MUFG Asia Transition White Paper 2023

Accelerating Asia's power sector decarbonization
with a focus on Indonesia and Thailand

MUFG

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Preface

The disastrous effects of global warming and rising CO_2 emissions are becoming more apparent with each passing day. Thus, the need to address these challenges is growing more urgent if we are to leave a sustainable world – where societal, environmental, and economic growth can coexist – for future generations.

MUFG defines its corporate purpose as being “Committed to Empowering a Brighter Future” and has pledged to achieve carbon neutrality by 2050, aligned with the Paris Agreement. As a global financial organization based in Japan, we have been helping our customers worldwide reach their net-zero objectives. We believe it is important to work towards emissions reductions in the real economy through engagement, not divestment. This means engaging with customers on realistic approaches, promoting transition financing, and taking an active role in developing international frameworks aimed at reducing CO_2 emissions.

MUFG has been leading the way through various global initiatives. We became a member of the Glasgow Financial Alliance for Net Zero in June 2021 – the first Japanese bank to join the Net-Zero Banking Alliance. We also led the Asia Transition Finance Study Group to promote ambitious but realistic energy transition in Asia. Moreover, we published two editions of our MUFG Transition Whitepaper, in 2022 and 2023, to help financial authorities and policymakers outside of Japan better understand the net-zero pathways of leading Japanese companies.

With this new Asia Transition White Paper, we aspire to support the broader Asia region – our extended home market – through our Partner Bank networks, noting that the region produces roughly half of the world’s CO_2 emissions. The paper recognizes that each country has its unique pathway towards carbon neutrality, based on geography, industrial structure, and energy mix, and acknowledges the different pathways our stakeholders must travel towards responsible transition.

This White Paper focuses on the power sectors of Indonesia and Thailand. We conducted in-depth discussions with policymakers and customers to understand the decarbonization levers that support national net-zero ambitions. We merged what we learned from these discussions with our financing expertise to identify key challenges and potential solutions to accelerate the bankability of these levers at scale. We believe that the analysis in this paper can be applied to other Asian countries that share similar market characteristics.

I hope this White Paper provides insight from MUFG’s perspective on how we can support decarbonization efforts of our customers in Asia, and in doing so, ultimately allows MUFG to help contribute to a more sustainable and brighter future.

Hironori Kamezawa

President & Group CEO

Mitsubishi UFJ Financial Group, Inc.

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Executive Summary

Objective of the White Paper

Financing decarbonization needs to be accelerated further, and MUFG, through this analysis and other focused efforts, is committed to having an impact in helping the world and Asia, in particular, move towards net zero.

Several studies point to the vast amount of financing required to enable the transition to a net zero economy, as well as the gap in fulfilling these funding needs. For example, the International Energy Agency (IEA) cites the need to triple the power generation capacity from renewables by 2030 globally.[1] The McKinsey Global Institute (MGI) has estimated that under the 2050 net zero scenario of The Network of Central Banks and Supervisors for Greening the Financial System (NGFS),[2] annual expenditures of about USD 950 billion will be needed for the Asia power sector through 2050. MGI also estimated that existing investment only amounts up to about USD 520 billion annually, leaving a significant gap in financing.[3]

To accelerate financing for decarbonization and reduce the annual gap, this paper explores bankability challenges of critical decarbonization levers against structured criteria and strives to provide tangible solutions to unlock real economy transition and financing. We focus on Asia's power sector because this segment represents the largest source of CO_2 emissions globally.[4] Within Asia, we have taken a closer look at Southeast Asia and, in particular, Indonesia and Thailand as key markets of MUFG's Asia business given our partnership with Bank Danamon in Indonesia and Bank of Ayudhya (Krungsri) in Thailand, as well as the ability to showcase a coal and gas decarbonization pathway.

This White Paper strives to go beyond existing literature by providing perspectives through the lens of a financial institution with deep expertise in the markets discussed and from the viewpoint of refreshed assessment, which considers actionability of proposed activities and solutions. In doing so, we have assessed the bankability of each decarbonization lever announced by governments and state utilities for each of Indonesia and Thailand. In deconstructing bankability, we see a set of constraints or considerations that are mostly technical and commercial. Technical feasibility considerations include resource availability, technology maturity, and operational complexity, which also determine whether projects are even likely to emerge. Commercial feasibility considerations include project economics, market structure factors, and environmental, social, and corporate governance (ESG) and taxonomy matters. By examining these considerations, we aim to identify challenges and potential solutions of each announced decarbonization lever to achieve bankability at scale.

Highlights from Indonesia

Although Indonesia has CO_2 per capita lower than developed economies, its power sector has one of the highest carbon intensity due to its large footprint of coal-fired power plants. Nevertheless, the country has committed to accelerating the decarbonization of its power sector. While Indonesia commits to achieving net zero by 2060 in the nationally determined contributions (NDCs), the country has a more ambitious plan of reaching net zero in the power sector by 2050 under the condition that the Just Energy Transition Partnership (JETP) is implemented.

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[1] "Tripling renewable power capacity by 2030 is vital to keep the 1.5°C goal within reach," IEA, July 21, 2023.

[2] The MGI analysis is based on the NGFS Net Zero 2050 scenario and mirrors global aspirations to cut emissions by about half by 2030 and to net zero by 2050. The scenario reaches net zero CO_2 emissions by 2050 for the global economy; meaning that there are some low residual gross CO_2 emissions in hard-to-abate sectors and some regions that are counterbalanced by CO_2 removals.

[3] "The net zero transition: What it would cost, what it could bring," McKinsey Global Institute, 2022, https://www.mckinsey.com/capabilities/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring.

[4] "CO_2 Emissions in 2022," IEA, 2023.

Despite the momentum, key challenges that need to be addressed include:

1) **Overcapacity with young fleet of coal assets:** Overcapacity in the power market is delaying the rapid development of renewable energy sources (RES). Coal occupies the largest share of Indonesia's power mix, and the fleet is relatively young with about 56% being in service for fewer than 10 years.[5] In this situation, the managed phaseout (MPO) of coal power plants is one measure that could address overcapacity and expand RES development. Already, mechanisms have been proposed to allow multiple parties to share the financial burden of MPO, such as introducing concessional capital or generating revenue by issuing carbon credits. Another potential unlock to the overcapacity comes from the demand side, by growing RES demand from leading commercial and industrial (C&I) companies with net zero ambition.

2) **Large new and upgraded grid infrastructure required:** To integrate RES into the power system at scale, grid infrastructure must be expanded to connect the RES supply and demand centers. Smart grid upgrade is also required to better manage the intermittency from the RES generation. In fact, PT Perusahaan Listrik Negara's (PLN – an Indonesian government-owned integrated electricity utility company) 10-year investments plan – Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) – estimates that USD 25 billion in investment is required by 2030[6] for grid expansion and USD 2.5 billion to USD 4.9 billion for smart grid upgrades.[7] Investment in the grid is particularly challenging as the project economics does not favor commercial investment. To unlock more investment into the grid, PLN could explore new models for project development, such as build-operate-transfer (BOT) or build-lease-transfer (BLT) to invite third-party. Under such schemes, PLN could also seek financing from concessional capital such as multilateral development banks (MDBs) to minimize the financing cost.

3) **Balancing incentives amidst the energy trilemma:** The country's need to balance environmental aspiration with affordability and energy security (commonly referred to as "energy trilemma") could send mixed signals to promote energy transition. For example, the Tingkat Komponen Dalam Negeri (TKDN) program mandates local content requirement of different goods, including the clean energy value chain (e.g., photovoltaic (PV) panel, battery). While this program strives for competitive local manufacturing, this could hamper the economics of RES projects unless local component suppliers quickly develop capabilities to produce high-quality and cost-competitive components. Another example is the subsidy on PLN's coal procurement. Although such subsidies have lowered the electricity tariff and, as a consequence, mitigated household's economic burden as well as bolstered the competitiveness of Indonesia's local businesses, it could make switching to cleaner technologies in Indonesia less economically attractive.

Highlights from Thailand

Thailand's power plant fleet generates less greenhouse gas (GHG) emissions (in terms of share of total emissions) compared to other countries in Southeast Asia because most of its electricity, about 64%, is produced using natural gas. Thailand has committed to reach carbon neutrality by 2050 and net zero GHG by 2065 under its long-term decarbonization targets. These commitments are underpinned by sector-specific plans, such as the Power Development Plan (PDP) and Alternative Energy Development Plan (AEDP) for power generation. Published in 2018, the latest PDP covers 2018-2037 and projects that 20-36% of Thailand's energy will come from RES by 2037. The share of RES will likely be higher in the next release of the PDP to align with the latest Long-Term Low Emissions and Development Strategies (LT-LEDS), which calls for 68% of the country's energy to come from RES by 2040. Various incentives have been explored to support the implementation of these plans, such as feed-in tariff (FIT) scheme and sandbox of Third-Party Access (TPA) and Utility Green Tariff (UGT).

Despite the momentum, key challenges that need to be addressed include:

1) **Investment in grid infrastructure while keeping affordability:** Expansion and upgrade of the transmission and distribution (TnD) system is also required in Thailand to accommodate more generation from RES technologies. Thailand has budgeted THB 199 billion (USD 5.6 billion) cumulative investments

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[5] Information provided by PLN.

[6] "Electricity Supply Business Plan 2021-2030," PT PLN, 2021.

[7] "PLN Continues to Encourage Smart Grid Development," Denis Riantiza Meilanova on Bisnis.com, June 25, 2021, https://ekonomi.bisnis.com/read/20210625/44/1409135/pln-terus-dorong-pengembangan-smart-grid.

2015-2036 in Thailand Smart Grid Development Master Plan 2015-2036.[8] However, Thailand also faces the energy trilemma. Financing the required investment could be challenging since passing the cost directly to the customers by raising the electricity tariff could be difficult depending on the economic situation of the country. For the past few years, the government and the utilities have been under pressure to maintain the electricity tariff low[9] to protect the households and the businesses amidst the COVID-19 pandemic and rising fuel import cost of LNG after War in Ukraine. To minimize the cost as much as possible, integrated planning for RES and grid development is key to optimize CAPEX. Financiers could also contribute by providing low-cost finance leveraging concessional capital such as MDBs.

2) **Technical advancement required to decarbonize the "last one mile":** While gas power plants serve energy transition in the short-term by providing flexibility to support intermittent RES, gas power plants will also need to decarbonize in the long-term to reach net zero. Hydrogen-gas co-firing and carbon capture, utilization, and storage (CCUS) are considered an option but both technologies are at a pre-commercialization stage. As with any nascent technology, deploying hydrogen co-firing and CCUS applications at natural gas-fired power plants would face challenges in the beginning due to unfavorable project economics without scale. These technologies would require backing from clear incentives and support from the public sector, for instance, tax incentives and development of critical infrastructure, such as a hydrogen supply chain and carbon storage hubs.

MUFG's contribution

A concerted effort from multiple stakeholders could mobilize the funding needed to drive efforts to decarbonize the power sector in Indonesia and Thailand. As a leading global financial institution, MUFG aspires to support the transition, not only in our capacity as a financier, but also by mobilizing real economy players through our customer network. Beyond our existing business activities of providing our full suite of sustainable finance products and customer engagement activities, we propose three possible solutions:

A) **Stimulate the green economy through demand orchestration:** We are exploring an initiative called the Renewable Energy Alliance (REAL), a coalition of RES buyers in Indonesia and Thailand. REAL would bring together companies willing to purchase RES in their respective countries. By aggregating RES demand, we hope to benefit RES developers by providing greater visibility to future demand and a unified voice to advocate new modes of RES procurement with regulatory bodies. It would also support project development in partnership with local power companies to explore syndication of financing.

B) **Mobilize capital at scale through blended finance:** For measures that are inherently non-bankable, such as nascent technology and grid and storage infrastructure, we propose blended finance as a potential solution, in particular the implementation through a portfolio approach with securitization capabilities. The proposed platform structure would enable efficient sourcing of capital from investors who agree to invest in a portfolio with set boundaries. This would minimize the administrative burden of agreeing on specific terms of the deal among multiple public and private investors individually for each deal, which has been the major challenge to expand use of blended finance. To further accelerate blended finance, the proposed structure also opens the investor pool through its securitization capabilities. Features of securitization, by their innate nature, draw a diversified set of investors with differing risk appetites.

C) **Bring proven financing solutions to unlock additional value:** MUFG will introduce innovative financing solutions from other markets once market condition in Asian markets allow. For example, in the United States, community solar has grown significantly, underpinned by a supportive policy landscape, and paired with financing solutions to overcome commercial feasibility issues with small ticket sizes and need for individual credit assessments. The community solar case highlights how regulation and finance can work together to drive rapid decarbonization.

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[8] "แผนปรับปรุงระบบส่งและระบบจำหน่าย ให้มีความทันสมัยรองรับเทคโนโลยีระบบไฟฟ้าในอนาคต (Grid Modernization of Transmission and Distribution)," EGAT, Provincial Electricity Authority, Metropolitan Electricity Authority, May 20, 2020; "Thailand Power Development Plan 2015-2036 (PDP2015)," Ministry of Energy, Thailand, June 30, 2015.

[9] "Behind the power tariff decision," Bangkok Post PCL, August 9, 2023, https://www.bangkokpost.com/business/general/2626143/behind-the-power-tariff-decision .

1. Introduction

1.1. Objectives of the White Paper

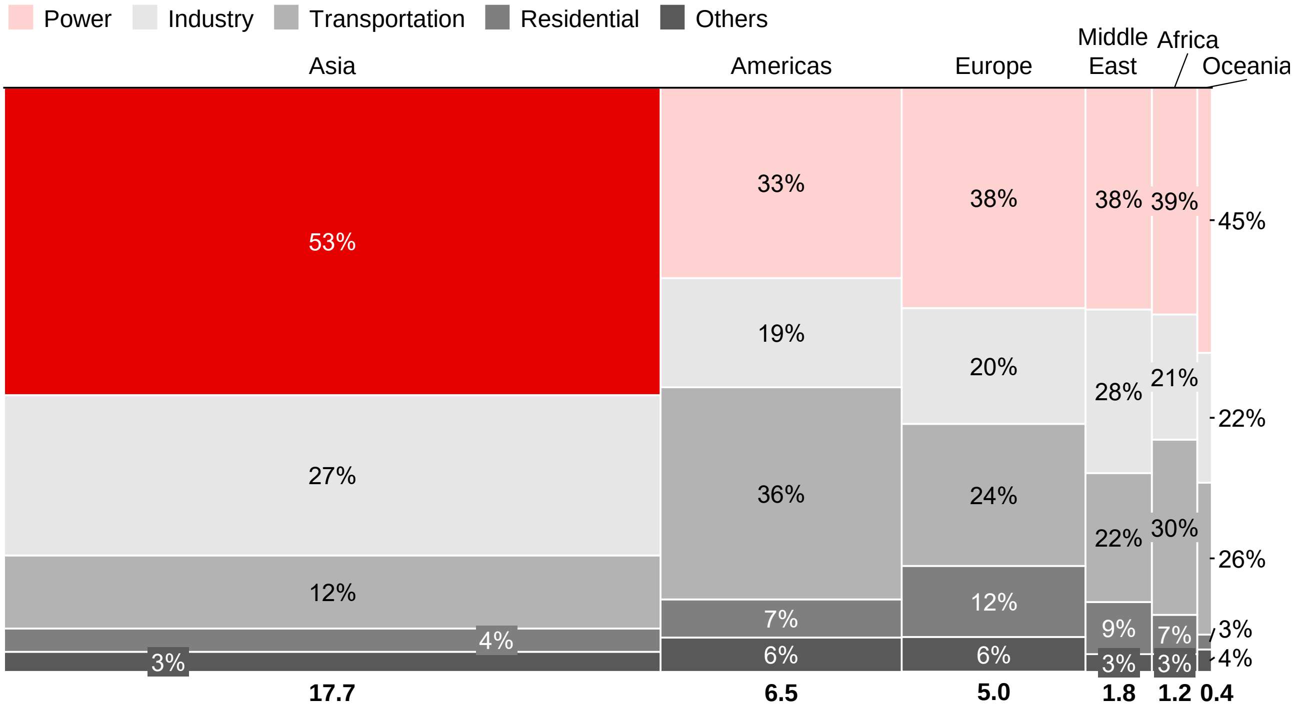
MUFG is dedicated to supporting the global effort towards decarbonization. Beyond our business activities, MUFG has invested in activities to shape industry standards and shared knowledge. This White Paper will add to these efforts by providing a holistic view of the challenges faced in decarbonizing the power sector in Asia, the region with the largest source of CO_2 emissions. Through a detailed assessment of Indonesia's and Thailand's power sectors, we aim to identify possible unlocks that various stakeholders, including energy policymakers, financial regulators, public finance providers, power sector players, power purchasers, and MUFG among other financiers, can put into action.

1.2. Case for change in Asia's power sector

As the largest population center in the world and a hub for economic growth, Asia plays a significant role in contributing to global net zero objectives. The region contributes about half of the world's CO_2 emissions and is home to 60% of the global population. Within Asia's CO_2 emissions footprint, the power sector represents 53% in 2021 owing to the reliance on fossil fuels for generation. As such, decarbonizing the power sector is a key priority for Asia, notwithstanding the catalytic effect in decarbonizing other downstream sectors such as transportation and manufacturing.

Exhibit 1: CO_2 emissions by sector and region, 2021[10]

% of region total CO_2 emissions, billion tonnes of CO_2



Momentum towards decarbonizing the power sector in the region has been building, with about 80% of Asian countries committing to net zero goals as part of their long-term decarbonization targets.[11] However, there is a significant financing gap for these initiatives. Energy transition in Asia will require a vast amount of capital of around USD 950 billion a year, and a cumulative investment of between USD 20 trillion and 30 trillion by 2050 (**Exhibit 2**).[12] To meet the current policy scenario of NGFS, which refers only to the financing required to meet current policies, an additional USD 50 billion in capital would be required each year in Asia. However, to

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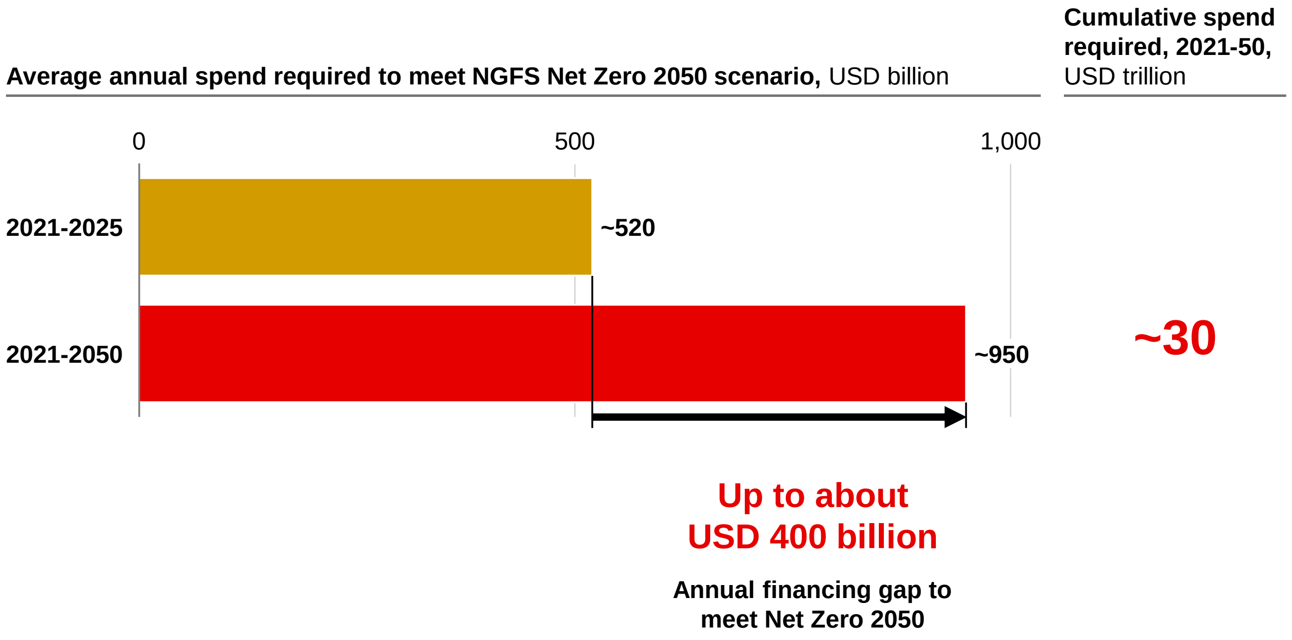
[10] "Global Energy Review: CO_2 Emissions in 2021," IEA, March 2023.

[11] "2022 Review of climate ambition in Asia and the Pacific," the Economic and Social Commission for Asia and the Pacific (ESCAP), the United Nations Environment Programme (UNEP), and United Nations Children's Fund (UNICEF), November 1; 2022. As of August 2022, 39 of 49 Asia-Pacific countries have made net zero pledges.

[12] "Asia's net-zero transition: Opportunity and risk amid climate action," McKinsey & Company, April 29, 2022, Link.

achieve net zero by 2050, power sector decarbonization financing would need to increase significantly, by as much as USD 400 billion a year. This gap can be attributed to numerous factors explored in our analysis.

Exhibit 2: Average annual spend on physical assets required for power sector decarbonization in Asia[13]



1.3. Approach of this paper

Scope of the countries

We provide an overview of the status of energy transition of five Southeast Asian countries — Indonesia, the Philippines, Singapore, Thailand, and Vietnam — and further deep dive into two countries — Indonesia and Thailand. Southeast Asia is responsible for a meaningful share of CO_2 emissions from Asia's power sector, albeit not the largest share. Notably, the sub-region has experienced some of the fastest growth in CO_2 emissions over the past decade because of its economic growth, which was met by rapid development of fossil fuel power plants (**Table 1**).

Table 1: CO_2 emission share and growth across APAC[14]

	Southeast Asia	China	India	Japan	Korea	Australia/ New Zealand
CO_2 emission share within Asia's power sector in 2020	9%	62%	13%	6%	3%	2%
Growth in CO_2 emission from power sector (2010-2020)	43%	28%	32%	-13%	-1%	-5%

Moreover, since MUFG has a significant presence in Southeast Asia, with partner banks in Indonesia, the Philippines, Thailand, and Vietnam, as well as our regional headquarters in Singapore, we believe we may be able to create more tangible impact in these countries (**Exhibit 3**).

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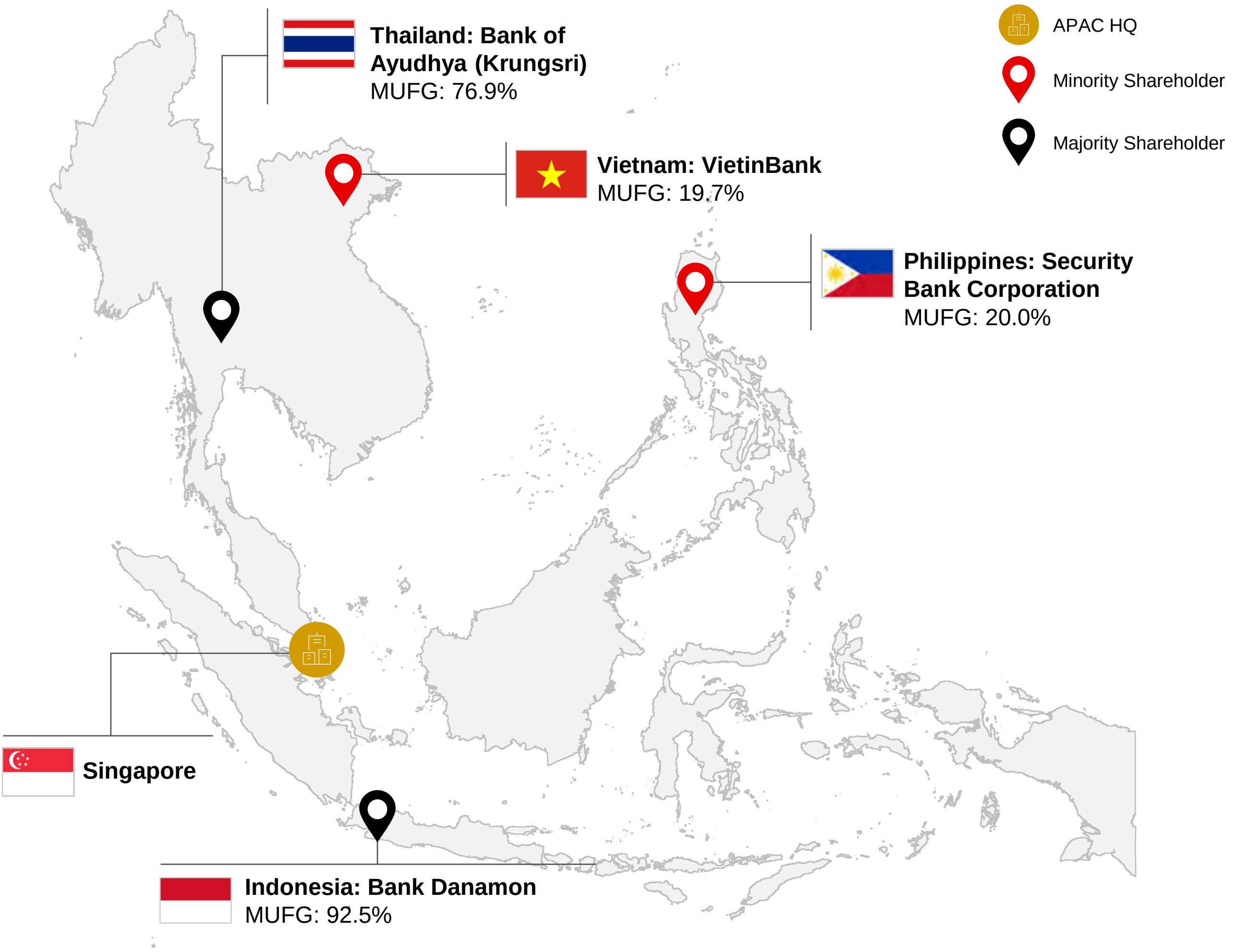
[13] "The net-zero transition: What it would cost, what it could bring," McKinsey Global Institute, 2022, https://www.mckinsey.com/capabilities/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring; Based on the NGFS Net Zero 2050 scenario, a hypothetical scenario and not a projection.

[14] "Greenhouse Gas Emissions from Energy," IEA, Last updated August 2, 2023, https://www.iea.org/countries/.

Exhibit 3: MUFG’s footprint in Asia



Furthermore, we look closely at Indonesia and Thailand and provide detailed analyses on their power sectors, momentum towards energy transition, and bankability assessment of the decarbonization measures. By exploring these two countries, we can account for two major decarbonization pathways: Indonesia represents a coal-dependent country, while Thailand represents natural gas-dependent country, thus requiring different approaches to decarbonization.

Analytical approach

In examining power sectors of Indonesia and Thailand, we begin by identifying the key decarbonization levers announced by the respective government and major power producers. A decarbonization lever is broadly defined as any technology, product, or process that contributes to the reduction or mitigation of GHG emissions in the power sector.

From this list of key decarbonization levers, we will analyze the challenges and potential solutions required from the perspective of ‘bankability at scale’.

Bankability is a crucial factor in ensuring fund flows can reach these decarbonization levers. While bankability may be first thought of as driven solely by project economics, we find that it alone does not explain why decarbonization levers cannot be scaled easily. A broader set of factors must be considered, for example external market structure factors that affect the cash flow of a project. Moreover, where a lever becomes bankable, we also consider the necessary steps to achieve scalability to contribute towards national net zero ambitions.

We assess bankability of each decarbonization lever based on **technical feasibility** and **commercial feasibility**. Technical feasibility and commercial feasibility are functions of a holistic set of criteria (**Exhibit 4**). Based on these criteria, the technical and commercial feasibility of each announced decarbonization lever is assessed on a scale of 1 through 4, with 1 representing high feasibility and 4 low feasibility.

Exhibit 4: Bankability assessment criteria

Criteria definition

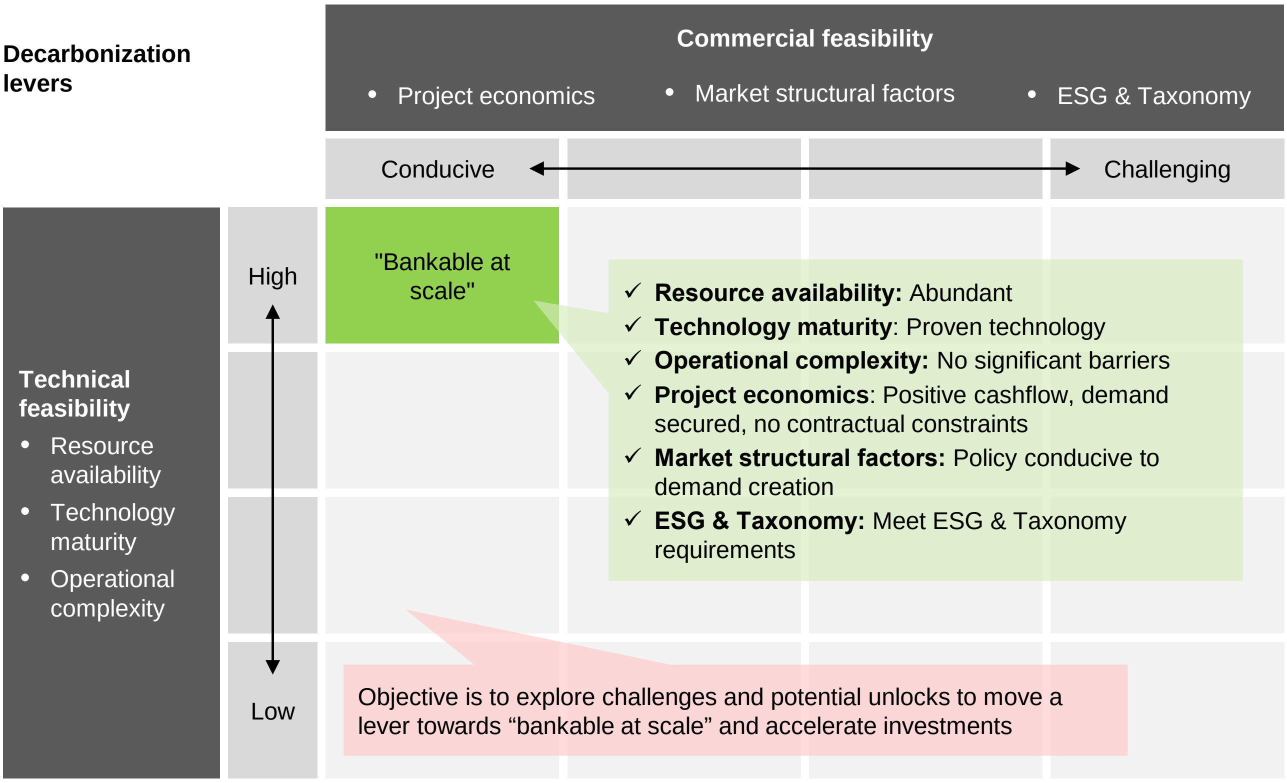
Technical feasibility

- **Resource availability:** Whether the natural resources (e.g., solar, wind, biomass) are abundant in the country
- **Technology maturity:** Whether the technology has a proven track record and is safe
- **Operational complexity:** Whether the decarbonization lever faces challenges in the end-to-end physical implementation

Commercial feasibility

- **Project economics:** Whether cashflow is attractive and size is large enough
- **Market structural factors:** Whether market factors external to the project are conducive e.g., state of energy market, feedstock and supply chain risk, policy and regulatory risk
- **ESG & Taxonomy:** Whether projects comply to internal risk policies for ESG, reputational risk, clear taxonomy of investment and classification of financed emissions

Decarbonization lever assessment framework



- ✓ **Resource availability:** Abundant
- ✓ **Technology maturity**: Proven technology
- ✓ **Operational complexity:** No significant barriers
- ✓ **Project economics**: Positive cashflow, demand secured, no contractual constraints
- ✓ **Market structural factors:** Policy conducive to demand creation
- ✓ **ESG & Taxonomy:** Meet ESG & Taxonomy requirements

Objective is to explore challenges and potential unlocks to move a lever towards “bankable at scale” and accelerate investments

We assume bankability as a spectrum ranging from low to high. A lever with low bankability does not mean it cannot receive financing, but rather that funding would be more challenging compared to one with high bankability.

Through this lens, our analysis aims to identify the challenges and potential solutions to improving the technical feasibility, commercial feasibility, or both for each decarbonization lever, to increase its bankability and accelerate the project pipeline.

Definitions of axis, pillars, and sub-pillars used to assess bankability

1) **Technical feasibility** is an assessment of whether a decarbonization lever can be physically implemented at scale. The assessment comprises evaluations on resource availability, technology maturity, and operational complexity.

   A) **Resource availability:** The natural endowment, such as solar irradiation, wind speed, and geothermal potential, in an area and the distance between power supplies and demand centers.

B) **Technology maturity:** How well the technology can be applied to a large-scale operation in a safe and proven manner. Referenced the IEA's technology readiness level (TRL) scale.

C) **Operational complexity:** The extent of challenges involved in the end-to-end physical implementation of a decarbonization lever, for instance the difficulty encountered in the biomass supply chain.

2) **Commercial feasibility** is an assessment of whether a decarbonization lever is commercially viable as measured by project economics, market structural features, and ESG & taxonomy considerations.

A) **Project economics:** Project-level cash flows, visibility of revenues, costs, and factors such as contractual undertakings, scale, and any economies or diseconomies of scale.

B) **Market structural factors:** The broader market conditions and supply chains that may impact the standalone project economics and its commercial feasibility. For example, the existing electricity market's ability to accommodate additional capacity from RES and local TnD networks' abilities to address RES intermittency can make renewable power more or less viable.

C) **ESG & Taxonomy:** Intangible factors that play into an investment decision, such as implications for communities, exposures classified as financed emissions, and clarity of taxonomy.

Potential unlocks for each challenge are framed across the corresponding stakeholders—energy/financial policymakers, ecosystem players, and public/private financiers in Indonesia and Thailand—that are expected to be in the best positions to act. Aligned with the unlocks identified, MUFG proposes initiatives to support accelerating power sector decarbonization in Asia from a commercial financer's perspective. These are summarized and outlined in Section 5.

Sidebar: MUFG's net-zero work to date

MUFG has pledged to achieve net zero financed emissions by 2050 and became a signatory of the Net Zero Banking Alliance (NZBA) in June 2021. To date, MUFG has disclosed interim GHG reduction targets through 2030 for five sectors and has engaged with its clients to support their journeys towards net zero.[15]

To accelerate the transition in the real economy and meet this commitment, MUFG has been shaping industry initiatives and leading the development of knowledge on the topic. For example, MUFG chaired the development of the NZBA Transition Finance Guide,[16] which laid out the principles of transition finance and recommended protocols. MUFG has also led the discussion, as part of the secretariat of the Asia Transition Finance Study Group (ATFSG). The ATFSG brings together financial institutions and regulators to discuss challenges and solutions to accelerate transition finance in Asia.[17] This work has produced knowledge and resources for stakeholders, such as the publication of Technology List and Perspectives for Transition Finance in Asia under the name of Energy Research Institute of Asia (ERIA), which defines transition technologies for Asia.[18]

As the global leading financial institution in Japan, MUFG has also published a series of papers focusing on the transition pathway of Japan. "Transition Whitepaper 2022" conveys MUFG's perspective on the transition pathway for core sectors in Japan and how Japanese companies are moving towards carbon neutrality. The subsequent paper, "Transition Whitepaper 2023," delves into the critical technologies required to decarbonize Japan and outlines how MUFG will assess and support its clients' transitions.

The next section provides broader analysis across five countries—Indonesia, the Philippines, Singapore, Thailand, and Vietnam—a strong presence through its partner bank network. This will be presented from the perspective of current energy mix and pathway to decarbonization in the power sector.

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[15] The five sectors are maritime, oil and gas, power, real estate, and steel.

[16] "NZBA Transition Finance Guide," UNEP Finance Initiative, October 2022, https://www.unepfi.org/wordpress/wp-content/uploads/2022/10/NZBA-Transition-Finance-Guide.pdf.

[17] "Publication of guidelines by Asia Transition Finance Study Group (ATFSG)," MUFG, February 2022.

[18] "Technology List and Perspectives for Transition Finance in Asia," ERIA, September 2022.

2. Power sector decarbonization pathways in 5 Southeast Asian countries

Highlights

The power sectors in Indonesia, the Philippines, Singapore, Thailand, and Vietnam are all experiencing strong growth, driven by each country's rapid development. The growth in power demand has largely been met by introducing coal and natural gas-fueled power plants, which are affordable, reliable, and secure. However, this poses a challenge for each country to decarbonize given their relatively new power plant fleets that rely on fossil fuels.

Nevertheless, each country has set a NDC under the Paris Agreement. Specific targets for power sector have also been clarified either as a decarbonization target or a share of RES target.

Considering the varying starting points in terms of energy mix and natural endowment, these five countries can be categorized roughly into two archetypes of decarbonization pathway: **1) Countries predominantly powered through coal generation, and 2) countries predominantly powered through natural gas generation.**

1) **Indonesia, the Philippines, Vietnam:** Coal-dependent countries looking to diversify the power generation mix using RES and natural gas. Indonesia and Vietnam have committed to early retirement of coal-fired plants and transitioning to RES.
2) **Singapore, Thailand:** Fuel mix with large share of natural gas generation. Focused on increasing RES while decarbonizing the existing natural gas fleet using technology innovations such as hydrogen co-firing and CCUS.

Singapore is also an important market given its pivotal role in driving multiple initiatives affecting the region, such as grid development in member states of the Association of Southeast Asian Nations (ASEAN) and the Project Greenprint led by Monetary Authority of Singapore (MAS).

2.1. Overview of the power sector

2.1.1. Current state of the power market

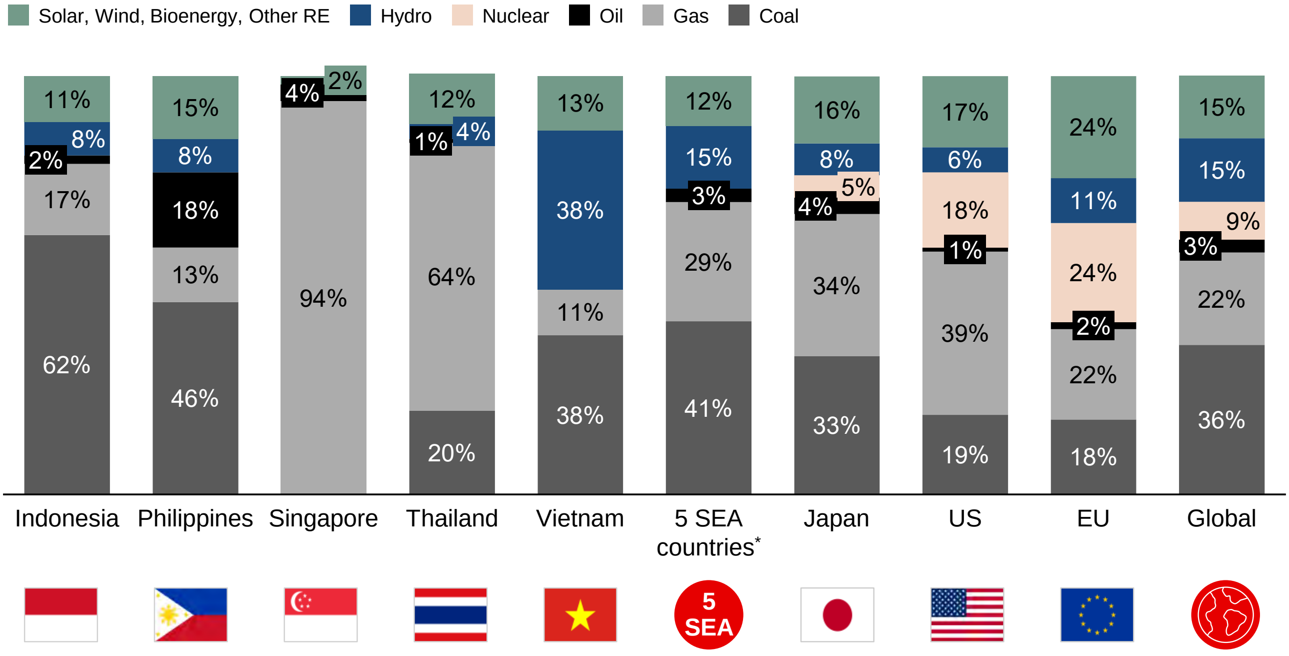
Asian countries are at different stages of development compared to each other, unlike in Europe where the differences between countries are smaller. Many Asian countries are experiencing rapid GDP growth and rapid power demand growth – in the five ASEAN countries (Indonesia, the Philippines, Singapore, Thailand, and Vietnam), electricity demand rose by nearly 50% from 599 TWh in 2012 to 955 TWh in 2022. Therefore, they will need to balance sustainability, reliability, and affordability to support social and economic development and realize a Paris-aligned transition.

Table 2: Electricity generation and GDP trend

	Indonesia	Philippines	Singapore	Thailand	Vietnam
Electricity generation in 2022 (TWh)[19]	334	113	55	191	218
Annual electricity generation growth over last 10 years[20]	4.8%	4.5%	2.1%	2.0%	8.6%
Annual GDP[21] growth over last 10 years[22]	4.2%	4.9%	3.3%	1.8%	6.1%

Reflecting the need to balance the sustainability, reliability, and affordability trilemma, many Asian countries have relied on fossil fuels in the past years to match economic growth. In Indonesia, the Philippines, Singapore, Thailand, and Vietnam, 73% of electricity production came from fossil fuels in 2022, higher than the global share of 61%, the US share of 59%, and the EU share of 42%.

Exhibit 5: Electricity production by source, by country or region, 2022[23]



* 5 SEA (Southeast Asia) countries are Indonesia, the Philippines, Singapore, Thailand, and Vietnam

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[19] "Energy," Hannah Ritchie, Max Roser, and Pablo Rosado on Our World in Data, 2022, https://ourworldindata.org/energy/country/.

[20] Ibid.

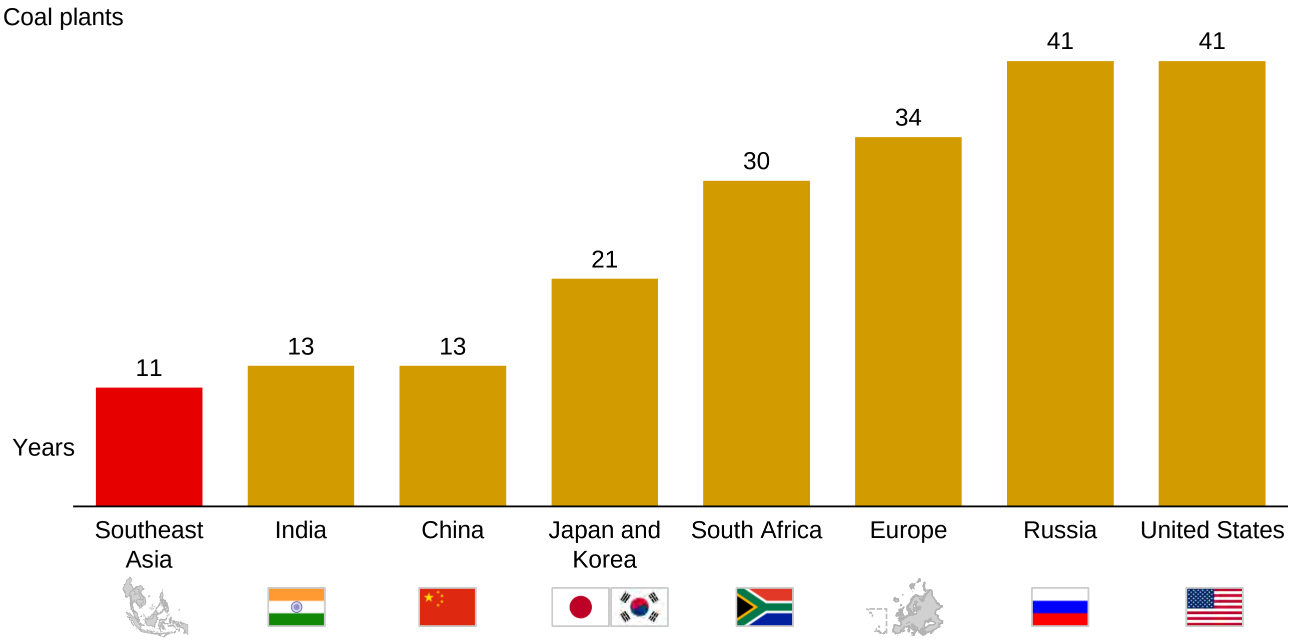
[21] Real GDP in constant local currency.

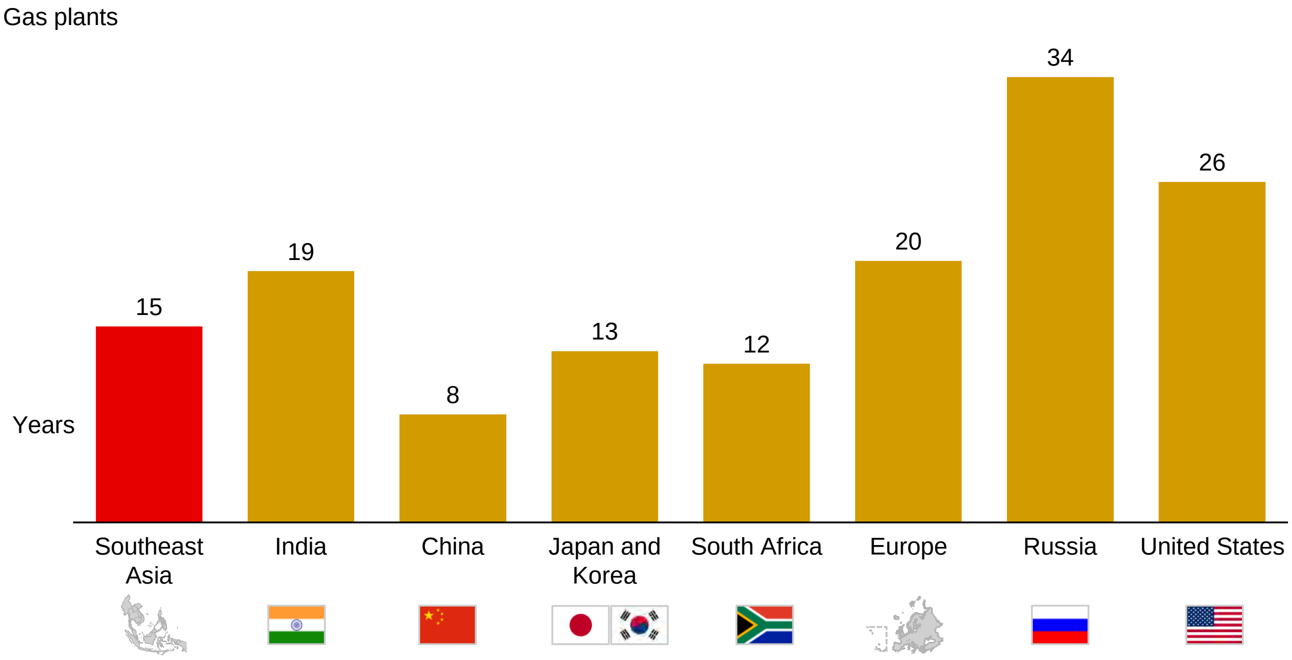
[22] "DataBank World Development Indicators", World Bank, Last updated on October 26, 2023, https://databank.worldbank.org/source/world-development-indicators.

