sensitivity analysis – WACC +/- 2% for Rapid Transformation and 100% Renewable Energy Scenarios (Million THB)

	Rapid Transformation			100% Renewable Energy		
	WACC - 2%	Base case	WACC + 2%	WACC - 2%	Base case	WACC + 2%
IPP	129,214	**111,081**	93,900	243,692	**208,298**	52,355
Government-owned	35,321	**42,279**	35,321	90,978	**109,720**	29,103
Captive	24,156	**20,524**	17,839	25,685	**21,940**	9,958
SPP	204,470	**186,562**	163,814	208,767	**190,583**	49,611
Total	393,161	**360,446**	310,874	569,122	**530,541**	141,027

We found that increasing WACC by 2% reduces the stranded assets value by approximately 14% in both scenarios, while decreasing WACC by 2% increases the stranded assets value by about 8%. Therefore, we conclude that the present value of stranded assets is quite sensitive to changes in WACC, though not as much as to changes in fuel price.

7. Implication for investors and lenders

The potential stranded losses may have significant implications for the stock market, particularly affecting listed coal and gas utilities companies and other companies invested in energy utilities. Assuming the efficiency of the stock market as per the Efficient Market Hypothesis (EMH) and that the current market capitalization of companies reflects the business-as-usual pathway outlined in PDP 2018 Revision 1, a sudden shift in energy policy could lead to substantial stranded losses. For instance, the adoption of the upcoming National Energy Plan, potentially aligning with Thailand's recent NDC or the 1.5°C climate goals, may result in considerable stranded losses for listed companies, estimated at 234 billion THB and 309 billion THB, respectively, due to the early decommissioning of coal-fired and gas-fired power plants.

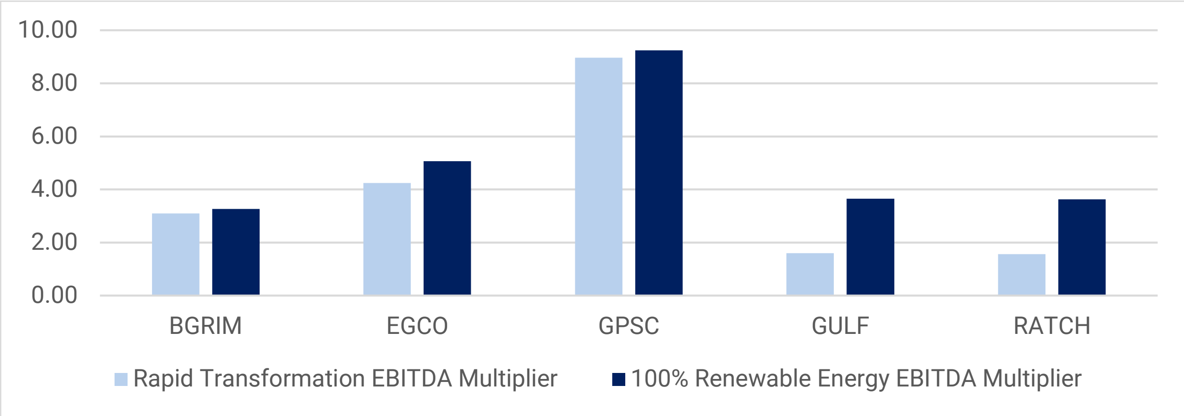
Table 6 illustrates the potential downside risk for five major energy utilities companies in Thailand – BGRIM, EGCO, GPSC, GULF, and RATCH – all of which are included in the SET50 index. This index represents the most valuable and actively traded stocks in Thailand. Note that the comparison of stranded losses is made against the market capitalization as of 2nd January 2024.

Table 6 Net present value of stranded loss distributed by ownership of major Thailand publicly traded companies for Rapid Transformation and 100% Renewable Energy scenarios (Million THB)

Company	NPV - Rapid Transformation				NPV - 100% Renewable Energy			
	Coal	NG	Total	Potential Downside Risk	Coal	NG	Total	Potential Downside Risk
BGRIM	-	26,700	26,700	**37%**	-	28,172	28,172	**39%**
EGCO	111	34,791	34,902	**51%**	2,862	38,690	41,552	**61%**
GPSC	20,309	42,888	63,197	**44%**	20,380	44,787	65,167	**46%**
GULF	-	30,510	30,510	**6%**	-	69,999	69,999	**13%**
RATCH	-	15,871	15,871	**23%**	-	36,842	36,842	**53%**

The results depicted in Table 6 reveal a significant risk of stranded assets for major energy utilities in Thailand under the transition scenarios aligned with the Rapid Transformation and the 100% Renewable Energy goals. The downside risks presented for each company illustrate the potential financial impact of this transition, with percentages indicating the proportion of their market capitalization at risk due to stranded assets. Notably, companies such as RATCH EGCO and GPSC face higher risks, with downside risks exceeding 40% in some scenarios. It should be noted that the downside risks illustrated are the maximum possible in the absence of any government compensation for phasing out operations prior to the end of the power plant's economic life or the power purchase agreements.

Figure 6 Stranded EBITDA multiplier of major Thailand publicly traded companies for Rapid Transformation and 100% Renewable Energy scenarios.



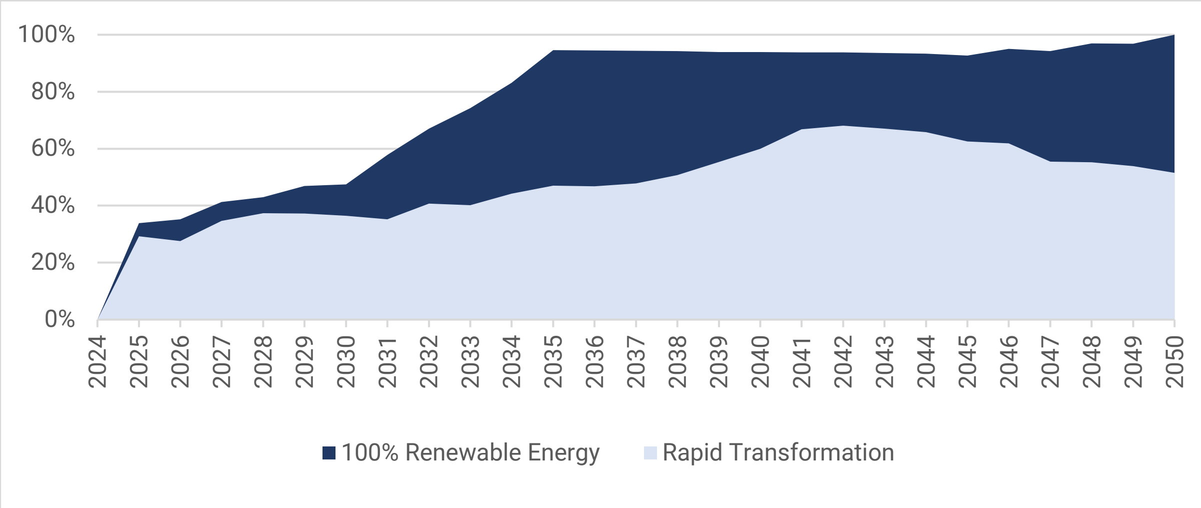
Recognizing the inherent volatility of market capitalization, we alternatively opted to utilize the 2023 EBITDA as a basis for calculating the ratio of present value of stranded EBITDA to the recent EBITDA, hereby presented as a 'stranded EBITDA multiplier.' This approach provides insight into the cash flow risks faced by these companies, highlighting their dependency on revenues from power plants in Thailand. The EBITDA multiplier ranges from 1.56 to 8.96 in the Rapid Transformation scenario and from 3.27 to 9.24 in the 100% Renewable Energy scenario.