[23] "Electricity Mix," Hannah Ritchie and Pablo Rosado on Our World in Data, 2022, https://ourworldindata.org/electricity-mix. The source includes comparable data across countries. However, it may differ slightly from other sources due to definition difference.

Since investments to build up power generation capacity through fossil-fuel power plants happened recently, fossil-fuel power plants have a relatively young vintage. The average age is 11 years for coal-fired power plants in Southeast Asia and 15 years for natural gas-fired power plants (**Exhibit 6**).

Exhibit 6: Average age of existing coal plants and gas plants in 2020[24]





As a result, power sectors in these countries produce the largest share of their country's overall GHG emissions. For example, in the Philippines, the power sector contributes 57% of the country's GHG emissions compared to 45% globally.

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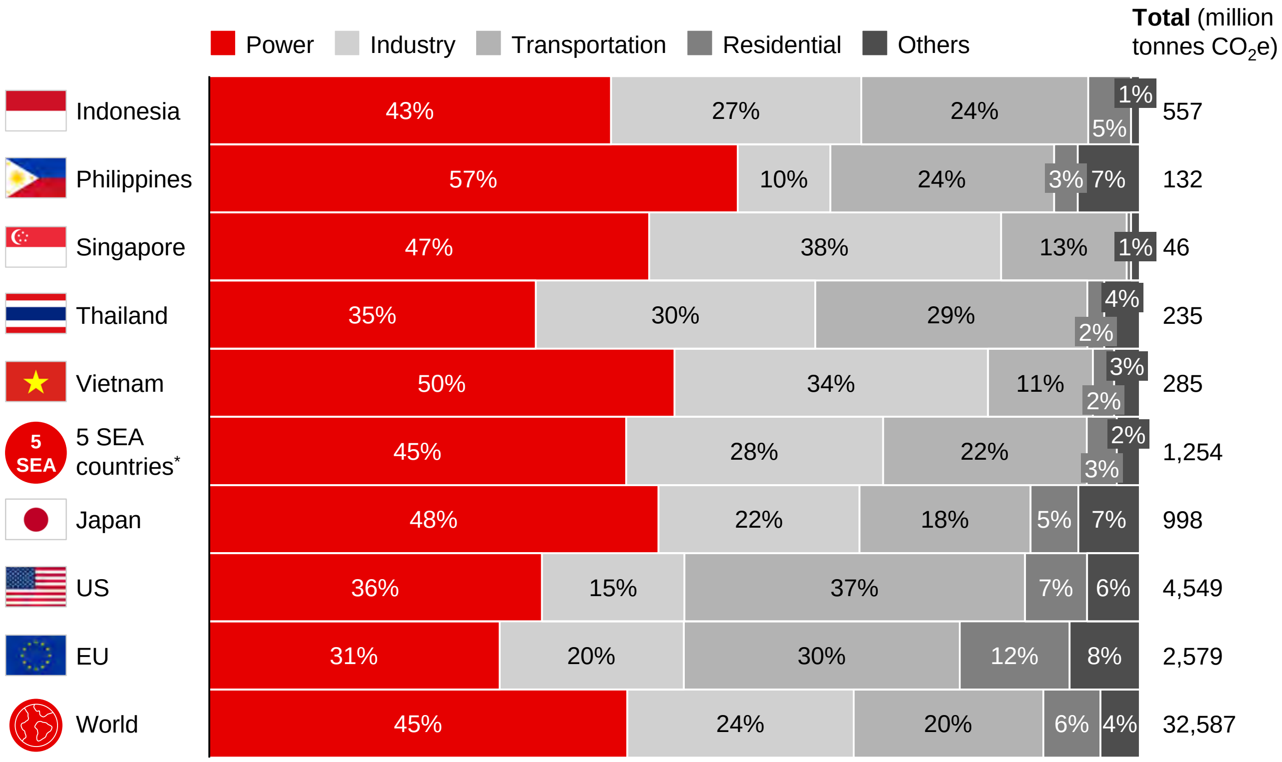
[24] "World Energy Outlook," IEA, 2021. For gas plants, the analysis is based on data from "Platts Market Data Electric Power Database," S&P Global, accessed in October 2023, https://www.spglobal.com/commodityinsights/en/products-services/electric-power/market-data-power.

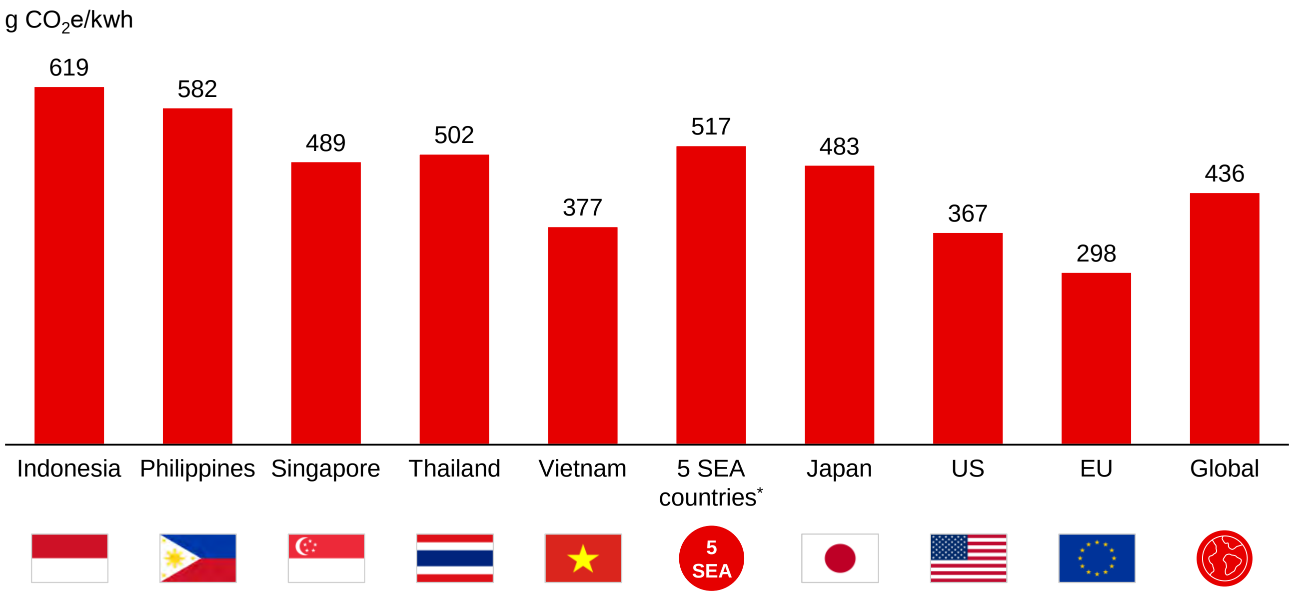
Exhibit 7: Share of power sector contribution to GHG by country or region, 2021[25]



* 5 SEA (Southeast Asia) countries are Indonesia, the Philippines, Singapore, Thailand, and Vietnam

Furthermore, most of these five countries have a high GHG emission intensity of electricity and are left with young fossil-fuel fleets. For example, Indonesia's GHG intensity of 619 gCO_2e (CO_2 equivalent) per kWh was 40% higher than the global average of 436 gCO_2e per kWh in 2022, 69% higher than the United States, and twice as high as the European Union.

Exhibit 8: GHG intensity of electricity, 2022[26]



* 5 SEA (Southeast Asia) countries are Indonesia, the Philippines, Singapore, Thailand, and Vietnam

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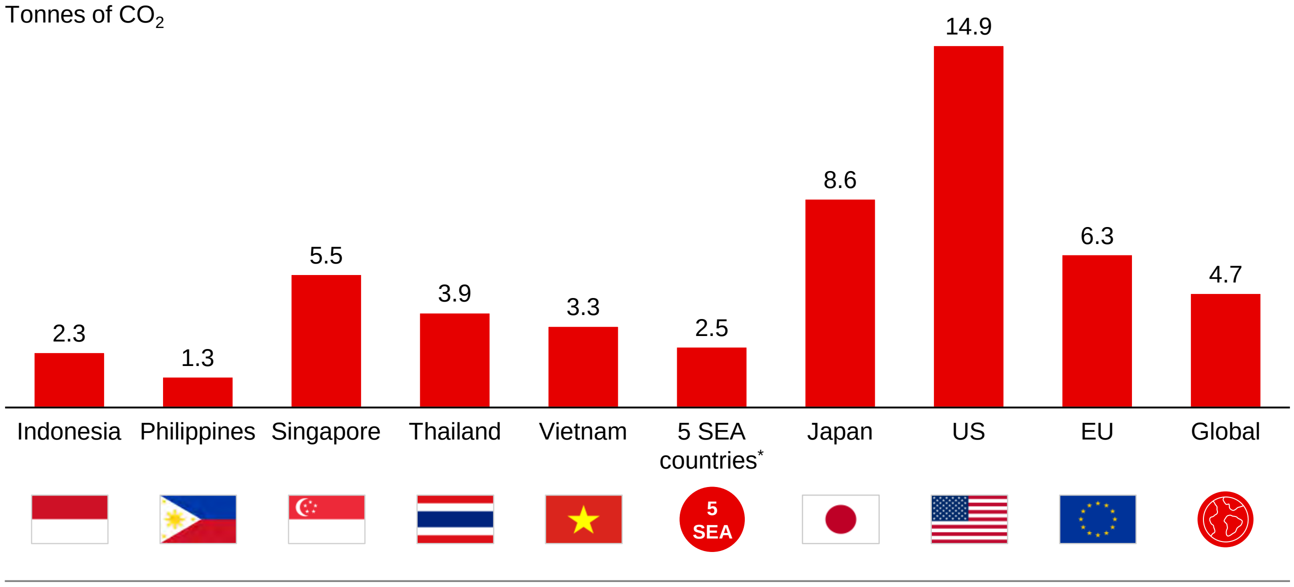
[25] "Greenhouse Gas Emissions from Energy," IEA, Last updated August 2, 2023, https://www.iea.org/countries/. Herein by power sector we are referring to electricity and heat.

[26] "Carbon intensity of electricity," Our World in Data, accessed November 1, https://ourworldindata.org/grapher/carbon-intensity-electricity?tab=table&time=latest&country=.

Nonetheless, emission intensity of electricity is only one of the potential hurdles for gauging a country's carbon footprint and does not reflect a full picture. Even with the high growth in power demand, the CO_2 per capita in many Asian countries remains at relatively modest levels. For example, Indonesia was 2.3 tonnes and the Philippines was 1.3 tonnes vs. the U.S. at 14.9 tonnes and global average of 4.7 tonnes CO_2 per capita in 2021.[27]

Exhibit 9: CO_2 emission per capita, 2021[28]



* 5 SEA (Southeast Asia) countries are Indonesia, the Philippines, Singapore, Thailand, and Vietnam

2.1.2. Momentum towards energy transition

In line with the accelerating global trend towards clear decarbonization targets and pathways, these five countries have defined a NDC target. By setting decarbonization targets for the power sector, each country is slowly transitioning away from fossil fuel. Target levels vary because of differences such as energy mixes, reliance on fossil fuels, RES penetration, levels of development, and energy demand growth. Some of these countries have set an ambitious 2050 NDC target to adhere to the 1.5°C pathway in the Paris Agreement. For example, Singapore aims to decarbonize the economy by transitioning its natural gas-fired power plants to hydrogen-based power plants.

In addition to NDCs, most of the five countries have set ambitious renewable energy targets recognizing the potential RES at their disposal and the urgency of environmental and sustainability concerns. In terms of cost, clean energy sources are rapidly approaching highly competitive levels compared to conventional fossil-fueled energy source. While Singapore has a very limited potential for RES given its small land area, Vietnam leads the five countries in installed solar- and wind-power capacity and is on the way to achieve an ambitious target of an RES share of 80-85% in its energy mix by 2050.[29] Thailand, Indonesia, and the Philippines still have low installed capacity considering their renewables potential.

On this basis, the five countries can be separated into distinct categories in looking at their pathways. Indonesia, Vietnam, and the Philippines are all coal-dependent and seeking a pathway to gradually shift away from coal. In particular, Indonesia and Vietnam are working towards early retirement of coal-fired power plants under the JETP initiative. The second group, Singapore, and Thailand, is characterized by a cleaner fuel mix with a large share of natural gas. They have plans to decarbonize their natural gas-fired plants fleet with technology innovations such as hydrogen co-firing and CCUS. In this effort, Thailand has a larger natural endowment potential for RES and as a result, a higher appetite for renewables development than Singapore.

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[27] "CO_2 emissions per capita, 2021," Our World in Data, accessed November 1, https://ourworldindata.org/grapher/co2-per-capita-marimekko?tab=table

[28] "CO_2 emissions per capita, 2021," Our World in Data, accessed November 1, https://ourworldindata.org/grapher/co2-per-capita-marimekko?tab=table. Five Southeast Asian countries (Vietnam, Thailand, Singapore, the Philippines, and Indonesia) are shown based on population-weighted average GHG emissions per capita.

[29] Vietnam's National Energy Master Plan: Key Takeaways," Dezan Shira & Associates, Vietnam Briefing, August 8, 2023, https://www.vietnam-briefing.com/news/vietnams-national-energy-master-plan-key-takeaways.html/.

Table 3: Comparison of renewable energy target and potential

	Indonesia	The Philippines	Singapore	Thailand	Vietnam	US	EU
Renewables Overall							
Renewable energy used for electricity generation, 2022 (TWh)[30]	65 TWh	25 TWh	1 TWh	29 TWh	136 TWh	968 TWh	905 TWh
Share of renewable energy used for electricity generation in 2022 (% of total electricity generation)[31]	19%	23%	2%	16%	51%	23%	35%
Renewable energy target by 2030 (% in the energy mix)	25%[32]	35%[33]	3% (for solar)[34]	30% (by 2036)[35]	31%-39%[36]	35%-60%[37]	42.5%[38]
Net zero target[39]	2060	Not defined[40]	2050	2065	2050	2050	2050
Solar PV							
Target solar capacity (GW)	5 GW (2030)[41]	19.6 GW (2030)[42]	2 GW (2030)[43]	15.6 GW (2037)[44]	21 GW (2030)[45]	(550 GW) (2035)[46]	600 GW (2030)[47]
Installed solar capacity (GW)[48]	0.3 GW (2022)	2.6 GW (2022)	0.6 GW (2022)	3.0 GW (2022)	17.6 GW (2022)	110.7 GW (2022)	162 GW (2021)

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[30] "Electricity Mix," Hannah Ritchie and Pablo Rosado on Our World in Data, 2022, https://ourworldindata.org/electricity-mix. The source includes comparable data across countries. However, it may differ slightly from other sources due to definition difference.

[31] Ibid.

[32] "Enabling high share of renewable energy in Indonesia's power system by 2030," the Institute for Essential Service Reform (IESR), 2022.

[33] "Philippines Energy Plan (PEP) 2020-2040," Republic of Philippines Department of Energy, last updated June 2023.

[34] "Singapore Green Plan 2030," Singapore Government, 2021, https://www.greenplan.gov.sg/.

[35] "Alternative Energy Development Plan 2015 - 2036," Ministry of Energy, Thailand, 2014, https://aeds.aseanenergy.org/policy/renewable-energy-target-of-thailand/.

[36] "National Energy Master Plan (NEMP) 2021 – 2030," Government of Vietnam, 2023.

[37] The target varies by state, and the values herein reported are based on select states with reported target. Based on "Renewable portfolio standards targets for selected states", U.S. Energy Information Administration, 2019. https://www.eia.gov/todayinenergy/detail.php?id=38492

[38] "Renewable Energy Directive EU/2023/2413," European Commission, last updated in 2023. https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en.

[39] Based on each country's Nationally Determined Contribution (NDC).

[40] "No net-zero target in Philippine Energy Plan," BusinessWorld, July 23, 2023, https://www.bworldonline.com/editors-picks/2023/07/23/535557/no-net-zero-target-in-philippine-energy-plan/.

[41] "Diseminasi RUPTL 2021-2030," PLN, October 5, 2021.

[42] "Philippine Energy Plan (PEP) 2020-2040," Republic of Philippines Department of Energy, last updated June 2023. The target solar capacity is based on the Clean Energy Scenario.

[43] "Singapore Green Plan 2030," Singapore Government, 2021, https://www.greenplan.gov.sg/.

[44] "Thailand's Clean Electricity Transition", IEA, August 2023.

[45] "Vietnam's Eighth National Power Development Plan (PDP VIII)," Government of Vietnam, 2023.

[46] No official target defined (hence put in bracket). The value herein cited is a modeled capacity needed to reach the overall renewable target. Based on "the Solar Futures Study," Department of Energy, Solar Energy Technologies Office (SETO) and the National Renewable Energy Laboratory (NREL), September 2021.

[47] "Solar energy," European Commission, https://energy.ec.europa.eu/topics/renewable-energy/solar-energy_en.

[48] "Energy Profiles" (by country), IRENA. The installed solar capacity is calculated based on the reported total installed capacity, the renewable share, and the solar share among renewable in 2022. Source for EU: "Solar Energy," European Commission, https://energy.ec.europa.eu/topics/renewable-energy/solar-energy_en.

	Indonesia	The Philippines	Singapore	Thailand	Vietnam	US	EU
Wind							
Target Wind capacity (GW)	0.32 GW (2030)[49]	1.2 GW (2030)[50]	Limited information	3 GW (2037)[51]	28 GW (2030)[52]	300 GW (2030)[53]	510 GW (2030)[54]
Installed wind capacity (GW)[55]	0.13 GW (2022)	0.45 GW (2022)	Limited	1.58 GW (2022)	4.5 GW (2022)	138.4 GW (2022)	220 GW (2021)

2.1.3. Archetype of decarbonization pathway summary

Indonesia and Thailand are selected for more detailed analysis, given these are two large economies in Southeast Asia with different archetypes of pathway with different energy mixes: Indonesia more dependent on coal, and Thailand with a larger share of natural gas energy production. This is covered in Sections 3 and 4 for Indonesia and Thailand, respectively.

For the remaining of this section, we look more closely at the decarbonization pathways for the Philippines, Singapore, and Vietnam. The overarching points for these three countries include:

- **The Philippines:** To offset the high dependence on coal, the Philippines is seeking to expand power generation from solar, hydro, and geothermal sources. The country aims to transition from coal to natural gas.
- **Singapore:** Dependent on natural gas for its power, Singapore faces a unique challenge considering its limited RES potential because of its limited land area. The country relies on technology advancements, such as hydrogen co-firing for power plants, as well as decarbonization of its imported electricity from surrounding nations. Singapore is also in a unique position as the financial hub for Southeast Asia, promoting investment into energy transition initiatives across the region.
- **Vietnam:** Dependent on coal, Vietnam has a more aggressive plan to phase out coal-fired power plants by either shutting them down or converting them to alternative fuels. In parallel, the country is moving to natural gas and developing RES.

2.2. The Philippines

The Philippines' power supply is largely reliant on fossil fuels, predominantly coal, but diesel oil and natural gas, as well. As one of the fastest growing economies, the Philippines has increased its share of coal-fired power generation to power its economic growth over the last decade. While the country has yet to define its NDC, it has set a target of a 50% energy share from RES by 2040, focusing on solar, hydro, and geothermal.[56] The country also wants to increase the share of natural gas-fueled power plants as a transition fuel.

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[49] Calculated based on the RUPTL 2021-2030 goal of on-shore wind capacity addition from 2021 to 2030 and the 2021 installed wind capacity reported by IRENA energy profile. Reference: "RUPTL 2021-30: PLN steps up ambitions to accelerate clean energy investments in Indonesia," OECD, 2021

[50] "The Philippine Energy Plan (PEP) 2020-2040," Philippines Department of Energy, last updated June 2023. The target wind capacity is based on the Clean Energy Scenario.

[51] "Thailand's Clean Electricity Transition", IEA, August 2023.

[52] "Vietnam's Eighth National Power Development Plan (PDP VIII)," Government of Vietnam, 2023. The target wind capacity includes both onshore wind and offshore wind.

[53] "20% Wind Energy by 2030, Increasing Wind Energy's Contribution to U.S. Electricity Supply", U.S. Department of Energy (DOE), December 2018.

[54] "REPowerEU plan", the European Commission, 2022.

[55] "Energy Profiles" (by country), IRENA, The installed wind capacity is calculated based on the reported total installed capacity, the renewable share, and the solar share among renewables in 2022. The source for EU: "Wind energy in Europe - 2020 Statistics and the outlook for 2021-2025," Wind Europe, 2021.

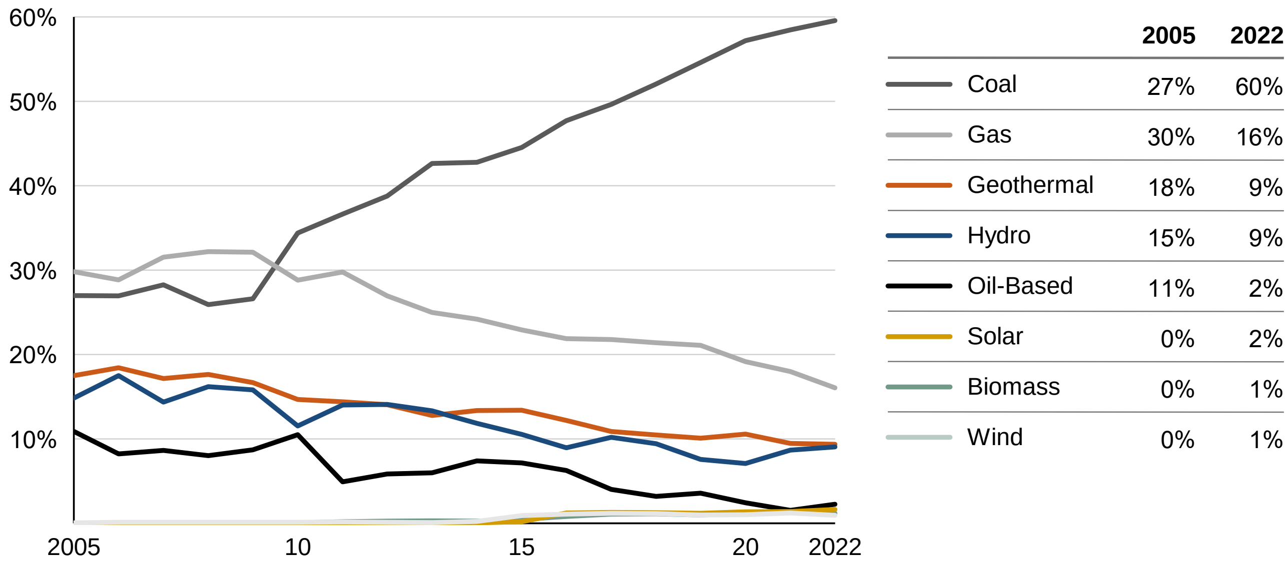
[56] "National Renewable Energy Program (NREP), 2020-2040," Department of Energy, Government of the Philippines, 2022.

2.2.1. Current state of power market: Demand and supply mix

The Philippines experienced robust economic growth in the past 20 years, driven by rapid urbanization, growing middle class, and robust workforce driven by a young population. Strong service-sector growth driven by business offshoring, as well as continued remittances from Filipino workers overseas, have driven strong consumer demand. Over the last 20 years, the total electricity sales nearly doubled, increasing from around 43 TWh in 2003 to around 83 TWh in 2022, at a CAGR of around 4%. Residential sector and industrial sector are among major contributors to electricity demand, which rose from 15 TWh to 34 TWh, and from 15 TWh to 25 TWh, respectively. To accommodate this increase in demand, the government has turned to coal-fired power plants in the last decade, with coal's share in the total energy mix increasing significantly since 2010.

In 2022, the Philippines' electricity production used mostly fossil fuels. Coal accounted for 60% of the power generation in 2022 (growing from 27% in 2005), natural gas 16%, and oil 2%.[57]

Exhibit 10: Share of gross power generation by energy source, the Philippines, 2005-2022[58]



2.2.2. Commitment and initiatives for power sector decarbonization

Although the Philippines has yet to announce the target year for net zero in the NDC, it has committed to gradual and incremental steps towards decarbonization. In 2021, the country committed to avoiding 75% of projected business-as-usual GHG emissions from 2020-2030, driven by emissions reductions from agriculture, waste, industry, transportation, and energy sectors.[59] The threshold to meet this target is based on a forecasted 3.3 billion tonnes of CO_2e emissions under the business-as-usual scenario by 2030.

In 2021, the Department of Energy (DOE) proposed the National Renewable Energy Program 2020-2040 (NREP) and established a road map to reach a 35% share from RES in the energy mix by 2030 and a further increase to 50% by 2040, with solar power as the main source.[60] This shift from fossil fuels to renewables is strengthened by a slate of regulatory developments, including a 2020 moratorium on new coal-fired power plants,[61] green energy auctions for RES capacity, and policies governing core technologies, such as energy storage systems and electric vehicles.[62]

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[57] "2022 Power statistics: Philippines," Department of Energy, Government of the Philippines, last updated on June 19, 2023.

[58] "Philippine Power Statistic – 2022 Power Statistics as of 31 December 2022, Released on 30 June 2023," Department of Energy, Government of the Philippines, last accessed on November 1, 2023, https://www.doe.gov.ph/energy-statistics/philippine-power-statistics. Department of Energy's gross power generation by plant type data differs from Our World in Data's Electricity production by source with different definitions. Department of Energy data used in this section as the forecast is provided by Department of Energy. Our World in Data's data used in previous section as it includes comparable data across countries

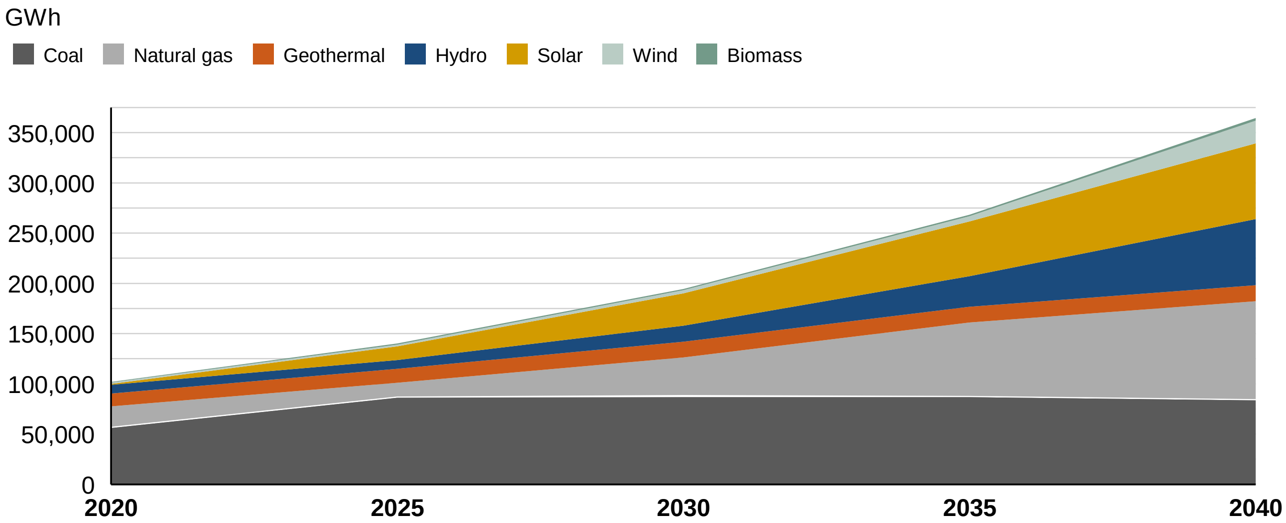
[59] "Republic of the Philippines: Nationally determined contribution communicated to the UNFCCC on 15 April 2021," United Nations Framework Convention on Climate Change (UNFCCC), April 15, 2021.

[60] "New RE plan targets 35% share of power generation by 2030," Philippine News Agency, November 13, 2021.

[61] "Philippines shuts door on new coal power proposals," Reuters, November 4, 2020, https://www.reuters.com/article/philippines-energy-idUSL4N2HQ1Z9/

[62] "Philippines," Climate Action Tracker, last updated on June 5, 2023.

Exhibit 11: The Philippines' power development plan, 2020-2040[63]



To achieve its target, the Philippines plans to expand deployment of multiple RES, including biomass, wind, and solar. The DOE was working to revise the Energy Plan in 2023, which is expected to feature a higher target for the renewable share in power mix.[64] The Philippines has ~246 GW renewables energy potential yet to be utilized. This includes the world's third largest geothermal capacity of 1.9 GW following the US and Indonesia.[65]

2.3. Singapore

Singapore's small land mass belies its large and highly developed economy. Strategically located at the intersection of many global trade routes, Singapore serves as a valuable logistics hub and is host to the regional headquarters of many global companies with presence in Southeast Asia. With its strong economic standing and innovation ecosystem, Singapore is well-positioned to adopt lower-emission fossil-fuel technologies.

Currently, Singapore's electricity generation comes mainly from natural gas. The switch from oil to natural gas has helped prompt a 32% drop in GHG emissions between 2009 and 2020 amid economic growth and greater electrification of Singapore. Additional decarbonization may be constrained by limited natural endowments for solar and wind, and to compensate for this, Singapore plans to import more renewable energy and pursue nascent low-carbon technologies, such as hydrogen and CCUS.

2.3.1. Current state of power market: Demand and supply mix

Singapore remains a vital financial and trading hub for Southeast Asia, and the city-state's continued economic growth has been driven not only by its diverse portfolio of industries and services, but also by its burgeoning technology ecosystem. Over the last 20 years, total electricity consumption has grown steadily at 3.2% p.a. from 29.9 TWh in 2003 to 54.9 TWh in 2022. Most of the consumption comes from industry sector contributing 41% to the total consumption in 2022, followed by 39% from commercial and public services, 14% from residential, and 5% from transportation.

Source-wise, Singapore's electricity generation comes almost completely from natural gas, which fueled 94% of the electricity used in 2022. Natural gas is a more environmentally friendly option compared to other fossil fuels and aligns with Singapore's pursuit for cleaner energy. The remaining electricity production comes from other sources – oil, 4%; solar, 2%; and bioenergy, 1% (**Exhibit 12**).[66]

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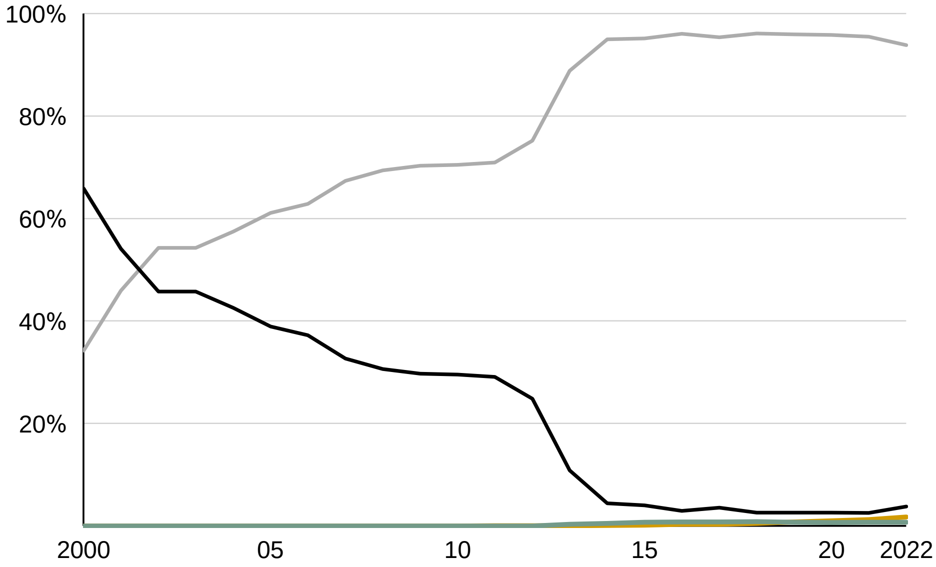
[63] "Power development plan 2020-2040," Department of Energy, Government of the Philippines, last accessed on September 14, 2023.

[64] "No net-zero target in Philippine Energy Plan," BusinessWorld, July 23, 2023, https://www.bworldonline.com/editors-picks/2023/07/23/535557/no-net-zero-target-in-philippine-energy-plan/.

[65] "Philippines Opens Renewable Energy to Full Foreign Ownership," Asean Briefing, January 11, 2023, https://www.aseanbriefing.com/news/philippines-opens-renewable-energy-to-full-foreign-ownership/.

[66] "Singapore energy statistics 2022: Chapter 2," Energy Market Authority of Singapore, 2022.

Exhibit 12: Share of electricity production by energy source, Singapore, 2000-2022[67]



	2000	2022
Gas	34%	94%
Oil	66%	4%
Solar	0%	2%
Bioenergy	0%	1%

2.3.2. Commitment and initiative for power sector decarbonization

In October 2022, Singapore announced plans to reach net zero by 2050, with an interim goal of reducing annual emissions to 60 million tonnes of CO_2e by 2030,[68] which is 7.7% lower than its previous target of 65 million tonnes of CO_2e.[69] Singapore has been making calculated strides towards integrating RES, most notably solar power. Given the country's limited land area and high urban density, installing large-scale renewables infrastructure is challenging. However, solutions such as floating solar farms, as well as solar panel installations on high-rise buildings, are being explored.

To achieve its emissions target, Singapore plans to focus on four areas[70]:

1) **Regional power grids:** This refers to solar- and wind-energy imports from Indonesia, Malaysia, Thailand, and Vietnam, which play an important part in diversifying energy sources.

2) **Low-carbon alternatives:** This refers to hydrogen and CCUS technologies. These technologies have received USD 184 million from 2021 to 2023 in government support for research and development (R&D) as part of the Low-Carbon Energy Research Funding Initiative.[71] Some companies are beginning to explore hydrogen or ammonia co-firing in natural gas turbines, such as combined cycle gas turbines (CCGTs) to lower emissions. For example, Keppel Infrastructure has started constructing a hydrogen-ready power plant. The project is expected to be completed in 2026, though the date of hydrogen co-firing has not been announced.[72] Furthermore, Keppel, Mitsubishi Heavy Industries (MHI), and DNV signed a memorandum of understanding (MOU) to explore the use of ammonia co-firing in natural gas turbines on Jurong Island in Singapore.[73]

3) **Domestic Solar:** Solar power is the only viable option to expand RES domestically because of the limitations in country's area.

4) **Natural gas:** Natural gas will continue to be an important power source in decarbonization efforts as it produces the least amount of carbon emissions per unit of electricity compared to other fossil fuels.

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[67] "Singapore: Energy Country Profile," Hannah Ritchie and Max Roser on Our World in Data, last accessed on November 2, 2023, https://ourworldindata.org/energy/country/singapore.

[68] "Singapore commits to achieve net zero emissions by 2050 and to a revised 2030 nationally determined contribution; public sector and Jurong Lake District to lead the way with net zero targets," National Climate Change Secretariat Singapore, October 25, 2022.

[69] "Singapore reduces its carbon emissions target for 2030 to 60 Mt CO_2e," Enerdata, October 26, 2022.

[70] "Singapore's Climate Action – Mitigation Efforts – Power," National Climate Change Secretariat, 2021, https://www.nccs.gov.sg/singapores-climate-action/mitigation-efforts/power/.

[71] "The low-carbon energy research funding initiative," IEA, updated November 4, 2022.

[72] "Keppel to develop Singapore's first hydrogen-ready power plant, with construction undertaken by Mitsubishi Power and Jurong Engineering consortium," Mitsubishi Heavy Industries, August 31, 2022.

[73] "Keppel to develop Singapore's first hydrogen-ready power plant, with construction undertaken by Mitsubishi Power and Jurong Engineering consortium," Mitsubishi Heavy Industries, August 31, 2022.

Given Singapore's limited landmass to achieve power decarbonization, it is dependent on facilitating the decarbonization of its energy imports from regional partners through policy and financing initiatives. These include implementing a carbon tax to encourage low-carbon energy, launching domestic RES projects, and planning to import electricity from low-carbon and renewable sources.[74] With its substantial strides in reducing emissions, Singapore can also serve as a catalyst for other countries and potentially provide green financing to help them achieve their own NDC targets.

Singapore's catalytic role in the region

Offshore investments – Singapore green investments across Southeast Asia

Institutions based in Singapore are the most active green investor in Southeast Asia, participating in 30% of the deals in the region in 2020-2022.[75] Singapore is also a prime destination for green investments, and together with Indonesia accounts for more than half of all green investments in Southeast Asia.

Offshore investments originating in Singapore include funding for renewable energy imports. By 2023, Singapore had begun importing hydropower from Laos, and is expanding renewables imports to decarbonize its energy sector.[76]

Project Greenprint – Using technology for efficient and trusted data flows to support green finance

Singapore is also at the forefront of using data to expand sustainable finance. Project Greenprint, a MAS initiative, seeks to establish an ESG data platform to facilitate the flow of consistent, clear, and reliable ESG data between the financial sector and the real economy to track, monitor, ensure compliance, as well as assist in making strategic decisions. One of its initiatives is to develop a green fintech ecosystem by establishing a marketplace to connect green technology providers with potential lenders and investors.[77]

Hub for carbon markets – Aspirations to become a leading global financial center for carbon markets

Singapore has plans to become a global financial center for carbon markets, comprising both voluntary and compliance carbon trading.[78]

Singapore began carbon pricing locally in 2019 and has since launched a carbon exchange and worked with different countries on carbon credits. By establishing itself as a global venue for carbon credits trading, aligned with international standards, Singapore hopes to introduce further innovation in its role as a regional financial hub.

A recent MAS report identified carbon credits as a critical means to boost the economic viability and scalability of early retirement of coal-fired power plants[79]; however, the incorporation of carbon credits for energy transition remains at a nascent stage. The MAS report cites crucial challenges, including lack of governance and unified standards, limited data availability, and insufficient market liquidity.

2.4. Vietnam

Vietnam has traditionally used hydropower as its main source of electricity, but the share of coal has increased in recent years to meet growing demand. Vietnam has committed to a more balanced energy mix by increasing its imports of LNG and by converting all coal plants to alternative fuels or ceasing their operations by 2050. Vietnam also has plans to continue to expand its solar power capacity, which has grown rapidly in recent years

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[74] "Which ASEAN countries will be the front-runners to decarbonize their power sectors?," Cecillia Zheng on S&P Global, August 24, 2022.

[75] "Renewable energy main draw for green investments in South-east Asia," Rosalind Ang on The Straits Times, updated June 6, 2023, https://www.straitstimes.com/business/renewable-energy-main-draw-for-green-investments-in-south-east-asia.

[76] "Singapore opens taps on renewable-energy imports with Laos deal," Mayuko Tani on Nikkei Asia, August 18, 2022, https://asia.nikkei.com/Business/Energy/Singapore-opens-taps-on-renewable-energy-imports-with-Laos-deal.

[77] "Project Greenprint," Monetary Autorith of Singapore, November 2021.

[78] "Singapore pushes to become carbon market hub," Mercedes Ruehl on Financial Times, June 15, 2023, https://www.ft.com/content/1b1af3cc-6081-4d4f-b4b4-63940ff9482f.

[79] "Accelerating the early retirement of coal-fired power plants through carbon credits," Monetary Authority of Singapore, September 2023.

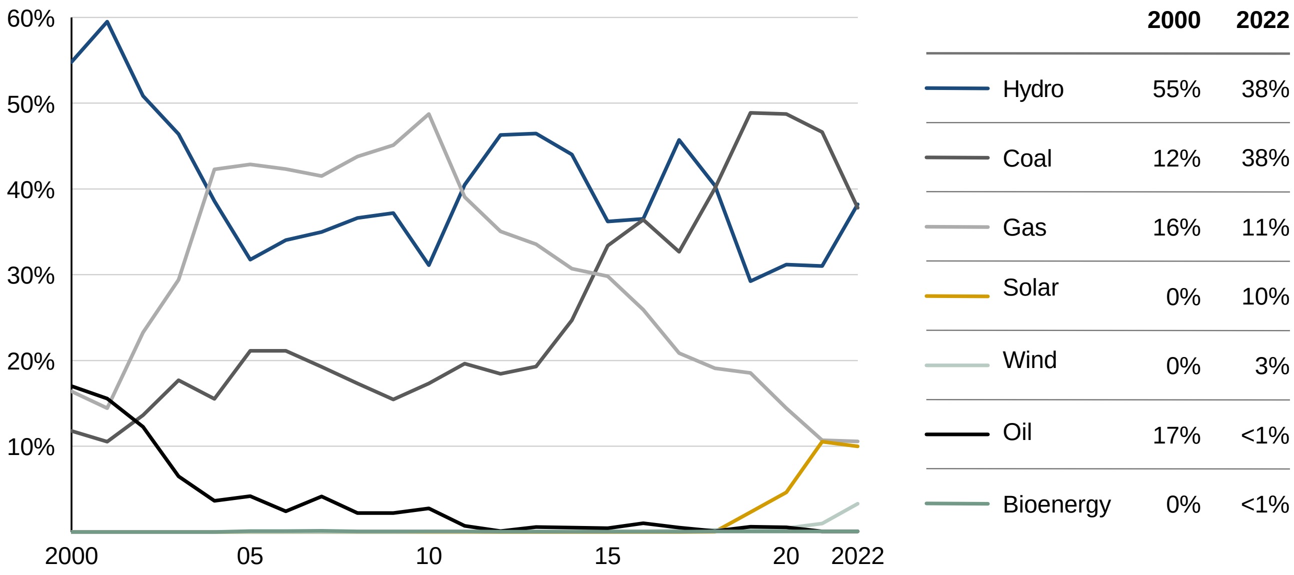
and is widely cited as a case study for rolling out renewables in Southeast Asia. Between 2010 and 2021, the country rose in the global ranking of solar power capacity from 196th to 9th.[80]

2.4.1. Current state of power market: Demand and supply mix

Vietnam has experienced fast growth in electricity consumption during the past two decades. Its electricity consumption has grown 11.4% p.a. from 61.3 TWh in 2003 to 218.0 TWh in 2020. The main contributors to electricity consumption are industry, with 54%, and residential, with 32% of the consumption in 2020. The rest comes from commercial and public services with 11% of electricity consumption, and agriculture/forestry, with 3% of electricity consumption in 2020.[81]

In 2022, hydroelectric power remained Vietnam's main source of electricity, accounting for just more than 38% of consumption, owing to the country's abundant riverscapes. Coal came a close second with just less than 38%, followed by natural gas, 11%, and solar power, 10%.

Exhibit 13: Share of electricity production by energy source, Vietnam, 2000-2022[82]



	2000	2022
Hydro	55%	38%
Coal	12%	38%
Gas	16%	11%
Solar	0%	10%
Wind	0%	3%
Oil	17%	<1%
Bioenergy	0%	<1%

Vietnam has distinct natural advantages that make RES, especially wind and solar power, promising for decarbonization. Vietnam has solar potential of about 386 GW and a wind potential of 651 GW, split 609 GW from offshore wind and 42 GW from onshore wind.[83] Although onshore wind is expected to contribute to the majority of the total wind power capacity by 2030, development continues in offshore wind, which has the potential of contributing larger share of Vietnam's wind power capacity by 2050.

2.4.2. Commitment and initiatives for power sector decarbonization

Vietnam has made significant strides in integrating RES into its energy mix. Investments in solar power have grown strongly, signaling the country's commitment to diverse power sources. While its current energy landscape leans heavily on coal and hydropower, policy adjustments and investments indicate a gradual transition towards a more balanced and environmentally conscious energy mix.

Vietnam has announced a series of ambitious plans to decarbonize its economy. It has pledged to reach net zero by 2050.[84] In July 2022, the government also committed to reducing the country's GHG emissions by 43.5% by 2030 under its National Strategy on Climate Change.[85] Then, in December 2022, it joined the

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[80] "5 Asian countries now at the top of global solar power rankings," Ember, July 4, 2022, https://ember-climate.org/press-releases/five-asian-countries-now-at-the-top-of-global-solar-power-rankings/.

[81] "Vietnam, Electricity consumption by sector," IEA, 2023, https://www.iea.org/countries/viet-nam.

[82] "Vietnam: Energy Country Profile," Hannah Ritchie and Max Roser on Our World in Data, https://ourworldindata.org/energy/country/vietnam.

[83] "Charting a path for Vietnam to achieve its net-zero goals," McKinsey & Company, October 14, 2022, https://www.mckinsey.com/capabilities/sustainability/our-insights/charting-a-path-for-vietnam-to-achieve-its-net-zero-goals.

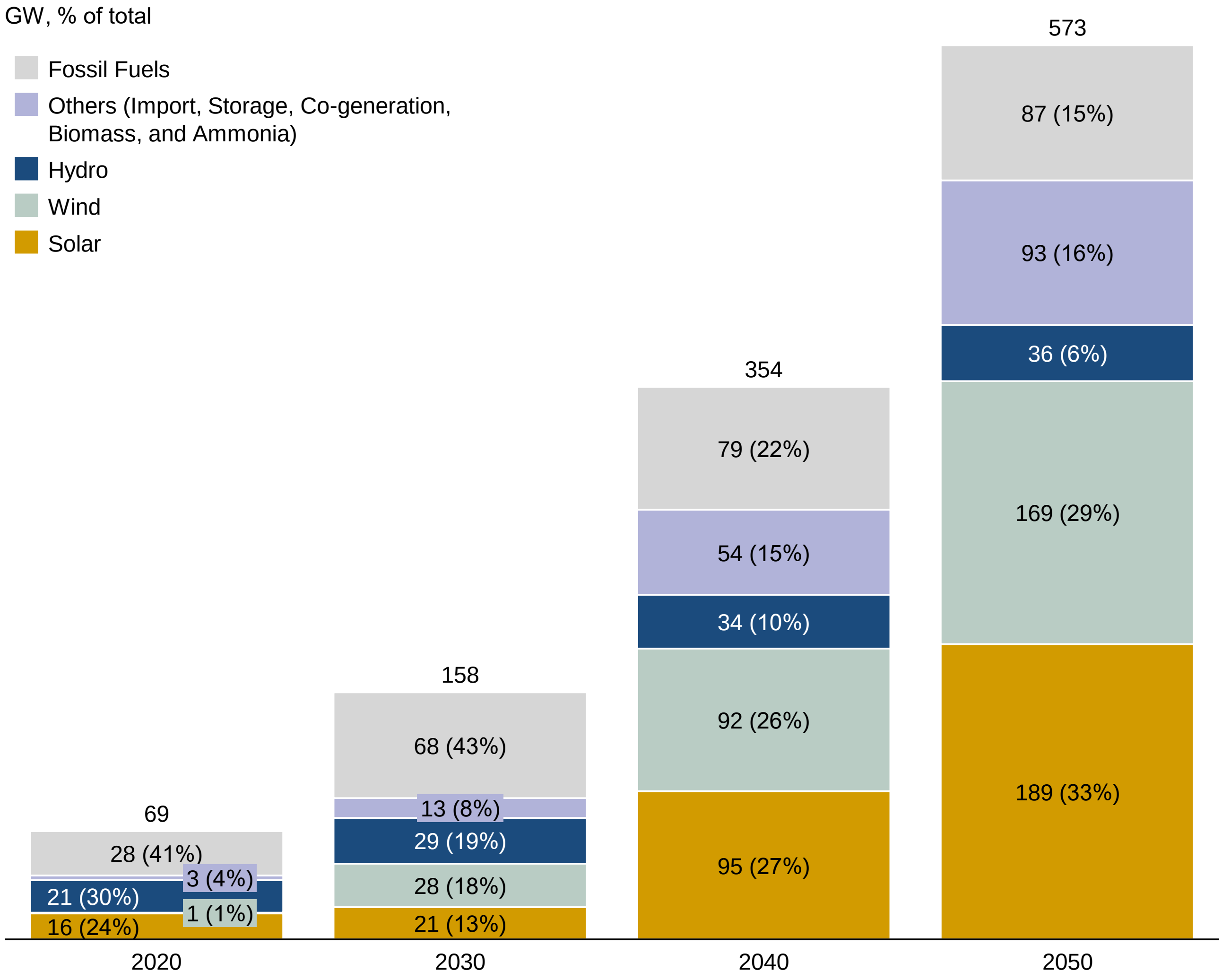
[84] "COP26 Energy Transition Council: National dialogue with Vietnam," United Nations Development Programme Vietnam, April 19, 2022.