GPSC emerges as the company most significantly impacted by stranded asset losses, attributable to its substantial reliance on domestic IPP and SPP contracts, which constituted nearly 78% of its revenue in 2022. Although EGCO appears to face a considerable downside risk from a market capitalization standpoint, its risk profile from an EBITDA perspective is less severe. This discrepancy is due to its substantial revenue from overseas power production, which accounted for 47% in 2022. It is important to note that stranded losses from overseas power plants were excluded from this analysis. Another entity of interest is GULF, which displays a relatively lower risk from a market capitalization viewpoint. However, from an EBITDA perspective, it demonstrates a higher risk in the 100% Renewable scenarios, attributed to a significantly higher P/E ratio compared to the industry average for utilities.

Furthermore, the risk may extend beyond company shareholders. Many of these companies finance their projects through syndicated loans and corporate bond issuances. As a result, lenders and bondholders are also exposed to increased risks of default, particularly due to unforeseen changes in energy policy trajectories. Currently, these five major energy companies have accumulated substantial debt and bond obligations, totaling over 800 billion THB presented in their 2023 financial statement. Figure 7 illustrates the percentage of stranded power plant capacity. Potential cash flow issues may emerge after 2032, when an estimated 41% and 67% of the available power plants become stranded to align with Thailand's NDC commitment and the 1.5°C Climate Goals, respectively. Consequently, these companies could face liquidity challenges in repaying their debts if the expected cash flows from power plants are compromised by early decommissioning.

These findings suggest that the transition towards a low-carbon economy, while critical for environmental sustainability, poses substantial financial challenges for traditional energy companies. The analysis underscores the importance of strategic planning by these companies to navigate the transition effectively, potentially through diversifying their energy portfolios or enhancing investments in renewable energy technologies.

Figure 7 The percentage of stranded power plant capacity.



Additionally, these financial implications have raised concerns regarding financial stability among various supervisory authorities. Reports from central banks, such as the European Central Bank (ECB) and European Systemic Risk Board, acknowledge that an abrupt transition to a low-carbon economy might destabilize the financial system (ECB/ESRB, 2021). Vermeulen, et al. (2019) from Nederlandsche Bank have noted that financial losses can be substantial, with portfolio values potentially declining by up to 11%. These findings underscore the urgency of addressing climate-transition risks from a financial stability perspective. Similarly, Finansinspektionen, the Swedish government financial supervisory authority, has emphasized the importance of proactive measures despite the absence of perfect data or fully standardized methods (Finansinspektionen & Riksbank, 2022). The continued expansion of fossil fuel infrastructure suggests that financial institutions might be underestimating these transition risks, and therefore our stranded assets valuation should help inform domestic lenders to design a feasible fossil financing phaseout plan that is in line with their Net Zero ambitions and 1.5°C goal of the Paris Agreement.

8. Policy Implications

As climate change impacts become more apparent and severe, the Thai government is likely to face increasing demands for more urgent climate actions. Thailand also needs to navigate post-COP28 trade negotiations and investment climate that increasingly call for a concrete and time-bound energy transition.

In this climate, our valuation of potential stranded coal and gas assets helps highlight the risks of locking in fossil gas infrastructure for decades, which as mentioned earlier could lead to significant sunk costs and may hinder the adoption of cleaner, more sustainable technologies.

On the upside, we believe our stranded assets valuation can help inform policy makers in designing a credible fossil phaseout plan that is just and transparent to all operators and other stakeholders. Moreover, we believe these stranded assets estimates can help inform policymakers should Thailand be interested in joining global initiatives such as the Just Energy Transition Partnership (JET-P), which provide an opportunity for financing Thailand's just energy transition.

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Appendix

A. The Energy Pathways

A.1 Thailand's Power Development Plan 2018 Revision 1 (PDP 2018 Rev1)

Thailand's Power Development Plan (PDP) 2018 Revision 1 is a crucial reference point for evaluating stranded asset values. Our analysis indicates that this plan does not adopt a sufficiently proactive stance in integrating renewable energy sources, which is necessary to meet the 1.5°C target established by the Paris Agreement. Consequently, we categorize this plan under a 'business-as-usual' scenario. The PDP, developed by the Thai government, serves as a strategic roadmap for the evolution and modernization of the nation's power sector. It undergoes regular revisions to accommodate evolving energy demands and delineates Thailand's approach to energy production, consumption, and infrastructure development over a designated period.

Covering the years 2018 to 2037, the PDP 2018 Rev1 aims to raise Thailand's power generation capacity from 46,090 MW to 77,211 MW. Additionally, the plan anticipates the retirement of 25,310 MW of existing powerplants within this timeframe. Despite setting a target to achieve carbon neutrality by 2065-2070 and projecting renewable energy to constitute 50 percent of new power generation, our examination indicates a potential slight increase or stability in the capacity of gas-fired and coal-fired power plants.

Until 2037, it is anticipated that some fossil fuel power plants will be decommissioned as outlined in the PDP 2018 Rev1. From 2037 onwards, in the absence of specific directives, it is presumed that these plants will continue to operate until the end of their economic lifespan, typically ranging from 25 to 30 years after their commissioning date.

A.2 Rapid Transformation Pathway

We have chosen another pathway for our research, based on the report titled 'National Energy Plan for the People' (often referred to as 'People NEP'), authored by The Institute of Industrial Energy and the Clean Energy for People Foundation. This report presents two scenarios: a conservative approach and a rapid technology transformation. Considering the current high adoption rate of electric vehicles in Thailand, we believe the Rapid Transformation Scenario revision 1 is more relevant and closely aligns with the country's second Nationally Determined Contribution (NDC).

In the Rapid Transformation Scenario revision 1, Thailand aims to eliminate carbon dioxide emissions in the power generation sector by 2050. This will be achieved partly through implementing a carbon offset mechanism, targeting 10 million tons of equivalent emissions from Land Use, Land Use Change, and Forestry (LULUCF) activities. The plan includes phasing out coal-fired power plants by 2040, while limiting gas-fired power plants to less than 10% of the energy mix, with the remainder being renewable sources. Additionally, it assumes that Thailand will meet its target of 100% electric vehicle usage by 2035.

Thailand's power generation capacity is projected to reach 70,620 MW by 2050. This scenario aligns with Thailand's ambition to achieve carbon neutrality by 2050, as outlined in the country's second NDC. It is noteworthy that while the Rapid Transformation pathway outlined by People NEP aligns with Thailand's second NDC, it deviates from the 1.5°C emission range analyzed for the country.

A.3 100% Renewable Energy Pathway

Our final selected scenario draws on insights from Climate Analytics, a globally recognized institute specializing in climate science and policy. This scenario aligns with the ambitious goal of limiting global warming to 1.5°C. Adhering to the principles of fair distribution and equity[1] outlined in the Paris Agreement, Climate Analytics emphasizes that achieving a 1.5°C-compatible path necessitates Thailand reducing its greenhouse gas (GHG) emissions by 78–83% below 2015 levels by 2050, excluding LULUCF.

As of 2020, Thailand's energy composition heavily leaned towards fossil fuels, with natural gas and coal comprising 66% and 20% of the energy mix, respectively (IEA, 2021). To align with the 1.5°C trajectory, a significant shift in Thailand's power industry is required. This involves increasing the share of renewable sources in electricity production from 16% in 2020 to 57–67% by 2030. Thailand should phase out fossil gas between 2040 and 2042 at the latest, and coal by approximately 2034. Furthermore, the emission intensity of Thailand's power sector must decrease 62–78% from 2019 levels.

We considered the '100% Renewable Energy' path developed by the LUT University and the Energy Watch Group. This scenario envisions a viable global shift to a fully renewable energy system across power, heat, transport, and desalination sectors before 2050. It emphasizes a cost-effective, cross-sectoral approach without relying on negative CO_2 emission technologies. The proposed energy mix also prioritizes locally available renewable resources.

This pathway displays a notably increase in investments in renewable capacity, potentially driven by increased electrification of end-use sectors and growing energy demand due to economic expansion. However, current policy indications suggest that Thailand is not currently on course to achieve this, as the government's revised Long-term Low Greenhouse Gas Emissions Development Strategy (LT-LEDS) targets a 74% share of renewable electricity generation by 2050, and the revised Power Development Plan only aims for renewables to constitute 37% of power generation by 2037.

B. Input Parameters and Data Collection

In this research, we employ datasets from various sources, encompassing power plant-level data, financial information, shareholders' data related to power plants, and detailed pathways of the energy mix for each scenario. This comprehensive dataset allows us to calculate the financial loss from stranded assets using the discounted cash flow method.

B.1 Power Plant Dataset

In the development of a comprehensive Power Plant level Dataset, our initial step involved sourcing data from the Global Energy Monitor (GEM). GEM, an esteemed non-profit entity, is renowned for its extensive tracking and analytical focus on global energy developments, particularly those with significant environmental impacts. The database provided by GEM encompasses a range of parameters including the name and location of the power plant, its installed capacity, operational

[1] In the context of the Paris Agreement, the fair share or fair distribution principle refers to the idea that the global effort to address climate change should be distributed equitably among countries. The principle recognizes historical and current disparities in contributions to greenhouse gas emissions and the varying capacities of countries to respond to climate change.

status, types of fuel utilized, year of commissioning, and projected retirement dates. For this study, we used the latest information from GEM, specifically the Global Oil and Gas Plant Tracker August 2023 release for gas power plants and the Global Coal Plant Tracker July 2023 release for coal power plants.

It is important to note that GEM's database includes gas-fired generating units of 50 MW and larger and covers coal-fired generating units of 30 MW and larger for Thailand. Additionally, this study specifically focuses on gas-fired and coal-fired power plants in Thailand. The inclusion of oil power plants was deliberately omitted after careful consideration, as they contribute minimal overall installed capacity compared to the former two categories.

To enhance the accuracy and reliability of this dataset, a thorough reconciliation of these parameters has been undertaken in December 2023. This process involved cross-referencing the GEM data with official sources which available in the Thai language, such as the licensee registration database available on the Energy Regulatory Commission's website, publications from EGAT, as well as annual reports and official websites of major Thai energy companies. Furthermore, we have also consulted relevant news sources, thereby ensuring that our database aligns as closely as possible with the actual situation in the energy sector. This comprehensive approach to data validation and integration serves to align our dataset with the realities of Thailand's energy landscape.

Based on GEM's dataset and reconciliation process, the descriptive statistics for natural gas-fired and coal-fired power plants can be summarized as follows.

B.1.1 Natural gas-fired power plant

We have compiled data on 147 natural gas-fired power units distributed across 72 plants in Thailand. As of December 31, 2023, the collective installed capacity of all gas-fired power plant units in the country stands at 53,388.96 MW, with an average unit capacity of 368.20 MW.

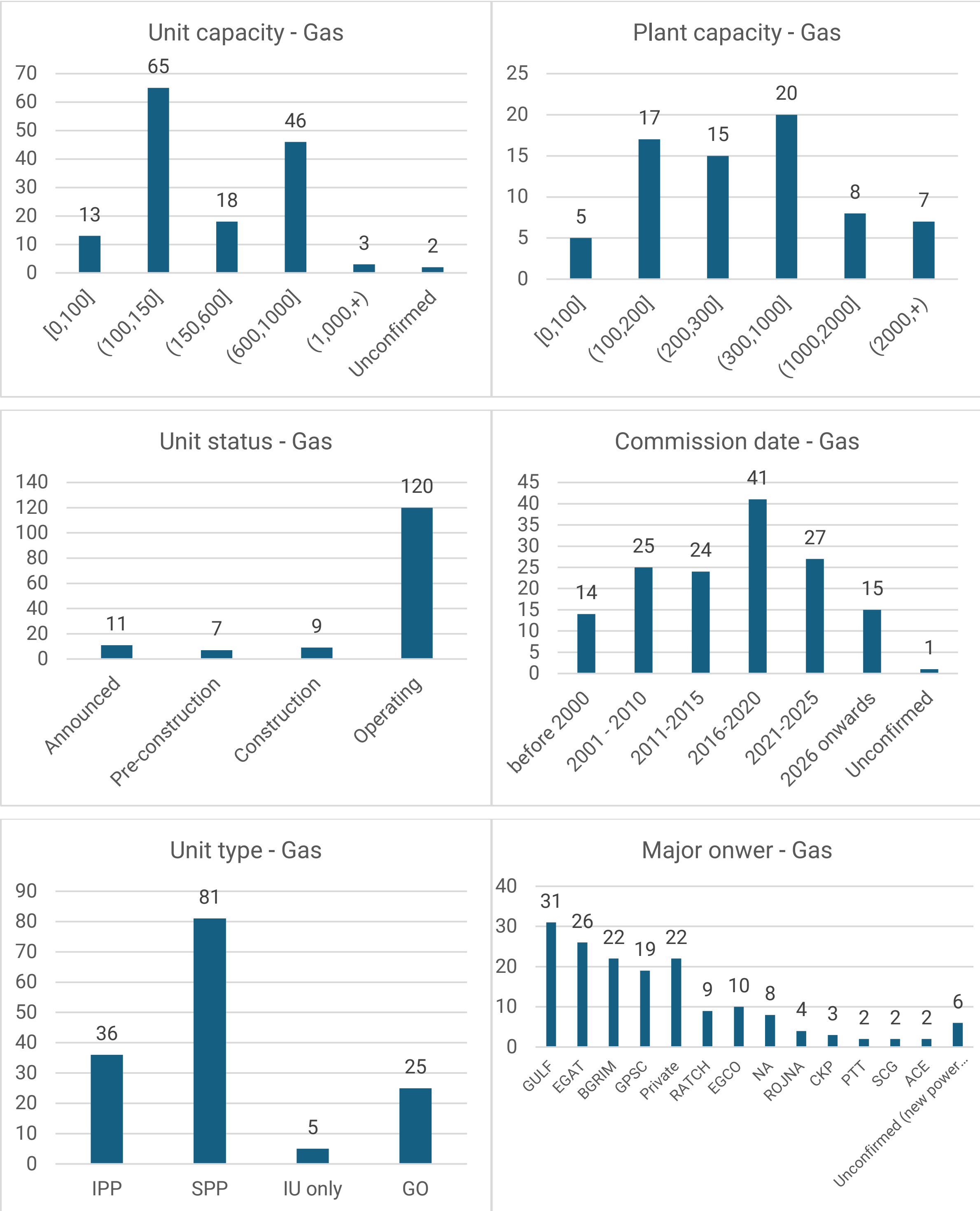
Approximately half of these gas-fired power units, precisely 65 out of 147, exhibit a capacity ranging from 100 to 150 MW. The second-largest cohort encompasses units with capacities between 600 and 1,000 MW, constituting approximately 31.29% of the overall units. Analyzing plant levels, where each plant may house several power units, reveals an average plant capacity of 741.51 MW, with 72.22% of gas-fired power plants exhibiting capacities within the 100-1,000 MW range.