[85] "Decision No: 896/QD-TTg," National Strategy for Climate Change, July 26, 2022; "Vietnam approves National Climate Change Strategy to 2050 to meet net-zero pledge," S&P Global, July 28, 2022.

JETP agreement with the International Partners Group (IPG). The coalition, whose members include Canada, Denmark, the European Union, France, Germany, Italy, Japan, Norway, the United Kingdom, and the United States, will provide USD 15.5 billion in funding for Vietnam's energy transition.[86]

In May 2023, after a two-year delay spent exploring coal alternatives, the country released its National Power Development Plan (PDP8), which outlines its electricity efforts through 2030. The PDP8 indicates that solar, wind, and hydro will provide ~50% of the total capacity by 2030 and ~68% in 2050. As domestic natural gas production declines, Vietnam plans to increase its imports of LNG for its natural gas-powered thermal generation (**Exhibit 14**).

Exhibit 14: Power development plan in Vietnam, according to PDP8[87]



Coal asset transformation is also an important measure included in PDP8, which targets coal-fired power plants to be retired or converted to low-emission fuel sources. By 2050, Vietnam plans to convert all coal-fired power plants to alternative fuels or cease operations. After 20-40 years of operations, coal-fired power plants are converted to alternative fuels, e.g., biomass or ammonia. If a plant cannot be converted to alternative fuels after 40 years of being operational, then the plant will be closed.[88]

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[86] "Unpacked: Vietnam's US$15.5 billion JETP agreement," Mark Barnes on Vietnam Briefing, December 19, 2022.

[87] "Decision No. 500/QD-TTg," Prime Minister of Vietnam, 15 May 2023.

[88] "Vietnam's Eight National Power Development Plan (PDP8)," Florian Wengeler on Green Finance and Development Center, June 5, 2023, https://greenfdc.org/vietnams-eight-national-power-development-plan-pdp8/. Figures show including existing rooftop solar capacity.

3. Spotlight on Indonesia

Highlights

Although Indonesia has CO_2 emissions per capita lower than developed economies, its power sector has one of the highest CO_2 emissions intensity due to its large footprint of coal-fired power plants. Nevertheless, the country has committed to accelerating the decarbonization of its power sector. While Indonesia commits to achieving net zero by 2060 in the NDC, the country has a more ambitious plan of reaching net zero in the power sector by 2050 under the condition that the JETP is implemented.

Despite the momentum, key challenges that need to be addressed include:

1) **Overcapacity with young fleet of coal assets:** Overcapacity in the power market is delaying the rapid development of RES. Coal occupies the largest share of Indonesia's power mix, and the fleet is relatively young with about 56% being in service for fewer than 10 years.[89] In this situation, the MPO of coal power plants is one measure that could address overcapacity and expand RES development. Already, mechanisms have been proposed to allow multiple parties to share the financial burden of MPO, such as introducing concessional capital or generating revenue by issuing carbon credits. Another potential unlock to the overcapacity comes from the demand side, by growing RES demand from leading C&I companies with net zero ambition.

2) **Large new and upgraded grid infrastructure required:** To integrate RES into the power system at scale, grid infrastructure must be expanded to connect the RES supply and demand centers. Smart grid upgrade is also required to better manage the intermittency from RES generation. In fact, PLN's 10-year investments plan – RUPTL – estimates that USD 25 billion in investment is required by 2030 for grid expansion and USD 2.5 billion to USD 4.9 billion for smart grid upgrades. Investment in the grid is particularly challenging as the project economics does not favor commercial investment. To unlock more investment into the grid, PLN could explore new models for project development, such as BOT or BLT to invite third party capital. Under such schemes, PLN could also seek financing from concessional capital such as MDBs to minimize the financing cost.

3) **Balancing incentives amidst the energy trilemma:** The country's need to balance environmental aspiration with affordability and energy security could send mixed signals to promote energy transition. For example, the TKDN program mandates local content requirement of different goods, including the clean energy value chain (e.g., solar PV, battery). While this program strives for competitive local manufacturing, this could hamper the economics of RES projects unless local component suppliers quickly develop capabilities to produce high-quality and cost-competitive components. Another example is the subsidy on PLN's coal procurement. Although such subsidies have lowered the electricity tariff and, as a consequence, mitigated households' economic burden as well as bolstered the competitiveness of Indonesia's local businesses, it could make switching to cleaner technologies in Indonesia less economically attractive.

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[89] Information provided by PLN.

3.1. Overview of the power sector

Indonesia has experienced rapid growth in power demand driven by robust economic development. Demand growth has been met by the fast development of coal-fired power plants. While these investments have secured cheap and reliable energy, they pose challenges when it comes to decarbonization: excessive reserve margin that limits the potential for adding new energy sources and an energy mix skewed towards recently built coal-fired power plants. As a regulated market semi-monopolized by PLN, decisions on new capacity investments for the country are conducted between PLN and the government.

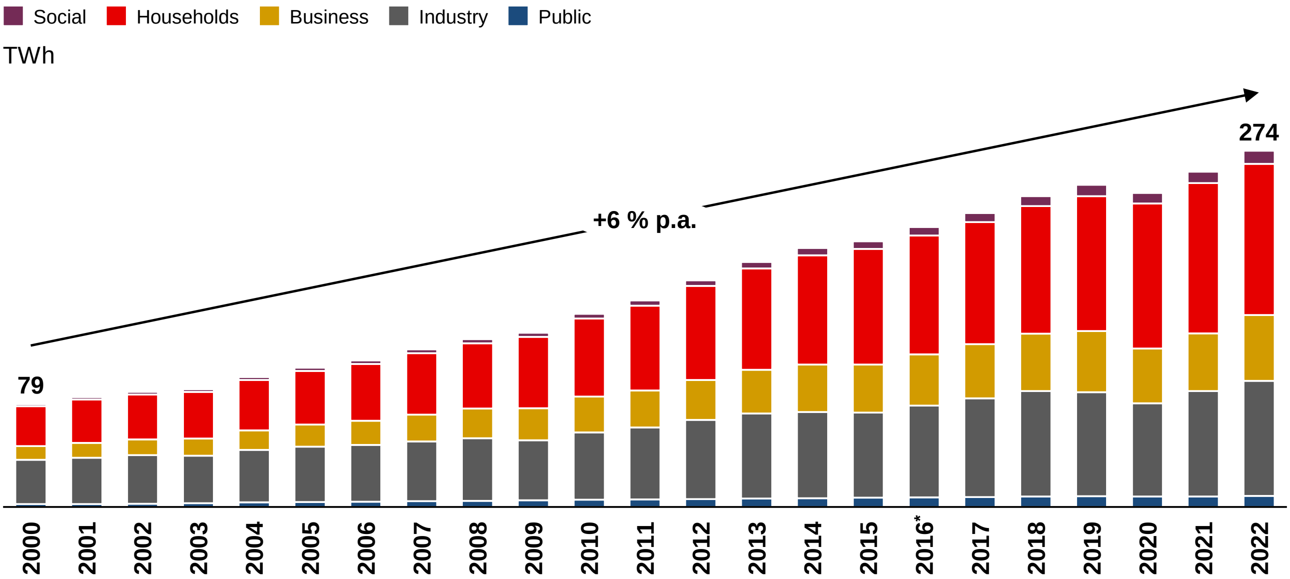
In our analysis, we examined Indonesia's power market by looking at its current energy mix, market structure, and the energy policy landscape supporting decarbonization.

3.1.1. Power demand and supply

Power demand

In recent decades, Indonesia has witnessed a significant surge in power consumption, driven by population growth, economic growth, and industrialization. Between 2000 and 2022, annual power consumption rose from 79 TWh to 274 TWh, at a compounded growth of 6% p.a.

Exhibit 15: Electricity consumption by sector, Indonesia, 2000-2022[90]



* The data for year 2016 was not reported and thus taken as an average of the corresponding values for year 2015 and year 2017

Looking forward, between 2022 and 2060 electricity consumption in Indonesia is expected to increase about five-fold, from 274 TWh to 1,499 TWh.[91] Growth will be driven across the economy, led by a fast-growing middle class and increasing urbanization of households, and C&I demand underpinned by rising levels of industrialization. Indonesia also intends to participate in the rise of clean energy industries, such as electric vehicles, batteries, and the renewables supply chain; these new ventures are also expected to drive greater electricity demand.

In 2022, the majority of electricity demand came from Java, using about 189 TWh or 69% of total consumption.[92] About 79% Indonesia's population lives in these regions. As electricity demand continues to grow across the archipelago, these demand centers are expected to continue to dominate.

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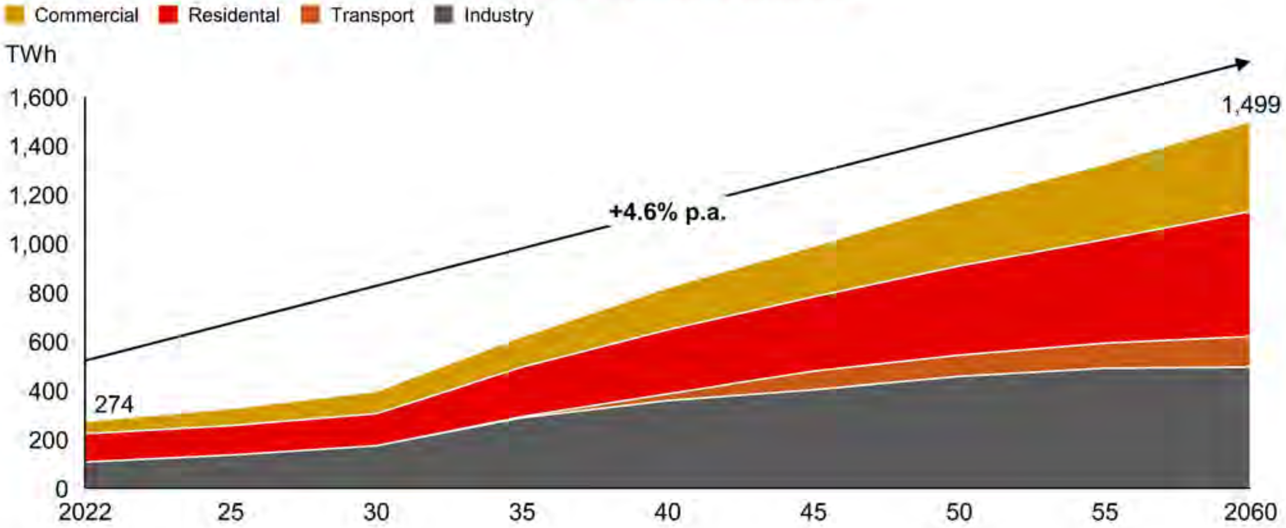
[90] "Statistics Indonesia, Electricity Sold to Customers by Electricity State Company (GWh), 2019-2021," Badan Pusat Statistik, last accessed on November 2, 2023, Link.

[91] "Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development," PLN, February 23, 2023, Link.

[92] "PLN Statistics, 2022," PLN, 2022.

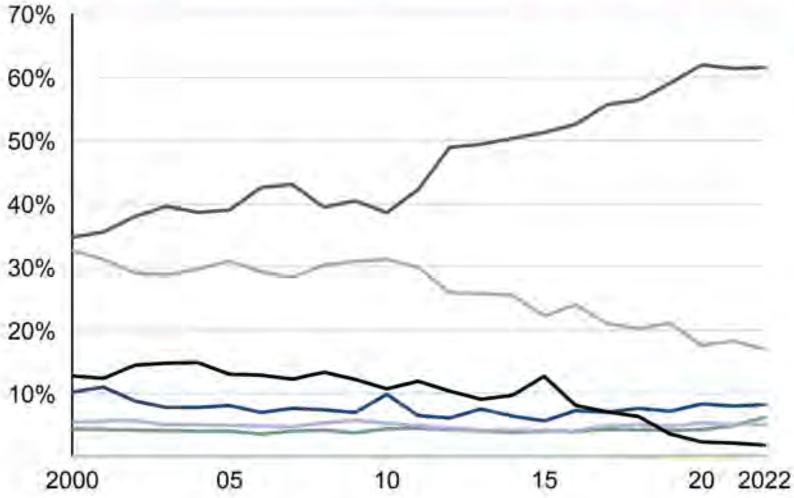
Exhibit 16: Electricity consumption by sector, 2022-2060, Indonesia[93]



Power supply

The rapid demand growth in power has been supported by building coal-fired power plants. Indonesia is one of the world's top coal producers and exporters, with a vast supply of coal reserves located primarily in Sumatra and Kalimantan. To illustrate, between 2000 and 2022, the share of coal in the country's energy mix almost doubled from 35% to 62%. The shares captured by other energy sources in 2022 are smaller: natural gas, 17%; hydroelectricity, 8%; bioenergy, 6%; and miscellaneous others, 7% (**Exhibit 17**).

Exhibit 17: Share of electricity production by energy source, Indonesia, 2000-2022[94]



		2000	2022
—	Coal	35%	62%
—	Gas	33%	17%
—	Hydro	10%	8%
—	Bioenergy	4%	6%
—	Other renewables	5%	5%
—	Oil	13%	2%
—	Solar	0%	<1%
—	Wind	0%	<1%

However, the rapid investment in coal-fired power plants has outpaced demand growth, leaving the country's power system with an excessive reserve margin.[95] Indonesia has a reserve margin of around 50%, which is above that recommended by the IEA of between 20% and 35%. This oversupply is expected to persist for several years. For example, in the Java-Bali grid, with demand forecasted to grow by roughly 1.3 GW each year to 2037, overcapacity is expected to persist until 2028 (**Exhibit 18**).[96]

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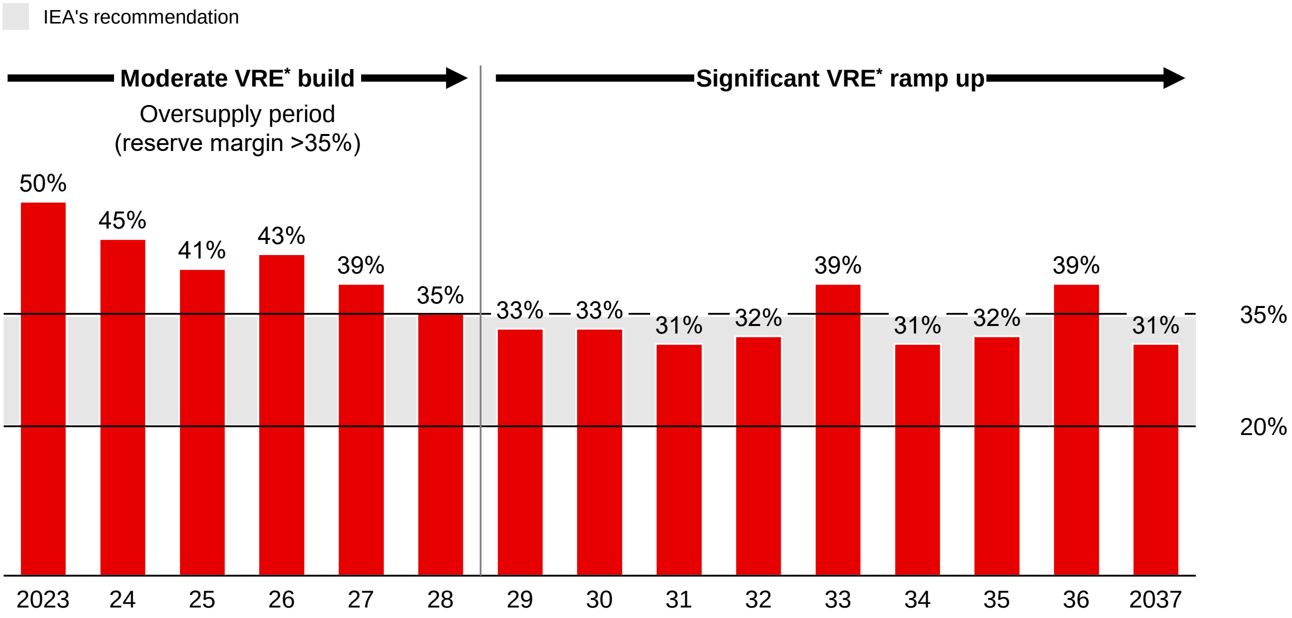
[93] "Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development," PLN, February 23, 2023. 2022 figures are based on reported actuals in "PLN Statistics, 2022".

[94] "Indonesia: Energy Country Profile," Hannah Ritchie and Max Roser on Our World in Data, accessed November 9, 2023, https://ourworldindata.org/energy/country/indonesia.

[95] Reserve margin defined as the margin between total dependable generation capacity and peak demand.

[96] "Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development," PLN, February 23, 2023.

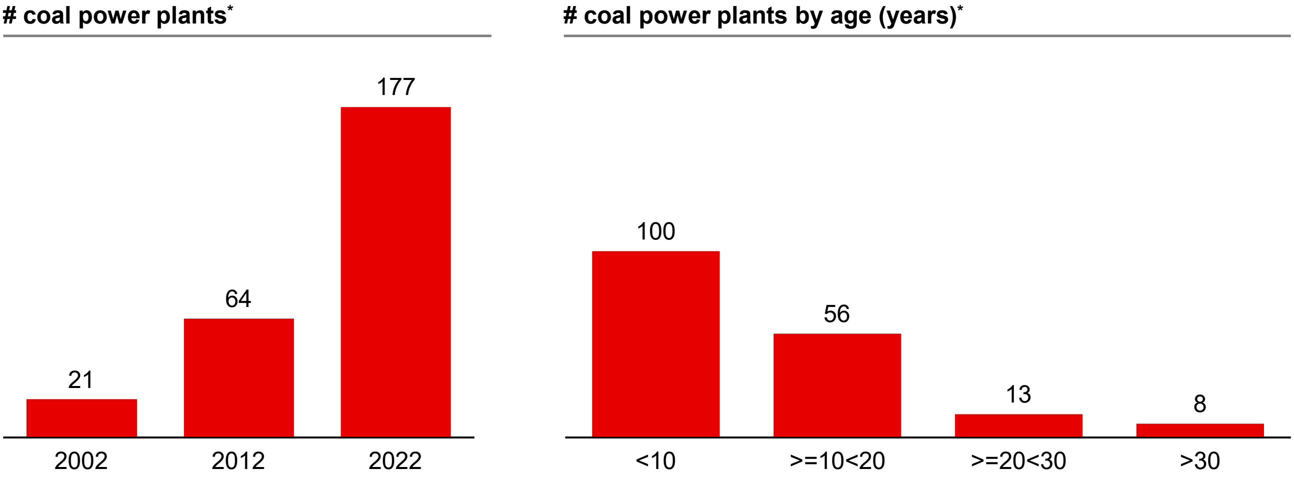
Exhibit 18: Reserve margin of Java-Bali system, 2023-2037 [97]



* VRE: Variable Renewable Energy

The rapid build-up also means that Indonesia has many coal-fired power plants that are relatively new. About 56% have been in service for fewer than 10 years. Generally, coal-fired power plants globally have had useful lives of roughly 46 years, with some in service for 60 years or even longer.[98] By the year of 2023, 88% of Indonesia's coal-fired power plant have been in operation for 20 years or less, and only 5% are older than 30 years.[99]

Exhibit 19: Growth in coal power capacity over the past 20 years[100]



* All plants established during or prior to the year in question, including all status (operational, maintenance, standby, temporary breakdown, etc.)

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[97] Ibid.

[98] "Quantifying operational lifetimes for coal power plants under the Paris goals," RY Cui, et al. on Nature, 2019.

[99] "Indonesia's Energy Transition from Coal to Renewables, 2023-2050 Policy Options and Technical Considerations," Roleva Energy on ADB Workshop on Energy Transition from Coal to Low-Carbon Future, February 2023.

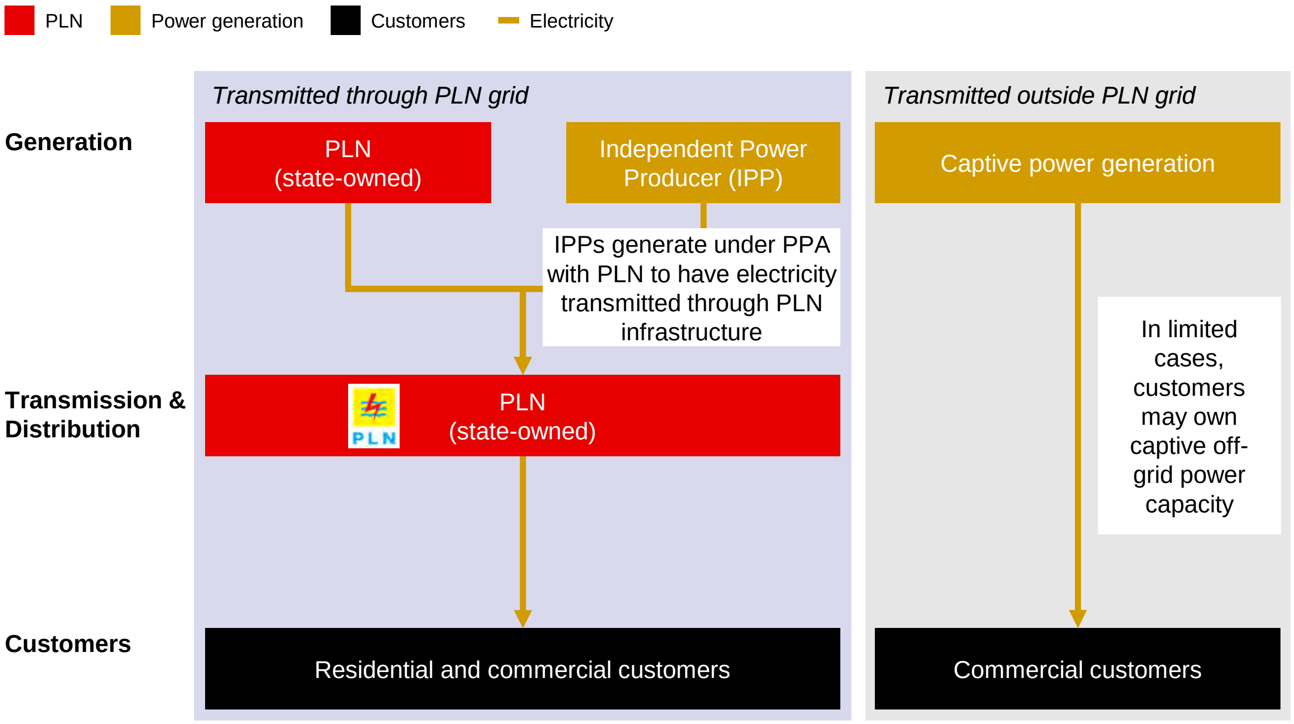
[100] Information provided by PLN, PLN, as of November 13, 2023. "Electricity Supply Business Plan 2021-2030," PLN, 2021.

3.1.2. Market structure and participants

3.1.2.1. Overall market structure

Indonesia's power sector is a semi-monopolized market where PLN, the state-owned company, controls most of the sector across the value chain (**Exhibit 20**). While power generation has been liberalized and producers other than PLN are present in the market, third-party power producers (known as Independent Power Producers or IPPs) must contract with PLN as the single buyer for access to the national TnD network which PLN controls. Retail electricity through the national grid is also monopolized by PLN, which means that except for isolated grids, IPPs cannot contract with end customers under a TPA arrangement. Given the single-buyer model and PLN's majority control of the market, electricity prices are necessarily regulated across the supply chain.

Exhibit 20: Indonesia power sector, structure, and participants



3.1.2.2. Generation

While the power generation segment has been liberalized, PLN still holds the majority share. In 2022, Indonesia had total installed capacity of about 84 GW, with PLN accounting for 69 GW or 82% of total capacity.[101] Of PLN's capacity, 45 GW are self-generated, and the remaining 24 GW are acquired through power plant rentals or contractual agreements with IPPs. The remaining 18% of installed capacity is owned by IPPs, with 13% transmitted through PLN's grid network and 5% generated off-grid.[102]

Given PLN's ownership of generation assets and the need for IPPs to contract with PLN to access the national grid, PLN has the central role of planning and investing in the future power generation needs for Indonesia.

3.1.2.3. Transmission and distribution

Transmission and distribution are held solely by PLN, except for isolated sections off the national grid. Altogether, 95% of the country's generation capacity is connected to PLN's grid network. PLN owns 68 thousand km of transmission network and 1 million km of distribution network.[103] The country is divided into eight major grid systems and 600 smaller grids.[104] Investment decisions and planning for transmission, substations, and distribution upgrades are reflected in the RUPTL, which is subject to oversight and support from the Ministry of Energy and Mineral Resources (Kementerian Energi dan Sumber Daya Mineral or

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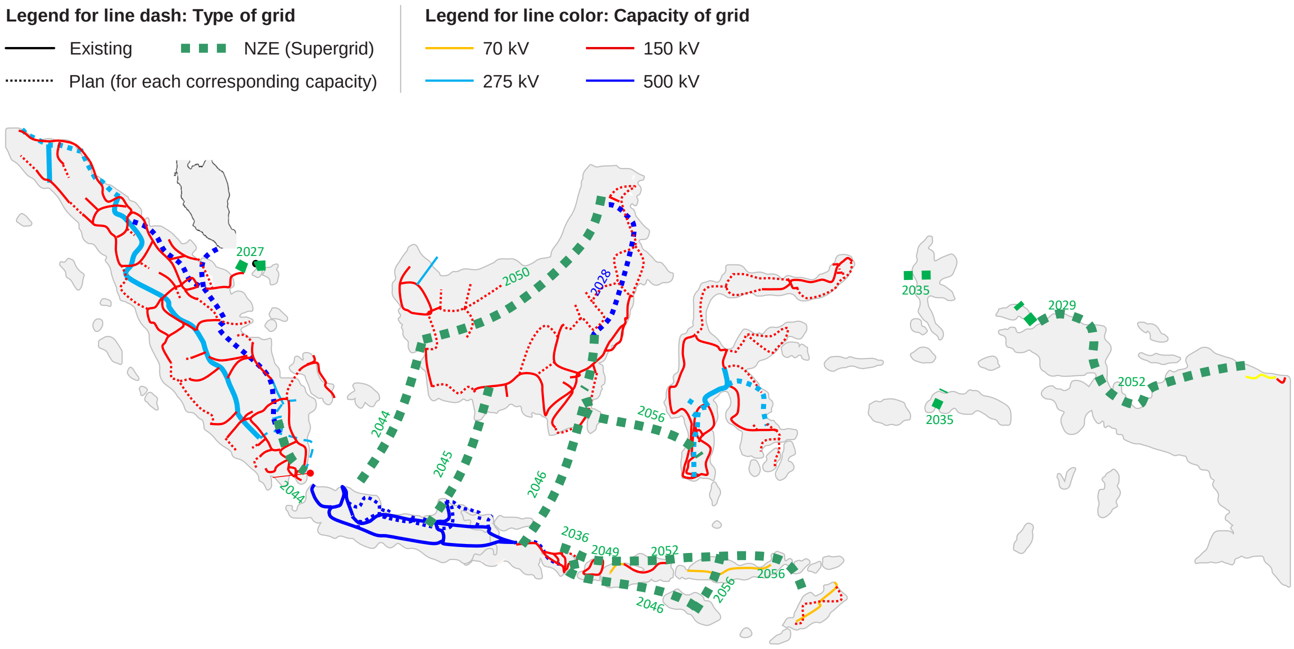
[101] "Handbook of Energy and Economic Statistics of Indonesia 2022," ESDM, 2022.
[102] "PLN Statistics, 2022," PLN, 2022; "Annual Report," PLN, 2022.
[103] "Leading the Way to Empower the Nation – Annual Report 2022," PLN, 2022.
[104] "Indonesia Energy Sector Assessment, Strategy, and Road Map," ADB, updated December 2020.

ESDM). The latest RUPTL, covering 2021-2030, includes continued investments in transmission systems with 150 kilovolts (kV) and 500 kV in Java-Bali, and 70 kV, 150 kV, 275 kV, and 500 kV in Sumatra and East Indonesia. Another 48 thousand km of transmission lines are also planned, as well as the further development of substation infrastructure.

Additionally, greater interconnection is planned not only domestically in Sumatra and Sulawesi, but also internationally with Malaysia and Singapore.[105] The interconnection between Indonesia and Malaysia is expected by 2030, with a capacity of 600 MW transmitted through the international grid.[106] Also, electricity exports from Indonesia to Singapore are being coordinated and developed by PLN, with operations expected to start by 2028.[107] This would support Singapore's plan to import 4 GW of clean energy by 2035, with about half delivered through this arrangement.[108]

Recently, measures that would open investment by the private sector are also being encouraged to reduce PLN's investment burden. The most recent RUPTL suggested introducing BOT or BLT models.[109] Together with the power generation segment, PLN generates profit from its TnD segment through electricity tariffs.

Exhibit 21: Existing and planned grid infrastructure in Indonesia[110]



3.1.2.4. Retail

PLN acts as the sole retailer of power on the national grid, which covers about 95% of the power generation capacity. As of 2023, PLN had 85 million customers.[111] Along with being the largest power company in Indonesia, it is also the largest in Southeast Asia. Since TPA to the grid owned by PLN is not allowed in Indonesia, customers can only purchase power directly from IPPs in very limited settings, such as off-grid, self-generation projects.

3.1.2.5. Electricity pricing mechanisms

In general, electricity pricing mechanisms fall into two core categories: retail pricing, or how PLN charges general customers, and generation pricing, or how IPPs contract with PLN.

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[105] "PLNs New Greener RUPTL Key Highlights," Ashurst, October 12, 2021, https://www.ashurst.com/en/insights/plns-new-greener-ruptl--key-highlights/.

[106] "RUPTL, 2021-2030," PLN, 2021, Link.

[107] "Singapore to start imports of renewable energy from Indonesia within 5 years," Hariz Baharudin on The Straits Times, September 8, 2023, https://www.straitstimes.com/asia/se-asia/singapore-to-start-imports-of-renewable-energy-from-indonesia-within-5-years.

[108] "Half of Singapore's electricity imports will be sourced from RI," Firda Dwi Muliawati on CNBC Indonesia, September 11, 2023, https://www.cnbcindonesia.com/news/20230911123700-4-471329/separuh-impor-listrik-singapura-akan-dipasok-dari-ri.

[109] "RUPTL, 2021-2030," PLN, 2021, Link.

[110] "The Electricity Infrastructure Planning and Investment Needs to Support Energy Transition," ESDM, August 2022.

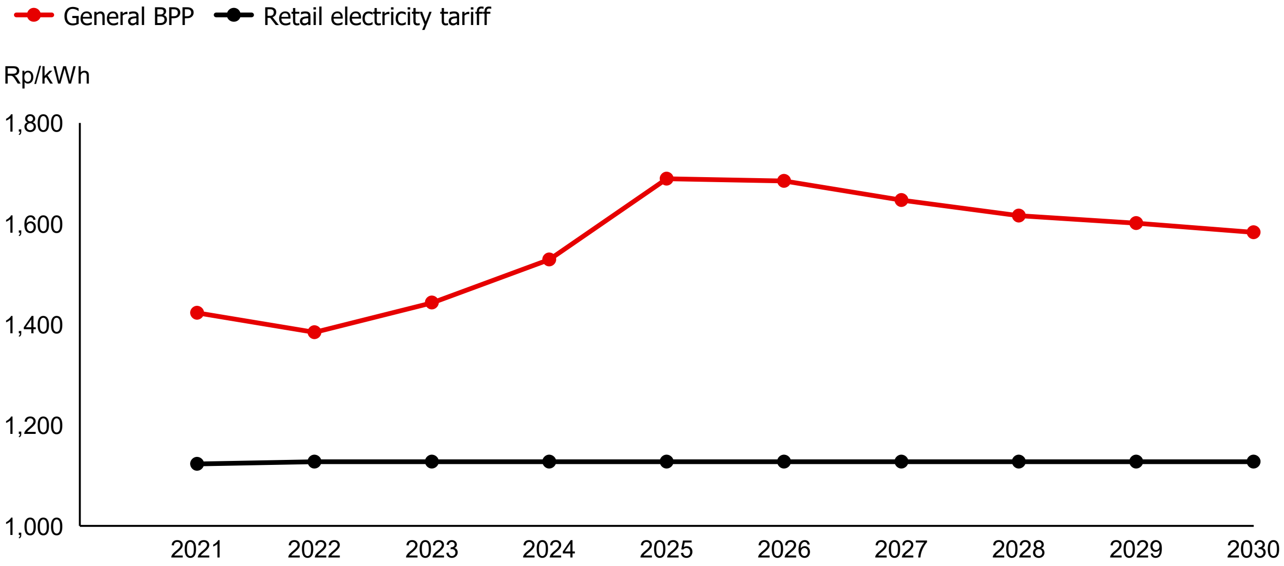
[111] "PLN (Persero) wins two prestigious honours at the Asian Experience Awards 2023," Asian Business Review, October, 2023.

1) **Retail electricity tariffs** charged by PLN are set by ESDM and reviewed every three months. This tariff is calculated from electricity basic cost of supply (Biaya Pokok Penyediaan or BPP) plus PLN's margin. BPP encompasses the expenses associated with generation, distribution, and transmission. Herein, we refer to the BPP encompassing all expenses as "General BPP" and a subset of that cost being associated to generation as "Generation BPP."

   In 2022, the average retail electricity tariff was ~1,137 IDR/kWh.[112] To mitigate the increase in General BPP, a government subsidy is provided to PLN to compensate for rising costs and hold down electricity prices for the general population. Government comes into play when the General BPP starts to increase, which is offset by an increase in subsidies to PLN.

   Looking ahead, the RUPTL 2021-2030 projected that General BPP will increase from IDR 1,445 per kWh (USD 0.09 per kWh) between 2021 and 2024, to IDR 1,637 per kWh (USD 0.11 per kWh) beween 2025 and 2030 to support government's target of 23% RES in the energy mix by 2025. Along with this increase, the plan projected that the government subsidy would increase from IDR 91 trillion (USD 6 billion) annually for 2021 to 2024 to IDR 186 trillion (USD 12 billion) annually in 2025 to 2030 to achieve this RES share, assuming the electricity tariff stays constant at IDR 1,127 per kWh (USD 0.07 per kWh) in 2021 to 2030).[113]

Exhibit 22: General BPP projection under RUPTL, 2021-2030[114]



2) **IPP electricity tariffs** between IPP and PLN are set through power purchase agreements (PPAs). IPPs bid in open tenders held by PLN, with quotas based on RUPTL and PLN's own business plans and benchmarked against a Generation BPP, which is the average cost of generation and a portion of the General BPP. If selected, the IPP enters a PPA with PLN which stipulates the power tariff, validity of the PPA, and other contractual obligations. Among these stipulations is a "take-or-pay" provision that obligates PLN to purchase a minimum volume regardless of demand. Such provisions can help guarantee project cash flows for the IPP. For RES, since 2022, a Presidential Regulation designed to encourage RES development has enabled IPPs using RES to bid higher than PLN's Generation BPP when selling electricity into the grid.[115]

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[112] "BPP for national electricity generation has decreased, electricity supply has become more efficient," ESDM, 2022, https://www.esdm.go.id/id/media-center/news-archives/bpp-pembangkitan-listrik-nasional-turun-penyediaan-listrik-semakin-efisien.

[113] "RUPTL, 2021-2030," PLN, 2021, Link.

[114] Ibid.

[115] "Jokowi signs presidential decree on EBT tariffs, doesn't give feed in tariffs and prepares subsidies," Nyoman Ary Wahyudi on Bisnis.com, September 15, 2022, https://ekonomi.bisnis.com/read/20220915/44/1577759/jokowi-teken-perpres-tarif-ebt-tak-berikan-feed-in-tariff-hingga-siapkan-subsidi.

Sidebar: Renewables tariff support from Presidential Regulation 112/2022

In 2022, the Presidential Regulation 112/2022 introduced a tariff pricing mechanism for contracts between PLN and IPPs. It established a ceiling price for renewable PPAs, which is calculated based on technology-specific levelized cost of electricity (LCOE). The ceiling price is held constant for the first ten years of project operation and is reduced after ten years based on the assumption that the project has recouped sufficient CAPEX to maintain in operation. A location multiplier (F) is also factored into account for different generation costs. As shown in **Exhibit 23**, the ceiling price bears a strong dependence on technology type and location and is generally higher than Generation BPP. This allows IPPs to bid higher, and thus the ceiling price mechanism allows more economic benefit to IPPs than the original mechanism using the Generation BPP.

Exhibit 23: Ceiling price for the first 10 years of project operation from Presidential Regulation 112/2022, US cent/kWh[116]

🟨 Shaded areas represent projects where the ceiling price is cheaper than generation BPP in 2022 (7.05 US cent/kWh), or where IPPs might have experienced lower PPA ceiling price under the PR 112/2022 regulation

Technology		Locations				
No.	**Capacity**	**Java, Madura, Bali** (F = 1)	**Sumatra, Kalimantan, Sulawesi** (F = 1.1)	**Nusa Tenggara** (F = 1.20)	**North Maluku, Maluku** (F = 1.25)	**West Papua/Papua** (F = 1.50)
Hydro power plant						
1	up to 1 MW	11.23	12.35	13.34	14.04	16.85
2	>1 – 3 MW	10.92	12.01	13.10	13.65	16.38
3	>3 – 5 MW	9.65	10.62	11.58	12.06	14.48
4	>5 – 20 MW	9.09	10.00	10.91	11.36	13.64
5	>20 – 50 MW	8.86	9.75	10.63	11.08	13.29
6	>50 MW – 100 MW	7.81	8.59	9.37	9.76	11.72
7	>100 MW	6.74	7.41	8.09	8.43	10.11
Solar PV						
1	up to 1 MW	11.47	12.62	13.76	14.34	17.21
2	>1 – 3 MW	9.94	10.93	11.93	12.43	14.91
3	>3 – 5 MW	8.77	9.65	10.52	10.96	13.16
4	>5 – 10 MW	8.26	9.09	9.91	10.33	12.39
5	>10 – 20 MW	7.94	8.73	9.53	9.93	11.91
6	>20 MW	6.95	7.65	8.34	8.69	10.43
Wind power plant						
1	up to 5 MW	11.22	12.34	13.46	14.03	16.83
2	>5 – 20 MW	10.26	11.29	12.31	12.83	15.39
3	>20 MW	9.54	10.50	11.45	11.93	14.31
Biomass power plant						
1	up to 1 MW	11.55	12.70	13.86	14.44	17.33
2	>1 – 3 MW	10.73	11.80	12.88	13.41	16.10
3	>3 – 5 MW	10.20	11.22	12.24	12.75	15.30
4	>5 – 10 MW	9.86	10.85	11.83	12.33	14.79
5	>10 MW	9.29	10.22	11.15	11.61	13.94

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[116] "Presidential Regulation No. 112 Year 2022," Government of Indonesia, 2022. The ceiling price is for the first 10 years of operation; F = location multiplier. Shaded areas represent projects where the ceiling price is cheaper than generation BPP in 2022 (7.05 US cents/kWh), or where IPPs might have experienced lower PPA ceiling price under the PR 112/2022 regulation.

3.1.3. Energy policy landscape

Many government institutions are responsible for energy governance in Indonesia. Closest to the president is the National Energy Council (Dewan Energi Nasional or DEN), comprising seven government ministers and prominent academics. DEN is responsible for developing the national energy plan and easing energy policy at the highest level for approval by the Indonesian House of Representatives (Dewan Perwakilan Rakyat or DPR).

The ESDM is responsible for the overall governance of the energy sector and is instrumental in formulating energy policies and setting the retail electricity tariffs, as well as overseeing the RUPTL in conjunction with PLN. While PLN is directly responsible for executing PPAs, ESDM provides the policy framework and regulations that govern the terms and conditions. The Ministry of Environment & Forestry (Kementerian Lingkungan Hidup Dan Kehutanan or KLHK) drives national sustainability strategy, reports to UN, and oversees environmental and forestry affairs.

The Ministry of State-Owned Enterprise (Kementerian Badan Usaha Milik Negara or KBUMN) oversees the state-owned enterprises and owns PLN, managing the corporation’s performance targets and approving annual budget. The Ministry of Industry (Kementerian Perindustrian) oversees the TKDN program that governs the local content requirement of different goods, including the clean energy value chain.

The Ministry of Finance (Kemenkeu RI) is responsible for the national budget and oversees any fiscal support schemes or subsidies to PLN for RES and other decarbonization levers.[117] The National Development Planning Agency (Badan Perencanaan Pembangunan Nasional or BAPPENAS) carries out national development planning, supports public-private partnerships on infrastructure projects, and plays a role in coordinating financing for clean energy projects.[118] The Financial Services Authority (Otoritas Jasa Keuangan or OJK) is responsible for regulatory frameworks for sustainable financing and oversight of the Indonesian Carbon Exchange (launched in 2023) and issues the green taxonomy.

The regulatory landscape is guided by various energy plans. The National Energy Policy (Kebijakan Energi Nasional or KEN), released in 2014, sets the government’s energy management policy.[119] The KEN covers multiple topics, including energy access and availability, utilization of local resources, and energy conservation. The National Energy Plan (Rencana Umum Energi Nasional or RUEN) contains a long-term national power plan as the foundation for other plans.[120] Both the KEN and RUEN contain national plans until 2050, are scheduled to be updated by 2024, and are led by the DEN.[121]

The National Electricity Plan (Rencana Umum Ketenagalistrikan Nasional or RUKN) and Regional Electricity Plan (Rencana Umum Ketenagalistrikan Daerah or RUKD) establish goals for the electricity sector with guidance from the RUEN.[122] In addition, the Regional Energy Plans (Rencana Umum Energi Daerah or RUED) contain region-specific energy plans aligned with the RUEN and cover Indonesia’s 38 provinces.[123]

RUPTL, prepared by PLN with support from ESDM, contains the medium-term investment plans for PLN. The latest version spans from 2021 to 2030.[124]

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[117] “Renewable Energy Tariffs and Incentives in Indonesia,” Asian Development Bank, September 2020.

[118] “About Us,“ Indonesian Green Growth Program, last accessed on November 2, 2023, http://greengrowth.bappenas.go.id/en/about/.

[119] “Government Regulation No. 79/2014 on National Energy Policy,” Government of Indonesia, 2014, https://peraturan.bpk.go.id/Details/5523/pp-no-79-tahun-2014.

[120] “National Energy General Plan (RUEN),” ESDM, 2017.

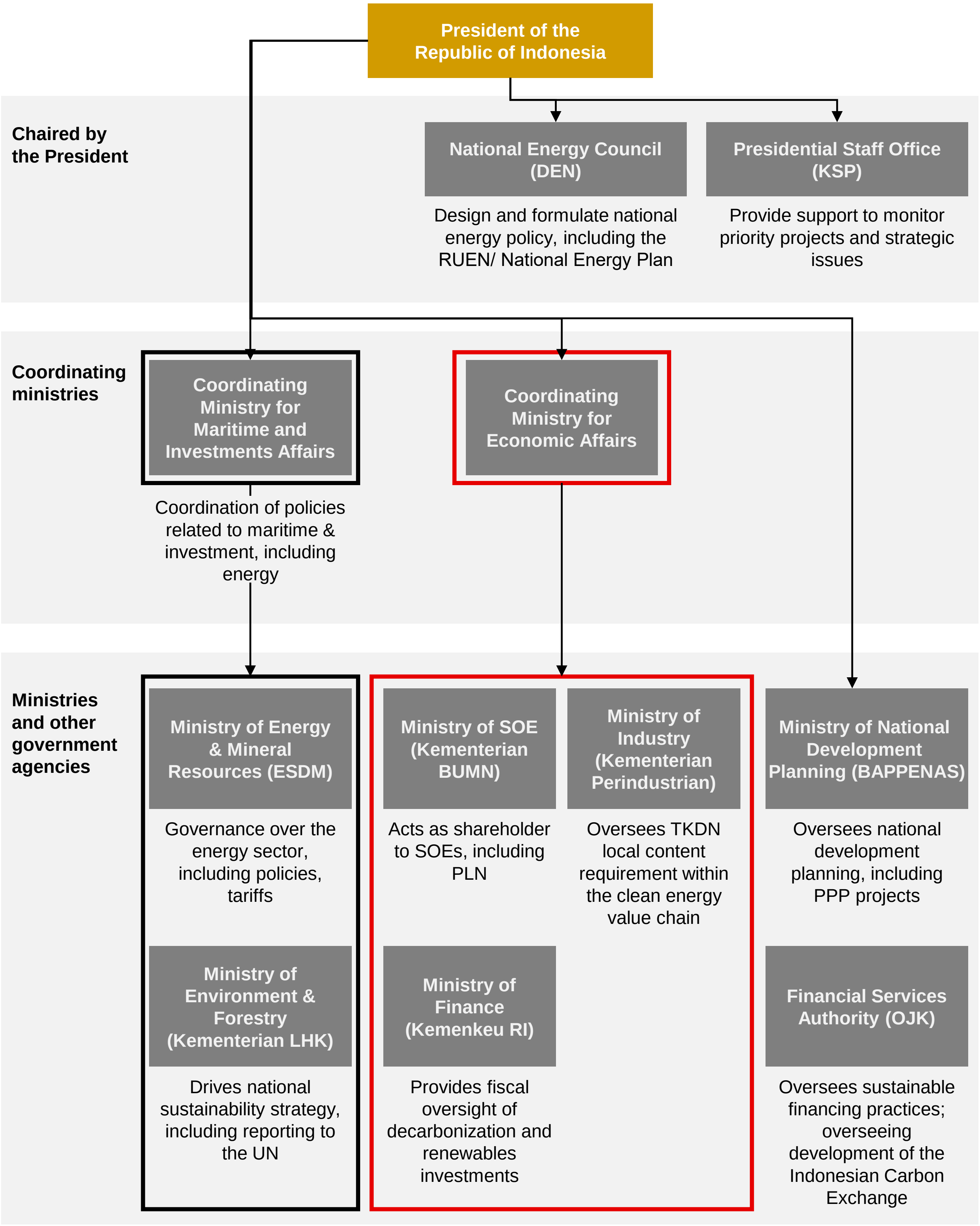
[121] "Streamlining Government of Indonesia Plans as a Pathway to Achieve Net Zero Emissions Target,” Energy Transition Partnership, September 2022, https://www.energytransitionpartnership.org/resource/streamlining-government-of-indonesia-plans-concept-note/.