As of December 31, 2023, most gas-fired power units are operational, while the remaining units are either in the announced phase or under pre-/construction[2]. A significant portion of gas-fired power units commenced operations prior to the end of 2020 (61.22%). Six power units were commissioned in 2023, and 24 power units are slated to begin operations between 2024 and 2037. More than half of all power units fall under the SPP category, with the second-largest group being IPP, followed by those owned by the Government (by EGAT) and power plants exclusively supplying electricity to industrial users (IUs).

[2]Announced: Projects that have been publicly reported but have not yet moved actively forward by applying for permits or seeking land, material, or financing.
Pre-construction: Projects that are actively moving forward in seeking governmental approvals, land rights, or financing.
Construction: Projects where physical construction (i.e. equipment or building, not just a ground-breaking ceremony or early site preparation) has begun.
Permitted: Projects that have secured all environmental permits but have not broken ground.
Operating: Commercial operation has begun (Global Energy Monitor, 2023).

In terms of ownership, the top five public companies/government agencies that serve as major owners and possess the majority of power plants are Gulf Energy Development PCL (21.99%), EGAT (18.44%), B.Grimm Power PCL (15.60%), Global Power Synergy PCL (13.48%), and Ratch Group PCL (7.09%).

Figure 8 Descriptive statistics for natural gas-fired power plants



B1.2 Coal-fired power plant

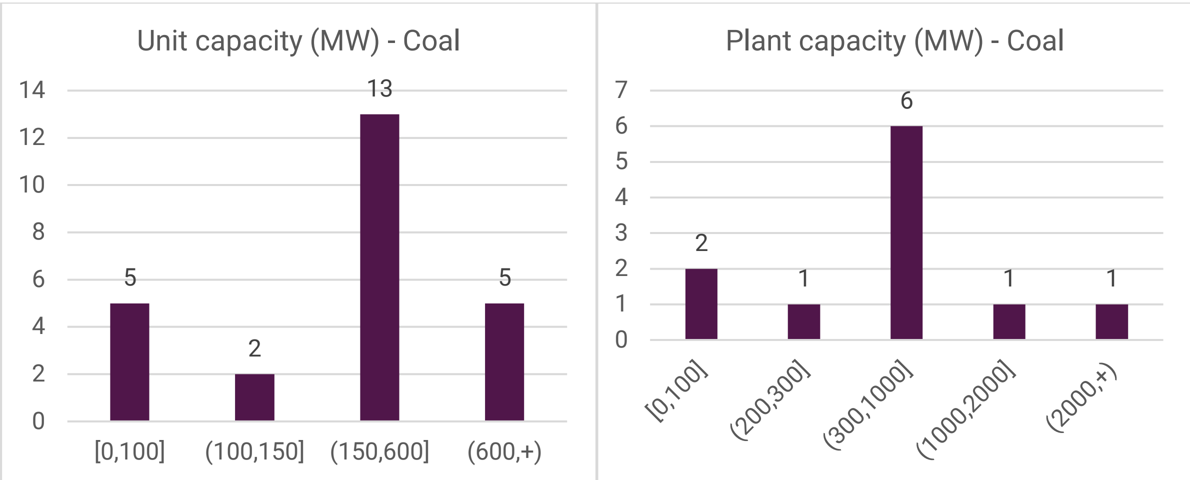
Data for coal-fired power plants were collected from 25 units across 11 facilities. Notably, these figures differ significantly from those of gas-fired power plants. As of December 31, 2023, the total installed capacity of coal-fired power plants stands at 8,565 MW, with an average capacity of 342.6 MW.

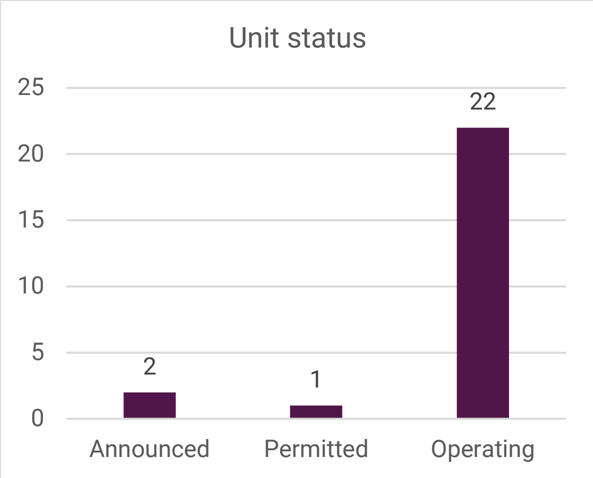
More than half of the total power units exhibit an installed capacity falling between 150 to 600 MW. When aggregated at the plant level, we observe that the average plant capacity is 407.86 MW. The majority of coal-fired power plants possess a capacity ranging from 300 to 1,000 MW (54.55%), while several are relatively small (18.18%), with installed capacities of less than 100 MW each.

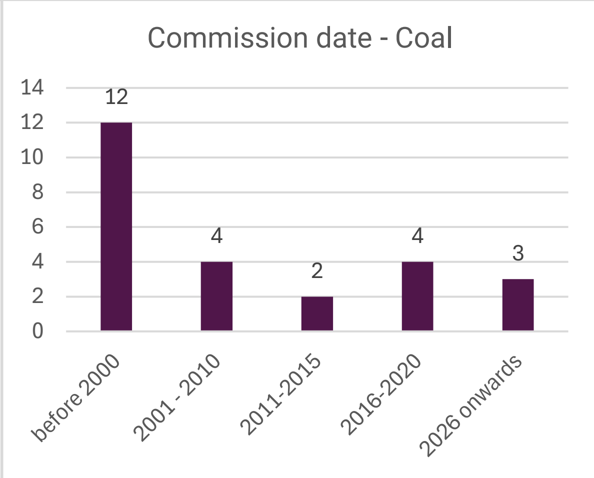
Nearly all coal-fired power units under analysis are operational as of December 31, 2023, with the exception of Mae Moh Power Plant Project unit 15 (intended to replace units 8-9), which received permitting in 2022. Additionally, two new coal-fired power plants (one in the Eastern Region and another in the Southern Region) are anticipated to commence operations in 2033 – 2034 as per the Power Development Plan 2018 Revision 1. Almost half of the coal-fired power units have been in operation since before 2000, and no new units were commissioned in 2023.