[122] “An Energy Sector Roadmap to Net Zero Emissions in Indonesia,” IEA, September 2022, https://www.iea.org/reports/an-energy-sector-roadmap-to-net-zero-emissions-in-indonesia.

[123] “What is the basis for the Regional Energy General Plan?,” National Energy Council of Indonesia, March 13, 2019, https://www.den.go.id/index.php/dinamispage/index/811-apa-sih-dasar-penyusunan-rencana-umum-energi%20daerah.html.

[124] “RUPTL, 2021-2030,” PLN, 2021, Link.

Exhibit 24: Central clean energy policymakers in Indonesia



President of the Republic of Indonesia

Chaired by the President

National Energy Council (DEN)

Design and formulate national energy policy, including the RUEN/ National Energy Plan

Presidential Staff Office (KSP)

Provide support to monitor priority projects and strategic issues

Coordinating ministries

Coordinating Ministry for Maritime and Investments Affairs

Coordination of policies related to maritime & investment, including energy

Coordinating Ministry for Economic Affairs

Ministries and other government agencies

Ministry of Energy & Mineral Resources (ESDM)

Governance over the energy sector, including policies, tariffs

Ministry of Environment & Forestry (Kementerian LHK)

Drives national sustainability strategy, including reporting to the UN

Ministry of SOE (Kementerian BUMN)

Acts as shareholder to SOEs, including PLN

Ministry of Industry (Kementerian Perindustrian)

Oversees TKDN local content requirement within the clean energy value chain

Ministry of Finance (Kemenkeu RI)

Provides fiscal oversight of decarbonization and renewables investments

Ministry of National Development Planning (BAPPENAS)

Oversees national development planning, including PPP projects

Financial Services Authority (OJK)

Oversees sustainable financing practices; overseeing development of the Indonesian Carbon Exchange

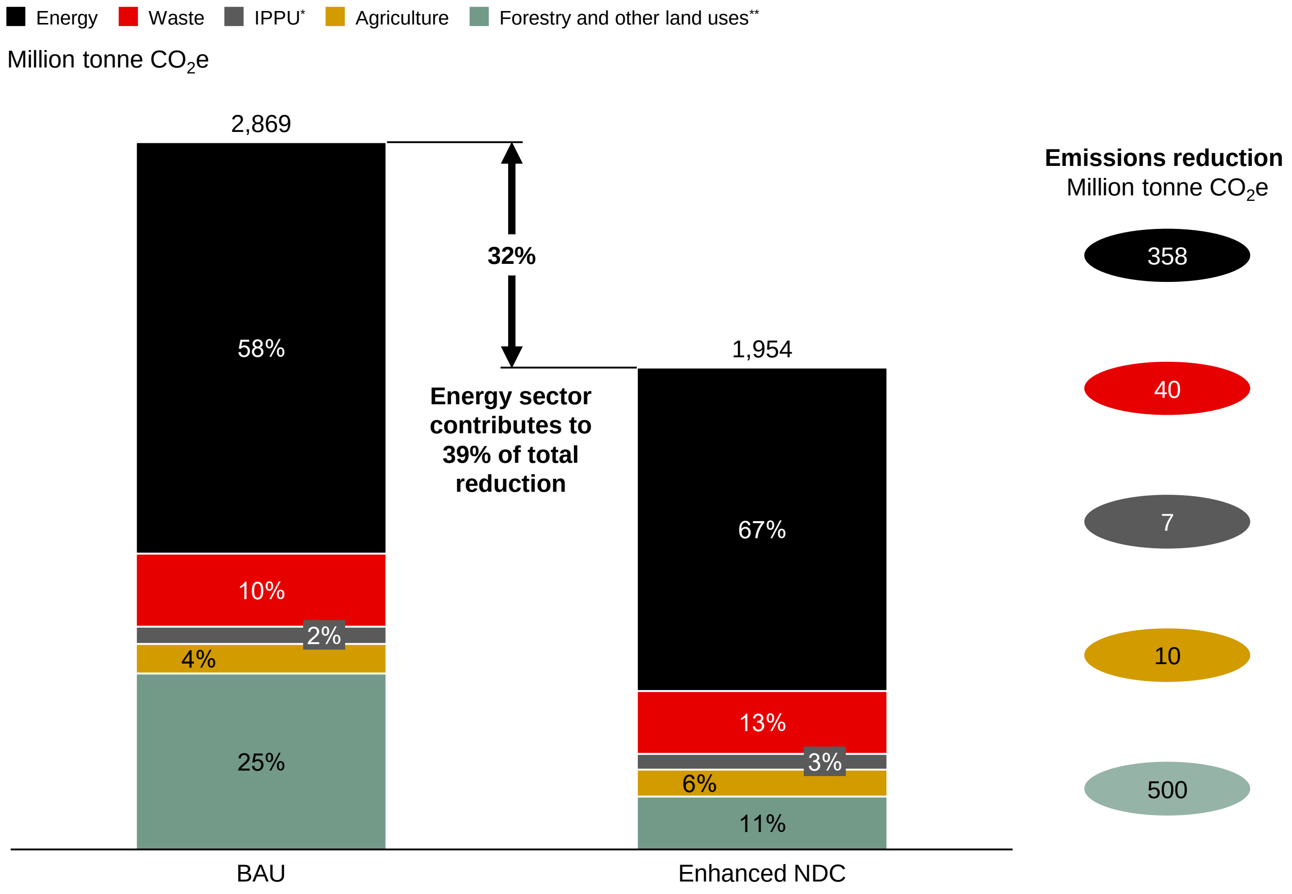
3.2. Momentum towards energy transition

An array of stakeholders in Indonesia spanning from public to private sectors have announced commitments towards decarbonization, and the momentum is building as initiatives are being implemented.

3.2.1. National commitments

Aligned with the global community, Indonesia has set a long-term aspiration to reach net zero. At the 2021 United Nations Climate Change Conference (COP26), Indonesia announced its commitment to achieve net zero emissions by 2060.[125] In September 2022, Indonesia's Ministry of Environment and Forestry (Kementerian Lingkungan Hidup Dan Kehutanan or KLHK) submitted an enhanced NDC with an updated commitment of reducing annual emissions by 32% by 2030, from 2.9 billion tonnes of CO_2e currently to 2 billion tonnes of CO_2e. About 39% of this reduction would come from the power sector.[126]

Exhibit 25: Indonesia's 2030 emissions under different scenarios[127]



* IPPU refers to Industrial Processes and Product Use

** Including emission from estate and timber plantations

In its enhanced NDC, Indonesia highlighted core 2030 targets for the power sector:[128]

1) Install 20.9 GW of on-grid RES (includes biofuel, biomass, geothermal, hydropower, solar PV, and wind) and 15.3 GW of off-grid RES (such as industrial parks and solar rooftops in residential and C&I sectors).

2) Use 9 million tonnes of biomass for co-firing in coal-fired power plants.

3) Adopt a 27.5 GW clean-coal technology and natural gas power plant.[129]

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[125] "An energy sector roadmap to net zero emissions in Indonesia," IEA, September 2022.

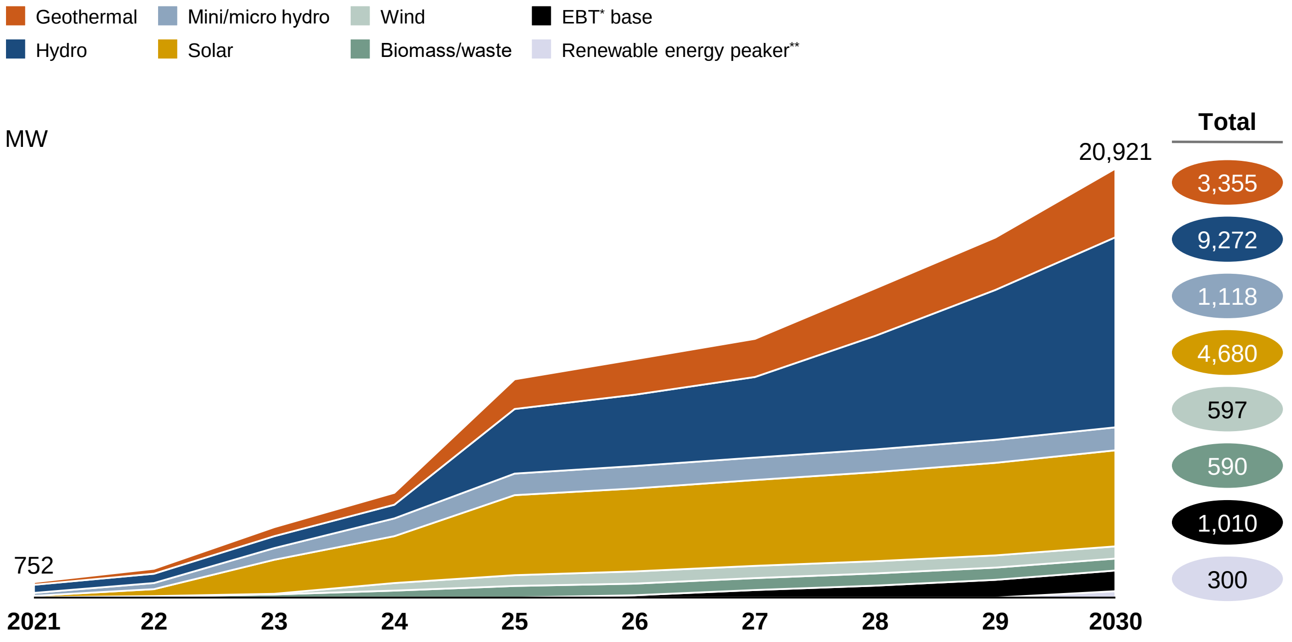
[126] "Enhanced nationally determined contribution: Republic of Indonesia," UNFCCC, 2022.

[127] Ibid

[128] Ibid

[129] Supercritical and ultra-supercritical coal-fired power plants.

Exhibit 26: Renewables growth plan under RUPTL 2021-2030[130]



* An EBT (“Energi Baru Terbarukan” in Indonesian, meaning “New and Renewable Energy”) power plant generates electricity using new and renewable energy sources (e.g., solar, wind, geothermal, hydro power).

** Type of power plant that operates during periods of high electricity demand.

In November 2022, at the G20 Leaders’ Summit in Bali, Indonesia also announced that the net zero target for its power sector could be brought forward to 2050 and that emissions from the sector should peak in 2030 under the condition that JETP will be successfully implemented.[131]

3.2.2. Public and private sector initiatives

To help achieve Indonesia’s ambitions to decarbonize the power sector, public and private stakeholders have announced significant efforts and have implemented many landmark initiatives. Both sets of stakeholders are critical to push the transition: Public stakeholders create policy, the regulatory environment, and incentives, while private stakeholders drive project execution and ensure decarbonization aspirations are sustainable with appropriate project economics.

Public sector

Public sector stakeholders comprise three core groups: energy policymakers, financial regulators, and public finance providers.

Energy policymakers (e.g., ESDM, DEN): In 2022, the president issued a Presidential Regulation, PR112/2022, covering the Acceleration of Development of Renewable Energy for Electric Power Supply,[132] which accelerates RES development by offering incentives, curbing coal power, and introducing flexible procurement and pricing mechanisms. The regulation required PLN to create an updated RUPTL that focused on RES and called for fiscal incentives such as tax benefits and non-fiscal incentives provided by the central and regional governments to encourage greenfield renewables. In addition, PR112/2022 prohibited the development of new coal-fired power plants except those in RUPTL or where the pre-defined criteria are met. Electricity procurement between PLN and RES power generators could be accelerated through direct appointment, those completed within 90 days, or direct selection, those completed within 180 days, and when purchasing electricity from RES, purchase price would be based on factors including capacity, years of operation, and location. Pricing models for RES procurement were also clarified to provide greater transparency for renewables developers.

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[130] “RUPTL, 2021-2030,” PLN, 2021, Link.

[131] “Indonesia and International Partners Secure Groundbreaking Climate Targets and Associated Financing,” The White House, November 15, 2022,

[132] “Indonesia to boost the development of the Renewable Energy Sector,” Rödl & Partner, https://www.roedl.com/insights/newsflash-asean/2022-04/indonesia-boosting-development-renewable-energies.

PR112/2022 also mandated numerous fiscal incentives for RES granted through the Kemenkeu RI, including:

- An income tax holiday of 5-20 years with over IDR 500 billion investment (max. 100% deduction).
- A "mini" tax holiday of five years for investments of IDR 100-500 billion (max. 50% income tax deduction).
- A net income tax allowance reduction for six years of 5% each year or 30% of the investment value.
- An import duties exemption for capital goods used for RES electricity generation industry.
- Land and building tax reductions for plots used for geothermal business exploration stage.

Financial regulators (e.g., OJK): In January 2022, OJK issued the first version of Indonesia's national green taxonomy, which serves as a framework to define environmentally sustainable investments. Notably, the current version of the Indonesia green taxonomy contains the Company Performance Rating Assessment Program (PROPER), a program that provides a framework to assess compliance for entities involved in activities related to controlling pollution and environmental damage, including the management of hazardous and toxic waste. Future updates to the taxonomy are expected to add content addressing the social and governance considerations around these activities. OJK is updating Indonesia's taxonomy to align with the ASEAN taxonomy by the end of 2023, assigning quantitative thresholds from the ASEAN taxonomy adjusted to Indonesia's circumstances. OJK is also expected to update the Transition Finance Guideline for financial institutions in 2024.

Public finance providers (e.g., MDBs): These include government funds such as PT Sarana Multi Infrastruktur (SMI), a special mission vehicle (SMV) managed by the Kemenkeu RI that eases investment in infrastructure, and the Indonesia Investment Authority (INA), which functions as the sovereign wealth fund of Indonesia, as well as MDBs and other financiers including the Asian Development Bank (ADB) that provide financing at preferential rates.

Blended finance providers mobilize funds towards development targets. The four major initiatives in Indonesia led by public finance providers are:

- **SDG Indonesia One:** A blended finance fund overseen by SMI.[133] The fund supports new infrastructure projects linked to reaching the UN Sustainable Development Goals in Indonesia.
- **Climate Investment Funds (CIF):** Multilateral fund for decarbonization in emerging markets. The CIF-ACT investment program accelerates financing into early retirement for coal-fired assets.
- **Energy Transition Mechanism (ETM):** A program by the ADB to accelerate decarbonization in Asia through concessional and commercial finance.
- **Just Energy Transition Partnership (JETP):** A public finance initiative co-led by Japan and the US with participation from other nations. It provides financial support to transition away from fossil fuels.

Private sector

Private sector stakeholders are comprised of power sector players, power purchasers, and private financiers.

Power sector players (i.e., PLN): Given PLN's scale and influence in Indonesia, it is the dominant power player in the country and our focus compared with IPPs. PLN's unmatched scale gives it massive influence in setting the overall direction of power sector decarbonization in Indonesia.

Echoing the NDC, the 2021 RUPTL provided a plan for 2021-2030 to rapidly expand RES in Indonesia. It outlines PLN's effort to increase electricity supply with the 35 GW power generation plant and strategic development of RES. It is the most green and sustainable RUPTL to date and provides the basis to reach Carbon Neutral 2060. PLN has committed to reaching a RES share in the energy mix of 23% by 2025 and supporting RES for additional planned power generation for up to a 50% share. The growth in RES will be led by hydro, solar, and geothermal under the plan.

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[133] "Strategic cooperation: SDG Indonesia One," Sarana Multi Infrastruktur, last accessed on September 15, 2023, https://ptsmi.co.id/sdg-indonesia-one.

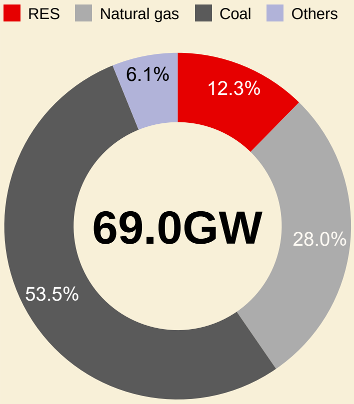
Spotlight on select power sector players

PLN

Company profile[134, 135]

- **FY2022 Revenue**:
  IDR 441.1 trillion (USD 28.5 billion)
- **Market share**:
  PLN operates 85% of Indonesia's electricity generation in 2022 (69 GW of Indonesia's total installed capacity of 81 GW)

Total installed capacity of PLN by generation type (operated power plants, as of December 2022)[136, 137]



GHG Emissions (2022)[138]

- **Scope 1**: 163.5 million tonnes of CO_2e
- **Scope 2**: 9.7 million tonnes of CO_2e
- **Scope 3**: 97.2 million tonnes of CO_2e

Carbon intensity (scope 1):
0.88 tonne of CO_2e per MWh

Shareholder information[139]:
KBUMN (Indonesia): 100%

Goals and commitments[140]

- **2030**: Achieve Indonesia's NDC (targets a conditional reduction in GHG emissions of 43.2%)
- **2060**: Net zero

PT Perusahaan Listrik Negara (PLN) is wholly owned by the government of Indonesia through KBUMN. PLN has a vast portfolio of assets, including power generation, coal supply, operations and maintenance, and engineering and construction services. It serves more than 85 million customers in Indonesia. In 2022, the company's portfolio included 69 GW of installed capacity, of which 45 GW was self-produced.

The sole buyer of electricity In Indonesia, PLN owns all TnD infrastructure and controls retail sales in the country, except where the government permits other companies, such as industrial estates, to operate isolated power production. In January 2023, PLN maintained a wide distribution network of 2,327 substation units, 551,303 distribution substation units, 68,200 km of transmission lines, and 1 million km of distribution lines.[141]

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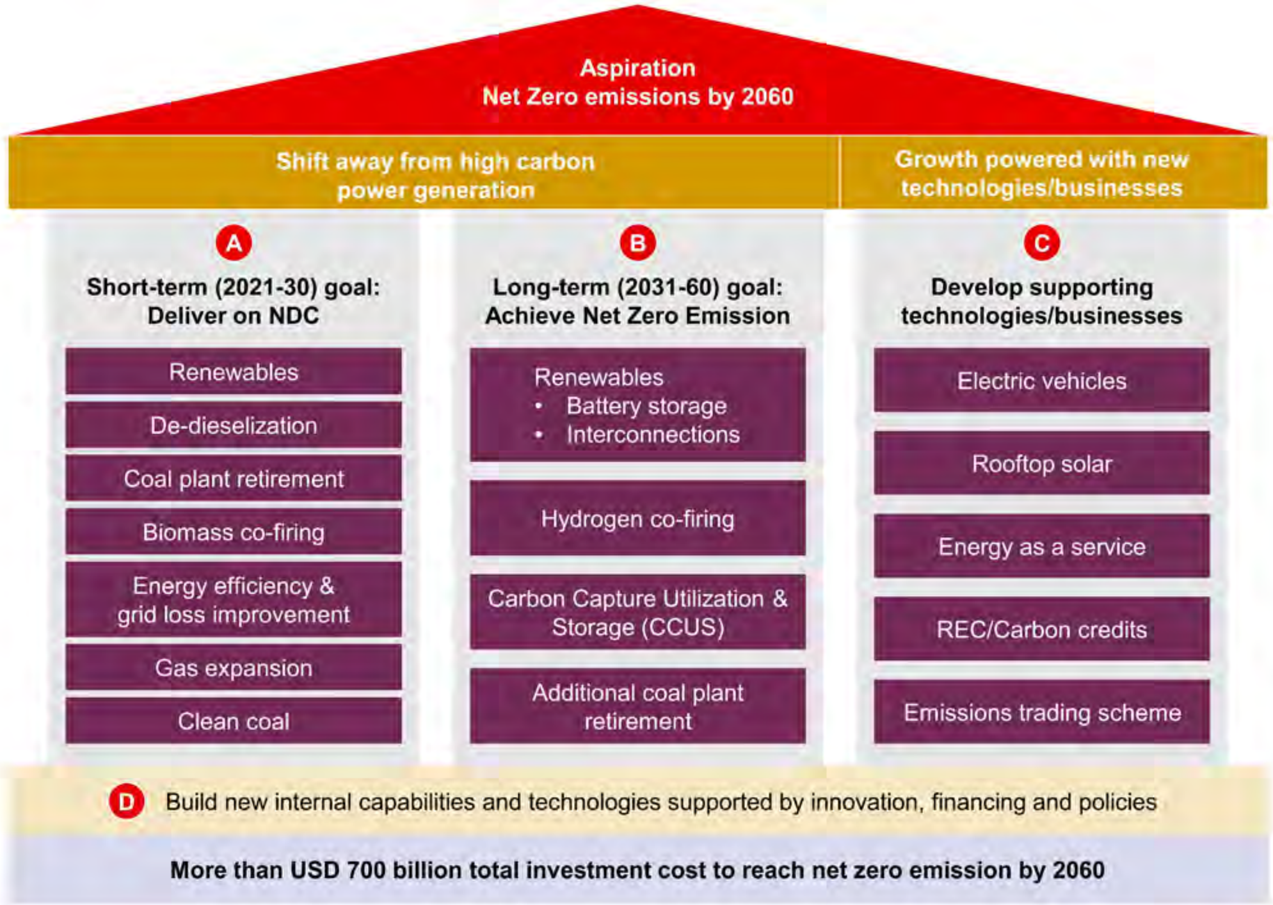
[134] "Annual Report," PLN, 2022.
[135] "Handbook of Energy and Economic Statistics of Indonesia 2022," ESDM, 2022.
[136] Installed capacity including power plants owned by PLN (44.9 MW in 2022), IPP (23.0 MW in 2022), and leased (1.1 MW in 2022); "Annual Report," PLN, 2022. The total of generation share does not equal to 100% due to rounding of numbers.
[137] "Annual Report," PLN, 2022.
[138] "Sustainability Report," PLN, 2023.
[139] From public PLN and KBUMN disclosures.
[140] "Climate change management," PLN, accessed November 7, 2023, https://web.pln.co.id/en/sustainability/climate-change-management#commitment; Environmental, Social, and Governmental Framework PT PLN (Persero)," PLN, August 2023.
[141] "Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development," PLN, 2023.

Exhibit 27: PLN's technology portfolio for its 2030 and 2060 decarbonization goals[142]



For 2021-2030, PLN plans to incorporate more RES into its energy portfolio.[143] It operates several renewable power plants, including hydro and geothermal facilities, and plans to significantly expand its RES capacity with about 1.5 GW of capacity in the pipeline across various energy sources.[144]

Looking further, PLN's plans through 2060 include retrofitting of coal-fired power plants with CCUS technology. On condition that the JETP is implemented, PLN could also reach net zero by 2050, 10 years ahead of the initial schedule, as part of the investment and policy plan for Indonesia's JETP,[145] that was released recently.[146]

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[142] "Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development," PLN, 2023

[143] "RUPTL, 2021-2030," PLN, 2021, Link.

[144] "Ini Ya, Rencana Pengembangan Pembangkit Listrik EBT PLN di Tahun 2023 (This is PLN's EBT Power Plant Development Plan in 2023)," Godang, Ruangenergi.com, January 4, 2023, https://www.ruangenergi.com/ini-ya-rencana-pengembangan-pembangkit-listrik-ebt-pln-di-tahun-2023/.

[145] "Risks and Challenges of the Just Energy Transition Partnership (JETP) Indonesia," CSIS Indonesia & Tenggara Strategics, July 2023.

[146] "Comprehensive Investment and Policy Plan 2023," JETP, November 2023.

Sidebar: PLN green transition initiatives

De-dieselization program: To reduce reliance on fossil fuels, PLN plans to replace 5,200 diesel oil-fueled generators with RES and mini-grid solutions.[147]

Coal MPO: PLN plans to retire coal-fired power plants early. Under the current plan, 1 GW of capacity from coal- and gas-fired power plants will be replaced with RES by 2030.[148]

Biomass co-firing: PLN has targeted deploying co-firing technologies in 52 coal-fired power plants in 2025, with total biomass use of about 10 million tonnes a year.[149] PLN's subsidiary, PLN Nusantara Power, is increasing biomass co-firing across its coal assets, some of which have already piloted co-firing in very high ratios of more than 80% of biomass.[150] In 2022, PLN introduced biomass co-firing in 36 coal-fired power plants.[151] This program was able to produce 575 GWh in clean energy and reduce GHG emissions by 570 thousand tonnes using 542 thousand tonnes of biomass.

CCUS: PLN is developing CCUS technology in partnerships with other organizations. PLN plans significant CCUS retrofitting for 19 GW in coal-fired assets,[152] collaborating with the Bandung Institute of Technology (Institut Teknologi Bandung or ITB), INPEX, and MedcoEnergi.[153]

Hydrogen and ammonia co-firing: PLN plans to introduce co-firing with hydrogen and ammonia in its fossil fueled power plants. PLN Enjiniring is working with Korea Electric Power Corporation (KEPCO) Engineering and Construction Company of South Korea to develop hydrogen and ammonia co-firing technology.[154] By the end of 2022, three pilot projects had begun in PLTU Gresik, PLTU Suralaya, and PLTGU Priok.[155]

Smart grid investment: PLN has announced plans for significant investment in smart grid development. According to RUPTL, the estimated investment to the overall grid infrastructure will be over USD 25 billion by 2030 and specifically into smart grid about USD 2.5-4.9 billion.[156]

PLN also ran a study in Zhangbei, China, focused on smart grid and high-voltage, direct-current projects as part of an effort to explore technology partnerships in China.[157] PLN is also working with Accenture, the Global Power System Transformation Consortium (G-PST), and the US Agency for International Development (USAID) to create a flexible smart grid.[158]

Renewable Energy Certificates (RECs): PLN's use of RECs, in partnership with the Clean Energy Investment Accelerator (CEIA), provides a standardized and marketable way to verify RES.[159] In 2022, sales of RECs represented 1.7 TWh of electricity, more than five times the 2021 volume of 308 GWh.[160]

Global collaboration: PLN works with organizations like the Japan International Cooperation Agency (JICA) and Kyudenko (a Japanese facilities engineering service provider) to expand power to remote areas using RES.[161] PLN has also collaborated with the China Renewable Energy Engineering Institute (CREEI) to provide technical support for implementing and operating low-carbon technologies in a way that protects the environment and local communities.

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[147] "Indonesia Energy Transition Outlook 2022," IESR, 2022.

[148] "Intersessional Meeting of the CTF Trust Fund Committee," Climate Investment Fund, October, 2022.

[149] "ESG Performane Report 2022,"PLN, September 2023.

[150] "Co-Firing Future Generatoin Technologies," PT PLN Nusantara Power, January 2, 2023, Link.

[151] "Kaleidoscope 2022, Implementation of Co-Firing at PLN Generates 575.4 GWh of Clean Electricity - Press Release No. 002.PR/STH.00.01/I/2023," Rifky Syofiadi, PLN, January 2, 2023, Link.

[152] "Paparkan Upaya Pengurangan Emisi di Konferensi BUMN Negara G20 PLN Siap Pimpin Transisi Energi Indonesia (Presenting Emission Reduction Efforts at the G20 BUMN Conference, PLN Ready to Lead Indonesia's Energy Transition)," Santikaaristi, PLN, October 18, 2022, Link.

[153] "Ready for Energy Transition, PLN Explains Strategy to Reduce Emissions," Eqqi Syahputra, CNBC Indonesia, October 17, 2022, Link.

[154] "Accelerating energy transition, PLN collaborates with South Korean company," November 5, 2022.

[155] "PLN Gandeng 2 Perusahaan Korsel Kembangkan PLTU Pakai Amonia (PLN Collaborates with 2 South Korean Companies to Develop PLTU Using Ammonia)," CNBC Indonesia, November 5, 2022, Link.

[156] "Smart Grid Development in Indonesia," Dr. Zainal Arifin, PLN, June 22, 2021. "RUPTL 2021-2030," PLN, 2021. Smart grid CAPEX in a short term (2021-2025) IDR 10-25 trillion (USD 0.6-1.6 billion) and a long term (2026-2031) IDR 30-50 trillion (USD 1.9-3.2 billion).

[157] "Mau Kembangkan Smart Grid, PLN Berguru Hingga ke China (Wanting to Develop Smart Grid, PLN Learns to China)," CNBC Indonesia, May 2023, Link.

[158] "EBT Jadi Energi Masa Depan, PLN Siap Perkuat Smart Grid (Renewable Energy Becomes the Energy of the Future, PLN Ready to Strengthen Smart Grid)," CNN Indonesia, November 14, 2022, Link.

[159] "Indonesia's PLN to issue RECs, promote clean energy," The Phnom Penh Post, February 2, 2020, Link; "PLN Provides 404 MWh Green Energy Certificate Services to Data Center Companies," JPNN.com, May 15, 2022, Link.

[160] "Naik Signifikan Sepanjang 2022 REC PLN Mampu Suplai 17 Juta MWh Listrik Hijau (Significant increase, throughout 2022 PLN's REC will be able to supply 1.7 million MWh of green electricity)," PLN, January 20, 2023, Link.

[161] "Signing of Memorandum of Understanding (MoU) on Joint Study of 100% Electricity Supply from Renewable Energy Based Power Plants in Remote Areas," JICA, September 22, 2022, Link.

Power purchasers: Corporations, industrial clusters, and other industry associations, among others, which drive RES demand. Given the regulated power market structure of Indonesia, power purchasers have limited scope to drive renewable initiatives. Currently, the only option to procure RES, other than captive generation, is to purchase RECs.

Exhibit 28: Options to purchase RES in Indonesia

✓ = Fully allowed ✓ = Discussions underway ⊗ = Few/No discussions

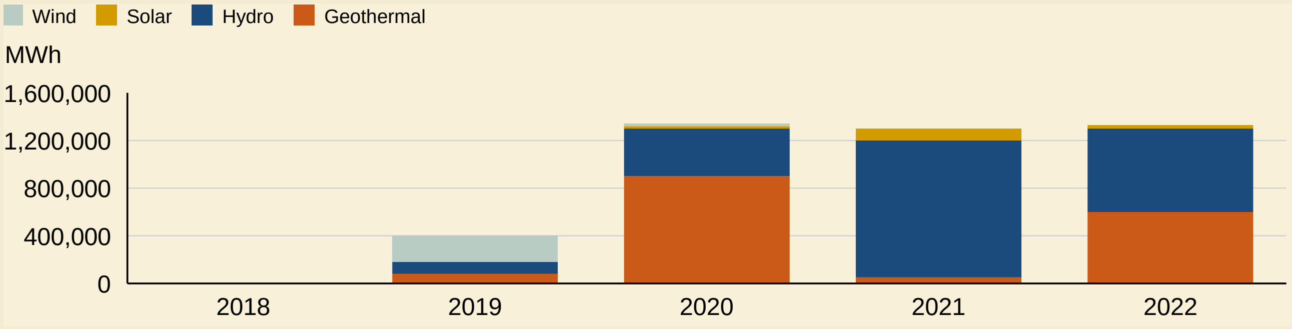
Acceptability: High → Low

Options to purchase RES				Status in Indonesia
Captive generation *(Direct investment in production for self-consumption)*	Customer	Directly owns/leases	RES asset	✓ **Available today**
Corporate PPA	Customer	Direct contracts to guarantee supply of RES (physically or virtually)	Power generator	⊗ **TPA and direct PPA not possible**
Green tariffs *(Green procurement from utilities)*	Customer	RES purchase product offered by utilities	Utility	✓ **PLN – Amazon RE supply agreement**
Renewable Energy Certificates *(Unbundled Energy Attribute Certificates)*	Customer	Purchases REC, which represents 1 MWh of RES	Issuing body	✓ **Available today**

Sidebar: RECs in Indonesia

Indonesia initiated in 2018 a REC market using International REC (I-REC) standards and the Tradeable Instrument for Global Renewables (TIGR). REC is a repository system that allows customers to claim the energy they used was supplied from a certain RES power plant. RECs were originally issued by PLN and other IPPs, but in 2020 PLN claimed exclusive rights to green attributes, such as RECs. As such, IPPs may no longer issue their own RECs directly to the market for projects with a commercial operation date after 2020 (**Exhibit 29**). PLN sold about 750 MWh of RECs from January to March 2023, for about IDR 27 billion (USD 1.7 million).[162]

Exhibit 29: Total RECs issued in Indonesia (2018 – 2022)[163]



In recent years, there have been positive developments and early indications of large corporations with net zero ambitions procuring RES other than RECs. In 2022, Amazon signed with PLN on direct RES procurement from four solar projects – PLTS Bali Barat, 25 MW; PLTS Bali Timur, 25 MW; PLTS Karangkates, 100 MW; and PLTS Saguling, 60 MW – totaling 210 MW in capacity. Under the agreement, Amazon Web Services operations in Indonesia will use the electricity generated by these plants, in line with Amazon's commitment to power all its operational activities with RES by 2025, ahead of the original target of 2030.[164]

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[162] "PLN booked IDR 26.6 bn revenue from 749,151 MWh of renewable energy certificates," TanahAir.net, May 9, 2023, Link.

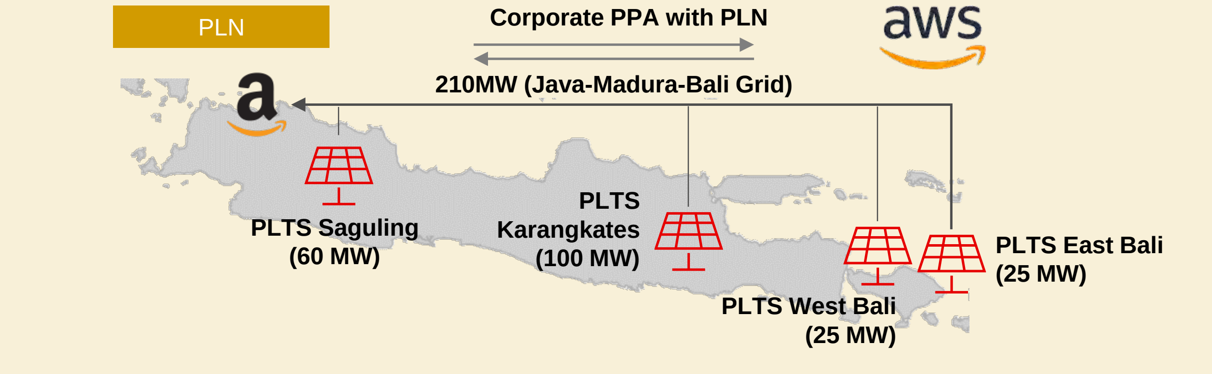
[163] "Renewable Energy Certificates (RECs) in six APEC Southeast Asia economies," Asia Pacific Energy Research Centre, May 19, 2023.

[164] "PLN signs agreement with Amazon for 210 MW solar power project in Indonesia," PLN, November 15, 2022.

Similarly, several companies, including Hitachi Astemo, L'Oréal, Pertamina, and Unilever, formed a net zero industry cluster in 2022.[165] The World Economic Forum (WEF) supported the cluster as part of the WEF's Transitioning Industrial Clusters towards Net Zero initiative. The agreement's main goal is to develop decarbonization solutions to help the Jababeka Industrial Estate achieve net zero emissions by 2050 as part of Indonesia's overall 2060 net zero goals.

In addition, the Indonesian Chamber of Commerce (Kamar Dagang dan Industri or KADIN) formed the KADIN Net Zero Hub in collaboration with the Indonesia Business Council for Sustainable Development (IBCSD), WRI Indonesia, and the Carbon Disclosure Project (CDP).[166] By 2023, 70 private companies had joined the program, and 10 companies had completed the KADIN NZH Corporate Assistance Program (CAP), mapping net zero commitments based on SBTi standards.[167, 168] At a minimum, member companies have pledged to achieve net zero by 2060 in line with the government's net zero goal.

Case study 1: In 2022, Amazon signed a supply agreement for off-site facilities in Indonesia with PLN to buy a total of 210 MW of solar power through the Java-Madura-Bali grid. Amazon's goal is to power all its operations with RES by 2025 globally.[169]



Case study 2: In 2022, companies including Hitachi Astemo, L'Oréal, Pertamina, and Unilever formed a net zero industry cluster supported by the WEF and Accenture to develop decarbonization solutions for the Jababeka Industrial Estate and reach net zero by 2050. [170]

Financiers: Commercial and investment banks that arrange and originate sustainable financing, as well as asset managers and institutional investors such as insurance companies and pension funds. Sustainable lending in Indonesia has expanded meaningfully in recent years. For example, since the publication of OJK

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[165] "Perusahaan Ini Bentuk Klaster Net Zero di Kawasan Jababeka (This company forms a net zero cluster in the Jababeka area)," Khoirul Anam on CNBC Indonesia, November 12, 2022, Link.

[166] "About KADIN Net Zero Hub," KADIN Net Zero Hub, accessed September 15, 2023, Link.

[167] "70 Perusahaan Jadi Anggota, Kadin Net Zero Hub Siap Berlanjut (70 companies become members, Kadin Net Zero Hub is ready to continue)," Rezza Aji Pratama on Katadata.co.id, June 20, 2023, Link.

[168] "10 Companies Graduated from KADIN Net Zero Hub (NZH) Corporate Assistance Program (CAP), Showing Real Commitment of Private Parties in Decarbonization Efforts in Indonesia," IBCSD, March 10, 2023, Link.

[169] "Pasok Kebutuhan Amazon, PLN Bangun Empat PLTS Berkapasitas Total 210 MW (To supply Amazon's needs, PLN builds four PLTS with a total capacity of 210 MW)," Dunia Energi, November 14, 2022, Link.

[170] "Perusahaan Ini Bentuk Klaster Net Zero di Kawasan Jababeka (This company forms a net zero cluster in the Jababeka area)," Khoirul Anam on CNBC Indonesia, November 12, 2022, Link.

regulation No. 60/POJK.04/2017 on Green Bonds in 2017 and Green Sukuk Framework in 2018, green bonds have been issued each year, with a cumulative volume of USD 3.8 billion as of 2022.[171]

In addition to green or sustainable lending to corporate clients, banks have also explored innovative ways to expand sustainable finance to a broader customer base.

Sidebar: PT Bank Danamon Indonesia Tbk's sustainability initiatives [172]

Bank Danamon, one of MUFG's Partner Banks, has engaged in various sustainability related activities and, in 2022, the bank:

- Increased the total financing for the sustainable business activities category (KKUB)
- Amended the Sustainability Credit Guideline
- Developed digital financial literacy activities
- Implemented various efforts to support decarbonization
- Included Platinum Green Building certification
- Launched Electric Vehicle Charging Station in Menara Bank Danamon head office
- Installed solar panels in several branch offices
- Developed water and sanitation infrastructure in five new regions
- Planted mangrove and productive trees in several locations

Bank Danamon's sustainable finance loans account 21% of the total loan portfolio in 2022 with the aim to increase the share to 25% by 2027. In pursuit of this target, Bank Danamon has collaborated with MUFG and Adira Finance to generate business prospects and product enhancement related to sustainability, including exploring government's initiatives on various sustainability related projects and bond markets opportunities related to sustainable finance.

Bank Danamon has grown total financing based on sustainable business activity category to IDR 25,142 billion in 2022 from IDR 1,006 billion in 2019. Majority of this comes from business activities and/or other activities of micro and SMEs with IDR 21,486 billion followed by sustainable water and wastewater management with IDR 1,600 billion, and sustainable management of natural resources and land use with IDR 1,281 billion.

Bank Danamon created a comprehensive sustainable ecosystem that supports its employees and customers in transitioning to clean energy by providing ESG related program to expand sustainable finance to a broader customer base.

i. Solar panel financing program

ii. EV financing program for customers through Adira Finance

iii. EV financing and electric motorcycle rental programs for employees through Employee Cooperative

In addition, Bank Danamon has also been implementing various efforts to support the bank's own operation decarbonization, such as Platinum Green Building certification, EV charging station, solar panel, water, and sanitation infrastructure, as well as mangrove planting.

Danamon

A member of MUFG, a global financial group

Sustainable business activity category	**Total financing by Danamon in 2022,** Billion Rupiah
Renewable energy	644
Pollution prevention and control	2
Sustainable management of natural resources and land use	1,281
Environmentally friendly transportation	8
Sustainable water and wastewater management	1600
Product which can reduce the use of resources and produce less pollution	81
Environmentally friendly buildings that meet national, regional or international recognized standards	32
Other business and/or activities with an environmental perspective	8
Business and/or other activities of micro and SMEs	21,486
Total	**25,142**

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[171] "Green bonds, the way to drive more sustainable development in Indonesia," EY, November 14, 2022, Link.

[172] "Sustainability Report 2022," PT Bank Danamon Indonesia Tbk, March 2023.

3.3. Bankability assessment matrix for Indonesia

Although momentum towards energy transition in Indonesia is building, with commitments from the government, policy updates, and PLN's strategy for decarbonization, projects contributing to the transition are still under way. To identify the underlying challenges and lay out potential unlocks to accelerate the transition, we assessed the announced decarbonization levers to identify the hurdles to building scale. In this section, we will provide an overview of the prioritized decarbonization levers and highlight the major challenges and potential solutions to each. In addition, we will offer a matrix across technical feasibility and commercial feasibility to gauge the scalability of these levers which we outlined in Section 1.

3.3.1. Scope of decarbonization levers

We have identified core decarbonization levers announced in the NDC, RUPTL and PLN's climate change management strategy that are crucial to Indonesia's effort to decarbonize. We see five prominent investment themes for the country:

1) **Solar, hydro, geothermal, and mini-grids:** RES are expected to reach 69% of PLN's energy mix by 2060, requiring significant development of renewables, notably solar, geothermal, and hydro. These include distributed solutions, such as residential and C&I solar or mini-grid solutions. Mini-grids are gaining traction from PLN as a way to replace diesel generators on remote islands with solar power plants. PLN plans to replace 5,200 units of diesel oil-fueled power plants.

2) **Biomass co-firing with coal:** Biomass co-firing with coal is a high priority for the government and PLN to reduce emissions from coal-fired power plants.

3) **Grid upgrade and energy storage:** Grid upgrade and energy storage are critical to enable RES use, particularly for Indonesia where the national grid does not reach to some islands, and electricity demand and supply potential are separated by geography.

4) **MPO:** The orchestrated early retirement of coal-fired power plants is a critical lever for PLN, and initiatives from JETP and other efforts from financial institutions are being explored.

5) **CCUS and hydrogen/ammonia co-firing with fossil fuel plants:** PLN is piloting the co-firing of low-carbon fuels (hydrogen/ammonia) to decarbonize fossil fuel power plants. Ammonia-coal co-firing can play a significant role given Indonesia's large number of existing coal-fired power plants, while hydrogen is envisioned to serve Indonesia's fleet of gas-fired power plants. CCUS is also another potential measure to decarbonize thermal assets since Indonesia also has suitable geological storage for carbon sequestration.

Some themes have been de-prioritized from the analysis, largely because of the relatively smaller scale and significance in the energy transition or uncertainty around implementation. Although small, individual projects may be financed or explored, these areas are outside the scope of this report for Indonesia:

- **Wind:** Indonesia does not have particularly favorable wind conditions. Most parts of Indonesia experience consistently low wind speeds, making the prospect of large-scale wind generation unviable. South Sulawesi and East Timor show localized areas with slightly higher wind speeds, ranging from six to seven meters per second, but even these regions fall within the lower range of potential wind power generation, categorized as Class three (low wind) areas by International Electrotechnical Commission (IEC) standards. Wind LCOE for Indonesia is estimated at around USD 0.07-0.16/kWh,[173] and not competitive with solar power when considering cost per unit of electricity generated, excluding generation profile implications. In addition, the planned wind capacity addition is only about 597 MW, which is much smaller compared to hydro 9.3 GW, solar 4.7 GW; and geothermal 3.4 GW under the RUPTL.

- **Nuclear:** Nuclear power has been explored as a potential solution for Indonesia, but whether the country will pursue this option remains unclear. PLN's current decarbonization plan does not include a nuclear power option.

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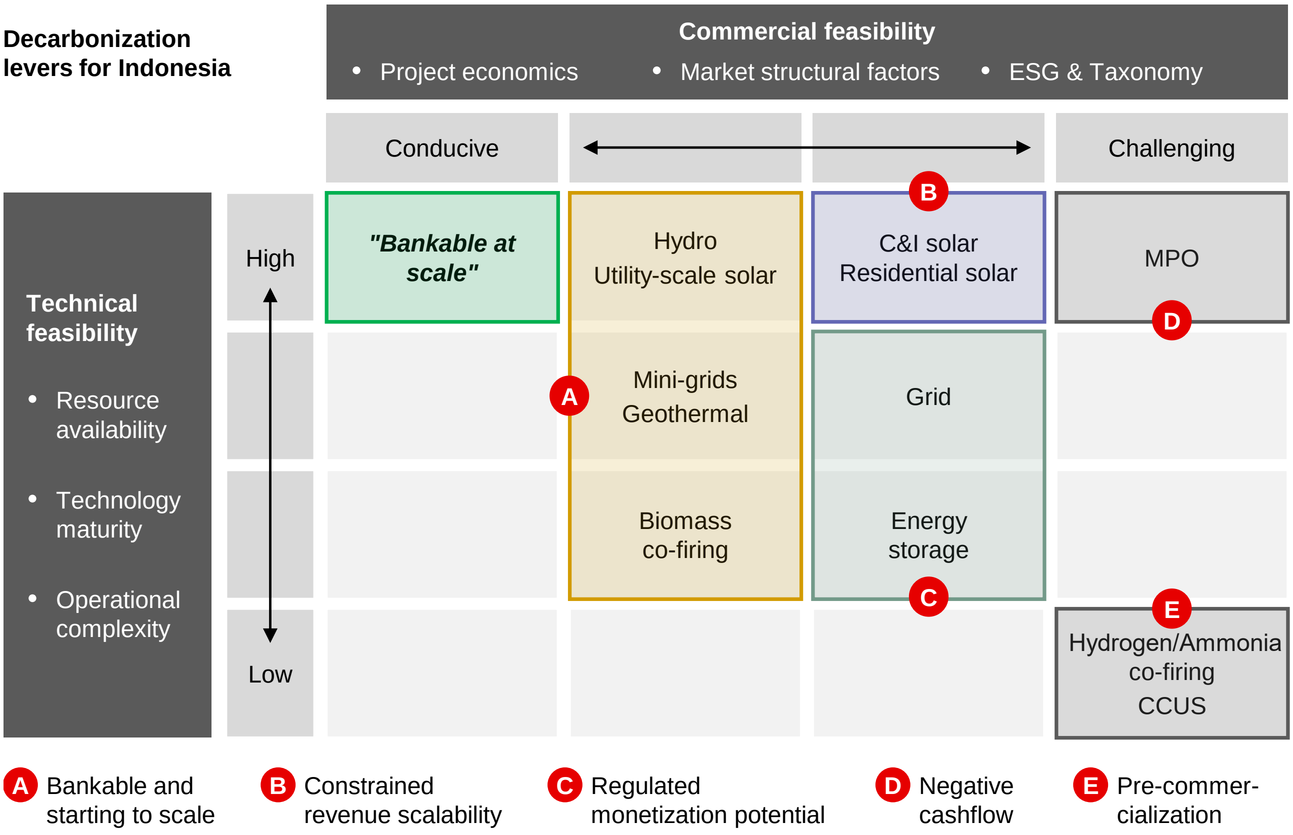
[173] "Levelized cost of electricity in Indonesia, Understanding the levelized cost of electricity generation," IESR, December 2019.

3.3.2. Bankability assessment

For each decarbonization lever, we applied our methodology to assess bankability based on commercial and technical feasibility.[174] Based on this assessment, decarbonization levers fall under five categories: bankable and starting to scale, constrained revenue scalability, regulated monetization potential, negative cash flow, and pre-commercialization (**Exhibit 30**).

Exhibit 30: Decarbonization lever assessment matrix – Indonesia



	Conducive			Challenging
High	*"Bankable at scale"*	Hydro Utility-scale solar	C&I solar Residential solar	MPO
		Mini-grids Geothermal	Grid	
		Biomass co-firing	Energy storage	
Low				Hydrogen/Ammonia co-firing CCUS

Ⓐ Bankable and starting to scale
Ⓑ Constrained revenue scalability
Ⓒ Regulated monetization potential
Ⓓ Negative cashflow
Ⓔ Pre-commercialization

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[174] Section 1 and Exhibit 4 detail the bankability assessment methodology.

Category A: Bankable and starting to scale

“Bankable and starting to scale” comprises of hydropower, utility-scale solar power, mini-grid, geothermal, and biomass co-firing. Market structural factors pose the central commercial challenge to deploy these levers at scale. For example, overcapacity in the power market and TKDN influence multiple levers and weigh on investment decisions for new RES developers. Grid investment is also required to manage intermittency of solar and connect between RES supply and demand centers. From a technical feasibility perspective, the levers have high resource availability and stand as proven technologies but can face operational complexity. Hydro, mini-grids, and geothermal face operational risks at the exploration, planning, permits, and construction phase. Biomass carries complexity of logistics between available supply centers and fossil fuel power plants.

Category B: Constrained revenue scalability

“Constrained revenue scalability” comprises C&I and residential solar power programs. Distributed solar is technically feasible today; however, the bankability is constrained by project economics and market structural factors.[175] Owing to concerns around excess supply and grid compatibility, self-generation capacity is capped. Further, individual ticket sizes, and varying individual credit evaluations affect the project economics and attractiveness to obtain financing.

Category C: Regulated monetization potential

“Regulated monetization potential” comprises RES enablers of grid development and energy storage solutions. Both levers share similar commercial feasibility challenges to project economics due to the regulated retail electricity tariff, making it difficult to pass additional costs to customers. The internal rate of return (IRR) for TnD projects are generally near the cost of capital. The project economics for energy storage is also limited by the absence of an ancillary services (AS) market such as frequency control.

While grid development is very mature technology, technical feasibility in Indonesia reflects the country’s distinctive geography with eight major networks and about 600 isolated grids. The resulting interconnection among islands is thus more challenging than conventional TnD projects. Although energy storage, especially batteries, has demonstrated technical scalability, large-scale systems pose challenges around implementation within Indonesia’s complex grid system.

Category D: Negative cash flow

“Negative cash flow” is solely populated by MPO, which present no technical challenges, but is impacted by project economics from negative net present value (NPV) and constraints from unclear taxonomy and reputational risk. Shutting down existing coal-fired power plants incurs direct costs, as well as lost revenue potential, and on the revenue side, an MPO will not generate any income without an effective carbon credits scheme.

Category E: Pre-commercialization

“Pre-commercialization” comprises hydrogen/ammonia co-firing and CCUS, which still have limited technical and commercial feasibility due to the nascent stage of the technology yet to be proven at scale. For hydrogen/ammonia co-firing to serve as decarbonization levers, the feedstock needs to be produced through low-carbon green methods, which are still emerging technologies, and the accompanying supply chain awaits to be developed. For CCUS, although the strategy has been deployed for decades in the oil and gas industry, it is relatively new for power plants and faces operational challenges, particularly around transport and storage of captured CO_2. Consequently, these levers show the least favorable project economics due to high operational costs. For example, the IEA estimates that co-firing with 60% low-carbon ammonia would quadruple the cost of electricity generation in Indonesia compared to using traditional coal-fired power plants.

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[175] Distributed energy generation refers to a variety of technologies that generate electricity at or near where it will be used.

3.4. Decarbonization lever deep dive

Following the bankability matrix and categories, we will examine the key challenges and potential unlocks for each decarbonization lever to raise the technical and commercial feasibility and achieve bankability at scale.

3.4.1. Hydropower

Category A: Bankable and starting to scale

Exhibit 31: Summary of challenges and unlock ideas, hydropower in Indonesia

Ratings: 🟩 1 🟩 2 🟥 3 🟥 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	**Resource availability** • Mismatch between hydropower potential and demand due to regional differences in topography	• **Expand grid infrastructure** to dispatch power from supply to demand centers	EP
Commercial feasibility	2	**Project economics** • Likelihood of cost overruns in development of large-scale hydropower plants due to hurdles to land acquisition and social and environment assessments, as well as operational complexity posed by hydrology risk	• **Offer capacity building programs for IPPs** such as innovation center development and education programs • **Seek foreign expertise** on construction and project planning and meteorological forecast	EP PM
		ESG & Taxonomy • Social and environmental concerns on construction of water dams	• **Mitigation measures** e.g., protection for aquatic life; provide compensation for displaced communities	EP PM

Hydropower is a very mature technology, but it is subject to the topography and ability to connect the available potential and energy demand centers. The commercial feasibility must also consider expenses linked to land acquisition and build, as well as environmental and social impact assessments. Unlocking the potential of hydropower requires investment in grid infrastructure to connect areas of supply and demand, as well as collaboration across stakeholders including local IPPs, policymakers, and foreign energy companies to help build project planning and engineering capabilities to avoid cost overruns.

3.4.1.1. Lever description and overview

Description

Hydropower harnesses the kinetic energy from flowing water to generate electricity. It is a RES with significant potential to provide clean, sustainable power and reduce GHG emissions.

Growth potential

As one of the world's largest archipelagos replete with more than 800 rivers, Indonesia is well positioned to take advantage of its geography to produce hydroelectricity. IRENA estimates the country's potential for hydropower at 95 GW.[176] While this estimate puts Indonesia among the world's top four countries in terms of potential hydropower, by 2022, total installed hydropower capacity in Indonesia was 6.7 GW or about 8% of the national energy mix.[177]

Stakeholder initiatives

With such potential, hydropower could play a much greater role in Indonesia's power supply over the coming decade. PLN plans for 52% of new power capacity installed by 2030 to be fueled by RES, and of this about half is expected to come from hydropower.[178] In this period, PLN expects to develop another 10.4 GW in hydropower plants, split between 9.3 GW in conventional hydropower plants and 1.1 GW in micro

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[176] "Renewable Energy Outlook," IRENA, 2022.

[177] "Handbook of Energy and Economic Statistics of Indonesia," ESDM, 2022.

[178] "RUPTL, 2021-2030," PLN, 2021, Link.

plants.[179] The micro hydropower plants are seen to be especially suited to introduce RES to remote areas with small nearby rivers.

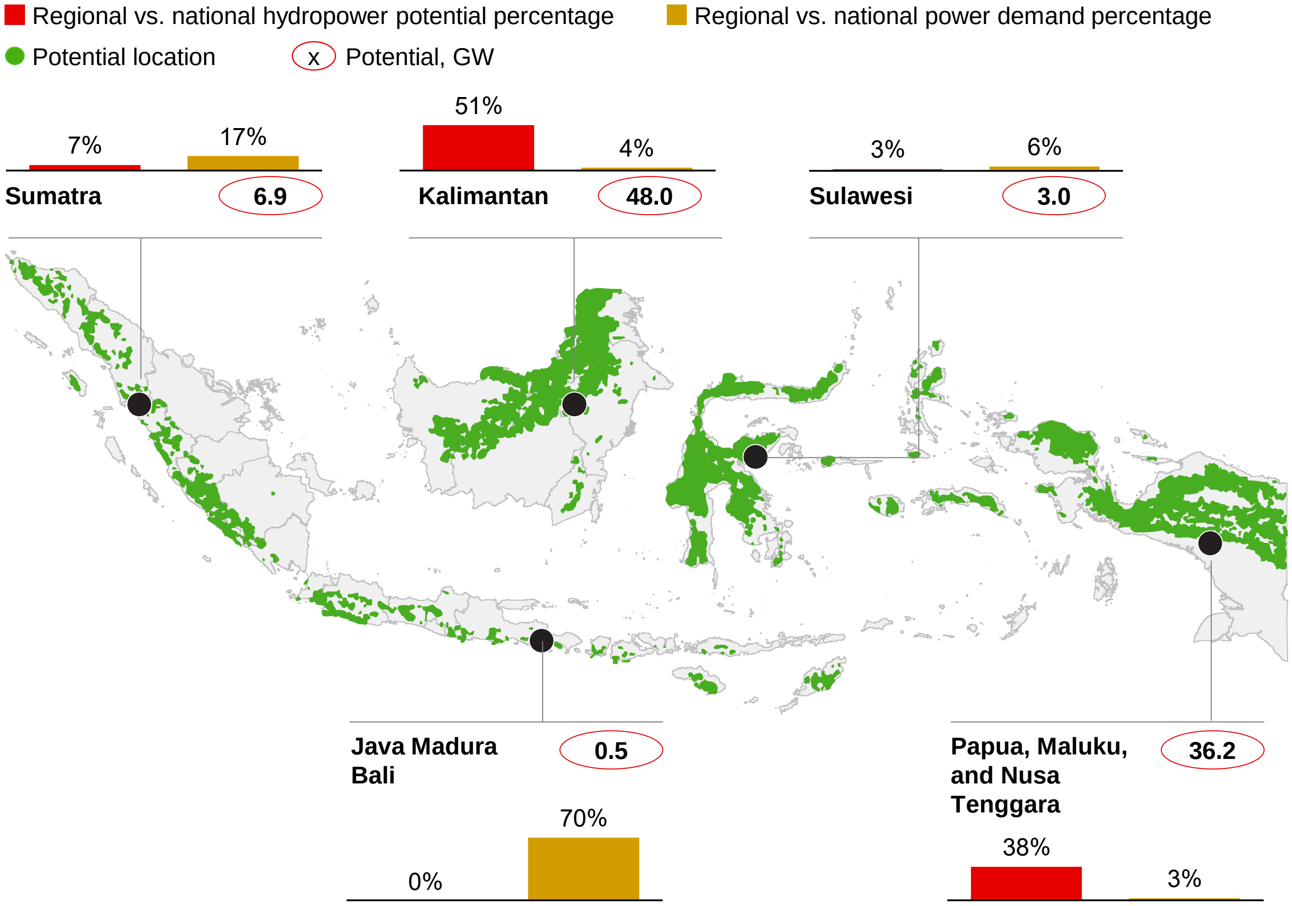
3.4.1.2. Challenges and potential solutions

Local resource availability constrained by topography [technical feasibility – resource availability]

The separation of areas with hydropower potential and those with electricity demand could limit the development of hydropower plants, despite extensive river systems. Hilly topography is ideal for hydroelectric dams, but in 2022, 88% of the country's power demand came from Java, Bali, and Sumatra, areas whose flat and coastal terrain is ill-suited for dams. In contrast, the terrain on the island of Kalimantan, presents tremendous potential of about 48 GW (**Exhibit 32**).

In addition, rivers in Indonesia are relatively short, which is not optimal for large hydropower projects, and overcoming this challenge will require significant engineering acumen.[180]

Exhibit 32: Indonesia's hydropower potential vs. power demand[181]



The national grid could be expanded to connect hydropower resources to demand centers, but grid connections between islands pose their own challenges and require complicated engineering to ensure energy stability across undersea cables. Each island would also need suitable transmission lines. The current grid-expansion plan is focused on the connection between Java and Bali, and therefore does not directly address the mismatch between demand and supply of hydropower, which would then require the connection between Sumatra and Kalimantan. A key unlock to harness the full hydropower potential could be further expansion of current interconnection programs, which would need to be planned ahead due to the long build and planning time required.

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179 "PLN begins the construction of a 1 GW hydropower plant in Indonesia," Enerdata, September 2022: https://www.enerdata.net/publications/daily-energy-news/pln-begins-construction-1-gw-hydropower-plant-indonesia.html.

180 For more, see Link.

181 "Indonesian hydro energy potential map with run-off river system," ESDM, 2021.

Cost overruns from operational and executional complexity [commercial feasibility – project economics]

Cost overruns are a common challenge worldwide for large infrastructure projects with long build tenors and operational complexities. With hydropower, the time and costs incurred with land acquisitions, feasibility studies, regulatory approvals and permits, engineering design & construct, and grid connection can carry risks to profit margins.

As cost overruns in hydropower projects are typically from initial capital expenses, IPPs could mitigate some of this by building capabilities, particularly around front-end engineering. PLN and IPPs could also collaborate with international peers to share experiences and knowledge in engineering, hydrology, and other operational aspects. The government could also provide training and education programs to build needed capabilities. Already, the ESDM is working with Renewable Energy Skills Development (RESD), a Swiss initiative, to create an informal curriculum to teach the installation, operation, and maintenance skills needed for hydropower plants.[182] Finally, the project should be informed by rigorous operational due diligence and involve high-quality contractors to assess the scope and appropriate risk allocation.

Environmental and social risk assessments [commercial feasibility – ESG & Taxonomy]

Like hydropower projects worldwide, those in Indonesia must also address environmental and social concerns, which add costs and complexities to projects. Creating reservoirs and altering waterflows can have an impact on wildlife upstream and downstream of the project, changing habitats irrevocably and even the water's characteristics. Communities surrounding the project may also be displaced or livelihoods altered as with the fish life in the area. These are important areas that financiers are increasingly aware of and must be addressed and mitigated.

As part of the solution, IPPs could develop and implement mitigation measures, such as fish ladders or bypass channels to minimize the impact on aquatic life and migratory routes, soil erosion and waste management controls, reforestation of cleared lands, and compensation and support to affected support in the form of housing, infrastructure, and support. Such measures should follow international best practices and independent advisors and shared with financiers to assess their internal ESG policies as part of the investment decision-making process.

3.4.2. Utility-scale solar

Category A: Bankable and starting to scale

Exhibit 33: Summary of challenges and unlock ideas, utility-scale solar in Indonesia

Ratings: 1 2 3 4 ⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	**N/A**	**N/A**	
Commercial feasibility	2	**Market structural factors** • Overcapacity of power market constrains expansion • Grid constraints poses challenge for meeting the long-term flexibility requirement • TKDN requirement adds operational hurdle for component procurement or increases cost	• **Accelerate MPO** to take coal-fired power plants offline and make room to add renewable capacities • **Upgrade the grid system through step-wise initiatives** • **Investment into local solar PV production capacity as well as capability building**	PM EP

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182 "Indonesia-Swiss Kerja Sama Capacity Building Tenaga Terampil Bidang Energi Terbarukan (Indonesia-Swiss Collaboration in Capacity Building for Skilled Workers in the Field of Renewable Energy)," ESDM, 2021, https://ebtke.esdm.go.id/post/2021/07/09/2906/indonesia-swiss.kerja.sama.capacity.building.tenaga.terampil.bidang.energi.terbarukan.

Utility-scale solar power rests on well-established technology, allows targeted site selection and short build time with good technical feasibility. However, it is worth noting that the current grid system may not yet be able to handle the intermittency accompanied by utility solar expansion. Another major challenge is Indonesia's power market structure, where overcapacity hampers additional investment in RES because adding capacity amid overcapacity implies higher system operating costs linked to lower utilization rates. Growth in utility-scale solar power will either wait for the overcapacity to be resolved naturally by demand growth or encouraged through MPOs.

3.4.2.1. Lever description and overview

Description

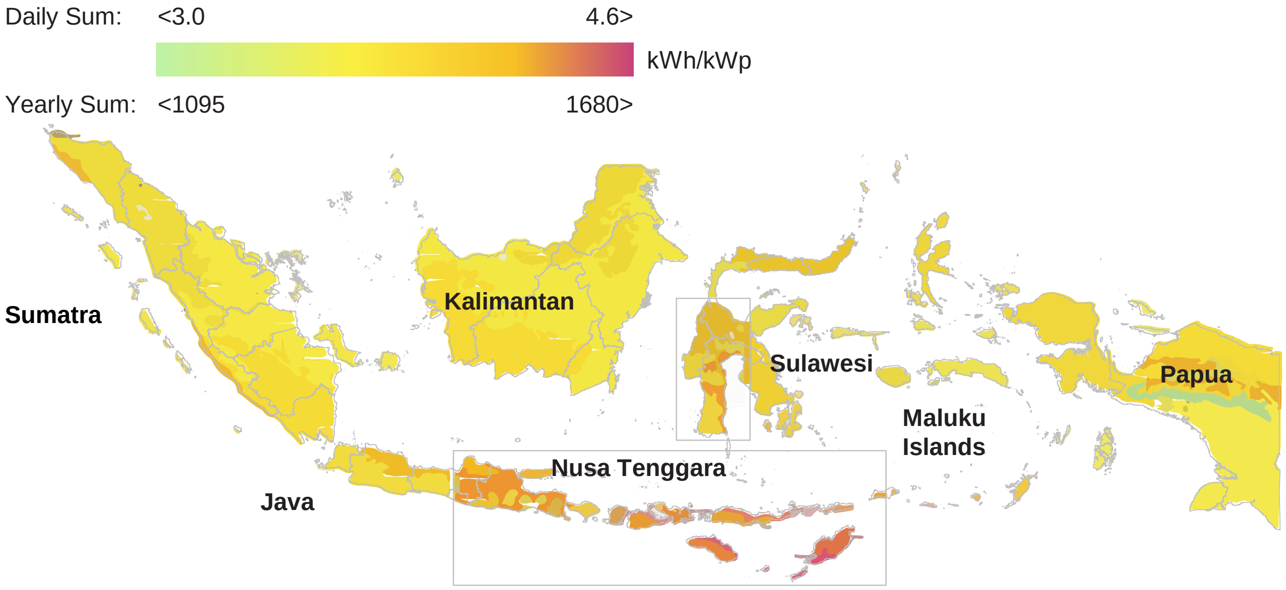
Utility-scale solar refers to a large scale (often defined as larger than 1 MW) solar power plants. Unlike C&I solar projects that supply power directly to corporate organizations and industrial plants, utility-scale solar projects are built primarily to serve utility companies to generate electricity to the power grid.

Growth potential

Indonesia has untapped potential for solar energy. It is estimated by the International Renewable Energy Agency (IRENA) that the country possesses 2.9 terawatt (TW) of solar potential. Particularly the East Nusa Tenggara and South Sumatra region shows more potential (**Exhibit 34**). On the other hand, as of 2022, Indonesia's installed solar capacity remained limited with about 0.3 GW of installed capacity, accounting for less than 1% of the electricity generated that year.[183]

Exhibit 34: Solar potential in Indonesia[184]

Long-term average of daily/yearly sum, period from 2007 (1999 in the West) to 2016



Stakeholder initiatives

Despite the substantial potential, a large gap remains between installed capacity and the government's target, which calls for the energy mix by 2025 to include 23% from RES.[185] In the longer term, Indonesia aims to generate a third of its electricity from solar power by 2060.[186]

Floating solar projects are gaining traction with several projects announced. For example, discussions have begun for a 2 GW floating solar project in Cilamaya, West Java.[187] Additionally, the 145 MW PLTS Apung

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[183] "Indonesia solar energy outlook 2023," IESR, October 2022.

[184] Global Solar Atlas, accessed on November 2, 2023, https://globalsolaratlas.info/map.

[185] "U.S., Japan to offer Indonesia USD 15 bln in energy transition funds-Bloomberg News," Reuters, November 11, 2022.

[186] "Indonesia solar energy outlook 2023," IESR, October 2022.

[187] "Indonesia Energy Transition Outlook 2023," IESR, December 2022.

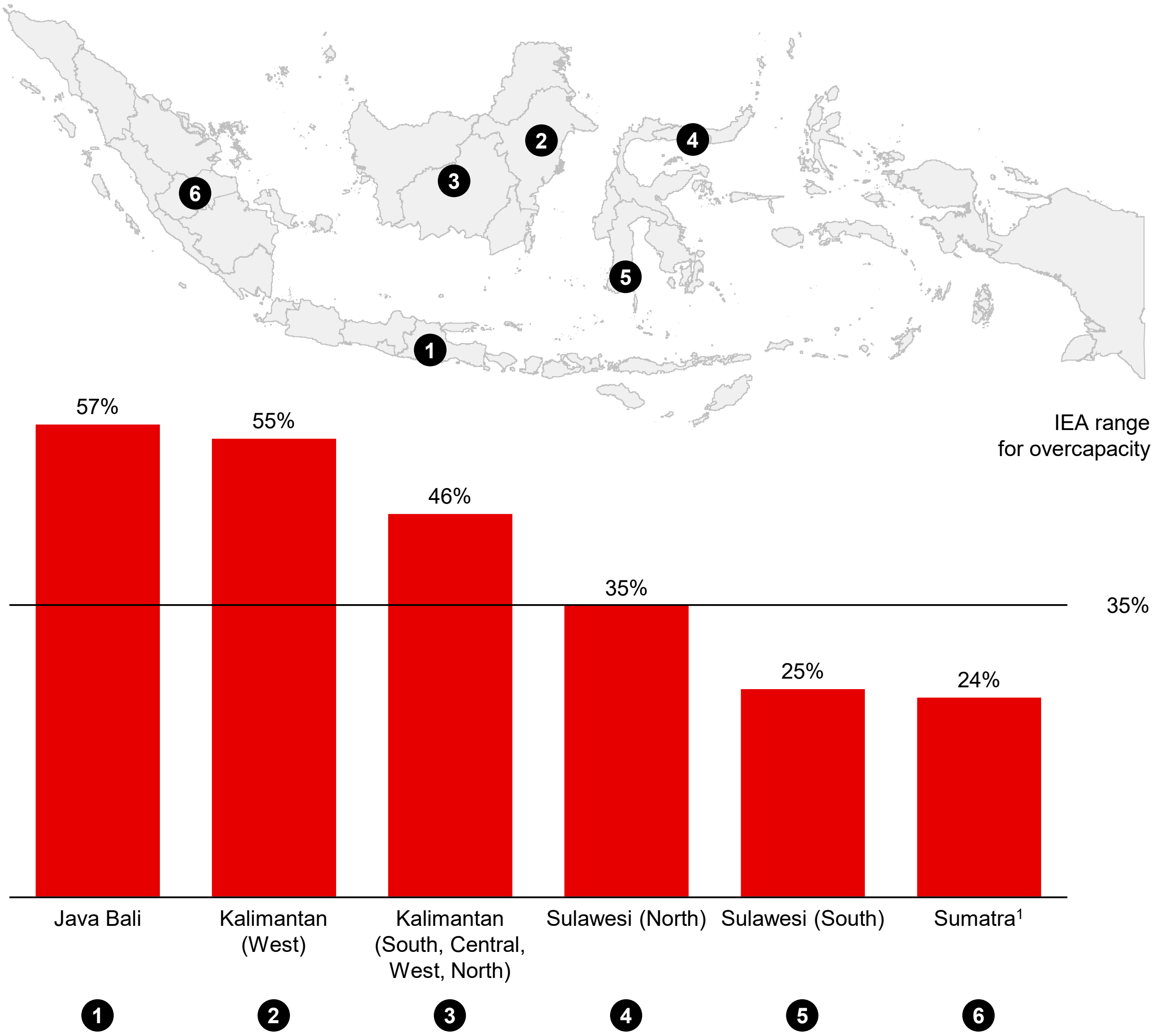
Cirata floating solar project covering 250 hectares was launched recently in November 2023.[188] In the same year, PLN launched the Proyek Hijaunesia initiative aimed at seeking equity partners and financiers for a multi-project solar (floating and land-based) in Java-Bali and wind-based in Aceh.[189]

3.4.2.2. Challenges and potential solutions

Overcapacity of power market constrains expansion
[commercial feasibility – market structural factors]

In 2022, the reserve margin in Java, Bali, and Kalimantan was generally above 40%, with Java's reserve margin particularly high at 57% in 2022 (**Exhibit 35**). IEA defines a reserve margin above 35% as overcapacity. This overcapacity limits the potential to add additional renewable energy capacity into the grid.

Exhibit 35: Reserve margin in Indonesia by region, 2022[190]



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[188] "Indonesia launches Southeast Asia's 'largest' floating solar plant," Nikkei Asia, November 9, 2023, Link.

[189] "Invitation to Participate in the Development of Renewable Investment (Solar-based in Java-Bali & Wind-based in Aceh) Projects Opportunity," PLN, 2023.

[190] "Electricity Supply Business Plan 2021-2030," PLN, 2021; Katadata Insight Center.

Overcapacity is structurally difficult to address beyond waiting for demand to catch up with supply. One approach is to encourage initiatives to introduce flexibility of output or earlier retirement of coal-fired power plants to allow growth in RES.[191] Considerations for MPO are covered in 3.4.10.

From the demand side, growing RES demand from leading C&I companies with net zero ambitions to identify future energy needs and investments is another potential unlock. This is further explored in Section 5.1.

TKDN requirement adds operational hurdle [commercial feasibility – market structural factors]

Local content requirements or TKDN also present hurdles to expanding electricity generation from RES. TKDN requires certain goods and services in Indonesia to contain a minimum percentage of components or materials sourced from local suppliers. Although the rule will not apply to solar power projects until 2025, the transition could be challenging unless the local supply chain needed for the transition is built up in time.

Before the government temporarily postponed application of these rules for solar power, local-content requirement (MoI 5/2017) mandated that 60% of solar PV modules production to be sourced from local suppliers by 2019, and this ratio was slated to increase further to 90% by the end of 2025.[192]

Since the global solar PV panel supply chain is dominated by Chinese producers, about 80% of production in 2020,[193] once the TKDN holiday is lifted for solar power in 2025, solar projects in Indonesia could struggle to meet the requirements. No solar projects currently commissioned in Indonesia would meet a 60% local-content requirement. Before the holiday from TKDN, some projects, such as the Cirata Floating Solar Power Plant, required waivers that allowed them to use imported components, but the process for securing such waivers is unclear.

In addition, solar PV modules procured from Chinese producers are often of higher quality and can be cheaper than those produced locally.[194] The quality of locally produced solar PV modules mainly suffer from less experience and lower production capacities. Because of this, locally manufactured PV panels are potentially less efficient than the imported versions, resulting in less power generated and less favorable project economics.

TKDN also stipulates that all manufacturing, assembly, and service must be done by local labor, and suitable talent is difficult to find in the national labor pool.

Stakeholders are exploring ways to meet TKDN in implementing solar power projects beyond the end of the 2025 moratorium. One potential measure is to develop the domestic solar PV value chain to ensure adequate domestic supplies. This would dovetail with the government's goal of building the local economy and could allow local producers to team with leading global manufacturers to build capacity and learn. Currently, there are many initiatives around solar power ecosystems and partnerships. For example, the Indonesian government is partnering with the Xinyi Group to develop integrated facility from polysilicon to solar cell production. Government training programs would also help build necessary capabilities in the local labor force, which could include vocational programs and apprenticeship opportunities. A third prong for strengthening the local solar supply chain would be to encourage and incentivize foreign investment into local factories, which would not only help build needed scale but also transfer knowledge.

Grid constraints poses challenge for meeting the long-term flexibility requirement [commercial feasibility – market structural factors]

To allow for expanded share of utility-scale solar to be incorporated into Indonesia's power generation structure, grid flexibility needs to be enhanced. A shift towards solar PV poses intermittency challenge to the grid system, resulting in higher ramping requirements as well as wider gap between daily minimum and peak net demand. Although both Java-Bali and Sumatra system have the capacity to meet the flexibility requirement in the short term (based on the 2025 scenario modeled by IEA), grid upgrades can be needed to provide sufficient flexibility in the long term (beyond 2028).[195]

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[191] MPOs come with their own challenges, such as the negative cashflows, which we address later.

[192] "Indonesia solar energy outlook 2023," IESR, October 2022.

[193] "IHS PV Supply Chain Tracker Q2 2020," IHS Markit, 2020; "BNEF Solar Manufacturers 2019 Production 2020-5-27," BNEF, 2020; "IHS PV Installations Tracker Q3 2020," IHS Markit, 2020.

[194] Industry expert interview.

[195] "Enhancing Indonesia's Power System," IEA, 2022.

Unlocking the grid constraints entails integrating a series of initiatives such as smart grid development, operational optimization, and infrastructure upgrades to allow flexibility potential introduced by a certain approach to be fully harnessed. Under the guidance of the ESDM Presidential Decree 18/2020, PLN is already working towards a target to develop five smart distribution network per year in Java-Bali from 2020 to 2024. The initiative involves multiple pilot projects as well as targets for deployment of advanced metering infrastructure. Meanwhile, it is just as important to ensure that the deployed digital equipment is used efficiently, and that the benefit of the smart grid infrastructure is passed down along the value chain. For example, as IEA analysis pointed out, it can be difficult to tap into the flexibility potential of smart grid without a pricing scheme that also incentivize consumer flexibility. These considerations call for planning to be coordinated under a transparent smart grid strategy, which can potentially be designed by ESDM using PLN's smart grid pilots as sources of reference. Indonesia has also taken steps towards optimizing its grid system's operational protocols. For example, it previously had distinct grid codes for different power systems, which were consolidated in 2020 under ESDM Regulation 20/2020, accompanied by the introduction of provisions for Voluntary Emission Reduction (VER).[196] These forward-looking modifications to the Connection Code are promising measures for unlocking grid flexibility at a low cost in the short term.

In the long term, Indonesia will likely encounter a need to upgrade its grid infrastructure to fully accommodate increased share of utility solar and other renewables. As IEA's analysis pointed out, the country's current grid infrastructure faces challenge of weak connections relative to the power demands, as reflected by the Ungaran-Pemalang transmission line issue in Central Java that contributed to the 2019 blackout. It is worth noting that the geographical topology of Indonesia poses an inherent challenge for the expansion of grid infrastructure. Currently, the general direction of electricity flows is from the east, where there is abundant coal and excess capacity, towards the higher demand regions in the west. This spans over a significant distance, with even the shortest distance between the two coastal cities of western and eastern Java being 960 km. Taking these geographical considerations into account, it can be highly beneficial to integrate planning of grid expansion with utility solar development to minimize the capital expenditures needed for the grid expansion.

3.4.3. Mini-grids

Category A: Bankable and starting to scale

Exhibit 36: Summary of challenges and unlock ideas, mini-grids in Indonesia

Ratings: 1 2 3 4 ⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	**2**	**Operational complexity** • Difficulty in managing intermittency at a smaller scale, requiring a better capability in energy management and supply and demand forecasting	• **Capability building** in demand and supply forecasting and energy management system	EP
Commercial feasibility	**2**	**Project economics** • Small ticket sizes of individual projects lead to lower economy of scale • The price ceiling in tendering is skewed towards that of utility-scale solar, squeezing profit for mini-grids IPPs	• **Bundle tenders** to forge economy of scale • **Establish a price-ceiling for mini-grid projects** incorporating the costs required to maintain supply stability in remote islands and achieve GHG reduction at the same time	EP

Mini-grids are essentially small-scale, self-contained energy systems. They show lower technical feasibility primarily because they are relatively complex to operate, while intermittency, common for many RES systems, poses an additional challenge. The economics are also sub-optimal because of the small individual project sizes with limited opportunities to gain economies of scale. Targeted investments and changes in tendering processes could help overcome these challenges.

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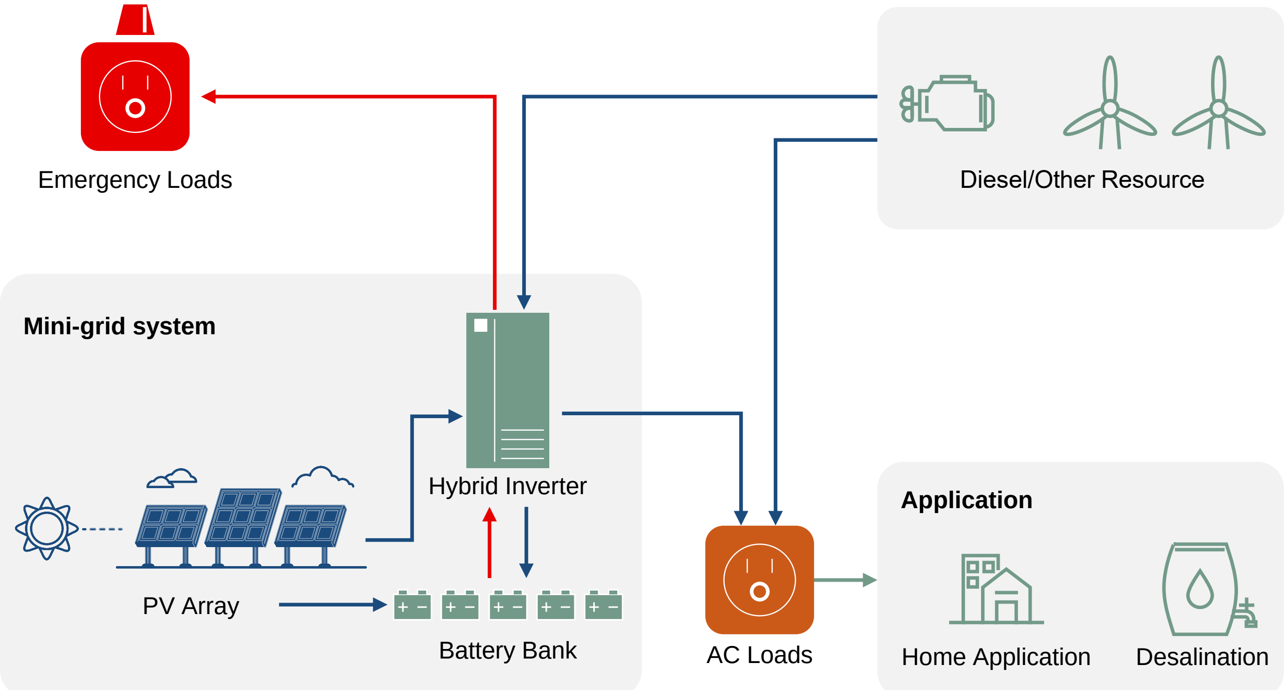
[196] Ibid.

3.4.3.1. Lever description and overview

Description

Mini-grids draw from multiple sources, usually generating between 10 kW to 10 MW on a combined basis, for a single power system supplying a small number of users in systems isolated from the national grid. In remote areas of the country, power is most often supplied by diesel generators, and PLN hopes to replace these with solar-powered mini-grids complete with generation, storage, and TnD attributes (**Exhibit 37**).

Exhibit 37: Hybrid mini-grid system components



Stakeholder initiatives

Because of geography, complete coverage of Indonesia by the national grid is very difficult, and in 2019 diesel generators provided about 4.2% of the country's electricity. PLN's ambitions would reduce that to less than half a percent, replacing about 499 MW generated by diesel generators with RES.[197] The first phase, which focuses on replacing about 250 MW in 183 locations with solar power, began in March, 2022 (**Exhibit 38**).[198] The second phase would draw from a greater range of RES. The conversions are expected to be completed by 2026.

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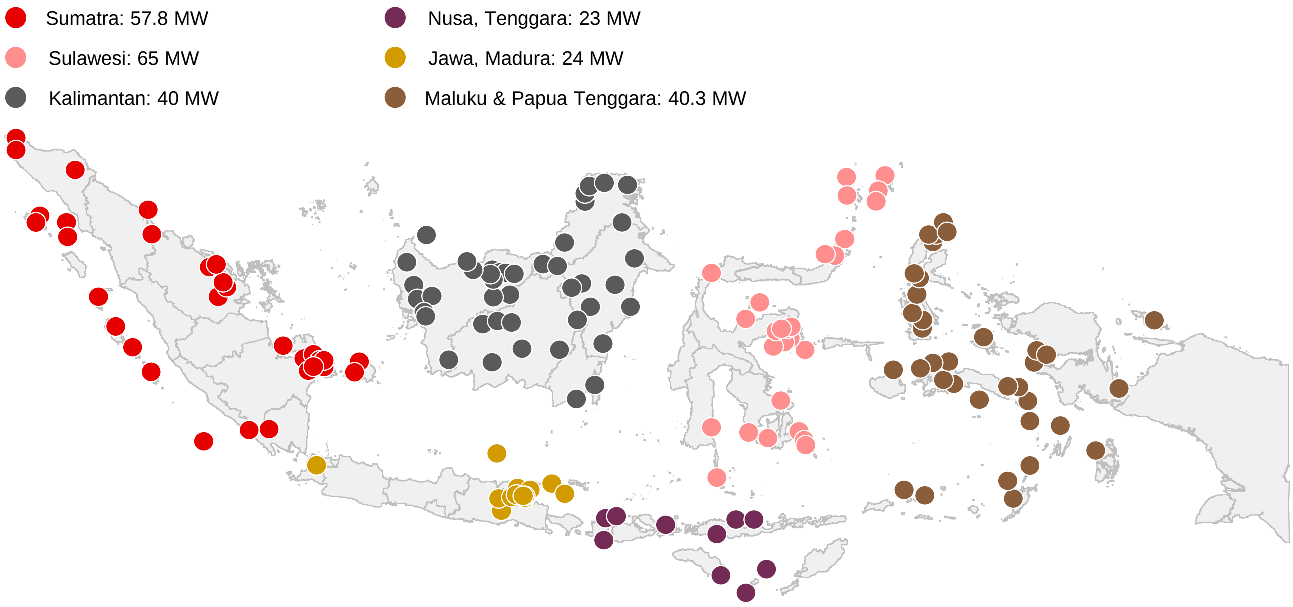
[197] "Supporting the de-dieselization program, Minister of Energy and Mineral Resources: Technology and competitive costs are the keys to success," ESDM, March 23, 2022.

[198] "Indonesia energy transition outlook 2023," IESR, December 2022.

Exhibit 38: Sites for phase one of PLN's diesel generator conversion program[199]



No	Unit	Total location	Diesel capacity (MW)
1	UIW ACEH	8	15
2	UIW SUMUT	1	1.5
3	UIW S2JB	1	1
4	UIW SUMBAR	4	6
5	UID LAMPUNG	2	0.3
6	UIW RKR	26	29
7	UIW BABEL	14	5
8	UIKL KAL	2	3
9	UIW KALBAR	21	24
10	UIW KALSELTENG	11	5
11	UIW KALTIMRA	14	8
12	UID BANTEN	1	1
13	UID JATIM	9	23
14	UIW SULUTENGGO	26	47
15	UIW SULSELRABAR	8	18
16	UIW MMU	35	40
17	UIW NTB	3	5
18	UIW NTT	8	18
19	UIW P2B	6	0.3
	Total		**250**

3.4.3.2. Challenges and potential solutions

Power intermittency of mini-grid [technical feasibility – operational complexity]

Mini-grids have an average size of about 1 MW, and operational complexities center on difficulties in managing intermittency on such a small system. For instance, in the first phase of the PLN effort to cut diesel generation, some generators were left in place to provide emergency backup for the system. In the second phase, with input from a larger range of RES, system management would become more complex.

Better supply and demand forecasting could be one way to reduce the complexity and intermittency of a mini-grid. As these skills are developed, however, power sector players could consider sizing the mini-grid system with an optimal share of renewables and battery storage, keeping in mind intermittency, project development costs, and the availability of local resources. Local companies could also seek to collaborate with foreign peers facing similar challenges to share experiences, knowledge, and solutions.

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[199] "Potential of PLTMH vs Dedieselization Program," PLN, 2022, https://www.slideshare.net/SonyJunianto1/pontensi-pltal-vs-program-dedieselisasi-ver4pptx.

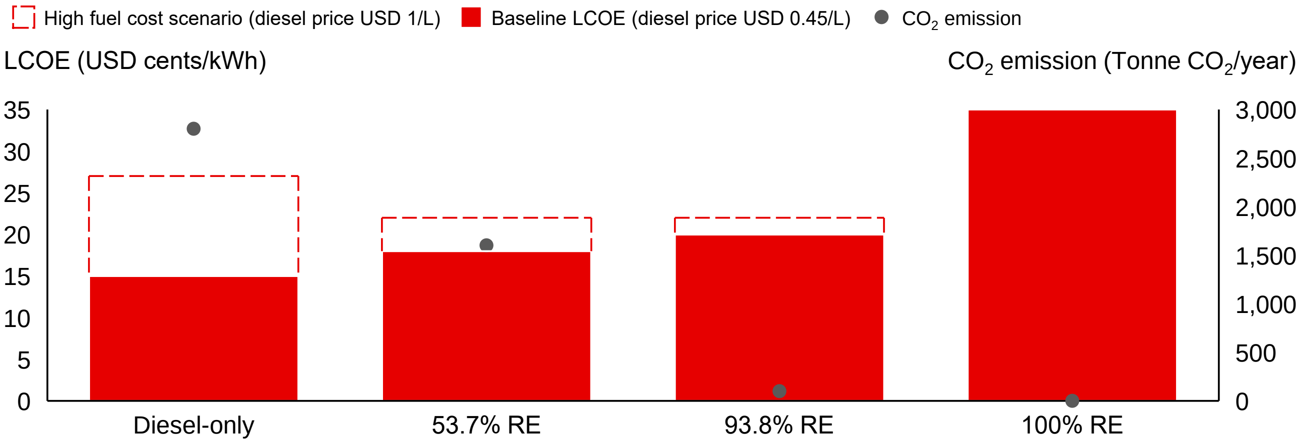
Small ticket sizes and price ceiling disincentivize developers [commercial feasibility – project economics]

The small scale of mini-grids also poses a commercial challenge. Building a solar power system includes fixed costs, such as engineering and design, permits, and financing, and larger projects can dilute these costs more effectively than smaller ones. PLN tenders are for individual mini-grid projects, rather than for packages of several projects, further dampening potential economies of scale.

In addition to the insufficient scale, another challenge surrounding project economics is the price ceiling that is skewed towards lower-cost, utility-scale systems. Project economics would likely vary based on whether PLN is leading the development or offers it as a tender. When PLN develops a mini-grid project, the revenue case is more promising because switching to RES system is cheaper than the current diesel generators due to the high fuel prices. PLN could also recover the cost since electricity supply to remote islands receive more subsidies from the government. On the other hand, IPP projects are governed by policies that set a price ceiling, which combined with higher costs, would severely squeeze IPPs' profit margins. Current price ceiling is benchmarked against the average cost of utility-scale solar projects which also allows to add cost for energy storage for up to 60% of the solar PV LCOE. However, given large scale utility-scale solar projects are more cost efficient, and requirement for storage capacity is lower, the price range could be lower than the expected cost for solar projects in mini-grid context.

Solutions centered around addressing the project economics could overcome both their small scale and the pricing quandary. Where possible, bundling of mini-grids across an area could provide some means to scaling up. This requires planning by PLN to co-ordinate tenders and provide some scale benefits of larger projects to developers. Another solution could be to establish a price-ceiling for mini-grid projects incorporating the costs required to maintain supply stability in remote islands and achieve GHG reduction at the same time. While mini-grid projects are generally viable against the high cost of operating diesel generators, storage systems remain expensive, cutting into that viability. The Institute for Essential Service Reform (IESR) - an Indonesian think tank - estimates that for a mini-grid system to be cost competitive, the RES share (combined with battery energy storage system (BESS)) for power would be about 54%, and the remainder coming from diesel generation (**Exhibit 39**).[200] The exact RES ratio and right pricing range rests on volatile diesel prices but establishing a pricing scheme favorable for small scale solar + BESS solution could bolster the project economics of mini-grid projects.

Exhibit 39: Mini-grid cost comparison with different RES ratio[201]



Notes: Analyzed using HOMER Pro software assuming:

1. Discount rate: 6%
2. Project time 25 years
3. Retrofit diesel generator of 800 kW capacity
4. Hypothetical community load profile (10,128 kwh/day) with 720 kW peak load
5. 18% PV efficiency
6. 3,3 MW PV capacity for hybrid systems cost USD 790/kW
7. 4.2 hour duration BESS with 15 years of lifetime cost USD 1790/kW
8. Diesel-only system's fuel consumptions of 990 kL/year compared to 63 kL/year of hybrid systems with 93.8 RE fraction

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[200] "Indonesia Solar Energy Outlook 2023," IESR, October 2022.

[201] Ibid.

3.4.4. Geothermal

Category A: Bankable and starting to scale

Exhibit 40: Summary of challenges and unlock ideas, geothermal in Indonesia

Ratings: 🟩 1 🟩 2 🟥 3 🟥 4 ⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	2	**Operational complexity** • Relatively high risk and upfront capital required for the initial exploration phase	• **Offer loan guarantees, loans, or other measures to de-risk** exploration phase	PM
Commercial feasibility	2	**Market structural factors** • Operational complexity translated into complexity of auction design and process • TKDN requirement adds operational hurdle for component procurement or increases cost	• **Updated auction design** that allows more transparency and accuracy in data sharing, a routine auction schedule, and better qualification standards • **Investment into local supply chain capacity as well as capability building –** pace TKDN implementation in line with the development	EP PM

Unique factors centered on exploration and assessment contribute to the operational complexities of geothermal power projects, while the market structure – auction processes and local-content rules – also poses some challenges. Greater support from the government, such as loss guarantees and exploration subsidies, could help lower these hurdles.

3.4.4.1. Lever description and overview

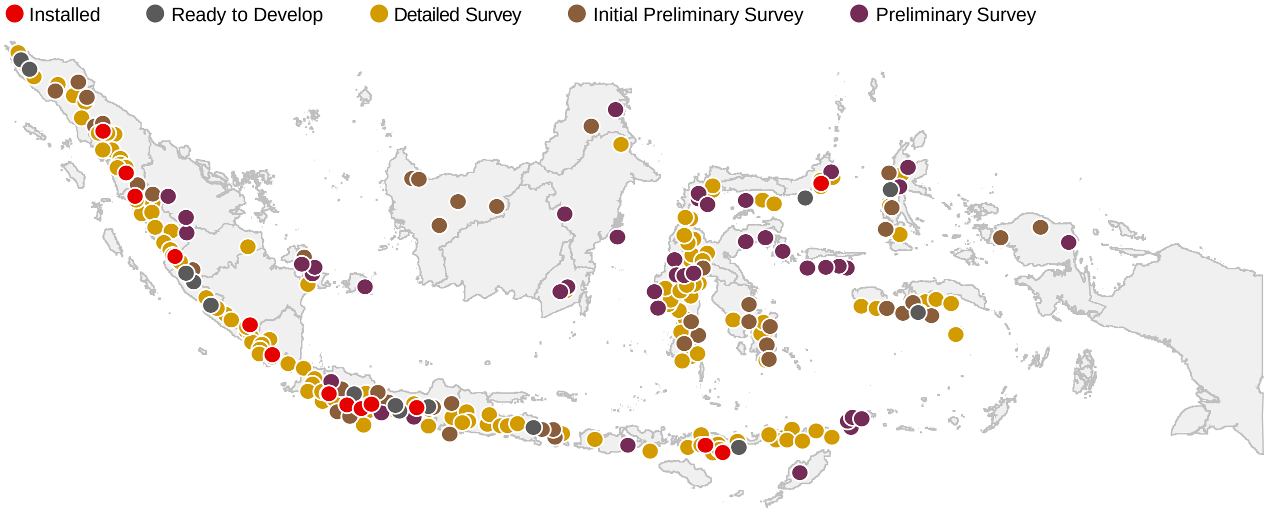
Description

Geothermal energy is a renewable source that uses heat from within the earth to produce electricity. Power plants generally draw geothermal fluids from underground to the surface to produce steam, which propels turbines that generate electricity.