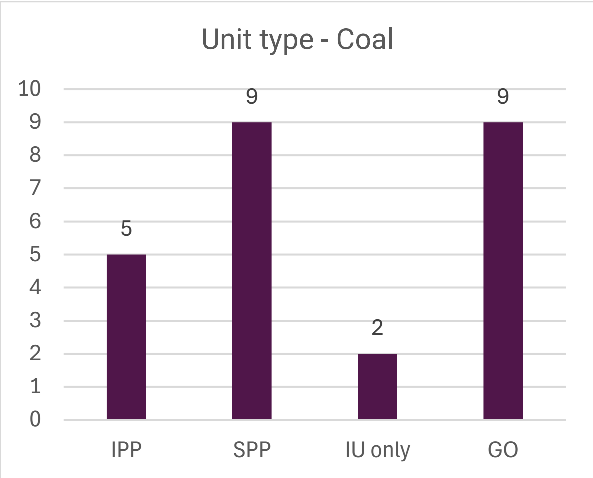
Similar to gas-fired power units, a substantial portion of coal-fired power units, amounting to 36.00%, function as SPPs. An equivalent number are under the ownership of EGAT, while 20.00% operate as IPPs, with only a minority exclusively supplying electricity to industrial users.

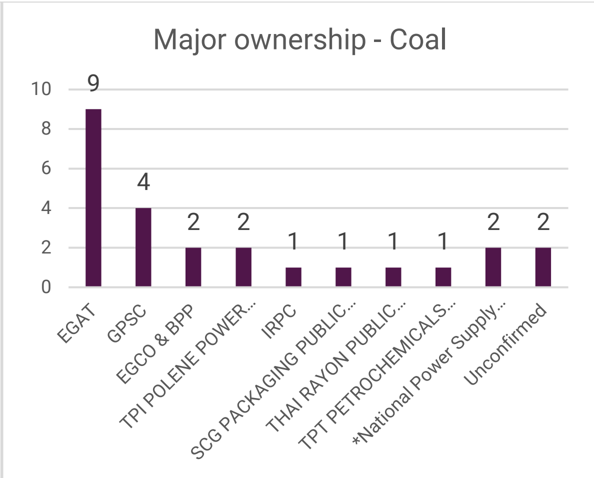
Figure 9 Descriptive statistics for natural coal-fired power plants











B.2 Financial and shareholders' data

The financial and shareholders' data for the power plant companies under consideration were collected from two primary sources: the Corpus X database, a private business data analytics platform, and SETSMART, which provides information on listed companies. To ensure data integrity, we reconciled our findings with information published in the annual reports of these public companies.

We employed these data sources to calculate the Weighted Average Cost of Capital (WACC) and the effective tax rate. Additionally, we analyzed shareholders' data to determine the equity-based installed capacity for each public company. This analysis aims to estimate the potential impact on each company resulting from stranded assets, which are a consequence of the early decommissioning of power plants. Further details regarding our calculation methods will be discussed in subsequent sections of this report.

B.3 Powerplant's Revenue

Gas and coal-fired power plants typically derive revenue from two primary sources: 1) the sale of electricity to major entities such as EGAT and 2) the supply of electricity to industrial consumers.

B.3.1 Electricity Price for EGAT, PEA, and MEA

In Thailand's electricity system structure, EGAT is the central entity responsible for electricity generation, procurement, and distribution to PEA and MEA, which subsequently distribute electricity to both the industrial sector and the general public. In order to meet the nation's domestic electricity demand, these entities engage in Power Purchase Agreements (PPAs) with private power producers, utilizing three distinct types: independent power producer (IPP), small power producer (SPP), and very small power producer (VSPP). However, due to their typically small installed capacity, VSPPs, particularly those with gas/oil-fired power plants, have been excluded from our analytical scope.

In the context of Thailand, the National Energy Policy Council (NEPC) has instituted an electricity pricing framework, categorized based on the nature of power producers:

1) Electricity Pricing of Independent Power Producer (IPP):

IPP revenue structure comprises two principal components. *The Availability Payment (AP)* constitutes a monthly premium remitted by EGAT to power plants, recognizing their readiness to generate and distribute electricity irrespective of the actual units purchased. AP serves to cover construction costs, debt burden, and fixed operating costs, encompassing maintenance and management costs. The second component is the *Energy Payment (EP),* representing the actual fuel costs incurred during power plant operations, inclusive of variable expenses related to production and maintenance (Energy Policy and Planning Office - Ministry of Energy, 2016).

2) Electricity Pricing of Small Power Producer (SPP):

SPP agreement pricing is differentiated into two distinct types based on fuel and contractual terms. The first category is Firm Agreement Pricing, constituting a PPA that delineates the specific amount of electricity capacity committed to supplying EGAT throughout the entire contractual period, typically extending over five years or more. The second category is Non-firm Agreement Pricing, representing a PPA with a validity period of less than five years.

It is important to note that this study exclusively encompasses gas-fired generating units with a capacity of 50 MW and above, along with coal-fired generating units of 30 MW and larger within the Thai context. Consequently, our investigation concentrates solely on the Firm Agreement Pricing type, omitting the Non-firm Agreement Pricing from the analysis. This decision was made due to their common characteristic of possessing relatively small installed capacities, compounded by the scarcity of publicly accessible data concerning these entities.

The pricing structure of SPP Firm Agreement Pricing encompasses three primary components: *Capacity Payment (CP),* covering the entirety of power plant investment costs; *Energy Payment (EP),* disbursed upon electricity generation, capturing fuel costs and variable operating and maintenance expenses; and *Fuel Saving (FS),* a revenue received when fuel consumption falls below the specified threshold in the PPA (EGAT; PEA; MEA, 2010).

For the purposes of this study, we gathered electricity pricing data for both IPPs and SPPs from the EGAT website. For IPPs, we utilized information extracted from the 'Estimated Electricity Purchase Cost by EGAT' dataset, which outlines the monthly electricity purchase costs paid by EGAT for 14 IPPs. Among these, 12 are gas-fired power plants, and 2 are coal-fired power plants[3]. In the absence of more detailed information, we assumed that these costs already incorporate both the AP and EP components.

Regarding SPP electricity pricing, we acquired data on CP and EP from the 'Estimated Electricity Purchase Cost from Small Power Producers (SPPs) of the FIRM type,' utilizing natural gas and coal as fuel sources (EGAT, 2023). It is important to note that the cost associated with Fuel Saving (FS) was not reported. Nevertheless, given its comparatively lower magnitude compared to CP and EP, we concluded that excluding FS from our calculations would not significantly impact the materiality of our analysis.

The data collection spanned the period from 2018 to 2023. However, due to an unusual surge in fuel prices attributed to geopolitical developments in Russia-Ukraine and heightened political tensions since the fourth quarter of 2021, we opted to utilize the average electricity purchase costs from IPPs and SPPs observed between 2018 and 2020[4].