Growth potential

Because of its proximity to the Ring of Fire volcanic zone, Indonesia holds the world's second-most-promising geothermal fields, with IRENA estimating the potential at about 30 GW of geothermal potential.[202] Geothermal boasts commercial advantages, such as a low LCOE of USD 0.046 to USD 0.087 per kWh, which is comparable to the least expensive RES in the country, such as solar.[203] Unlike solar and wind power, geothermal is also a stable energy source that doesn't suffer from intermittency.

Exhibit 41: Geothermal potential in Indonesia[204]



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[202] "Renewable Energy Outlook: ASEAN 2022," IRENA, 2022.

[203] "Levelized cost of energy Indonesia: Understanding the levelized cost of electricity generation," IESR, 2019.

[204] "Resource assessment methods selection for geothermal exploration project in Indonesia: What are the considerations?," Daniel W. Adityatama et al, Stanford University, February 2021.

Despite this potential and advantages, geothermal remains underused in Indonesia. In 2022, capacity was 2.4 GW across 18 projects.[205] Plant capacity can range from 10 MW (or less) projects typically situated in East Nusa Tenggara, through to 200-380 MW projects and located in West Java, Lampung, and North Sumatra.

Stakeholder initiatives

Beyond the 2.4 GW in installed capacity in 2022, PLN has targeted adding 3.4 GW in geothermal capacity by 2030.[206] Several investment initiatives are already in play, including PT SMI, a SMV owned by the Kemenkeu RI, which manages a special fund, Geothermal Sector Infrastructure Financing (Pembiayaan Infrastruktur Sektor Panas Bumi or PISP) to support financing of geothermal exploration.

International funding is also opening further for geothermal projects. In 2020, ADB approved a USD 300 million loan to PT Geo Dipa Energi (GDE),[207] and the Green Climate Fund runs the USD 410 million Indonesia Geothermal Resource Risk Mitigation Project, providing risk-mitigation financing for early-stage geothermal projects.[208] Additionally, under the Geothermal Energy Upstream Development Project (GEUDP), approved in 2017, the government and the World Bank would assume the risk of exploratory drilling if the effort proves to be economically unviable.

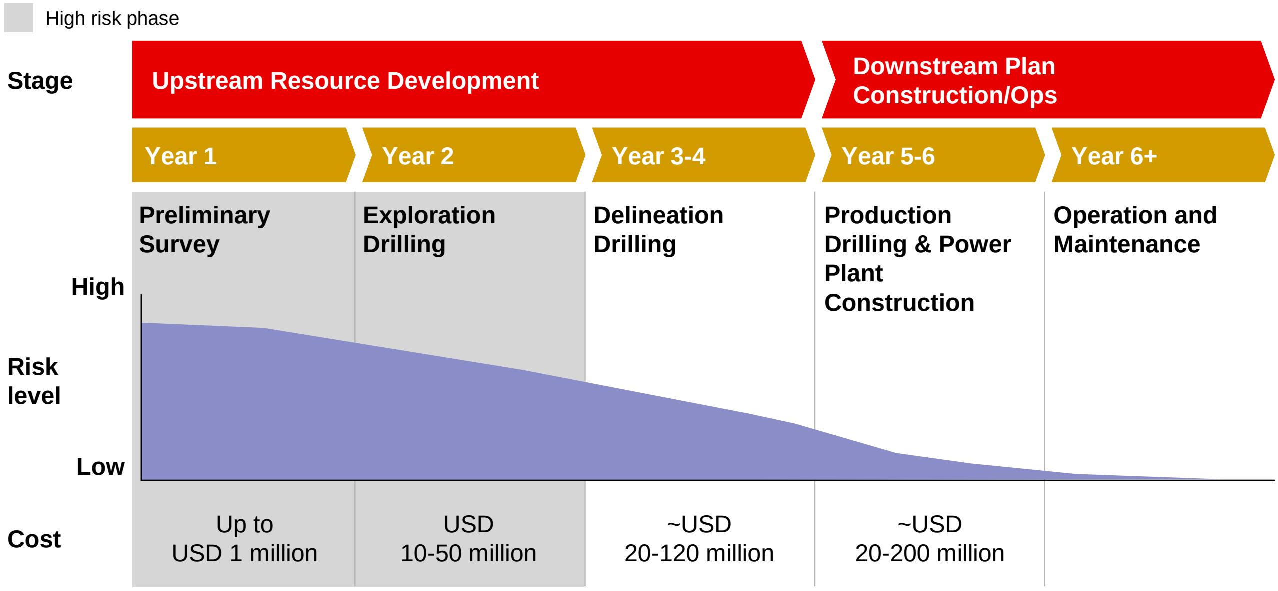
3.4.4.2. Challenges and potential solutions

Operational complexity highlighted by exploration risk [technical feasibility – operational complexity]

High exploration risks associated with geothermal project development makes it difficult for private companies to undertake the exploration process alone. Companies engaged in Indonesia's geothermal energy sector must first identify suitable locations and then drill activities to determine the site's resource viability. The actual energy output of a potential site remains uncertain until the expensive drilling phase is completed. Based on a study conducted in 2019 analyzing drilling data of five geothermal projects in Indonesia, the failure rate for exploration drilling or the likelihood that a drill would hit a useless dry spot was 33% to 67%.[209]

Exhibit 42: Risks in different phases of geothermal project development[210]

ILLUSTRATIVE



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205 "Unearthing the Dynamics of Indonesia's Geothermal Energy Development," Energies, 2022, Link.
206 "RUPTL, 2021-2030," PLN, 2021, Link.
207 "ADB approves USD 300 million loan to increase Indonesia's geothermal electricity generation," ADB, May 28, 2020, Link.
208 "FP083: Indonesia geothermal resource risk mitigation project," Green Climate Fund, accessed September 15, 2023, Link.
209 "Assessment of exploration strategies, results and costs of geothermal fields in Indonesia," Eko Hari Purwanto on United Nation University Geothermal Training Programme, 2019.
210 "Scaling up geothermal power," Elin Hallgrimsdottir on Global Geothermal Alliance, September to October 2022.

Geothermal exploration is also time-consuming, which, combined with the substantial upfront capital expenditures, can create challenges. Often, seven years or more are needed between beginning exploration and generating electricity.[211] The process spans identifying suitable sites, acquiring drilling equipment, constructing wells, and conducting tests to determine their suitability for full-scale energy production. As an example, estimated capital expenditure needed to explore a site with 3 GW site capacity in Indonesia is estimated at USD 2.8 billion.[212]

Loan guarantees made by the government or public institutions could ease the exploration phase and encourage private financing by reducing their risk. For example, the Japan Organization for Metals and Energy Security (JOGMEC) offers a loan guarantee of up to 80% for geothermal development,[213] and similar initiatives could help to mobilize funding from private banks.

Public and private efforts could also inject financing into geothermal projects in other ways. For instance, existing geothermal power plants have been covered with export credit agency (ECA) financing, and geothermal power plants have also issued project bonds to finance projects. Building on existing industry efforts, the government could also continue to provide loans, grants, tax credits, or other measures that reduce the exploration risk.

Complexity in market structure marked by low auction outcomes [commercial feasibility – market structural factors]

In recent years, few successful geothermal projects have been awarded. From 15 auctions held between December 2015 and July 2020, only three projects were awarded. Operational complexity in the exploration phase and lack of data poses a challenge for PLN to run an efficient auction. IRENA analyses that the low success rate of tenders was accredited to the design of pre-qualification standards, a shortage of information on auction schedules and tariffs, and insufficient time to assess high exploration risks. For example, bid hosts may have offered bid bonds that were initially too small, encouraging inexperienced bidders to underbid, and in some instances opaque tariff schedules for PPAs resulted in negotiations continuing after an auction. Unreliable data on the geothermal resource potential, which complicates making reliable cost estimates, has also been cited as a problem.[214]

A potential unlock could be to adjust auction process to enhance efficiency. For example, one of the measures that have been already discovered in the past is for PLN or the government procure enhanced geological data about exploration sites to share with potential bidders, allowing IPPs to make better estimates of exploration costs. In 2011, the government established the Geothermal Fund and allocated IDR 3 trillion (USD 250 million) through the end of 2013. The fund was meant to make geothermal projects financially viable by offering high-quality information about undeveloped geothermal sites, verified by reputable international institutions, to investors during the tendering process. Programs such as this could be extended or renewed to ensure the quality of data available to IPPs.[215] In addition, PLN could provide a routine tender schedule, allowing potential players ample time to prepare their bids, which could offset the risk of hastily drawn bids and reduce the likelihood of prolonged negotiations.

TKDN requirement adds operational hurdles [commercial feasibility – market structural factors]

As with other RES projects in Indonesia, TKDN requirements could hinder geothermal power plants, for instance by discouraging foreign investors seeking more competitive procurement processes. The local-content requirements for geothermal projects range from 29% to 42%, depending on the project's capacity.

As seen with other RES technologies, building capabilities in the local supply chain, particularly by working with foreign partners, could be a viable solution to help overcome this challenge.

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[211] "Renewable energy auctions: Southeast Asia," IRENA, 2022.

[212] "Unlocking Indonesia's geothermal potential," ADB and the World Bank, April 2015.

[213] "Financial support," Japan Organization for Metals and Energy Security, accessed on September 15, 2023, Link.

[214] "Renewable energy auctions: Southeast Asia," IRENA, 2022.

[215] "Power in Indonesia," PwC, 2018, https://www.pwc.com/id/en/publications/assets/eumpublications/utilities/power-guide-2018.pdf.

3.4.5. Biomass co-firing

Category A: Bankable and starting to scale

Exhibit 43: Summary of challenges and unlock ideas, biomass co-firing in Indonesia

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	3	**Resource availability** • Biomass supply is not co-located with coal-fired power plants, which boosts the cost of transportation and procurement • Locally available biomass supply is not compatible with the type of coal boilers in PLN's coal-fired power plants targeted at co-firing	• **Optimize asset mix by capitalizing on available local biomass resources**, while consider other alternatives such as MPO, ammonia co-firing, and CCUS	EP
Commercial feasibility	2	**Project economics** • Government's co-firing policy to procure biomass at a price 20% higher than coal, which limits PLN's ability to compete with foreign demand. Higher prices are not able to be passed through.	• Consider **revising the policy on procurement price** or mandate biomass supply to co-firing operators	PM
		ESG & Taxonomy • The carbon neutrality of biomass energy is conditional and highly depends on its production process • The broader environmental and social risks in the feedstock supply chain need to be taken into consideration	• **Ensure life cycle emission is negative** by following rigorous standards in each stage • Closely monitor the potential impact on **biodiversity** and risks of **supply chain labor issues** through sustainability governance	EP

Since biomass is expected to replace coal in existing power plants, this lever is unaffected by issues of overcapacity. However, other technical and commercial challenges could slow its deployment. From a technical standpoint, sourcing the necessary biomass locally would be a hurdle because only certain biomass fuels are useful for co-firing and the feedstock supply and demand is not co-located. Implementing biomass as part of a comprehensive MPO plan could soften this challenge.

Market structural factors also affect commercial feasibility of biomass co-firing. PLN faces challenges to procure biomass feedstock due to a regulation that sets the biomass procurement price benchmarking coal price – not the market price of biomass feedstock. Potential unlocks could be to allow PLN to procure at market price or mandate local feedstock suppliers to supply biomass at a regulated price. However, these options must balance the impact to electricity tariff and development of local biomass business. Moreover, broader ESG concerns along the biomass supply chain is often pointed. Close monitoring and safeguard mechanisms should be put in place.

3.4.5.1. Lever description and overview

Description

Biomass co-firing means using a combination of organic matter or biomass and coal to fuel power generation. Because of the large percentage of coal in Indonesia's energy mix, biomass could be a critical measure for lowering GHG emissions. Wood is the primary biomass fuel used for heat and power generation. The most cost-effective sources are the byproducts from manufacturing and mills, such as sawdust and shavings, as well as discarded wood products like crates and pallets.[216]

The ratio of biomass to coal is important to co-firing, along with the compatibility with various types of coal boilers. While a 20% co-firing rate (20% biomass) is feasible, currently the usual practice at coal power plants is a co-firing rate of about 5%, as a higher ratio may result in technical issues.[217] Specifically, even though

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[216] "Biomass Cofiring in Coal-Fired Boilers," National Renewable Energy Laboratory, 2009, Link.

[217] "IEA-ETSAP and IRENA© Technology Brief E21 – January 2013: Biomass Co-firing Technology Brief," IEA-ETSAP and IRENA, January 2013, Link

a higher biomass ratio would lower emissions further, it could also create combustion problems such as slagging, fouling, and corrosion.[218] With co-firing ratio of up to 20%, retrofitting of the existing coal facilities is generally not required. Compatibility issues could still develop around the size of biomass particles. For instance, while pulverized coal boilers would require the most granular biomass particles, fluidized bed boilers are less stringent about particle size.

Growth potential

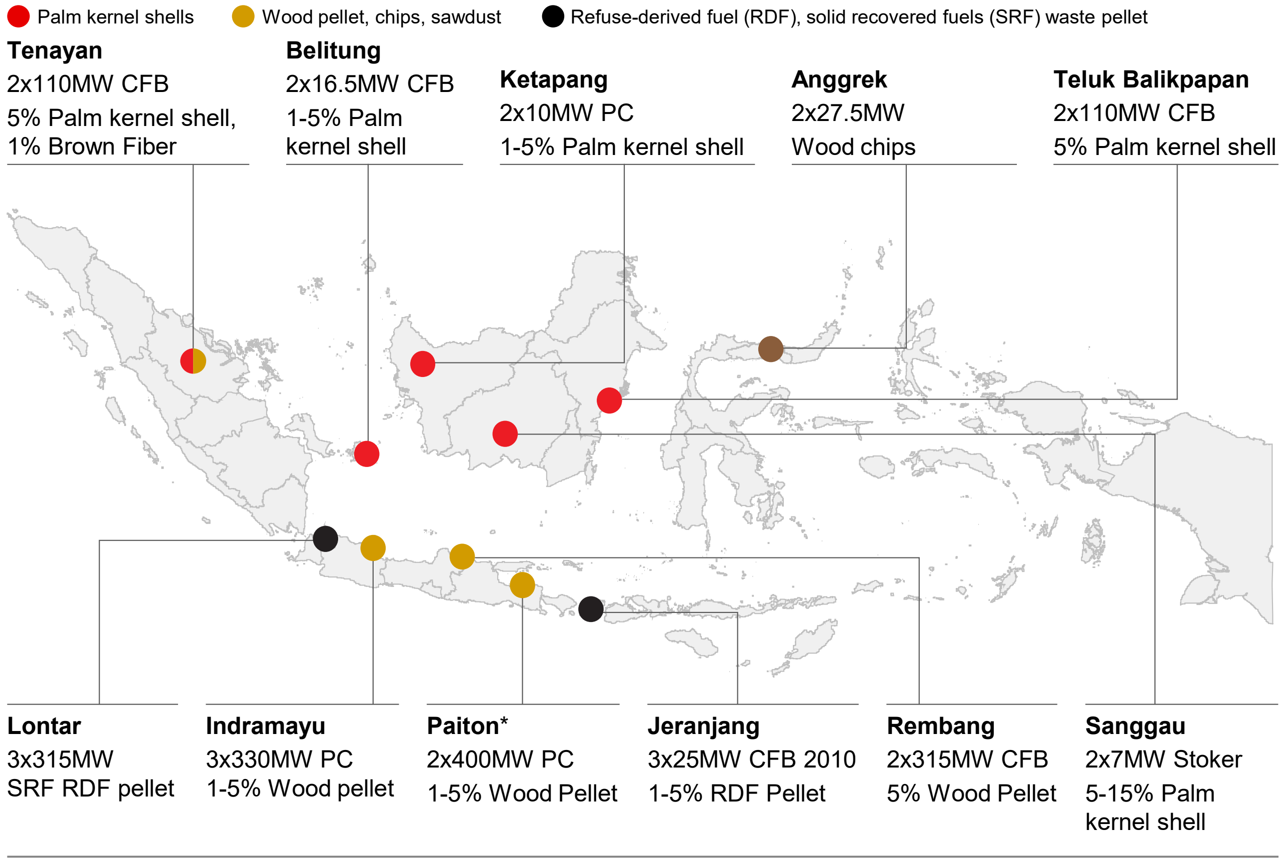
The most abundant biomass sources in Indonesia include palm oil residue (especially palm kernel shells), rice husks, and rubber wood.[219] In Indonesia, the diverse range of biomass resources has paved the way for various avenues of electricity production, and IRENA has estimated the country possesses 43 GW of biomass potential.[220] By 2020, the country had only 2 GW of installed biomass-fired capacity.[221]

Stakeholder initiatives

In March 2017, the RUEN targeted a bioenergy power capacity of 5.5 GW by 2025. In parallel, PLN has announced plans to convert 105 coal-fired power plants to co-firing by 2024, which would require about 1.6 million to 1.8 million tonnes of biomass fuel a year.[222]

PLN already conducted a co-firing pilot project by incorporating 5% biomass co-firing across 32 coal-fired power plant units, and the pilot program will be expanded to 52 units by 2025, with a total capacity of 18 GW, including 2.7 GW RES energy from co-firing.[223]

Exhibit 44: PLN biomass co-firing initial trial runs plan[224]



Note: Trial runs by August 2020 with further trails planned

* Paiton 1 & 2 has performed continuous cofiring since June 2020, consuming 3,800 tonne in 103 days (average 37 tonne/day)

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[218] "Biomass Co-fi ring Technology Brief," IEA-ETSAP and IRENA, 2013, Link

[219] "Biomass Energy," Matthew Hardhi on Penerbit BRIN, 2022, Link

[220] "Renewable Energy Outlook: ASEAN 2022," IRENA, 2022.

[221] "Indonesia's biomass cofiring bet," Institute for Energy Economics and Financial Analysis, February 2021.

[222] Information provided by PLN, as of November 13, 2023.

[223] "RUPTL 2021-2030," PLN, October 5, 2021, Link.

[224] "Indonesia's biomass cofiring bet," Institute for Energy Economics and Financial Analysis, February 2021.

3.4.5.2. Challenges and potential solutions

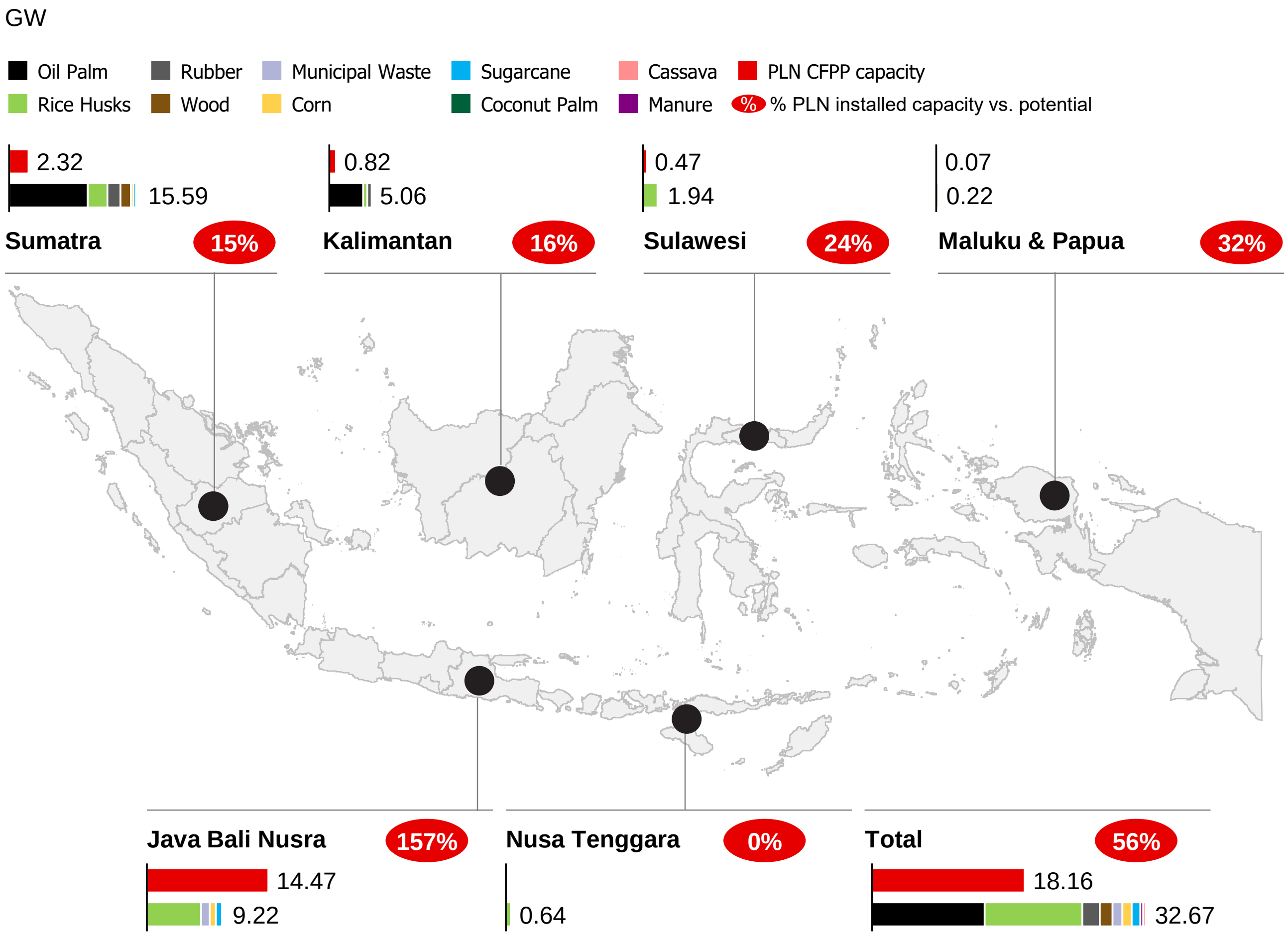
Abundant supply distant from demand centers, not compatible with local power plants [technical feasibility – resource availability]

The biomass supply in Indonesia is abundant but dispersed. Perhutani, the state-owned forestry management company, plans to produce 20 million tonnes of biomass each year, more than enough to meet demand from the country's power sector, which is estimated to need 10 million tonnes a year for biomass co-firing by 2025.[225]

However, about half of the country's usable biomass is in Sumatra, but only 13% of PLN's coal power plants intended for biomass co-firing are located there (**Exhibit 45**). Because biomass supply is not convenient for coal-fired power plants, logistics costs can account for 50% of the final feedstock price.[226] Java-Bali possesses moderate biomass supply, but the most abundant types of biomasses there, municipal waste and rice husks, are less optimal or not suitable for co-fired combustion. Biomass with lower bulk energy density requires more to be transported, increasing costs again.

Also, not all types of biomass are compatible with PLN's coal-fired infrastructure, creating additional challenges. Palm kernel shells, the most abundant type of biomass in Indonesia, is generally not compatible with PLN's coal-fired plants. About 85% of these plants use pulverized or powdered coal, and biomass for co-firing in these plants must be equally granularized, roughly to the texture of sawdust. Standard palm kernel shells must either be ground to meet these specifications or be co-fired with coal in a meticulously controlled ratio.

Exhibit 45: Biomass potential and PLN's installed coal-fired power production capacity[227]



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[225] "Indonesia Energy Transition Outlook 2023," IESR, 2022.

[226] "Transport Cost Estimation Model of the Agroforestry Biomass in a Small-Scale Energy Chain," Sperandio et al. on Forests, 2021, https://doi.org/10.3390/f12020158.

[227] "Indonesia's Biomass Cofiring Bet - Beware of the Implementation Risks," Institute of Energy Economics and Financial Analysis, 2021.

A carefully designed blend of measures to reduce coal emissions – biomass co-firing, MPOs, and CCUS – could help optimize Indonesia's energy mix by capitalizing on the availability of local resources. For example, biomass co-firing could be given priority in regions endowed with ample resources compatible with PLN's coal boilers. Transportation costs can weaken the case for biomass, and where local biomass sources are unsuitable for co-firing in PLN's plants, options such as MPO and CCUS could be considered.

High feedstock costs with inability for pass through [commercial feasibility – project economics]

Current government policy sets a price ceiling on biomass procurement cost up to 20% above the price of coal, with adjustments for quality. However, the tariff system makes it difficult to pass through the higher cost.

This situation is further complicated by the high feedstock prices of biomass which could exceed the 20% cap for PLN to adequately source biomass and slowing its use as a co-firing option. Although the LCOE of biomass is generally on par with coal, the upper range can be much higher depending on the type of biomass used, the co-firing ratio, and biomass transportation costs for Indonesia. The most common sources of biomass in Indonesia – wood pellets and palm kernel shells – are more expensive than coal when priced by the kilogram. Wood pellets, for example, create similar energy from combustion as coal, but cost about twice as much by weight (**Exhibit 46**). Palm kernel shells, the most abundant type of biomass in Indonesia with 10 million tonnes of production in 2019,[228] is on average 15% more expensive than coal but 10% less energy efficient when combusted.

Exhibit 46: Price range of biomass sources compared to coal, Indonesia[229]

Fuel type	**Typical price range,** IDR/kg	**Typical calorific value,** kcal/kg NCV	**Feasibility**
Wood pellet	1,520	4,170	• **Export market has a premium price** compared to local market • Most potential supplies are located **outside of Java-Madura-Bali region** (Jamali)
Palm Kernel Shell (PKS)	893	3,850	• **Export market has a premium price** compared to local market • Pulverized coal boiler which constitutes 85% of PLN coal-fired power plant capacity is largely unsuitable for PKS
Refuse Derived Fuel (RDF)	425	3,000	• **No viable commercial model** has been developed • With limited potential of other biomass sources, co-firing in Jamali region will likely be **constrained towards RDF**
Sawdust	350	2,450	• **Limited availability** as also used as raw material for wood pellet production • Unsuitable for long haul transport so **consumption is confined locally**
Coal	774	4,200	

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[228] "Palm shells becoming more promising at global market," Indonesian Palm Oil Association, November 11, 2022, https://gapki.id/en/news/2022/11/11/palm-oil-shells-becoming-more-promising-at-global-market/.

[229] "Indonesia's biomass cofiring bet," Institute for Energy Economics and Financial Analysis, February 2021.

Competing demand from foreign countries drives up biomass feedstock prices. For example, the prices of palm kernel shell have skyrocketed in the last few years because of increasing demand from China, Japan, South Korea, and Thailand. The average price of palm kernel shell in West Sumatra, Indonesia, almost doubled from IDR 1,378 (USD 0.09) per kilogram[230] in November 2022 to IDR 2,619 (USD 0.17) per kilogram[231] in April 2023.

There are several potential ways to enable PLN to steadily procure biomass feedstock, but each comes with differing implications to electricity tariff affordability and development of biomass business. For example, PLN could adopt feedstock procurement based on market price or accommodate IPP biomass project with adjusted PPA price incorporating biomass feedstock price, but this would imply higher electricity tariff when the cost is passed through. Another example is to mandate local biomass suppliers to supply biomass feedstock to PLN under a regulated price, but this would hinder the profitability and growth of biomass supplier.

Considerations regarding the carbon neutrality and broader ESG impact of biomass [commercial feasibility – ESG & Taxonomy]

The commercial feasibility of biomass projects requires clear assessment of the feedstock's carbon neutrality and broader environment and social implications of its production.

First, while the European Union and the Intergovernmental Panel on Climate Change (IPCC) classify biomass as a renewable resource, the qualification depends on strict criteria and its standing is at the center of an ongoing debate.[232] The carbon neutrality of biomass rests not just on the final combustion, but also the production, processing, and transportation of feedstock, with each stage creating its own carbon footprint. Due to these complexities, the current biomass taxonomy has been challenged.[233]

To overcome these complexities, biomass energy production should follow rigorous and transparent disclosure standards at every stage of its lifecycle. Specifically, aspects such as scale of deployment, conversion technology, fuel displaced, and source of feedstock should be scrutinized to ensure that the lifecycle emissions is indeed negative. The recommendations of the European Commission's Renewable Energy Directive[234] suggest, among other valuable guidelines, which harvesting of biomass feedstock should be done to minimize impact on soil quality, and that public scrutiny of the auditing approach is needed to ensure close monitoring and an adequate level of transparency.

Moreover, the ESG risks surrounding biomass technology extend beyond pure carbon accounting to broader environmental and social impact all along the supply chain. Since the production of biomass spans both land and energy sectors, feedstock production can potentially compete for limited resources needed for biodiversity or food if not sourced carefully.

Sourcing a sustainable supply of biomass also raises potential social issues along the supply chain. Without close monitoring from a well-established governance system, risks of supply chain labor issues could be hidden throughout production, processing, and transportation. As IEA emphasized in its 2019 report, Governing Sustainability in Biomass Supply Chain,[235] "transparent sharing of information on the social, economic, and environmental costs and benefits" is crucial to ethical use of biomass. Enhanced communication among different stakeholders in the supply chain is necessary to work together towards unlocking sustainability governance over not just the carbon footprint, but also the environmental and social impact of biomass.

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[230] "Harga TBS Sumbar Periode Minggu IV November 2022 Ditentukan Jadi Segini (West Sumatra TBS prices for the 4th week of November 2022 are set)," Harga TBS Plasma, 2022, https://sumatera.infosawit.com/2022/11/24/harga-tbs-sumbar-periode-minggu-iv-november-2022-ditetapkan-jadi-segini/.

[231] "Masih Gelap, Ini Harga CPO dan Kernel Sumbar Periode IV (22-30) April 2023 (West Sumatra CPO and kernel prices)," Berita Sawit, 2023, https://sumatera.infosawit.com/2023/04/29/masih-gelap-ini-harga-cpo-dan-kernel-sumbar-periode-iv-22-30-april-2023/.

[232] "Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy," Environmental Research Letters, 2018.

[233] In 2022, a coalition of environmental NGOs from across EU has sued the European Commission over the inclusion of biomass and forestry activities in the EU taxonomy.

[234] "Renewable Energy Directive," European Commissions, 2021.

[235] "Governing sustainability in biomass supply chains for the bioeconomy," IEA Bioenergy, 2019.

3.4.6. Commercial and industrial solar

Category B: Constrained revenue scalability

Exhibit 47: Summary of challenges and unlock ideas, C&I solar in Indonesia

Ratings: 1 2 3 4

⬜ Policymakers 🟧 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	**N/A**	**N/A**	
Commercial feasibility	3	**Market structural factors** • Absence of TPA and direct PPA for C&I solar programs limits physical potential for project developments • TKDN requirement adds operational hurdle for component procurement or increases cost	• **Allow direct purchasing of RES** through PLN (i.e., expand Amazon case) • Investment into **local solar PV production capacity as well as capability building**	EP PM
		Project economics • Capacity cap on self-generation affects project economics • Split incentives between building owner and tenant, where the owner would bear installation cost and the tenant enjoys energy bills savings	• **Increase the self-generation capacity limit** as overcapacity and the constraint on grid flexibility is resolved • **Introduce innovative financing solutions existing in other markets** (e.g., C-PACE in the US)	EP F

C&I solar power is technically feasible but faces commercial obstacles. Due to the overcapacity in the overall power system and concerns arising from the intermittency inherent to solar generation, the capacity for self-generation is capped. Therefore, the full monetization potential cannot be realized. Moreover, misalignment of interests between building owners and the tenants poses a challenge for faster expansion. In addition, without TPA and direct PPA scheme, the scalability of C&I solar project is physically confined within the land availability of the property.

To promote expansion of C&I solar power, resolving the overcapacity and investing in flexibility solutions is required to increase the allowable capacity for self-generated solar energy. While not a full-fledged TPA and direct PPA scheme, expanding PLN's recent contract with Amazon to supply electricity from specific solar projects could serve to open up potential for growth. Meanwhile, financial institutions could also support by offering tailored financing solutions to address conflicting incentives.

3.4.6.1. Lever description and overview

Description

C&I solar is a distributed solar solution where commercial and industrial customers procure power from a solar power plant outside of the general utility tariff (e.g., self-generation). C&I solar power applications would include those with 20 kW between 300 kW in capacity which could generate electricity sufficient for isolated facilities, such as office buildings, small food-processing plants, or electric vehicle charging stations. For needs greater than 300 kW, large numbers of rooftop and ground-mounted solar panels could provide power for, for example, manufacturing plants or large-scale data centers.

Growth potential

C&I solar power systems can deliver substantial benefits. C&I businesses usually have ample space on their sites for solar panel installation, and these components usually have a long operational life. Solar modules can last up to 25 years, while other components, such as inverters, run for about 10 to 20 years. By using dedicated solar power, C&I businesses can cut their electricity bills by 15% to 40%.[236]

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[236] "Pemenang Lelang PLTMH Sudah Ada Kontrak Jual Beli Listrik Belum Beres (PLTMH Auction Winner Already Available, Electricity Sales and Purchase Contract Has Not Been Completed)," Alif Gunawan on Bisnis.com, 2020, https://ekonomi.bisnis.com/read/20200928/45/1297657/pemenang-lelang-pltmh-sudah-ada-kontrak-jual-beli-listrik-belum-beres.

In 2022, Indonesia had 34 MWp[237] of C&I solar capacity, spilt between commercial solar, 11 MWp, and industrial solar, 23 MWp.[238]

Stakeholder initiatives

Indonesia's National Strategic Project (Proyek Strategis Nasional) calls for a significant expansion of rooftop solar energy generation, targeting 2.1 GW of the new capacity from C&I solar.[239]

Existing C&I capacity in Indonesia was developed by a handful of companies which market their projects either directly or through partners. Many of the active players, such as Sun Energy and Surya Energi, have a significant presence in the global market. PLN has not conducted project development of C&I solar but works with these IPPs and provides necessary permits.

3.4.6.2. Challenges and potential solutions

Absence of TPA and direct PPA for C&I solar programs
[commercial feasibility – market structural factors]

Since the Indonesian power market is operated under a single buyer model, TPA to the grid and direct PPAs does not take place. This limits the potential solar resources that the C&I customer can exploit since the customer cannot directly engage with IPPs providing solar generation. The remaining option is to develop off-grid facilities, but such facilities have inherent limitations to expansion because of resource availability as C&I end-users may not have access to abundant sunshine on their properties.

While regulatory changes on TPA and direct PPAs could potentially unlock the expansion of C&I solar, PLN is developing a solution to cater to C&I demand for RES procurement without significantly changing the single buyer model. Recently, PLN has entered a contract with Amazon to exclusively supply renewables from specific solar projects in Indonesia. As this new contract model becomes more widespread, it would accelerate development of solar projects catering to C&I segment.

TKDN local content requirements adds operational hurdle
[commercial feasibility – market structural factors]

As with other decarbonization levers, TKDN mandates could dampen the expansion of C&I solar power systems. The key to unlocking this measure is also capability building to improve Indonesia's supply chain of components needed for decarbonization.

Capacity cap on self-generation affects project economics
[commercial feasibility – project economics]

The Indonesian government has taken steps to encourage more C&I solar adoption by updating regulations, especially net metering. Net metering is a mechanism that allows RES system owners to receive credit for any excess energy exported to the grid, and the latest regulatory update set the credit at 100% or the full value. Furthermore, charges for additional capacity and emergency energy for C&I customers have also been reduced, from 40 times to 5 times inverter capacity and electricity tariff. This will lower the cost for industrial end-users based on installed capacity of the solar module.

Despite these regulations, PLN imposed restrictions on self-generated solar capacity. Because of concerns about oversupply of electricity in the country's main demand centers – Bali, Java, and Madura – as well as increased intermittency, PLN limits C&I users to self-generate only 10% to 15% of their total electricity demand. Based on an analysis by the IESR, this restriction produces a suboptimal economic case for C&I solar due to the limited revenue potential for end users.

While capital requirements for these projects have fallen in recent years, a payback period of 10 to 12 years is longer than that of utility-scale solar projects and high single-digit IRRs are unattractive.

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[237] Megawatt peak is a unit of measurement for the output of power from a source such as solar or wind where the output may vary according to the strength of sunlight or wind speed.

[238] "Indonesia Energy Transition Outlook 2023," IESR, 2023.

[239] "Indonesia Energy Transition Outlook 2022," IESR, 2022.

The potential unlock to this challenge is to resolve the overcapacity challenge as well as continue investment into flexibility (e.g., smart grid) and gradually revise the limits to create greater incentives for adoption. In areas with no overcapacity, these measures could be implemented more rigorously.

Split incentive between owner and tenant hinders project economics [commercial feasibility – project economics]

In cases where the building owner and tenant are different, commercial solar projects could face financing hurdles because of the mismatch between the ownership or investor and the tenant or beneficiary. Termed a "split incentive," this mismatch discourages solar adoption by owners, often necessitating financing to transfer installation costs to tenants. Consequently, it complicates financing contracts for commercial rooftop solar, where owners initiate agreements and tenants repay through rent or alternate methods, depending on the specific terms. More specifically, the financial credibility of building owners does not represent the ability of the tenants to pay back the loans, complicating the capital acquirement process.

Financial institutions could help unlock the complexity around capital availability by accelerating financing for C&I solar projects. Particularly by using innovative financing terms, financial institutions could address the split incentives. Some options could include Commercial Property Assessed Clean (C-PACE) and green leases. C-PACE covers up to 100% of project costs at fixed interest rates with terms up to 25 years. This non-recourse financing is secured by the property and repaid via a special assessment on property taxes and is therefore transferable upon sale. The second solution, green leases, lays a foundation for the owner to recoup a portion of the utility savings from solar, in addition to the tax benefits and incentive income. Similar to existing cost-recovery clauses, green lease language details a path for landlords to be compensated for the utility savings that their asset provides to the tenant. In both solutions, the cost of installing rooftop solar systems is passed on from the owner to the tenant, so that the owner would have economic incentive to choose clean energy solutions.

3.4.7. Residential solar

Category B: Constrained revenue scalability

Exhibit 48: Summary of challenges and unlock ideas, residential solar in Indonesia

Ratings: 1 2 3 4 ⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	**N/A**	**N/A**	
Commercial feasibility	3	**Project economics** • Capacity cap on self-generation affects project economics • Constrained project economics with small ticket size and varying customer credit histories	• **Increase the self-generation capacity limit** as overcapacity and the constraint on grid flexibility is resolved • **Aggregate demand and explore innovative financing products**	EP F
		Market structural factors • TKDN requirement adds operational hurdle for component procurement or increases cost	• Investment into **local solar PV production capacity as well as capability building**	EP PM

Residential solar technology itself is well-established with strong technical feasibility. However, its commercial feasibility faces similar challenges as C&I solar to reach large-scale adoption. The underlying physical constraints on the grid's ability to absorb the intermittency is translated into the cap on self-generated electricity capacity. These market conditions limit the revenue scalability and hinders project economics. In addition, its small scale makes it less appealing to investors and implies greater credit risk, as the investment amounts are relatively small. Solutions to these challenges could involve addressing the underlying challenges on overcapacity and grid flexibility to revisit the cap on self-generation capacity. Also, offering financial solutions to bundled projects may improve overall creditworthiness.

3.4.7.1. Lever description and overview

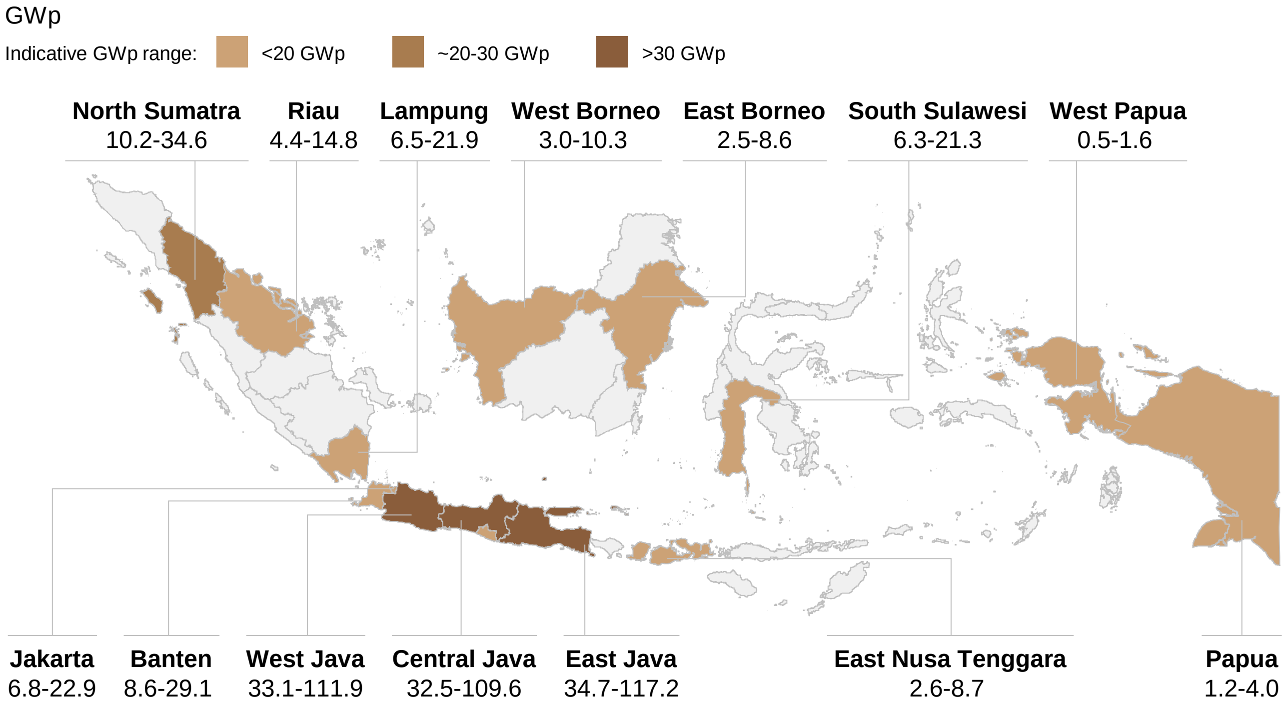
Description

Residential solar systems are installed for personal consumption, and usually used by homeowners to lower electricity costs and shield themselves from retail tariff increases. Most systems are between 9 and 10 kWp.

Growth potential

Residential solar is increasingly relevant to Indonesia's power market. The country's endowment of abundant solar radiation makes it ripe for the technology. The IESR estimates the total technical potential or the maximum amount of a resource that could be harnessed or utilized under ideal conditions of Indonesian residential rooftop solar is 655 GWp. The total market potential, which takes into account both technical feasibility and the economic, social and practical factors, is 116 GWp (**Exhibit 49**).

Exhibit 49: Total technical and market potential of residential solar in Indonesia[240]



Also, because of Indonesia's unique geographic features, the need exists to replace home-owned diesel generators with rooftop solar power on remote islands. These scattered islands can shift from diesel generators by installing small-scale solar mini-grids or privately owned residential rooftop solar installations.

Though residential solar in Indonesia has significant potential and dovetails with the government's ambitions to expand its use, the market remains in the early stages of development with only 16 MWp of cumulative installed capacity by mid-2022.

Stakeholder initiatives

As part of the 2025 National Strategic Project (2025 PSN), Indonesia plans to install 1.5 GW of residential rooftop solar by 2025.[241]

There are a handful of residential solar companies in Indonesia. Many of the active players, such as Sun Energy and Surya Energi, have significant presence in the global market in both residential solar and C&I solar. Smaller players in terms of installed capacity also exist, such as Nusa Solar, Atap Surya, and Solar Kita.

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[240] "Residential rooftop solar technical potential in 34 provinces in Indonesia," IESR, 2019.

[241] "Indonesia energy transition outlook 2022," IESR, December 2021.

3.4.7.2. Challenges and potential solutions

Capacity cap on self-generation affects project economics [commercial feasibility – project economics]

Similar to C&I solar, the main challenge hindering project cash flows of residential solar projects is the cap on self-generation. Despite the government's efforts to support residential solar adoption through a net metering program, self-generation, remains capped by PLN. This cap sets self-generation at only 10% to 15% of their total electricity demand and limits potential savings on energy bills.

Analysis by the IESR shows this restriction impedes the business case for households to adopt rooftop solar. Assuming a typical household has a 2,200 volt-ampere (VA) installed power connection, households would only be able to install a single solar panel with a capacity of 300 watt peak (Wp) to 400 Wp under the restriction. This scenario is suboptimal for energy cost savings and ROI since the unit cost (USD/kW) for residential solar installment is 60% higher in the case where capacity restriction is imposed as opposed when the constraint does not exist.[242]

To make residential captive solar more attractive, PLN could consider increasing the self-generation capacity limit with a focus on areas without existing overcapacity or grid constraints, considering MPOs, or witnessing growing demand amid overcapacities. These solutions echo those needed to encourage C&I solar.

Constrained project economics with small ticket size and varying customer credit histories [commercial feasibility – project economics]

Residential solar in Indonesia also faces many of the same challenge to project economics found elsewhere in the world. Individual projects are small, which makes financing difficult, and credit histories and income levels among prospective adopters vary considerably, requiring innovative financing solutions.

These projects are generally less than 10 kW each, and the average household's needs can be difficult to finance, and because of the smaller ticket size of residential solar systems, PLN may not find it worthwhile to contract directly with end-users. Another major obstacle to project economics is the ability of individuals to cover costs required for installation. While customers with strong finances may be able to pay the installation fee upfront, those with limited liquidity may have trouble finding financing options for solar. The availability of financing products for such customers is closely linked to their credit history, and options for those with unfavorable credit may be limited further.

Demand aggregation and innovative financing products solution could be a solution to these challenges. One potential aggregator is IPPs. In this approach, customers would not need to get direct bank financing. Instead, IPPs would consolidate customer portfolios into larger financing packages that could then be sourced from banks. This would happen if IPPs can provide an all-inclusive residential solar energy solution that encompasses customized energy plan designs, solar panel installation, financing products, and maintenance services. While there have been some leaders in Indonesia's residential sector, a greater level of participation is needed to fully realize the potential for expansion. Also, to appeal to a wider base of customers as an aggregation solution provider, IPPs could establish a mutually beneficial partnership model with PLN. Currently, PLN only provides permits and does not have a financial stake in IPPs' solar projects, which means that IPPs must rely on their own credit history for financing and their own customer base for demand. To promote further growth, a profit-sharing model could be implemented where PLN takes on the role of sales and marketing with its wider customer base, and IPPs share a portion of the revenue with PLN. If successful, PLN would benefit from increased revenue, and IPPs would gain access to a wider customer base. A partnership between PLN and IPPs could also allow IPPs to use PLN's full range of capabilities and network, enhancing their credibility and reducing financing costs.

Financiers can also step in by providing innovative financing products. One example observed in other markets is asset backed securitization (ABS) model where the credit assessment is decoupled from the credit rating of the homeowners. In a solar ABS, numerous residential solar assets are combined and restructured into interest-bearing securities. These securities then channel the interest and principal payments generated by the assets to the individuals or entities who have purchased the securities. Other forms of financing products observed in other markets are explored in section 5.3.

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[242] "Indonesia solar energy outlook 2023," IESR, October 2022.

TKDN local content requirement adds operational hurdle [commercial feasibility – market structural factors]

TKDN mandates on local content also present a challenge to expanding the use of residential solar, as seen in other potential decarbonization measures. The key to unlocking this measure is also capability building to improve Indonesia's supply chain of components needed for decarbonization.

3.4.8. Grid upgrade and expansion

Category C: Regulated monetization potential

Exhibit 50: Summary of challenges and unlock ideas, grid upgrade and expansion in Indonesia

Ratings: 🟩 1 🟩 2 🟥 3 🟥 4 ⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	2	**Operational complexity** • The development of inter-island connection networks faces challenges in construction and maintenance	• **Improve project planning** to enhance technical performance such as conducting detailed surveys of the seabed	EP
Commercial feasibility	3	**Project economics** • Regulated project cash flows and low profit margins despite high CAPEX needs	• Encourage private sector participation through **third-party project development models**, such as BOT (build-operate-transfer) • MDBs and other public financiers could support grid projects with **low-cost capex funding**	EP F
		Market structural factors • TKDN requirement adds operational hurdle for component procurement or increases cost	• **Investment into local supply chain capacity as well as capability building** – pace TKDN implementation in line with the development	PM EP

Grid update and expansion in Indonesia will be complex to develop and operate as a nation of islands, but the most significant challenge is the project economics. Revenue potential from upgrading and expanding the grid is low. Because the grid is a cost center for the system, regulators keep the profit margins of grid network projects low. Expected returns are set near projects' weighted average cost of capital. Capital-intensive grid projects, which will likely require USD 25 billion in funding by 2030, are unlikely to offset these capital expenses through revenue.

The government and PLN could explore opportunities to divide grid development projects using BOT or BLT approaches. Public finance from MDBs and foreign governments can help provide lower-cost financing and attract complementary commercial investments.

3.4.8.1. Lever description and overview

Description

An electrical grid is a network of power lines and substations which enable the TnD of electricity power from producers to consumers. Aging grid infrastructure and increasing demand for electricity necessitate regular expansion and upgrades to the grid. As the share of renewables in the energy mix increases and the RES portfolio becomes more diverse, TnD networks will need to cover a wider geographic area because RES projects tend to require more land than conventional generation. RES projects must also be where the relevant natural resources – water, wind, or abundant sunlight – are, which means they are often in remote areas far from demand. The resulting regional mismatch between supply and demand will require grid expansion.

Growth potential

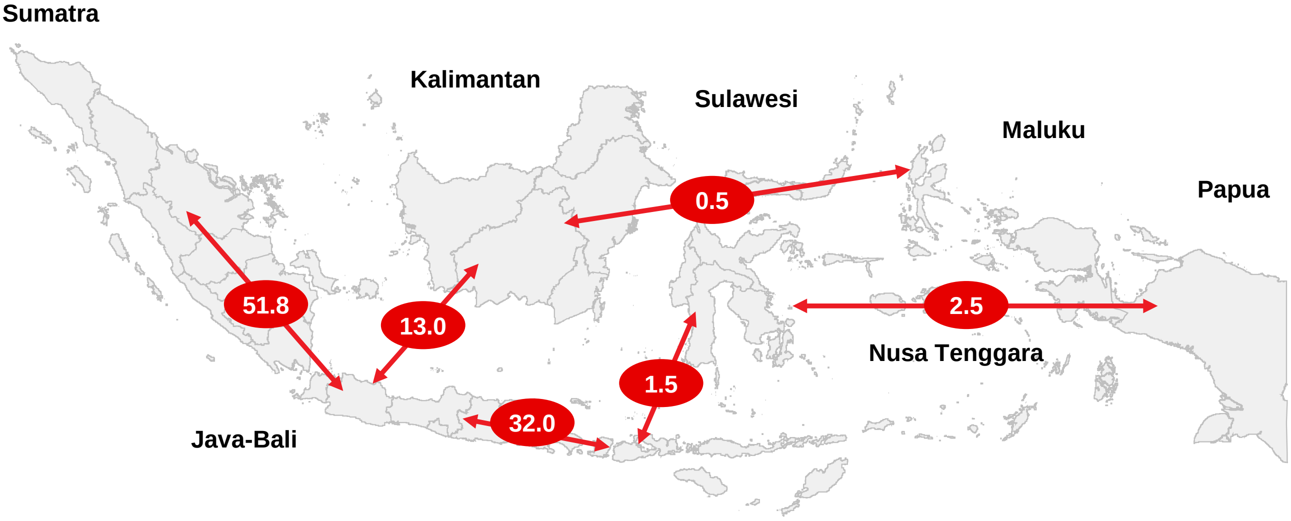
Grid expansion and upgrades are needed to enable expansion of RES power generation and to manage intermittency. Expanding RES across Indonesia's many islands, in particular, requires the development of a robust grid. In IESR's deep decarbonization scenario to net zero emission, demand for electricity in Java-Bali would increase from 189 TWh in 2022 to about 417 TWh in 2030. However, using large-scale solar panels in

Java is limited because of land constraints, which underscores the need to connect islands using underwater transmission lines and to bring in electricity from nearby islands with ample renewable energy resources and lower electricity demand. In addition, because considerable time is needed to build high-capacity RES, like geothermal and hydropower plants, growing demand could outstrip RES capacity additions in some regions, again arguing the need to connect various islands. As an example, about 87% of Indonesia's total electricity demand comes from Java and Sumatra, but the largest hydropower potential exists in North Kalimantan.

It is estimated that the required investment needs in grid network development could reach by 2040 and 2050, respectively to USD 34.8 billion and USD 53.9 billion.[243]

Exhibit 51: Required inter-island interconnection capacity and renewables potential in different islands[244]

Grid connection demand by 2030, GW



Note: The number of renewables capacity are technical potential according to IESR study, not the installed capacity

Stakeholder initiatives

PLN has several initiatives designed to address interconnections needed cross- and within-islands.

There are examples of initiatives designed to address interconnections needed cross- and within-islands.

- **The East Java-Bali interconnection:** A planned 500 kV, extra-high voltage power network. The project is designed to improve grid reliability. Part of the 2025 PSN, this project is expected to be completed by 2025 and will span from the Probolinggo Regency in East Java to Tabanan Regency in Bali.[245] The project will cost USD 1.2 billion, of which USD 890 million will come from PLN and USD 310 million from the Asia Infrastructure Investment Bank (AIIB).[246]
- **The Java-Bali and Sumatra interconnection:** Designed to upgrade and expand TnD lines in Java, Bali, and Sumatra, this interconnection can be expected in 2028 at the earliest. This project signifies a step forward towards enhancing connectivity among islands beyond Java-Bali and will contribute to enabling renewable-generated power to be shared across larger branching areas.[247]

Other projects are geared towards expanding connections within islands:

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[243] "Indonesia Needs Inter-island Electricity Interconnection for 100 Percent Renewable Energy Development," IESR, 2022, https://iesr.or.id/en/indonesia-needs-inter-island-electricity-interconnection-for-100-percent-renewable-energy-development.

[244] "Indonesia Energy Transition Outlook 2023," IESR, December 2022.

[245] "East Java – Bali power distribution strengthening project: Environmental & social management planning framework," PLN, January 2020, Link.

[246] "Project document: Project document of the Asian Infrastructure Investment Bank: Sovereign-backed financing," Asia Infrastructure Investment Bank, January 28, 2021.

[247] "Enhancing Indonesia's Power System," IEA, 2022.

- **The West Kalimantan-Central Kalimantan interconnection:** An ongoing effort comprising five projects to build 150 kV high-voltage transmission lines in West Kalimantan, seven projects in Central Kalimantan, and accompanying substations.[248] The project expects the operations to begin in 2024.[249]

Along with expansion, PLN also has targets for grid upgrade. According to RUPTL, the estimated investment to upgrade grid infrastructure will be more than IDR 39 trillion (USD 25 billion) by 2030.

3.4.8.2. Challenges and potential solutions

Operational complexity in laying undersea cables [technical feasibility – operational complexity]

As a nation of islands, Indonesia's geography imposes considerable operational complexity to developing its grid network. In particular, inter-island connection would face challenges in construction and maintenance. Specifically, in shallow waters, undersea cables are exposed to various external hazards including fishing gear, dragged anchors, and dropped objects, as well as waves and sediment movements.[250] Indonesia also witnesses seismic activity, adding to the difficulties.

To work past this challenge, PLN could conduct detailed surveys of the seabed before project sizing to understand better the geological conditions. They could also consider choosing optimal routes that avoid known hazards like anchors, fishing activity, or underwater obstructions. Although it might increase project cost, PLN could also design protective measures into a project such as burying the cable further beneath the seabed or installing protective layers to shield against abrasion or impact.

Low profit margins despite high CAPEX needs [commercial feasibility – project economics]

Low profit margin on TnD development projects limits the commercial feasibility. In a single-player market, project cash flows are regulated and kept low. Specifically, profit margins are set low by regulators, with IRRs expected to be near the cost of capital. Combined with large capital investment needs, the low IRR makes the bankability of many projects suboptimal.

Also, PLN may find it difficult to shoulder the high capital expenditures needed to expand and upgrade the national grid by leveraging its own balance sheet. In 2021, capital investment from PLN for TnD was USD 1.1 billion,[251] which presented a large gap to the estimated average annual investment needed between 2021 and 2030 of USD 2.7 billion.[252,253]

This financial quandary could be addressed by encouraging private investors to find opportunities in TnD developments in Indonesia. PLN could explore different project development models in collaboration with private companies. Already, ESDM has asked PLN to collaborate with private partners in TnD projects in recognition of PLN's limited capital conditions.[254]

PLN could explore partnership opportunities or adopt the BOT or BLT models, which could relieve pressure on PLN to secure and repay financing of these projects. Both approaches place the responsibility of financing and executing the project to a private company, then allows ownership to be transferred to the public utility. BOT is more common globally, especially in advanced economies.

In parallel, concessional capital, specifically MDBs and public financial institutions, could support grid projects with low-cost capital funding. Commercial financial institutions could use blended finance funds to invest in

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[248] "PLN Bangun Sejumlah Infrastruktur Listrik di Kalbar & Kalteng (PLN builds a number of electricity infrastructure in West Kalimantan & Central Kalimantan)," Nada Zeitalini on Detikfinance, April 25, 2022, Link.

[249] "Direksi PLN pastikan progres interkoneksi kelistrikan Kalbar -- Kalteng sesuai rencana (PLN directors ensure that the progress of the West Kalimantan - Central Kalimantan electricity interconnection is according to plan)," Antara Kalsel, February 14, 2023, Link.

[250] "Subsea cable key challenges of an intercontinental power link: case study of Australia–Singapore interconnector," Gordonnat et al. on Energy Transitions, 2020, https://link.springer.com/article/10.1007/s41825-020-00032-z.

[251] "Realisasi Investasi PLN Sepanjang 2021 Capai Rp 87,7 Triliun (PLN investment realization throughout 2021 reaches IDR 87.7 trillion)," Hiru Muhammad on Republika, January 2, 2022, Link.

[252] "RUPTL, 2021-2030," PLN, 2021, Link.

[253] World Bank's average IDR/USD ratio for 2021.

[254] "Kementerian ESDM meminta PLN menggandeng swasta untuk bangun transmisi listrik (ESDM has asked PLN to collaborate with the private sector to build electricity transmission)," Filemon Agung on Kontan.co.id, 2021, Link.

TnD projects. The Indonesian government and PLN have already received foreign funding for similar projects in the past.

TKDN requirement restricts project execution [commercial feasibility – market structural factors]

TKDN rules on local content could also be impediments to expanding and upgrading the national grid. This challenge is seen frequently with other measures analyzed to accelerate decarbonization in Indonesia. Building capabilities throughout the domestic supply chain could help mitigate this challenge.

3.4.9. Energy storage

Category C: Regulated monetization potential

Exhibit 52: Summary of challenges and unlock ideas, energy storage in Indonesia

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	3	**Technology maturity** • Large-scale or long-duration battery storage is still at pre-commercialization stage	• **Inject public finance into R&D** of large-scale or long-duration battery storage systems	F
Commercial feasibility	3	**Project economics** • Capacity cap on self-generation affects project economics • Restricted project cash flow for standalone storage projects • Potential of cost overruns because of operational complexity for pumped hydro project	• **Increase the self-generation capacity limit** as overcapacity and the constraint on grid flexibility is resolved • **Financially reward flexibility services provided by storage projects** e.g., offer ancillary services tenders • Avoid overruns by **building local IPPs' capabilities** in front-end engineering	PM EP
		Market structural factors • TKDN requirement adds operational hurdle for component procurement or increases cost	• **Investment into local supply chain capacity as well as capability building** – pace TKDN implementation in line with the development	EP PM

Energy storage faces challenges both in terms of technical and commercial feasibility. At a large scale the technology is still considered to be in the pre-commercialization phase. Current market constraints in Indonesia related to captive solar capacity and net metering have reduced the potential for excess power generation, limiting the demand for energy storage systems, and there is no established mechanism, for example AS, to ensure favorable cash flows for decentralized energy storage projects.

On the other hand, the financial viability of storage projects has improved because of revisions in price ceiling regulations. The benefit is contingent on avoiding overcrowding in the auction process to ensure that IPPs can realize the full financial benefits under the new price ceiling.

Expanding energy storage systems hinges on public finance or blended finance to enhance the technology's maturity. Meantime, energy policymakers could add incentives to expand distributed solar, and, in turn, the demand for storage systems.

3.4.9.1. Lever description and overview

Description

Energy storage is a solution to address the intermittency of RES. It enables balancing intra-day variability from solar generation, providing a more consistent energy supply, and it also allows for shifting of generation to match demand profiles. Thus, energy storage can help optimize RES capacity, reducing the need to overbuild RES to meet peak demand and increasing its utilization rate.

Energy storage can be thermal, such as heat/cold storage; mechanical, such as pumped hydro; chemical, such as BESS; or power-to-hydrogen conversion. Considering technology maturity, cost competitiveness, and functionality, BESS and pumped hydro are the most established and promising options.

Growth potential

The demand for energy storage is stimulated by the country's plan to make solar energy a large share of its energy mix. Demand for energy storage is expected to grow to about 20 TWh by 2030 and continue significant growth after this. Towards 2050, between battery energy storage and pumped hydro, most of the demand for energy storage will be met by batteries, with a total of nearly 900 TWh, mostly in utility-scale batteries. Demand for energy storage on distributed energy sources is likely to be substantial from sources such as the communal solar projects. PLN's program to replace diesel generators with RES could also catalyze battery storage demand. Pumped hydro projects have been earmarked for development to 2030, with batteries expected to play the major role beyond 2030 across utility-scale, C&I, and residential settings.[255]

Stakeholder initiatives

The government has set an ambitious plan to increase energy storage, with a goal of reaching 600 MW in battery energy storage and 2 GWh in pumped hydropower storage by 2028 for Java-Bali power system.[256] Among the efforts underway, PLN with its subsidiary, Indonesia Battery Corporation (IBC), began an initiative to develop 5 MW battery storage in 2022.[257]

Echoing the government target, the industry has also been actively piloting pumped hydro projects. For instance, the World Bank approved in September 2021, a USD 380 million loan to develop Indonesia's first pumped storage hydropower plant. The Upper Cisokan plant between Jakarta and Bandung is expected to start operations in 2027 with a capacity of 1 GW.[258]

3.4.9.2. Challenges and potential solutions

Large-scale battery storage remains at pre-commercialization stage
[technical feasibility – technology maturity]

Large-scale or long-duration battery energy storage still face technology constraints. For example, increasing the energy density of batteries is crucial for storing more energy in a compact space, but materials and designs are still being explored to achieve higher energy densities. Meanwhile, the availability of certain critical materials, such as lithium and cobalt, is also a concern.

Uptake of battery storage could be catalyzed by technology advancement, which could be enabled through funding initiatives for R&D focused on long-duration battery storage technologies, through either public finance into research related work, blended finance into battery storage projects, or low CAPEX funding at a project level. Local IPPs could also engage in collaborative R&D efforts with leading foreign companies to trigger an exchange of knowledge and expertise.

Capacity cap on self-generation affects project economics
[commercial feasibility – project economics]

Capacity restrictions on self-generation effectively limits demand for distributed battery storage systems. Generally, demand for installing a battery storage system on distributed solar sources is stimulated by financial benefits from unused electricity generation, either through cost savings from offsetting energy bills or through revenue gains from selling back to the grid. The current capacity constraint effectively limits any excess power generation potential, reducing the need for battery systems.

To encourage demand growth in battery storage systems in distributed solar sources, a conducive policy environment to allow excess revenue potential to end-users could be beneficial. With careful consideration to the implications on overcapacity and RES grid intermittency, PLN could consider lifting the capacity constraint on captive rooftop solar, which would also spur demand for energy storage systems.

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[255] "Battery energy storage system (BESS) market in Indonesia," Fabby Tumiwa on RE Invest Indonesia, April 20, 2021.

[256] "Indonesia Energy Transition Outlook 2023," IESR, December 2022.

[257] "PLN Grup Bersama Ibc Mulai Pengembangan Battery Energy Storage System (PLN together with IBC begins development of battery energy storage system)," PLN, 2022, https://web.pln.co.id/cms/media/2022/03/pln-grup-bersama-ibc-mulai-pengembangan-battery-energy-storage-system/.

[258] "Indonesia's first pumped storage hydropower plant to support energy transition," The World Bank, September 10, 2021, Link.

Limited project cash flows for battery storage systems on distributed solar sources [commercial feasibility – project economics]

Without a market mechanism to reward AS, project cash flows for battery storage at residential and C&I sites are limited. For example, where a liberalized wholesale power market exists, end-users can generate profit from arbitrage – store power when the price is low and sell to the grid when the price is high. Alternatively, in cases with a liberalized AS market, end-users can gain excess revenue by offering services for maintaining the frequency of the system, known as frequency control, or by securing long-term capacity payments.

In contrast, energy storage projects combined with utility-scale RES projects may achieve appropriate project cash flows. Revenue to utility-scale battery projects is governed by regulations that set a price ceiling for solar-plus-battery projects allowing for adding cost for energy storage up to 60% of the estimated LCOE for solar adjusted by location factor and scale. In general, the latest update may provide enough financial incentive for storage projects, although economics will differ by location and scale. The regulation offers a higher price for smaller producers that may not have good economics because they lack economies of scale. The ceiling price is set lower for systems larger than 20 MWp, which are expected to have better economies of scale.

To clear these hurdles, PLN could offer tenders for AS, rewarding energy storage solutions. In some other markets, TnD companies procure ancillary capability from third-party operators. In these contracts, the TnD company typically offers a fixed capacity payment to those who will reserve capacity and transfers it to the grid when needed. These tenders are generally divided into different products depending on the capacity size, expected ramp up speed, and expected response speed, and adjusted to different types of technologies.

Potential of cost overruns because of operational complexity for pumped hydro projects [commercial feasibility – project economics]

Because of high CAPEX and operational complexity, pumped hydro energy storage projects risk of cost overruns, especially from land acquisition costs, delays in obtaining permits and geo-technical engineering and construction.

Building better front-end engineering capabilities within local IPPs could reduce cost overruns by improving overall project execution and cost management. In addition. the public sector could inaugurate initiatives to build domestic capabilities, such as knowledge exchanges with international stakeholders.

TKDN local content requirement adds operational hurdle [commercial feasibility – market structural factors]

As with other potential decarbonization measures, the expansion of storage systems is potentially burdened by TKDN local content requirements. Although large-scale battery storage projects are exempt, residential and communal solar projects, which spur demand for storage systems, are not.[259] The national battery supply chain is focused on the upstream activities, including mining and refining (**Exhibit 53**), but as the country moves to a more localized battery supply chain, it could work to build capabilities in areas like cell production, assembly, manufacturing, and recycling capabilities to mitigate any local-content challenges.

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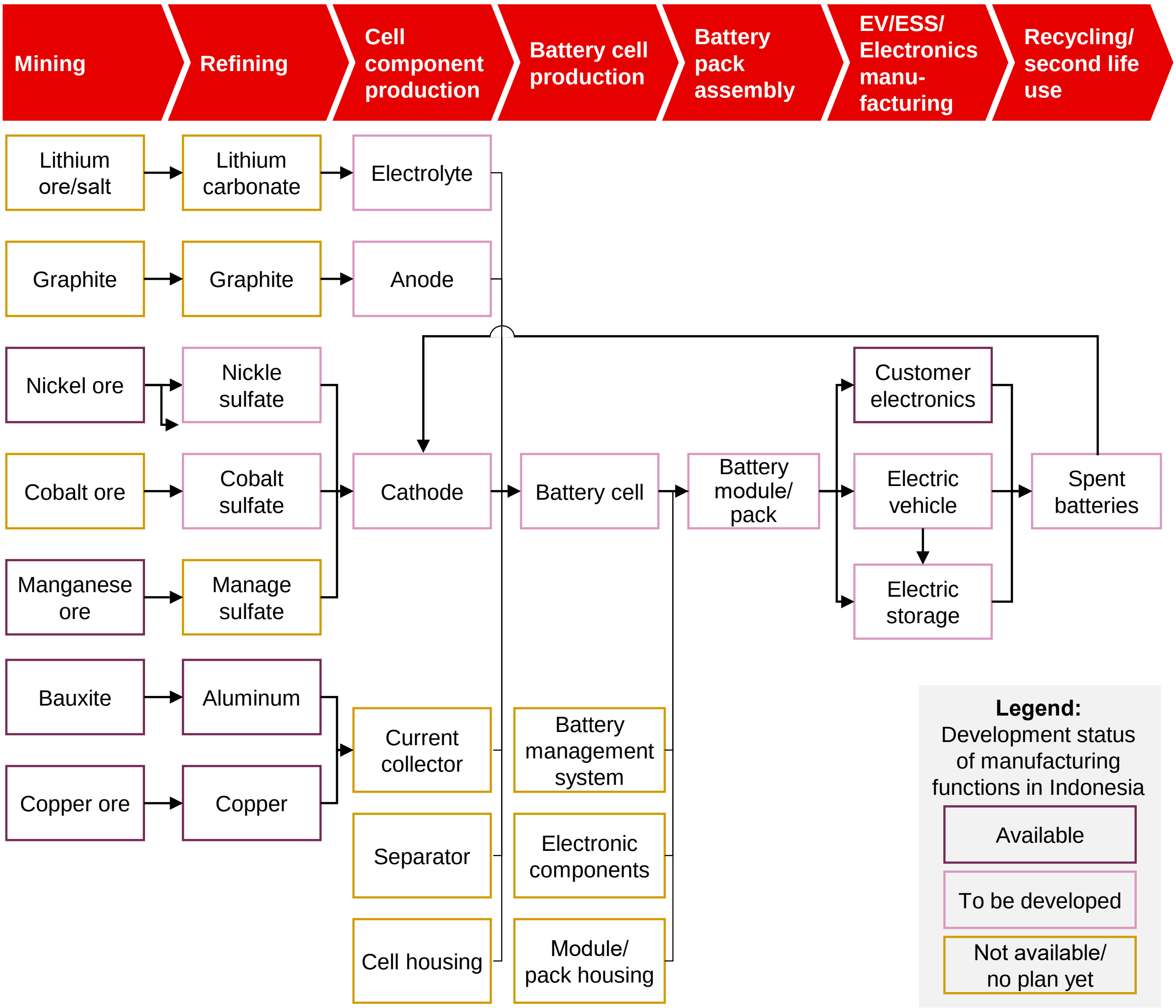
[259] "Regulation number 04/m-ind/per/2/2017: Concerning provisions and procedures for assessing domestic component level for solar electric power plant," Government of Indonesia, 2017.

Exhibit 53: Battery supply chain manufacturing capabilities in Indonesia[260]



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260 "Battery Energy Storage System (BESS) market di Indonesia," IESR, 2021, https://reinvestindonesia.com/assets/source/materials/southkorea/Fabby%20Tumiwa%20-%20IESR.pdf.

3.4.10. Managed phaseout

Category D: Pre-commercialization

Exhibit 54: Summary of challenges and unlock ideas, MPO in Indonesia

Ratings: 1 2 3 4

⬜ Policymakers 🟧 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	**N/A**	**N/A**	
Commercial feasibility	4	**Project economics** • Significant investment required with lack of mechanisms to generate returns • Contractual inflexibilities among PLN, IPP, financiers, fuel suppliers adds further complexity to the execution and distribution of the economic burden	• **Leverage concessional capital** such as MDBs and philanthropic funds to refinance with lower cost of capital	F
			• **Shape carbon pricing environment** to improve economic feasibility by implementing a carbon credits system for MPO	PM
		ESG & Taxonomy • Ambiguity regarding taxonomy and financed emissions, as well as risk-weighted asset allocation for MPO • Concerns with financed emission and whether MPO can qualify as "green financing"	• **Clarify and harmonize MPO's position within taxonomies** • **Clarify carbon accounting standard for MPO** with standard setting bodies	PM

While MPOs of coal-fired power plants are straightforward technically, commercial considerations impact their feasibility. An MPO requires not only capital funding for the physical closure, but loss of expected revenue because of early retirement also must be counted.

MPOs do not generate revenue, but several options could address this negative cash flow. For example, public finance, particularly from MDBs, could minimize the cost of finance or revenue could be generated by creating carbon credits from MPO projects.

3.4.10.1. Lever description and overview

Description

MPOs are the decommissioning of coal-fired power plants ahead of the end of their projected useful life. Early retirement means foregoing future expected project cash flows, making MPOs costly to execute, but they could be a strong lever to open RES capacity expansion in Indonesia.

Stakeholder initiatives

In 2022, Indonesia had 42 GW of capacity from coal-fired power plants.[261] This capacity is expected to grow during the next few years, with, for example, PLN planning 13.8 GW new coal-fired power plant capacity installations in RUPTL 2021-2030.[262]

The country could phase out coal-fired power by the end of 2056, possibly as soon as 2040 with international support. PLN has announced potential to retire coal-fired power plants, and in the first stage of this initiative it would retire two to three plants with a combined capacity of about 1 GW by 2030, followed by an additional capacity of 9 GW retired by 2035.[263]

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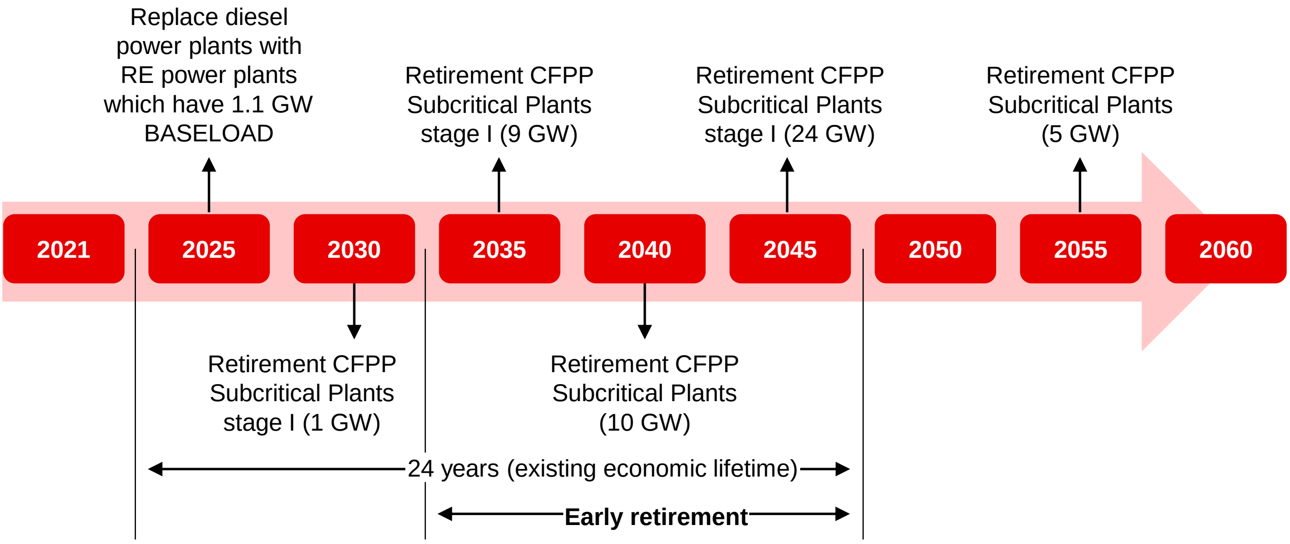
[261] "Annual Report," PLN, 2022, https://web.pln.co.id/statics/uploads/2023/06/Laporan-Tahunan-2022_Final_3005_Med-Res.pdf.

[262] "RUPTL, 2021-2030," PLN, 2021, Link.

[263] "Intersessional Meeting of the CTF Trust Fund Committee," Climate Investment Fund, October 2022, https://www.cif.org/sites/cif_enc/files/meeting-documents/CTF_TFC_IS_3_04_Indonesia_ACT_IP.pdf; "CIF Accelerating Coal Transition (ACT): Indonesia Country Investment Plan (IP)," Ministry of Finance, Government of Indonesia, October 3, 2022, https://fiskal.kemenkeu.go.id/docs/CIF-INDONESIA_ACT_IP-Proposal.pdf.

In the next stage, spanning 2030-2055, the company plans to retire 49 GW of capacity from coal-fired power plants.[264] However, the country would need international support and concessional capital to accelerate planned retirements by 5 to 10 years and clear the path to replace retired coal capacity with RES (**Exhibit 55**).

Exhibit 55: PLN roadmap for early retirement of coal-fired power plant[265]



Outside PLN, MPOs are being explored with IPPs. In 2022, an MOU between ADB and Cirebon Electric Power was signed to explore the early retirement of the Cirebon coal plants in West Java.[266] The ADB, CIF, and the Energy Transition Mechanism Partnership Trust Fund were listed as prospective sources of concessional capital.

3.4.10.2. Challenges and potential solutions

Significant investment required, with lack of mechanisms to generate returns [commercial feasibility – project economics]

The most significant challenges to MPOs in Indonesia and elsewhere are the amount of capital required and the low returns. Foregone cash flows can reach hundreds of millions of dollars in a MPO, not counting the substantial amount of capital expenses that PLN and IPPs have invested into coal generation over the past decades. On top of this, there are cases where the investment of IPPs gets tied into PPAs with PLN under long-term contract conditions (up to 30 years), inflexible take-or-pay amounts, or fuel-cost transfer that would require restructuring for MPOs to be feasible.[267] Other binding factors associated with a coal asset also include fuel supply contracts and revenue-dependent interest rates set by financiers. These various forms of binding conditions pose hurdles to MPO not only from an asset-by-asset basis, but to grid planning, which lack the certainty or visibility of the phase out to ensure sufficient replacement power supply.

Notwithstanding these factors, PLN has been evaluating the feasibility and commercial viability of candidate coal assets for MPO. In 2022, PLN shortlisted nine coal assets with a total book value of USD 5.6 billion as potential candidates to be considered for decommissioning before 2030.[268] In 2023, this list is further expanded to cover 16 coal fired power plants to be early retired conditionally before 2030.[269] Among this list, PLN and ADB further show that three plants – Suralya U1, Suralya U2, and Paiton U9 – can be the most suited for decommissioning and will be prioritized for retirement in the near-term.

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[264] “Intersessional Meeting of the CTF Trust Fund Committee,” Climate Investment Fund, October 2022; “CIF Accelerating Coal Transition (ACT): Indonesia Country Investment Plan (IP),” Ministry of Finance, Government of Indonesia, October 3, 2022.

[265] “Intersessional Meeting of the CTF Trust Fund Committee,” Climate Investment Fund, October, 2022, Link.

[266] “ADB and Indonesia Partners Sign Landmark MOU on Early Retirement Plan for First Coal Power Plant Under Energy Transition Mechanism”, ADB, November 14, 2022, Link.

[267] “Accelerating Just Energy Transition in Indonesia 2023,” JETP, November 2023, Link.

[268] “CIF Accelerating Coal Transition (ACT): Indonesia Country Investment Plan (IP),” Government of Indonesia, October 3, 2022.

[269] “Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development,” PLN, 2022.

Exhibit 56: Coal assets identified as priority for early phaseout before 2030, as of 2023[270]

Several options could be useful in tackling this challenge. For one, refinancing of existing assets with concessional loans provided by financiers such as MDBs or philanthropic funds could mitigate the loss by reducing the cost of capital.

In addition, incorporating carbon credits into MPOs is being explored. Such carbon credits would quantify emissions avoided and be sold to purchasers who want to help decarbonization efforts, need to purchase credits to offset their own emissions, or see credits as an investment opportunity. Scenario modeling by the MAS has found that to retire an example plant early would require USD 310 million in funding to offset foregone cash flows, of which USD 70 million could be covered by such carbon credits.[271]

Numerous considerations face any effort to create such carbon credits. MAS cautioned that adherence to multiple carbon credit principles are needed to ensure a robust system, including:

- Additionality, the project would not take place without revenue from carbon credits.
- Permanence, the abatement is irreversible.
- Robust quantification of emissions reduced and removed.
- No double counting of credits claimed.
- Effective governance.
- Appropriate tracking, credits are registered and monitored on a carbon registry.
- Transparency, the information on credits generated is public.
- Robust, independent third-party validation and verification.
- Sustainable development impacts and safeguards, the credits are aligned with the United Nations Sustainable Development Goals.

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[270] “Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development,” PLN, 2022.

[271] “Accelerating the early retirement of coal assets through carbon credits,” Monetary Authority of Singapore (MAS), September 2023.

- Transition towards net zero, the credits do not enable the creation of new sources of emissions.

Ambiguity regarding taxonomy and financed emissions, risk-weighted asset allocation for MPOs [commercial feasibility – ESG & taxonomy]

MPOs also suffer from regulatory ambiguity. While the intent of these transactions is to lower emissions, whether they count as green financing is unclear. This ambiguity creates additional risk for investors, who require a clear transition taxonomy, an established carbon credit registry, and standards and commonly accepted methodologies to guide MPO deals.

For instance, lenders are currently discouraged from financing MPO of coal-fired power plants because it is unclear if MPOs count as financed emissions. Even if Indonesia were to clarify its taxonomy of MPOs, this taxonomy would need to be consistent with that of other jurisdictions in which a bank operates. The financial system and regulators also have yet to reach consensus on how to treat MPOs as an asset class and how to weigh its risks. Treatment of short-term emission from the assets under MPO scheme is also an issue that has not reached consensus.

Clarifying global and national taxonomies for MPOs could help make them accessible and appealing to investors. Indonesia could align its national taxonomy with the ASEAN taxonomy, which classifies MPO transactions as "green" or environmentally sustainable. This would alleviate concerns from Indonesian investors that MPOs may count towards financed emissions. For global banks, broader taxonomy alignment may be necessary, especially at the country the bank is headquartered. Global taxonomy alignment of the environmental sustainability of coal MPO investments would be needed for true adoption at scale. Under the European Union's current taxonomy, for example, MPOs would not qualify as sustainable financing.

Indonesia could also continue to work with multilateral banks to clarify carbon accounting on risk-weighted asset allocation for energy transition financing. For instance, the Glasgow Financial Alliance for Net Zero (GFANZ) opened public consultations in 2023 for its framework on coal phaseout in Asia. The coalition hopes to use the resulting framework to guide future MPO transactions and provide clarity on the transaction classification of MPOs.[272]

3.4.11. Hydrogen/ammonia co-firing

Category E: Pre-commercialization

Exhibit 57: Summary of challenges and unlock ideas, hydrogen/ammonia co-firing in Indonesia

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	4	**Operational complexity** • Production of green/blue hydrogen and ammonia is a nascent technology, and its supply chain is yet to be developed	• **Continued feasibility studies** through pilot projects • Setting **national hydrogen/ammonia strategy** • **Provide public finance support** for supply chain development or creation of **"hydrogen hub"**	EP PM
Commercial feasibility	4	**Project economics** • Renewable hydrogen is significantly more expensive than natural gas but does not produce additional revenue • Potential financing difficulties before commercialization at scale	• **Public finance support tailored to different stages** of technology and project development (e.g., grants for R&D, tax incentives, guarantee of loss for initial commercial projects)	F
		ESG & Taxonomy • Unclear taxonomy and environmental concerns beyond GHG emissions for ammonia	• Additional investment to **install flue gas desulfurization facility** • **Clarify and harmonize co-firing's position within taxonomies**	EP PM

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272 "GFANZ's APAC network opens consultation for managed phaseout of coal in Asia-Pacific," Glasgow Financial Alliance for Net Zero, June 4, 2023.

When blended with fossil fuels during combustion, lower-carbon fuels such as hydrogen and ammonia can help cut emissions from fossil fuel plants. Despite appearing as an attractive strategy for decarbonizing the fossil fuel plants while simultaneously harvesting their existing capacity, both hydrogen and ammonia co-firing currently faces technical and commercial challenges given that the technology is still nascent. To expand the use of hydrogen/ammonia co-firing in Indonesia's fossil fuel plants, technological advancement, reduction of feedstock cost, and development of supply chain is required. In doing so, public finance support is required at the initial stage of commercial development, along with a clear national strategy and roadmap.

3.4.11.1. Lever description and overview

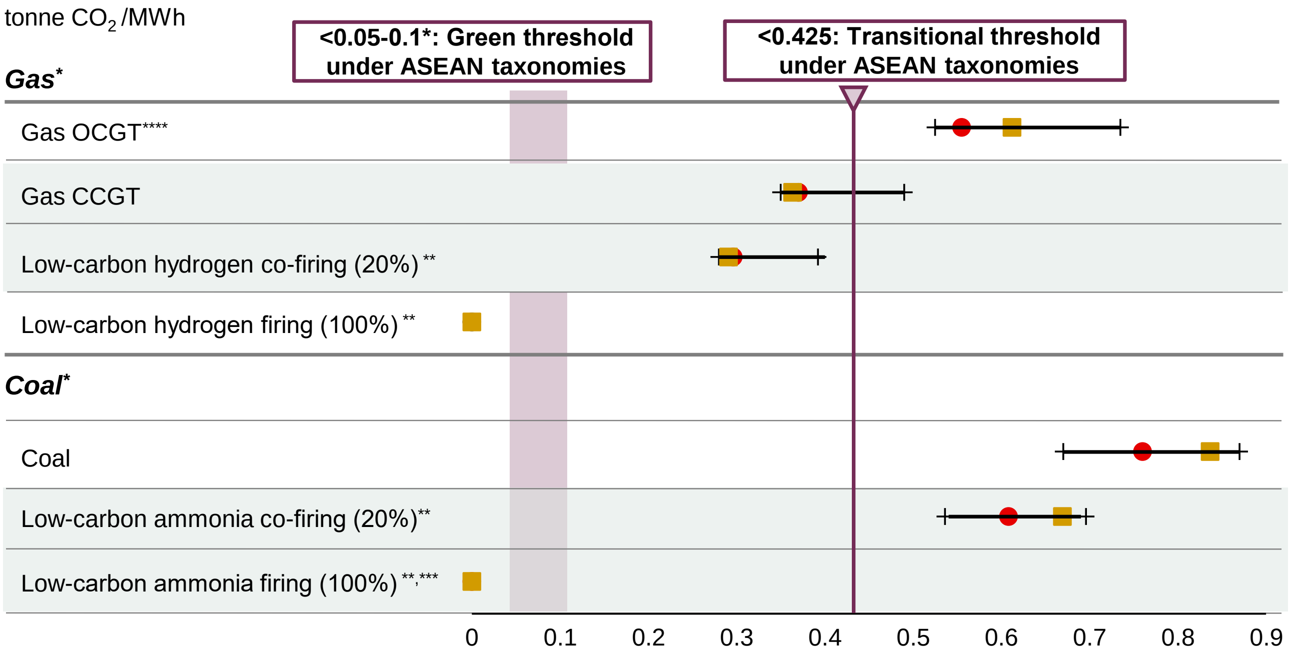
Description

The co-firing of low-carbon fuels in fossil fuel plants is explored as a potential pathway for decarbonizing the power sector while simultaneously leveraging the service of the existing fleet. Hydrogen and ammonia emerged as promising candidates for this co-combustion approach as they do not emit CO_2 upon combustion. Herein we will place the spotlight on hydrogen-gas co-firing and ammonia-coal co-firing – two technologies that are being actively explored in Indonesia as an option for the national's decarbonization pathway.

Retrofitting fossil fuels plants to incorporate hydrogen/ammonia requires limited capital expenditures, making this strategy an appealing option for decarbonizing fossil fuel plants. However, although hydrogen/ammonia emit no CO_2 via combustion, their production process can be accompanied by heavy carbon footprints. To truly tap into the decarbonizing potential of hydrogen/ammonia co-firing, it is necessary to source low-carbon feedstock, which is currently challenging due to high price and immature supply chain.

It is worth noting that the CO_2 emission impact of hydrogen/ammonia co-firing can depend on the different blending rate between low carbon fuels and fossil fuels. Further, the interpretation of the emission impact also varies by country/region, depending on its taxonomy. For example, under the ASEAN taxonomy, 20% ammonia co-firing does not meet the emission intensity threshold, while 20% hydrogen co-firing is viewed as transitional but not green. Only 100% hydrogen and potentially ammonia fueled firing process can be labeled as green.

Exhibit 58: Estimated emission after co-combustion[273]



* Direct emissions for power generation only; other lifecycle emissions not included; IPCC data for 2018; IEEJ data for 2017

** Emissions for co-firing of low-carbon fuels are estimated based on the co-firing ratios and the base emissions in respective Coal or Gas CCGT

*** The range for 100% ammonia firing in a steam turbine is shown as it may be technologically possible even though it may not be economically viable

**** Emissions for OCGT are estimated based on CCGT emissions and the efficiency of OCGT over CCGT

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[273] "Annex III Technology-specific cost and performance parameters," IEEJ, IPCC, 2018.

Growth potential

Hydrogen could serve Indonesia's fleet of gas-fired power plants. While holding a smaller share compared to coal, gas plants currently hold the second-largest share (about 16%) of electricity production in Indonesia, and PLN envisions that expanding capacity could be a solution for the short-term option (2021–2030) in their decarbonization strategy. Compared to ammonia, hydrogen could be more economical due to its lower production cost and carrier-agonistic nature. However, it is worth noting that ammonia co-firing may have a larger impact on GHG reduction considering its displacement of coal, which has a heavier carbon footprint than gas.

Ammonia can be co-fired with coal, the single largest source of power, which occupies about 64% of power generation capacity in Indonesia. Considering the relatively young age of coal power plants, ammonia co-firing could serve as an option to decarbonize the existing coal power plants before retirement.

Stakeholder initiatives

Recognizing these potentials, Indonesian power sector players have taken the initiative to explore hydrogen and ammonia co-firing in Indonesia. Working with the Japanese company MHI, multiple PLN subsidiaries have launched feasibility studies to better gauge the potential of both hydrogen and ammonia co-firing at pilot power plants.[274] For example, PLN Indonesia Power and MHI are jointly evaluating the prospect of hydrogen co-firing in an M701F gas turbine at the Tanjung Priok gas turbine combined cycle (GTCC) facility. Meanwhile, these companies are also investigating co-firing ammonia produced by existing ammonia plants in Indonesia, using Suralaya coal fired power plants as a reference plant. These wide range of initiatives aim to add momentum to the commercial adoption of ammonia and hydrogen co-firing in Indonesia's existing fossil-fuel plants. Additionally, PLN Engineering is partnering with KEPCO Engineering and Construction Company from South Korea to develop hydrogen and ammonia co-firing technology in fossil-fuel plants.[275]

3.4.11.2. Challenges and potential solutions

Nascent technology and supply chain [technical feasibility – operational complexity]

Although both hydrogen and ammonia are currently produced and used in Indonesia, the supply chain for low-carbon hydrogen and ammonia for co-firing has yet to be established. Currently, most of the hydrogen is produced near manufacturing utilization sites, such as petroleum-refinery and petrochemical-manufacturing plants. Therefore, dedicated hydrogen transport systems connecting prospective production sites with gas power plants are yet to be built. On the other hand, ammonia already has a certain level of supply chain infrastructure, given that Indonesia is the fourth-largest exporter of ammonia globally. Nonetheless, existing infrastructure needs to be reconfigured on both the supply and demand side. On the supply side, existing ammonia production facilities and export facilities must connect with blue or green hydrogen feedstock supply. On the demand side, last-mile supply chain connecting to coal power plants must be established.

Development of the supply chain can be facilitated by a clear national strategy or roadmap and public-finance support. A clear national strategy or roadmap is important to signal demand and build confidence in investing in the supply chain. The strategy should also provide a top-down and holistic supply chain development plan that balances several factors, including favorable production sites (for example, renewable-energy potential and gas supply), the distribution of sizable demand, and transportation methods connecting supply and demand to minimize costs. Creating a hydrogen hub can also be beneficial as it enhances economic efficiency by physically bringing supply and demand facilities together. As an example from other markets, the US Department of Energy selected seven regional clean hydrogen hubs that will receive USD 7 billion of Bipartisan Infrastructure Law funding.[276]

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[274] "MHI and PLN Nusantara Power to jointly investigate co-firing with hydrogen, ammonia and biomass in Indonesia's power plants," Mitsubishi Heavy Industries, March 23, 2023, Link.

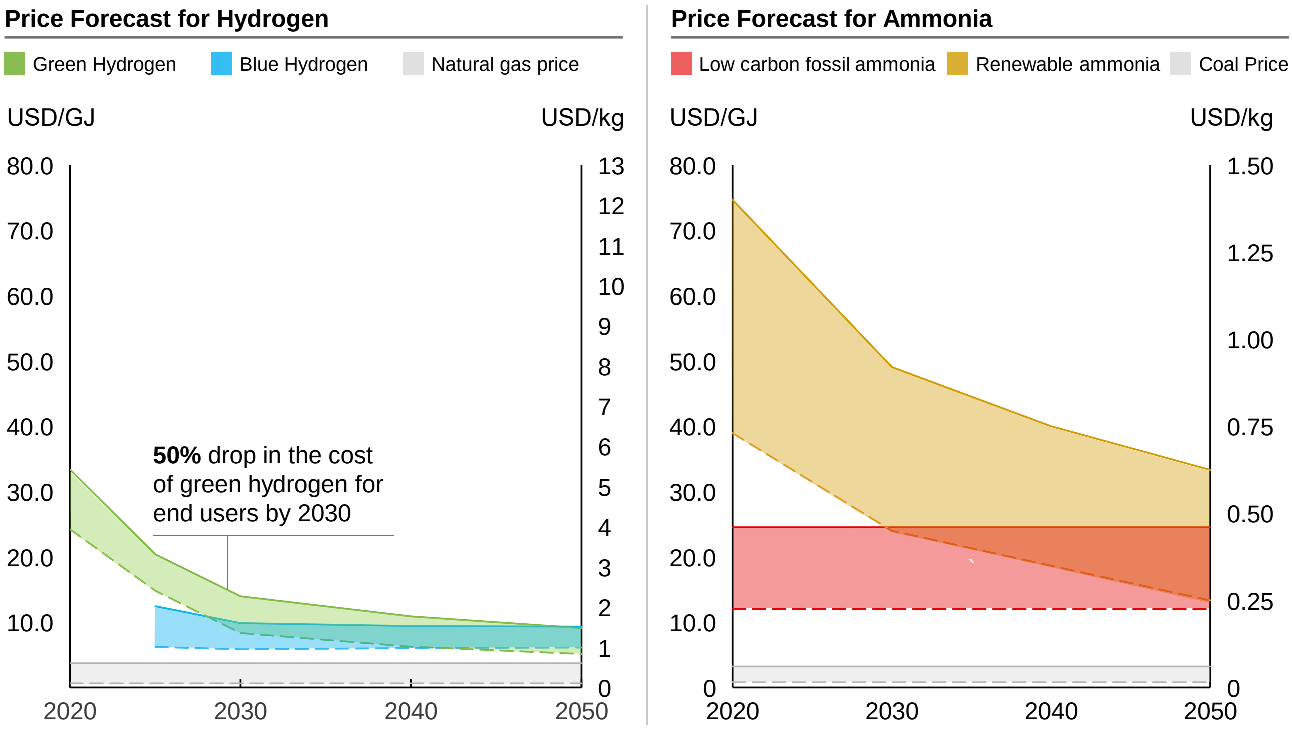
[275] "PLN Gandeng 2 Perusahaan Korsel Kembangkan PLTU Pakai Amonia (PLN Collaborates with 2 South Korean Companies to Develop PLTU Using Ammonia)," CNBC Indonesia, November 5, 2022, https://www.cnbcindonesia.com/news/20221105193640-4-385430/pln-gandeng-2-perusahaan-korsel-kembangkan-pltu-pakai-amonia.