B.3.2 Electricity Price for Industrial Users

SPPs and private power plants have the option of selling electricity directly to large-scale industrial consumers. These consumers span diverse sectors such as automotive, tire, packaging, and consumer products. The pricing mechanism for electricity sold to these industrial entities is based on the concept of 'avoided cost.' This refers to the expenses that industrial users would incur if they procured utility and energy services independently, typically through purchases from MEA or PEA, which are the principal wholesale electricity distributors in Thailand. This pricing approach is deemed efficient and is posited to optimize returns from the perspective of power plants.

The structure of electricity pricing in Thailand comprises a base rate added by an automatic tariff adjustment, commonly referred to as the Ft rate. The base rate encompasses assumptions regarding the fixed costs associated with electricity generation. The Ft rate, on the other hand, is a variable charge that fluctuates in response to changes in variable costs, notably fuel prices.

For our analysis, we extracted historical data on the Wholesale Tariff and Ft Wholesale Rate spanning from 2018 to 2023. This data assists in estimating the revenue generated from electricity sales to industrial users. As mentioned earlier, owing to an atypical surge in fuel prices since the fourth quarter of 2021, we have opted to use the average wholesale electricity price from 2018 to 2020. This timeframe is considered representative of the long-run electricity pricing trends for our analytical purposes.

We assumed that AP, CP, EP, and wholesale electricity price would remain constant through 2050. This approach serves to mitigate the risk of overestimating electricity prices, thereby preventing potential exaggeration of power plants' revenue and subsequent overestimation of stranded asset

[3] The grouping of the 12 gas-fired IPPs mentioned here encompasses Khanom Electricity Generating Company Limited (KEGCO), Global Power Synergy Company Limited (GPSC), Ratchaburi Electricity Generating Company Limited (RATCH), Glow Energy Public Company Limited (GLOW IPP), Eastern Power and Electric Company Limited (EPEC), Gulf Power Limited (GPG), Ratchaburi Power Company Limited (RPCL), Gulf JP Nong Saeng Company Limited (GNS), Gulf JP Uthai Company Limited (GUT), Gulf SRC Company Limited (GSRC), Gulf PD Company Limited (GPD), and Hin Kong Power Company Limited (HKP). Additionally, it also includes two coal-fired IPPs - BLCP Power Limited (BLCP) and GHECO-ONE Company Limited, Unit 1 (GOC-T1).

[4] As of September 2020, the reported estimated electricity purchase cost from SPPs of the FIRM type encompassed all fuel types without distinguishing between gas and coal-fired power plants. Consequently, we opted to rely on data spanning from January 2018 to August 2020 for the analysis of SPPs. Additionally, data for the months of May to August 2018 could not be located. As a result, information for this specific period has been omitted from the calculation.

values.

Figure 10 Gas and coal-fired power plants source of revenue.

IPP

Availability Payment: AP
- Capacity cost - construction cost
- Fixed O&M - operating and maintenance cost

Energy Payment: EP
- Variable cost - fuel cost

SPP (Firm Type)

Capacity Payment: CP
- Capacity cost - construction cost
- Fixed O&M - operating and maintenance cost

Energy Payment: EP
- Variable cost - fuel cost

Fuel Saving: FS
- Revenue granted when fuel consumption falls below the standard amount regulated by EGAT

IUs

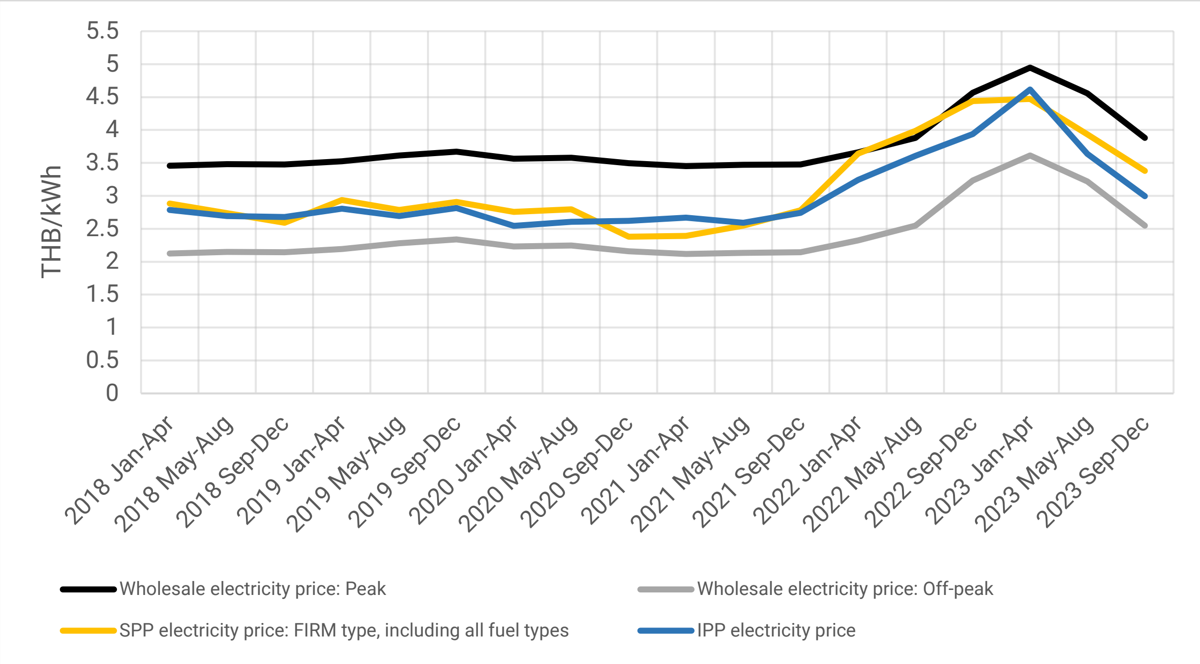
Wholesale Price

The summarized table below outlines the average electricity price for IPPs, SPPs, and IUs used in this study (a 3-year average from 2018 to 2020), while Figure 11 displays the quarterly average electricity prices for the same period from 2018 to 2023.

Table 7 The average electricity price for IPPs, SPPs, and IUs.

PPA type	Data point	Fuel type	Average 3 years (2018-2020)
IPP	Availability payment + Energy payment	Gas	3,218.40 THB/MWh
		Coal	1,678.98 THB/MWh
SPP	Capacity payment + Energy payment	Gas	2,849.43 THB/MWh
		Coal	2,068.93 THB/MWh
IU	Wholesale price	Gas and coal	3,275.65 THB/MWh

Figure 11 Quarterly average electricity prices for IPPs, SPPs, and IUs from 2018 to 2023



B.4 Powerplants' Operations Cost and Capital Expenditure

In our analysis, we categorize the power plants into two primary types: Subcritical Coal and Natural Gas Combined Cycle. These categories represent the majority of coal-fired and gas-fired power plants in Thailand. It is important to note that the costs associated with operating and constructing power plants vary by region. Consequently, our analysis primarily draws upon data presented in Handayani et al. (2022), which focuses on the power sector within ASEAN countries, including Thailand. The parameters considered in this study include facility lifetime, fixed operations and maintenance costs (fixed O&M), variable operations and maintenance costs (variable O&M), capital costs for newly built power plants, and fuel prices. However, it is notable that one critical variable, the heat rate, is absent from this literature. Therefore, we supplement our analysis with data from Lazard (2023), a reputable consulting firm.

For consistency, all costs have been adjusted to reflect the 2024 price level. Nevertheless, for the remainder of our analysis, we assume price stability. We recognize the limitations of this assumption, particularly regarding the recent volatility in fuel prices. Therefore, we intend to perform a sensitivity analysis after presenting our initial findings. The exchange rate utilized in this analysis is 32 THB/USD.

B.5 Weighted Average Cost of Capital

The Weighted Average Cost of Capital (WACC) is an integral metric used in financial models to assess the efficiency of investments, business valuation, and in estimating economic value added (Angelopoulos, et al., 2016). The computation of WACC involves two components: the cost of debt and the cost of equity. The cost of equity was determined in our analysis using the Capital Asset Pricing Model (CAPM). CAPM is favored for its simplicity which allows for the relative transparency of the obtained results (Franc-Dąbrowska, Mądra-Sawicka, & Milewska, 2021). From this model, the cost of equity was derived by adding the long-term risk-free rate to the product of the market's equity risk premium and the stock's Beta. We calculated the cost of debt from the historical financing costs during 2020 – 2022, as reported in the companies' financial statements.

The WACC was calculated with the following formula:

Equation 1 WACC calculation

$$WACC = \frac{E}{V} \cdot K_e - \frac{D}{V} \cdot K_d(1 - Tax_c)$$

where E is the value of equity, D is the company's debt, V is the total capital $(E + D)$, K_e is the cost of equity, K_d is the cost of debt, and Tax_c is corporate tax. It is important to note that the final component reflects the reduction in the cost of debt due to the tax shield.

In our analysis, we computed the WACC for five major Thai energy utilities listed publicly: Gulf Energy Development PCL (GULF), B.Grimm Power PCL (BGRIM), Electricity Generating PCL (EGCO), Global Power Synergy PCL (GPSC), and Ratch Group PCL (RATCH). Considering the potential inaccuracies of relying solely on historical data, which may not reflect the current heightened financing costs, we made appropriate adjustments to the WACC. Consequently, our computed average WACC is 8.11%, representing the energy utilities sector in Thailand.

B.6 Effective Tax Rate

The Effective Tax Rate (ETR) serves as a crucial metric for evaluating a company's tax strategy and management. It is defined as the tax provision represented as a percentage of income before corporate income tax, extracted directly from the income statement (PwC, 2015).

While the traditional approach typically calculates the Effective Tax Rate (ETR) by dividing the income tax expense with the earnings before taxes, our methodology opts to calculate the proportion of taxes in relation to the Earnings Before Interest, Taxes, and Depreciation (EBITDA) for each power plant. This decision is made to align with this study, in which EBITDA serves as the initial point for evaluating the free cash flow to the firm. This chosen methodology is consistent with the approach suggested by Breitenstein et al. (2021).

Data for tax expenses and EBITDA were collected on an annual basis from 2019 to 2023 for 75 gas power plant companies and 10 coal-fired power plant companies. Following this, we calculate a 5-year average ETR for gas and coal companies separately, utilizing the formula shown in Equation 2. These rates are then applied consistently to all companies since our analysis shows that company size does not significantly impact on the ETR. As a result, we find that the 5-year average ETR for gas and coal companies is 6.11% and 9.74%, respectively.

Equation 2 Effective tax rate calculation

$$Effective\ tax\ rate = \frac{Tax\ expense}{Earnings\ before\ interest, taxes, and\ depreciation}$$

C. Detailed Methodology

C.1 Sequencing Stranded Assets Criteria

In evaluating the stranded coal and gas powerplants in Thailand, a crucial aspect involves determining the sequence in which oil/natural gas and coal-fired power units may become stranded. While no standardized method exists for establishing this sequence, various studies have proposed multi-criteria assessments, often presented as a composite score. These indicators encompass economic, social, and environmental dimensions, including energy system efficiency, installation cost, electric energy cost, CO_2 production, and land use (Afgan & Carvalho, 2002).

Regarding the criteria for determining the sequence of stranding in coal-fired power plants, prior research, notably conducted in China by Zhang et al., has examined various factors guiding the decision-making process for decommissioning coal power units. These considerations encompass the duration of service since construction, capacity size, energy efficiency[5], technology type (with a specific emphasis on whether it is a Combined Heat and Power (CHP) unit), and ownership, distinguishing between power companies and industrial firms (Zhang, et al., 2021; Zhang, Ren, Kang, Zhou, & Yuan, 2022).

This study employs a weighted multi-criteria decision analysis, building upon the framework established by Zhang et al. In alignment with the Thai context and the constraints of data accessibility, we have chosen four indicators. Equal weights are assigned to each indicator to account for different aspects impacting the decommissioning of these power units. The selected indicators are:

1. **Unit Capacity Size (MW):** Larger power plants typically exhibit better efficiency (Sargent & Lundy, L.L.C., 2009; Ratanakuakangwan & Morita, 2021). We thus assumed that the probability of early retirement for power plants is negatively correlated with their capacity size. Consequently, power plants with smaller installed capacities are assigned to lower scores and are more likely to be early decommissioned if required.
2. **Plant Capacity Size (MW):** Similar to the rationale applied for unit capacity size, this criterion consolidates the capacity size at the plant level. In instances where two power units possess identical capacity sizes and comparable levels of other factors, the unit affiliated with a lower plant-level capacity is more likely to be earmarked for early retirement due to principles of economies of scale.
3. **Unit Status:** This indicator categorizes the stage of a power plant, classifying it as

[5] Energy efficiency is determined by the size of the coal-fired power plant, categorizing it as either 'Qualified' or 'Unqualified.' The classification hinges on whether the energy efficiency of the coal power unit aligns with the emission standards mandated by the government.

either announced, pre-construction, construction, or operating.[6] Aligned with the commission date indicator, operating power plants are expected to age before those under construction, leading to a quicker decline in efficiency.

4. **Commission Date:** Previous studies have demonstrated a negative correlation between power plant age and its operational efficiency (Ratanakuakangwan & Morita, 2021). Consequently, it is assumed that older power plants exhibit diminished efficiency and should be prioritized for early decommissioned.

Table 8 summarizes the composite scores for gas-fired power units, while Table 9 presents the same for coal-fired power units. A lower composite score indicates poorer unit performance and a higher risk of becoming stranded assets. The overall composite score is calculated using Equation 3, which integrates the various indicators into singular metrics.

Table 8 Composite scores of gas-fired power units

Dimension	Weight	1	2	3	4	5	6
Unit capacity size	25.0%	[0,100]	(100,150]	(150,600]	(600,1000]	(1,000, +)	
Plant capacity size	25.0%	[0,100]	(100,200]	(200,300]	(300,1000]	(1000,2000]	(2000, +)
Unit status	25.0%	Operating	Construction	Pre-construction	Announced		
Commission date	25.0%	before 2000	2001 - 2010	2011-2015	2016-2020	2021-2025	2026 onwards

Table 9 Composite score of coal-fired power units

Dimension	Weight	1	2	3	4	5	6
Unit capacity size	25.0%	[0,100]	(100,150]	(150,600]	(600, +)		
Plant capacity size	25.0%	[0,100]	(100,200]	(200,300]	(300,1000]	(1000,2000]	(2000, +)
Unit status	25.0%	Operating	Permitted	Announced			
Commission date	25.0%	before 2000	2001 - 2010	2011-2015	2016-2020	2021-2025	2026 onwards

[6] © Global Energy Monitor has defined power plant statuses as follows:
Announced: Projects that have been publicly reported but have not yet moved actively forward by applying for permits or seeking land, material, or financing.
Pre-construction: Projects that are actively moving forward in seeking governmental approvals, land rights, or financing.
Construction: Projects where physical construction (i.e. equipment or building, not just a ground-breaking ceremony or early site preparation) has begun.
Permitted: Projects that have secured all environmental permits but have not broken ground.
Operating: Commercial operation has begun (Global Energy Monitor, 2023).

Equation 3 Composite score calculation

$$\text{Composite score} = \sum_{i=1}^{4} W_i * S_i$$

Where:

- $\boldsymbol{W_i}$ represents the weightage assigned to each criterion,
- $\boldsymbol{S_i}$ denotes the score attributed to each criterion.

C.2 Stranded Powerplant Valuation

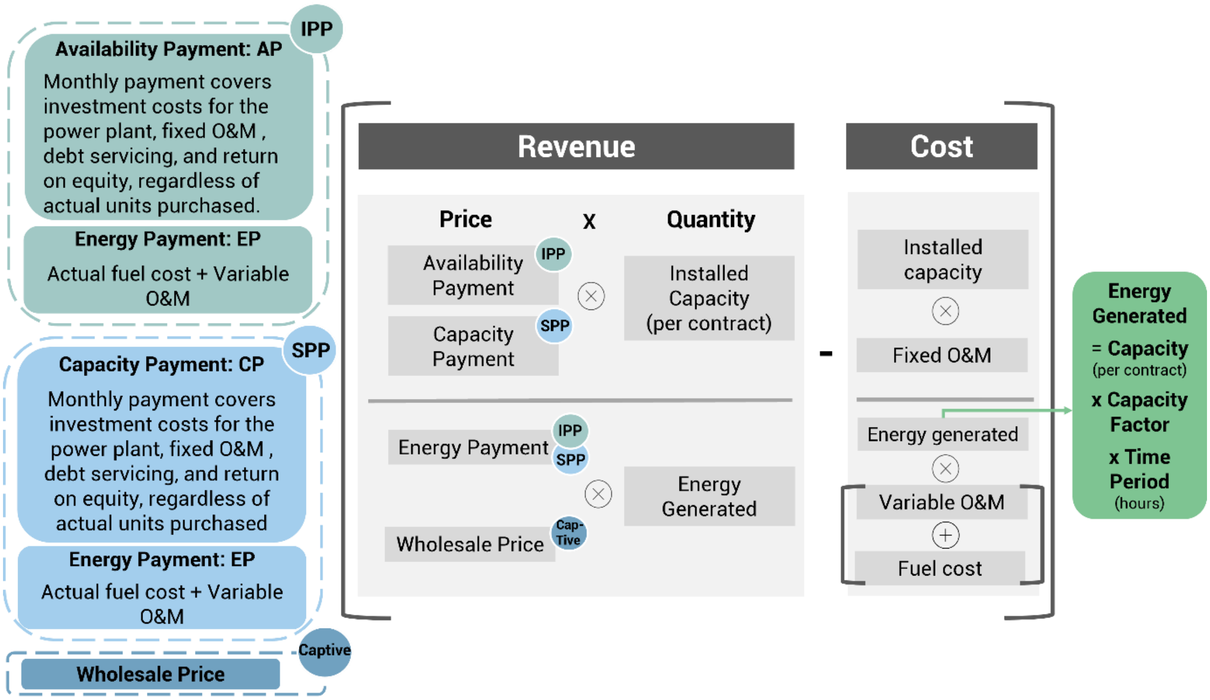
We align the installed capacity of each scenario with its respective energy pathway and determine the sequence of stranded assets based on a composite score. Once the years in which specific power plants will become stranded are identified, we proceed to calculate their stranded value using the Discounted Cash Flow (DCF) model.

The DCF model is extensively utilized at the physical asset, operator, and financial asset levels due to its forward-looking approach to valuation, as highlighted by Breitenstein et al. (2021). This model calculates the present value of anticipated future cash flows, explicitly incorporating investor-specific assumptions and expectations which allow for adjustment made within each scenario. This adaptability makes the DCF model particularly effective for scenario-based adjustments, a point emphasized by (French, 2006)

The DCF model comprises two primary steps. Initially, the model estimates the unleveraged free cash flows (FCF) for each year. Subsequently, these cash flows are discounted using the Weighted Average Cost of Capital (WACC) method, which accounts for the tax benefits and interest payments associated with debt capital (Breitenstein, Anke, Nguyen, & Walther, 2021). This step yields the net present value (NPV) that incorporates leverage.

The calculation begins at the power plant level, where earnings before interest, taxes, depreciation, and amortization (EBITDA) are determined. This involves deducing operation and maintenance costs from revenue streams including availability payment and energy payment (for IPPs and government-owned plants), capacity payment and energy payment (for SPPs), and sale of electricity (for captive power plants or IUs). The previous section briefly outlines key assumptions related to costs, including fuel, variable, and fixed expenses. In terms of capacity factors, we base our primary case scenarios on the PDP 2018 Revision 1 and utilize the information from the Rapid Transformation revision 1 for the alternate scenarios, acknowledging the dynamic annual changes in capacity factors according to each energy pathway assumption. FCF is then calculated by deducting taxes (based on the effective tax rate) from EBITDA. It is important to note that for existing power plants, no further investments are assumed; hence, capital expenditure (CAPEX) is relevant only for power plants that are pre-construction or announced.

Figure 12 EBITDA calculation



Equation 4 Free cash flow calculation

$$FCF_t = EBITDA_t \cdot (1 - Effective\ Tax\ Rate) - CAPEX_t$$

The FCFs are then discounted by the WACC described in Section 4 and Appendix B.5, and and Appendix B.5, and to determine the NPV of the gas-fired and coal-fired power plants.

Equation 5 Net present value calculation.

$$NPV_0 = \sum_{t=1}^{T} \left(\frac{FCF_t}{(1 + WACC)^t}\right)$$

To assess potential stranded losses in each energy pathway, we consider the premature decommissioning of power plants as a measure of stranded loss. This stranded loss is estimated using the DCF model, but only including the FCF generated during the years when the plant is considered stranded. It is crucial to emphasize that for new power plants, NPV is a key consideration. In scenarios where early decommissioning leads to a negative NPV, it is inferred that the construction of the power plant would not be a viable option. This assumes that firms will logically opt against pursuing projects that are projected to result in financial losses. Consequently, in these instances, we conservatively assume the stranded loss to be zero, reflecting the improbability of such projects proceeding to the construction phase.

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