[276] "Biden-Harris Administration announces regional clean hydrogen hubs to drive clean Manufacturing and jobs," DoE, October 2023.

High production costs with no incremental revenues [commercial feasibility – project economics]

To be a decarbonization lever, both hydrogen and ammonia must be produced, and the feedstock transported through low-carbon green methods. However, because of the technical feasibility challenges mentioned above, both green hydrogen and ammonia exhibit significantly higher costs compared to fossil fuels at this moment. In the future, green hydrogen will see a significant drop in production costs as the technology matures. However, though its cost is expected to drop by approximately 50% by 2030 and potentially will become lower than that of blue hydrogen by 2050, green hydrogen is unlikely to become cost-competitive with natural gas if carbon cost is not accounted. Since co-firing in itself will not generate any additional revenue, public-finance support (such as price differential compensation) or a carbon-pricing mechanism is needed to make the economics work. This also applies to ammonia co-firing, which may be considered more challenging when it comes to cost. As shown in Exhibit 59, ammonia has higher cost per gigajoule compared to hydrogen, and the price of renewable ammonia is not expected to fully reach parity with low-carbon fossil ammonia, even by 2050.

Exhibit 59: Projected global production cost of hydrogen and ammonia, compared with that of fossil fuels[277]


Price Forecast for Hydrogen

Price Forecast for Ammonia

Project economics may improve through technology maturity and scale; however, commercial finance will encounter difficulties supporting projects in the early stages. In other markets, different models of public-finance support targeting different stages of technological development have been explored to mobilize commercial finance. At the initial pre-commercialization phase, grants could be the viable option as R&D projects are not intended to generate positive cash flows. In Japan, the Green Innovation Fund was introduced in 2021, and it provides grants to early-stage technologies contributing to the green transformation (GX). At the initial stage of commercialization, public-finance support has been leveraged to provide first-loss guarantees or bolster cash flows. For example, the Inflation Reduction Act (IRA) in the US provides tax incentives for hydrogen projects to improve commercial viability. In Japan, the government is considering providing support to close the gap between hydrogen and other conventional fuels.[278]

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277 "The clean hydrogen opportunity for hydrocarbon-rich countries," McKinsey & Company, November 23, 2022, https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-clean-hydrogen-opportunity-for-hydrocarbon-rich-countries.

278 "Overview of Basic Hydrogen Strategy," METI Japan, June 2023.

At the private-sector level, long-term purchase commitments from off-takers could mitigate market risk. As an analogy, historically project financing for LNG projects has been supported by linking long-term take-or-pay contracts with off-takers such as power and gas companies.

Unclear taxonomy and environmental concerns beyond GHG emissions for ammonia [commercial feasibility – ESG & Taxonomy]

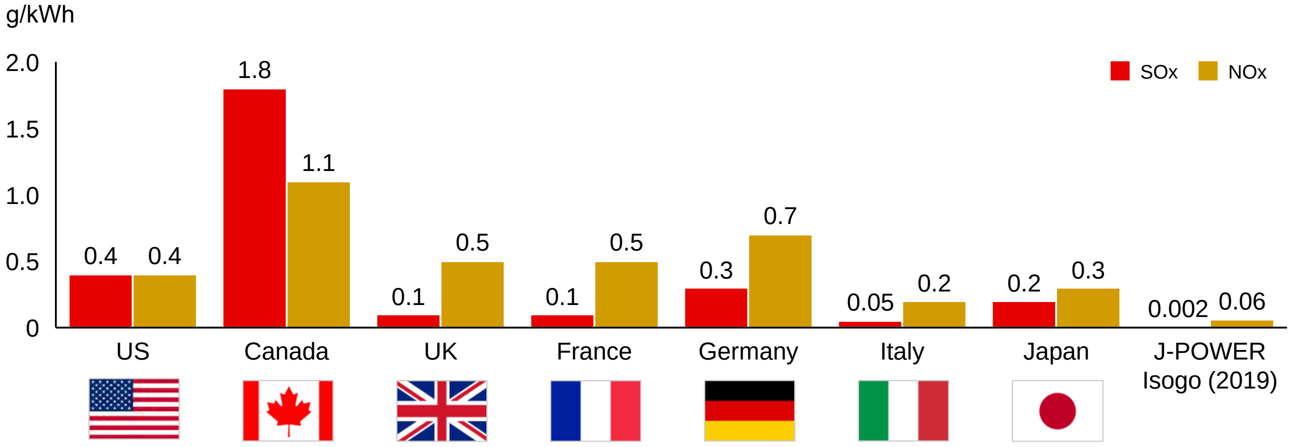
Particularly for ammonia-coal co-firing, unclear labeling across different taxonomies poses a challenge for financiers to provide financing. For example, while the ASEAN taxonomy recognizes the technology as "green" when the emission intensity is below 100 grams per kWh, the EU green taxonomy does not recognize any form of coal power plants as green. Unclear taxonomy also creates difficulty for weighing whether to introduce co-firing for a fossil-fuel plant or schedule it for retirement. To address this issue, continuous discussions to harmonize the taxonomy are required. In addition, government-led studies that investigate which fossil-fuel assets are more suited for co-firing rather than early retirement can help de-risk the uncertainty the taxonomy creates.

Concerns against co-firing technologies for potentially delaying transition to renewables has been pointed out.[279] To mitigate these concerns, co-firing technologies should be combined with clear exit strategy (e.g., retirement of fossil fuel power plants or conversion to 100% combustion of zero-emission fuel) and should be employed in situations where alternative decarbonization options are not feasible weighing impact to GHG emission, cost efficiency, and social impact through potential raise in electricity price.

Moreover, beyond CO_2, the emission of nitrogen oxides (NO_x) and sulfur oxides (SO_x) during ammonia-coal co-firing has been identified as a risk to the environment. For example, in a 2023 study, the Center for Research on Energy and Clean Air (CREA) found co-firing ammonia will increase NO_x, SO_x, and small-particulate (PM2.5) emissions into the air.[280] SO_x and NO_x have historically been identified as an air pollutant that potentially causes health issues and environmental damage, and research also states that NOx emissions have 273 times more global-warming potential than CO_2 and can remain in the atmosphere for 100 years.[281] On top of damages to the ecosystem, SO_x is also identified as an indirect GHG that has an effect on atmospheric warming due to its contribution to aerosol formation.

These concerns can be solved by applying existing technologies employed in conventional fossil fueled-power plants to remove pollutants from the exhaust gas. For example, the Isogo coal power plant operated by J-Power employs cutting-edge flue gas desulfurization facility and has significantly lower NO_x, SO_x emission than global standard (**Exhibit 60**).

Exhibit 60: Comparison of NO_x/SO_x emission, 2018[282]



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[279] "Challenging Japan's promotion of ammonia co-firing for coal power generation," E3G, 2023.

[280] "Air quality implications of coal-ammonia co-firing," Jamie Kelly and Lauri Myllyvirta, Centre for Research on Energy and Clean Air (CREA), May 16, 2023.

[281] "CO_2 equivalents," Climate Change Connection, updated June 23, 2020.

[282] "Japan's coal-fired power plants are clean," J-Power, accessed October 23, 2023.

3.4.12. Carbon capture, utilization, and storage

Category E: Pre-commercialization

Exhibit 61: Summary of challenges and unlock ideas, CCUS in Indonesia

Ratings: 1 2 3 4 ⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	4	**Operational complexity** • General knowledge and understanding of CCUS operations at scale still being developed • Transport and storage uncertainties, i.e., identifying storage sites require several years and trial and error; concerns regarding potential leaks	• **Build knowledge and capabilities early by continuing CCS pilots** with CCUS technology providers to test technology feasibility and accumulate learnings, and **working with oil and gas (O&G) players** to identify potential sinks, and potentially partner on O&G CCUS projects	EP
Commercial feasibility	4	**Project economics** • High cost to capture and store carbon, with limited opportunity to generate incremental revenue • Potential financing hurdles as financiers lack full understanding of project risks due to absence of precedent transactions	• **Develop carbon pricing environment** to enable economic feasibility by continuing plans to launch new carbon tax	PM
			• **Public finance support tailored to different stages** of technology and project development (e.g., grants for R&D, tax incentives, guarantee of loss for initial commercial projects)	F
		Market structural factors • Regulatory ambiguity with regard national strategy and lack of overarching legal framework	• **Provide regulatory clarity** by setting national CCUS strategy and further developing legal framework for CCUS to encompass application outside O&G	PM
		ESG & Taxonomy • Ambiguous position of CCUS application of fossil fueled power plants across different taxonomies	• **Clarify and harmonize co-firing's position within taxonomies**	PM

CCUS is one of the most challenging levers from both the technical and commercial perspectives. Though a few projects have commenced, project economics have not reached commercial viability. CCUS will find it difficult to establish favorable project cash flows because it is an added cost with no offsetting revenues. A carbon pricing mechanism would be essential to make an investment case.

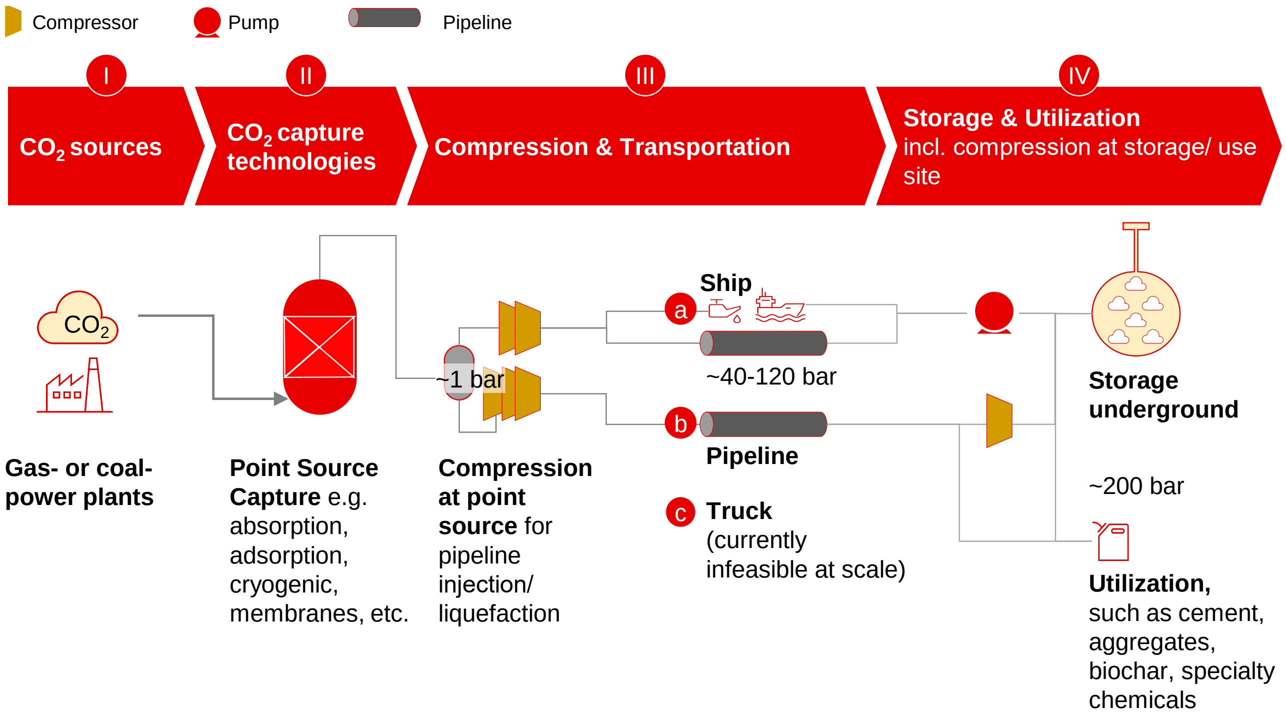
A further challenge is developing the required infrastructure to store the captured carbon. Public sector support would be needed to invest in identifying appropriate sites which require multiple trial and error. Comprehensive regulations and standards could also reduce risks faced by private sector companies, such as liability for potential leakages.

3.4.12.1. Lever description and overview

Description

CCUS entails capturing carbon to prevent its release into the atmosphere, and the subsequent use or storage of this captured carbon. In power generation, CCUS begins with the combustion of coal or natural gas, which emit flue gasses containing CO_2 that would pass through carbon capture equipment – solvents, membranes, or other technologies – that would isolate the CO_2. The CO_2 is then compressed and transported for storage or use. Because of its efficacy in controlling CO_2 emissions, CCUS could decarbonize coal- and natural gas-fired power plants not slated for early phaseout.

Exhibit 62: CCUS process flow



Growth potential

Despite plans to rapidly expand RES capacity, PLN expects coal and natural gas power to retain a meaningful share in energy mix. Because of Indonesia's large fleet of relatively young coal-fired power plants, power generation from fossil fuels will persist over the medium term, supporting the viability of CCUS as a potential decarbonization measure. In PLN's latest RUPTL, 23% of PLN's portfolio will still be fueled by coal or natural gas by 2060, of which 8% is expected to use CCUS technology.[283]

Stakeholder initiatives

Many CCUS initiatives have been announced in Indonesia, predominantly for the oil and gas sector. As of 2023, at least 15 CCUS projects were in the preparatory stages, and most of these are expected to start up by 2030.[284] In the power sector, PLN is planning a CCUS pilot in a coal-fired power plant in 2028.[285] On the storage side, Pertamina is working on multiple CCUS projects on potential fields off the shores of Sumatra, Java, Kalimantan, and Sulawesi.[286] Several sites in Indonesia, such as ExxonMobil's mega Cepu block in East Java[287] and Pertamina's Rokan block onshore Central Sumatra,[288] are being evaluated as potential carbon sinks. While not all projects are directly involved in deploying CCUS for the power sector, these initiatives can be used to evaluate the technical requirements for carbon transport, as well as the potential of carbon storage sites.

3.4.12.2. Challenges and potential solutions

High cost of capturing and storing carbon, with no incremental revenue [commercial feasibility – project economics]

The most significant challenge is high capital requirements without an offsetting revenue stream. Carbon capture technology has yet to achieve economies of scale, with systems essentially custom designed for

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283 "Enhanced Sustainable Financing for Investment in Renewable Energy and Infrastructure Development," PLN, February 23, 2023, Link

284 "Mubadala and Pertamina to explore CCUS in Indonesia," Anthony Wright, Gasworld, July 26, 2023, Link.

285 "PLN plans trial CCS application in coal power plant in 2028," William Jhanesta, Petromindo, July 10, 2023, Link.

286 "ExxonMobil signs USD 2.5bn carbon capture agreement with Indonesia's Pertamina," Offshore Technology, November 14, 2022, Link.

287 "ExxonMobil exploring carbon capture storage in Indonesia," The Economic Times Business Verticals, November 2, 2021, Link.

288 "Indonesia advances carbon capture, storage and utilization ambitions," Amanda Battersby, Upstream Online, April 12, 2022, Link.

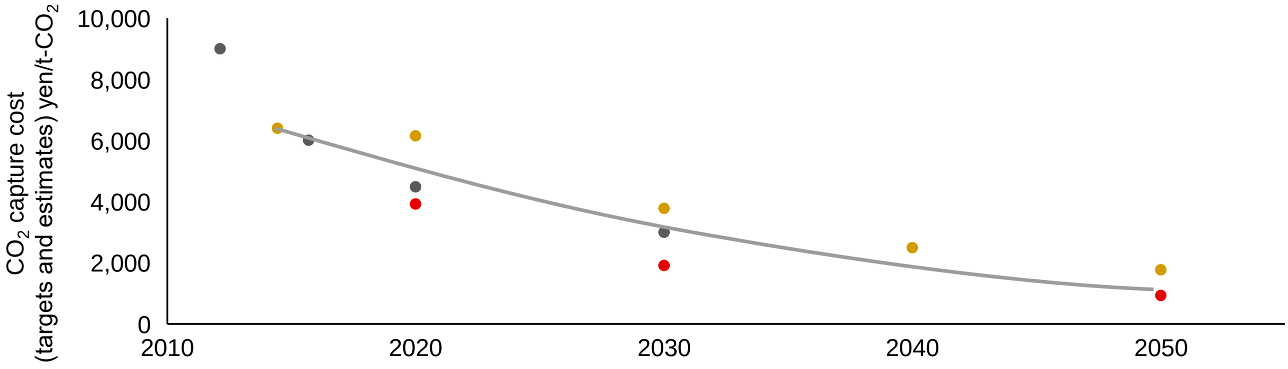
specific projects. Modular systems that could be produced at scale remain in development. As a result, a 2021 analysis estimated that retrofitting a 550 MW coal-fired power plant in the United States for CCUS would cost between USD 891 million and USD 1.5 billion or USD 33 to USD 149 per tonne of CO_2 captured. Retrofitting a 560 MW natural gas-fired plant would cost between USD 399 million and USD 666 million, the report said (**Exhibit 63**). By comparison, carbon credits for 1 tonne of CO_2 in Indonesia cost roughly USD 2 in 2023.[289]

Exhibit 63: Required CAPEX for carbon capture technology[290]

Facility type	**Reference plant size**	**Capacity Utilization, %**	**CO_2 Volume Captured** (tonne/year)	**Capital Cost Low-High** (USD millions)	**Unit Capital Cost 20-Year Life Low-High** (USD/tonne)
Coal Power plants	550 MW net	85	3,089,000	891-1485	33-55
		55	1,999,000		54-91
		85	1,272,000		89-149
Natural Gas Power plants	560 MW net	35	1,279,000	399-666	34-58
		85	827,000		57-95
		35	527,000		92-155

The IEA has reported costs for liquid amine-based post-combustion CO_2 capture in the power sector have declined by 35% between its first deployment at the Shell Cansolv Boundary Dam project in Canada in 2015 and its second project at the MHI Petro Nova in Texas. This drop is forecast to continue. A detailed feasibility study to retrofit the Shand coal-fired power station in Canada with CCUS has suggested around 70% in cost reductions relative to the Boundary Dam project for both capital investment and operating expenses are possible. In addition, capture costs may be reduced by nearly 30% with next-generation capture technologies.[291] Adding to the general consensus, Japan's Ministry of Economy, Trade, and Industry (METI) expects CCUS costs to decrease by two-thirds over the next three decades.

Exhibit 64: Carbon capture costs outlook 2010-2050[292]



Even with costs reductions, the high capital expenditures needed come with little to no opportunity to earn marginal revenue from the captured CO_2. Sequestration or the storage of captured CO_2 in depleted sinks, such as oil and gas wells or saline aquifers, is the main method for storing large volumes of captured CO_2 and has scarce revenue opportunity.

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[289] "Carbon pricing in ASEAN+3 economies: Progress and challenges," Dr. Andriansyah and Seung Hyun (Luke) Hong, ASEAN+3 Macroeconomic Research Office, November 28, 2022.

[290] "Carbon Capture, Use, and Storage (CCUS) Report," NPCR, https://dualchallenge.npc.org/downloads.php.

[291] "Energy technology perspectives 2020: Special report on carbon capture, utilization and storage," IEA, September 2020.

[292] "What is CCUS technology?," Ministry of Economy, Trade and Industry (METI), accessed September 18, 2023. The data is based on materials first presented by the GI Promotion Council Working Group.

Also, commercially viable and scalable uses for the captured CO_2 are rare, making it difficult to profit from CO_2 as a commodity. One exception is that captured CO_2 has been used for enhanced oil recovery, which involves pumping captured CO_2 into old oil wells to increase oil production. Many other uses for commercial CO_2 in construction materials, fuels, plastics, chemicals, and other materials are possible, but the cost of producing these products from CO_2 is either higher in general or the quantities of captured CO_2 far exceed the CO_2 required by these applications.

Without a clear revenue stream from CCUS efforts, carbon capture will likely require carbon pricing mechanisms to create positive cash flow. For instance, updated carbon trading scheme could encourage the deployment CCUS technologies, which is already being considered in Indonesia. In 2023, ESDM announced a mandatory emissions trading system that will initially cover power plants with capacities of more than 100 MW. This emission trading system will be rolled out in three phases, covering on-grid coal-fired power plants in 2023 to 2024, expanded to include natural gas-fired power plants in 2025 to 2027, and expanded further to cover off-grid coal-fired power plants in 2028 to 2030.

Levying carbon taxes could also promote CCUS deployment. Indonesia had planned to introduce a carbon tax in 2022, but the levy was delayed until 2025.[293] In the interim the country has implicit carbon pricing through fuel excise taxes, but considering its fossil fuel subsidies, the net effective carbon rate (ECR) is zero or negative, reducing the financial incentives for companies to decarbonize. In 2021, the ECR was zero or negative across major sectors in Indonesia.[294]

Execution uncertainties surrounding storage and transport [technical feasibility – operational complexity]

Along with carbon capture itself, the transport and storage of the captured carbon must be developed to expand CCUS deployment in the power sector. One of the logistical challenges associated with transport and storage is that captured CO_2 must be converted either through compression or potentially liquification into a form ready for transport, usually through pipelines. The process requires energy and infrastructure investment. Pipelines must also be highly secure to prevent leaks, which would raise safety and environmental concerns.

Locating high-potential storage sites adds further complexity. Optimal storage sites, such as deep geological formations or depleted oil and natural gas fields, are not always near coal- or natural gas-fired power plants and captured carbon may need to travel vast distances. Identifying and verifying prospective storage sites is a long process which may require several years, and ultimately some degree of trial and error.

Potential leaks add a final uncertainty and risk. The IEA has cited studies that found the risk of seepage is generally low and could get lower over time. Rigorous monitoring and detailed modeling to anticipate the movement of CO_2 would still be necessary to minimize the risks.

Regulatory guidelines and frameworks would also be needed to assure secure sequestration underground. In 2023, Indonesia announced regulation clarifying many aspects of CCUS, including planning and execution, monitoring, measurements, and reporting. Additional refinements, such as ownership of carbon credits and the liability held by the project contractor in the event of leaks, if any, would help ensure greater clarity and predictability for overall project design and, by extension, its bankability.

Indonesian energy companies could expand their pipelines of pilot projects and build valuable capabilities. Indonesia has already initiated CCUS R&D, as well as feasibility studies. For example, in 2017 the ITB National Centre of Excellence for carbon capture and utilization (CCU) and carbon capture and storage (CCS) was opened with support from ADB, and the support was shown for an updated feasibility study of the Gundih pilot CCS project.[295] CCUS pilots help gather operational expertise, identify risks, and send positive signals to the market that progress in CCUS continues. Power companies can work with O&G companies to identify potential transport and storage solutions and potentially pursue CCUS partnerships with them.

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[293] “Indonesia launches emissions trading system for power generation sector,” International Carbon Action Partnership, February 27, 2023.

[294] ”Pricing Greenhouse Gas Emissions: Key findings for carbon pricing in Indonesia,” OECD, 2022.

[295] “Indonesia: Pilot Carbon Capture and Storage Activity in the Natural Gas Processing Sector, Gundih Block Feasibility Design and Costing,” ADB, September 27, 2019.

Potential challenges with financing first large projects [commercial feasibility – project economics]

As with other nascent technology, the first large CCUS projects may experience financing hurdles because there are no precedents for these transactions and commercial banks may lack the needed technical knowledge. The lack of revenue stream from CCUS and cost pressure from carbon taxes will affect bankability and constrain financing.

Blended finance could help accelerate deployment of CCUS technology by unlocking private capital. A blended finance fund, coupled perhaps with concessional financing, would not only support project financing but also signal lower risk assessments for corporate banks. These funds are typically anchored with large, reputable financiers, and their involvement suggests clear potential for the technology.

Need for more comprehensive national CCUS strategy or legal framework outside oil and gas [commercial feasibility – market structural factors]

Indonesia's 2023 Regulation on the Implementation of CCS and CCUS in Upstream Oil and Gas Business Activities was a first for Southeast Asia and serves as a case study for the region. This included incentives such as exemptions from import duty and land and building tax deductions, and similar measures could be used to support CCUS applications for power generation.[296]

Nonetheless, definitive national strategy for CCUS outside the oil and gas sector is not in place yet. Such national strategy would provide power companies and investors a clear policy framework and long-term perspective on CCUS opportunities. Such strategies are being developed in markets globally. For example, France is drafting a national strategy for CCUS that indicates target emissions to be captured, priority areas to focus CCUS initiatives, a framework for CO_2 transport, and other provisions.[297]

Ambiguous position across taxonomies, concerns with public perception [commercial feasibility – ESG & Taxonomy]

Without a clear, universal taxonomy for CCUS programs, progress is likely to be slow. In both the Indonesian and ASEAN taxonomies, there is no clear provision for coal- or natural gas-fired power generation with CCUS.

Public perception could also create a hurdle. Many environmentalists perceive that CCUS is simply prolonging the operational lives of fossil fuel-fired assets and should have a lower priority against decarbonization alternatives. Some are also concerned that installing CCUS at fossil fuel-fired power plants would reduce the urgency to expanding RES. The potential for carbon leaks during transport and storage is also a pressing concern and should be addressed.

Continued effort on harmonization of taxonomy across international bodies would help alleviate such situation.

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296 "Indonesia introduces CCS/CCUS regulation," JD Supra, April 20, 2023.

297 "France Releases CCUS Strategy and Launches Consultation," Global CCS Institute, July 3, 2023. https://www.globalccsinstitute.com/news-media/latest-news/france-releases-ccus-strategy-and-launches-consultations/.

3.5. Summary

Indonesia has been spearheading the energy transition through clear and powerful commitments from the government outlining powerful growth of renewables in the next decade in the most recent RUPTL. The government has also set forth an overarching legal framework through the Presidential Regulation 112/2022 to create an even more supportive environment for energy transition. PLN is also taking on innovative initiatives such as agreements with corporates to supply electricity from specific renewables projects as represented in the Amazon case. Nonetheless, multiple challenges should be addressed to further accelerate the transition from short to long term. These challenges must be unlocked by concerted efforts by multiple stakeholders including energy and environmental policymakers, power companies, and broader companies in the energy industry ecosystem, such as solar panel manufacturers and customers.

Policy enabler – Energy policymaker: Energy policymakers in Indonesia have contributed to the energy transition by setting clear goals and ambitions, as well as introducing several regulations and policy frameworks, such as the Presidential Regulation 112/2022.

Looking ahead, the government could continue to develop conducive regulatory environments. While there is a vast array of relevant regulations, some areas that might benefit from attention is direct PPA, TPA[298] and the cap on self-generated RES capacity, implementation schedule of TKDN. Energy policymakers could update such policies carefully, balancing the need to maintain reasonable electricity tariff and facilitating healthy market competition.

Moreover, policymakers also play a pivotal role by providing incentives. For example, exploration of geothermal sites, biomass procurement, development of nascent technology such as hydrogen/ammonia co-firing and CCUS could use direct support from the government to expand. This could include tax incentives, direct grants, and subsidies,[299] while revisiting the balance between existing fossil fuel subsidies and incentives for clean technologies.

Policy enabler – Financial regulator: The financial regulator could lay out the foundation to ease and offer incentives for the development of green and transition financing by financial institutions. For example, the central bank could provide low-cost capital to banks offering green finance.[300] The financial regulator could also play a supportive role by setting a clear and harmonized taxonomy.

Ecosystem enabler – Power sector players: PLN is already leading by signaling the change through ambitious targets around RES development, as well as MPOs. Looking ahead, PLN would be indispensable in implementing their commitments as well as changes made to regulations across the entire value chain. This could include reviewing the tendering process and pricing mechanism for IPPs for technologies with a high tender fail rate, such as geothermal and mini-grid, investment to enhance grid flexibility, adjusting grid management operations to absorb distributed generation, and implementing BOT or BLS programs and attracting a broader range of investors for TnD development.

Ecosystem enabler – Power purchasers and local manufacturers: Across the broader power value chain, customers can play a strong role in nudging utilities and regulators to accelerate the development of RES. For example, through direct investment into self-generation or through direct PPAs, customers can financially support the development of these power plants. Other integral players in the value chain are suppliers of needed technologies, and massive investment to build in local supply capacity and capabilities would be needed not only to meet TKDN requirements, but also to maintain favorable project economics.

Financing enabler: As decarbonization measures become more attractive, financiers can provide traditional lending to support the demand for capital. Financiers could also play a more proactive role by providing innovative solutions that could lower the cost of finance and ultimately influence the project economics.[301] In particular, blended-finance mechanisms involving foreign government and MDBs could play a pivotal role in providing low-cost finance to support near-bankable deals and accepting higher commercial risks on the new technologies.

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[298] See Appendix 7.1 for more on direct PPA, TPA, and auction mechanisms.

[299] See Appendix 7.2 for case studies from Japan's Green Innovation Fund.

[300] See appendix 7.4 for Bank of Japan's case.

[301] See appendix 5.3 for a US case on aggregation and securitization of a distributed solar project.

4. Spotlight on Thailand

Highlights

Thailand's power plant fleet generates less GHG emissions (in terms of share of total emissions) compared to other countries in Southeast Asia because most of its electricity, about 64%, is produced using natural gas. Thailand has committed to reach carbon neutrality by 2050 and net zero GHG by 2065 under its long-term decarbonization targets. These commitments are underpinned by sector-specific plans, such as the PDP and AEDP for power generation. Published in 2018, the latest PDP covers 2018-2037 and projects that 20-36% of Thailand's energy will come from RES by 2037. The share of RES will likely be higher in the next release of the PDP to align with the latest LT-LEDS, which calls for 68% of the country's energy to come from RES by 2040. Various incentives have been explored to support the implementation of these plans, such as FIT scheme and sandbox of TPA and UGT.

Despite the momentum, key challenges that need to be addressed include:

1) **Investment in grid infrastructure while keeping affordability:** Expansion and upgrade of the TnD system is required in Thailand to accommodate more RES generation. Thailand has budgeted THB 199 billion (USD 5.6 billion) cumulative investments between 2015-2036 within Thailand Smart Grid Development Master Plan 2015-2036.[302] However, Thailand also faces the energy trilemma. Financing the required investment could be challenging since passing the cost directly to the customers by raising the electricity tariff could be difficult depending on the economic situation of the country. For the past few years, the government and the utilities have been under pressure to maintain the electricity tariff low to protect the households and the businesses amidst the COVID-19 pandemic and rising fuel import cost of LNG after the War in Ukraine. To minimize the cost as much as possible, integrated planning for RES and grid development is key to optimize CAPEX. Financiers could also contribute by providing low-cost finance leveraging concessional capital such as MDBs.

2) **Technical advancement required to decarbonize the "last one mile":** While gas power plants serve energy transition in the short-term by providing flexibility to support intermittent RES, gas power plants will also need to decarbonize in the long-term to reach net zero. Hydrogen-gas co-firing and CCUS are considered an option but both technologies are at a pre-commercialization stage. As with any nascent technology, deploying hydrogen co-firing and CCUS applications at natural gas-fired power plants would face challenges in the beginning due to unfavorable project economics without scale. These technologies would require backing from clear incentives and support from the public sector, for instance, tax incentives and development of critical infrastructure, such as a hydrogen supply chain and carbon storage hubs.

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[302] แผนปรับปรุงระบบส่งและระบบจำหน่าย ให้มีความทันสมัยรองรับเทคโนโลยีระบบไฟฟ้าในอนาคต (Grid Modernization of Transmission and Distribution)," EGAT, Provincial Electricity Authority, Metropolitan Electricity Authority, May 20, 2020. Link; "แผนแม่บทการพัฒนาระบบโครงข่ายสมาร์ทกริดของประเทศไทย พ.ศ. Master Plan for Smart Grid Network System Development in Thailand 2015-2036," Ministry of Energy, 2015, Link.

4.1 Overview of the power sector

Like other Southeast Asian countries, Thailand has rapidly developed its power capacity in the past few decades. Owing to its natural gas reserves, the country has predominantly developed a fleet of natural gas-fueled power plants, which provide about 64% of its power. Because natural gas is a cleaner source of energy among fossil fuels, the country has a relatively low emission intensity. As a regulated market operated by a few state-owned enterprises – Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA), and the Provincial Electricity Authority (PEA) – capacity decisions on investment and energy mix are controlled by the government and the state-owned enterprises.

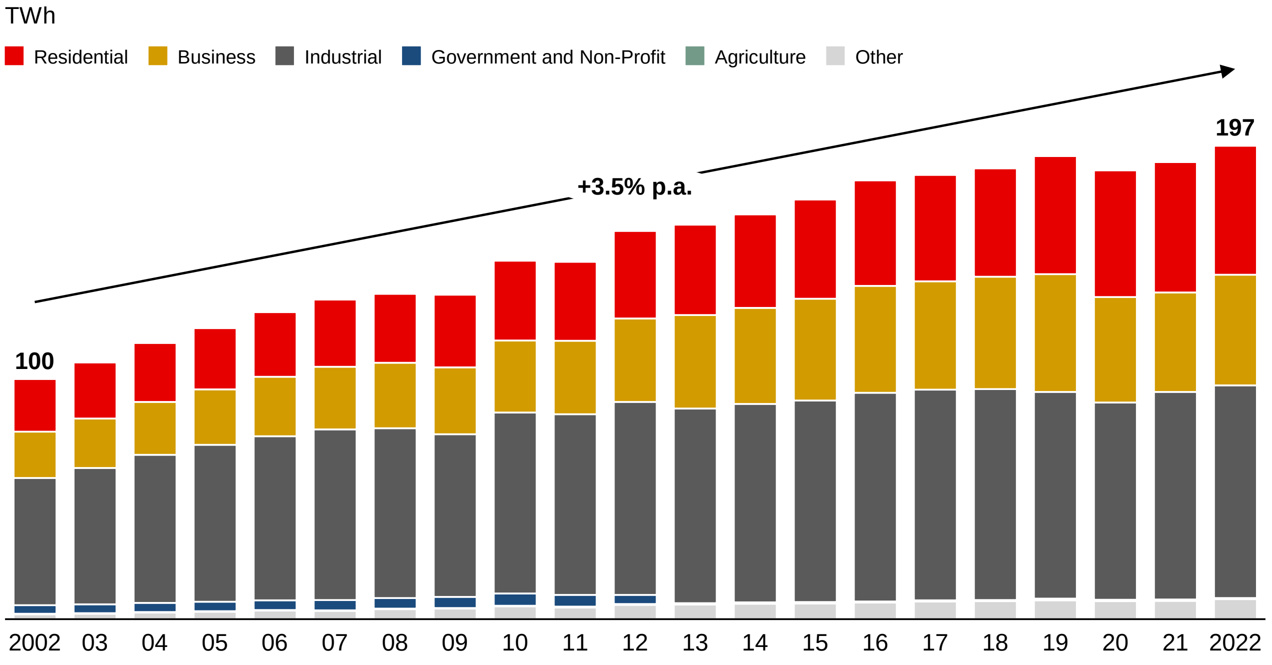
In our analysis, we examined the current state of Thailand's power market, its current energy mix and prospect, how the market is structured, and the energy policy landscape.

4.1.1. Power demand and supply

Power demand

In the past decades, Thailand has observed a significant increase in its power demand, driven by industrialization, urbanization, and economic growth. Thailand's steady economic expansion has established the nation as Southeast Asia's second-largest economy. This rapid development, alongside higher living standards and a growing population, has increased the country's consumption of electricity. Historical power consumption almost doubled from 100 TWh in 2002 to 197 TWh in 2022.

Exhibit 65: Electricity consumption by sector, Thailand, 2002-2022[303]



Thailand's power demand is expected to continue growing in the next few decades, driven by economic growth, though offset by improving energy efficiency and more sustainable consumption patterns. In the 2018 PDP, between 2017 and 2037, power demand is expected to nearly double, from 198 TWh to 367 TWh, roughly 3.1% p.a.[304] In 2021, The Economic Research Institute for ASEAN and East Asia (ERIA) forecast a similar increase in Thailand's electricity demand, 2.8% p.a., between 2017 and 2050.[305]

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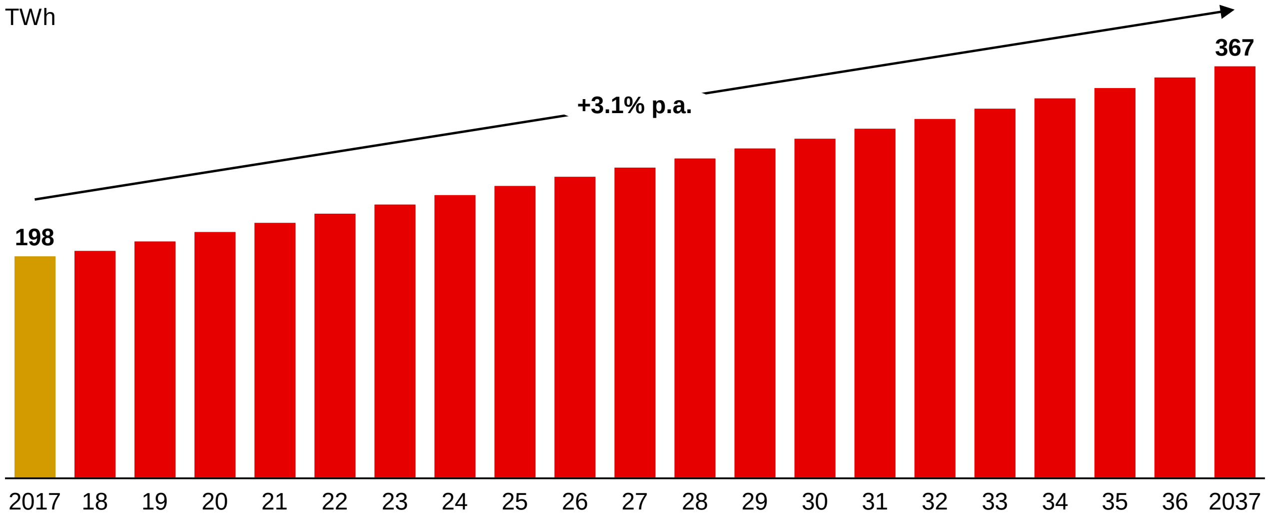
[303] "Electricity: Production capacity, production, maximum electric power, use, imports, exports, and fuels used in electricity production," EPPO, Link.

[304] "Thailand's Power Development Plan (PDP) 2018-2037," Thailand Ministry of Energy and Water Resources, 2019.

[305] "Thailand country report - Energy Outlook and Energy Saving Potential in East Asia," Supit Kamalad, ERIA, March 2021.

Exhibit 66: Forecasted electricity demand, Thailand, 2017-2037[306]

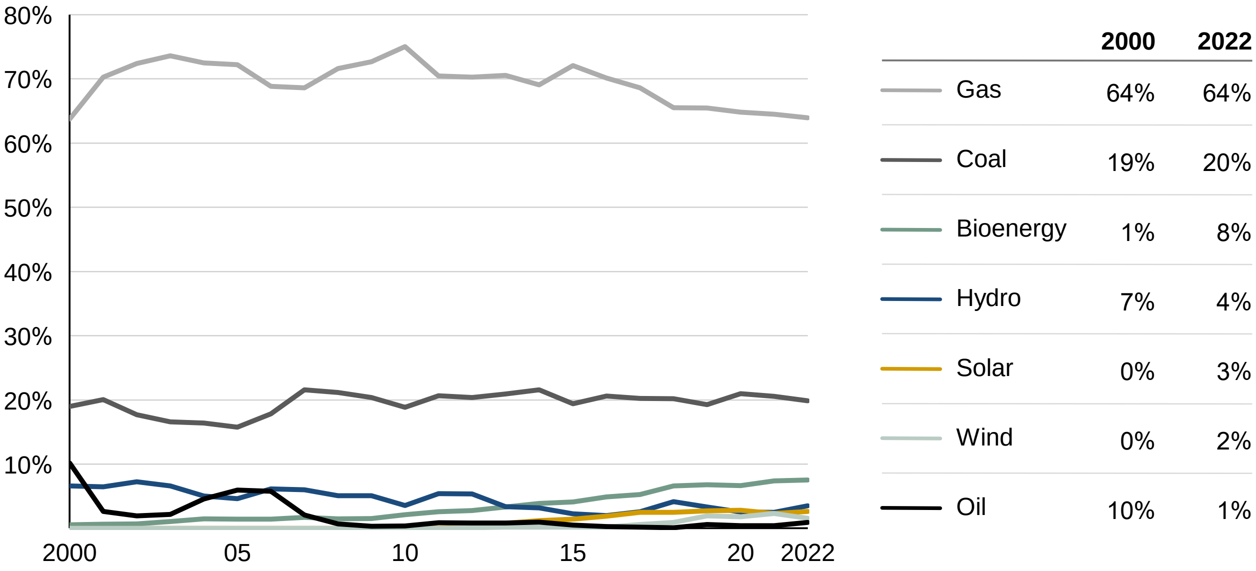


Power demand has concentrated in urbanized regions. The central region, which includes Bangkok and its neighboring areas, accounts for the highest consumption from both commercial demand from a high volume of businesses and industries and residential demand from its dense population. Bangkok consumes roughly one-fourth of total power consumption in Thailand.[307] Other regions – the northern, northeastern, eastern, and southern regions – have lower consumption.

Power supply

Natural gas has been the primary fuel for electricity generation in Thailand. This reliance stems from abundant domestic reserves and imports from neighboring countries such as Laos and Myanmar. Coal, though less prominent, contributes considerably to the energy mix. In 2022, the share of Thailand's electricity produced from gas was 64%, followed by coal, 20%, and bioenergy, 8%.

Exhibit 67: Share of electricity production by energy source, Thailand, 2000-2022[308]



	2000	2022
Gas	64%	64%
Coal	19%	20%
Bioenergy	1%	8%
Hydro	7%	4%
Solar	0%	3%
Wind	0%	2%
Oil	10%	1%

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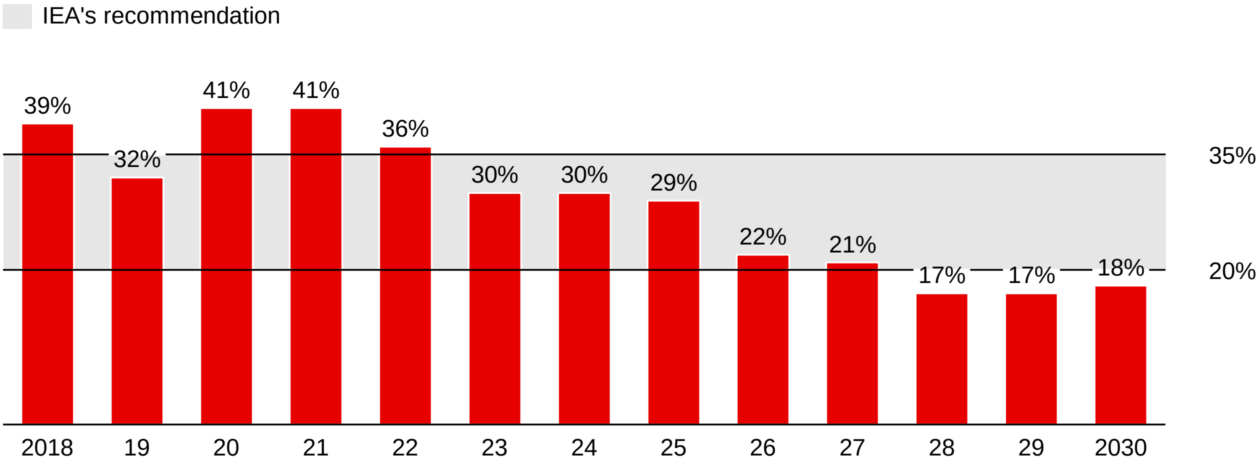
306 "Thailand's Power Development Plan (PDP) 2018-2037," Thailand Ministry of Energy and Water Resources, 2019.

307 "Factors affecting energy consumption of households in Bangkok metropolitan area," Dujduen Bhanthumnavin et al., Environment and Natural Resources Journal, June 2013, Volume 11, Number 1.

308 "Thailand: Energy Country Profile," Hannah Ritchie and Max Roser on Our World in Data, https://ourworldindata.org/energy/country/thailand.

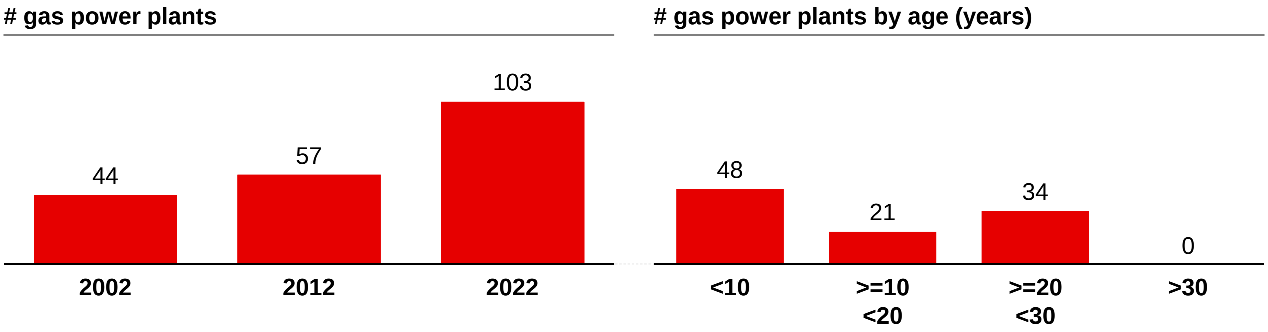
The reserve margin in Thailand saw a short term increase in 2020-2021 due to decreasing electricity demand from COVID-19 but stayed around the range of 35%, which is at the upper limit of the IEA's recommendation. On the other hand, the forecast reserve margin is expected to reduce within the IEA's recommendation as the demand continues to grow and some of the aging power plants retire.

Exhibit 68: Projected reserve margin in Thailand[309]



The rapid build-up of supply capacity means that Thailand has many gas-fired power plants that are relatively new. As an example, about 47% have been in service for fewer than 10 years.

Exhibit 69: Growth in gas power capacity over the past 20 years[310]



4.1.2. Market structure and participants

4.1.2.1. Overall market structure

Thailand's power generation industry is structured as an enhanced single-buyer model, and EGAT, a state-owned enterprise, is the majority buyer and distributor of power. EGAT acts as the principal buyer of electricity from power generators and maintains control over the national transmission network. Electricity distribution is managed by MEA for the Bangkok metropolitan area and PEA for areas outside the Bangkok metropolitan area. The Energy Regulatory Commission (ERC) provides oversight.

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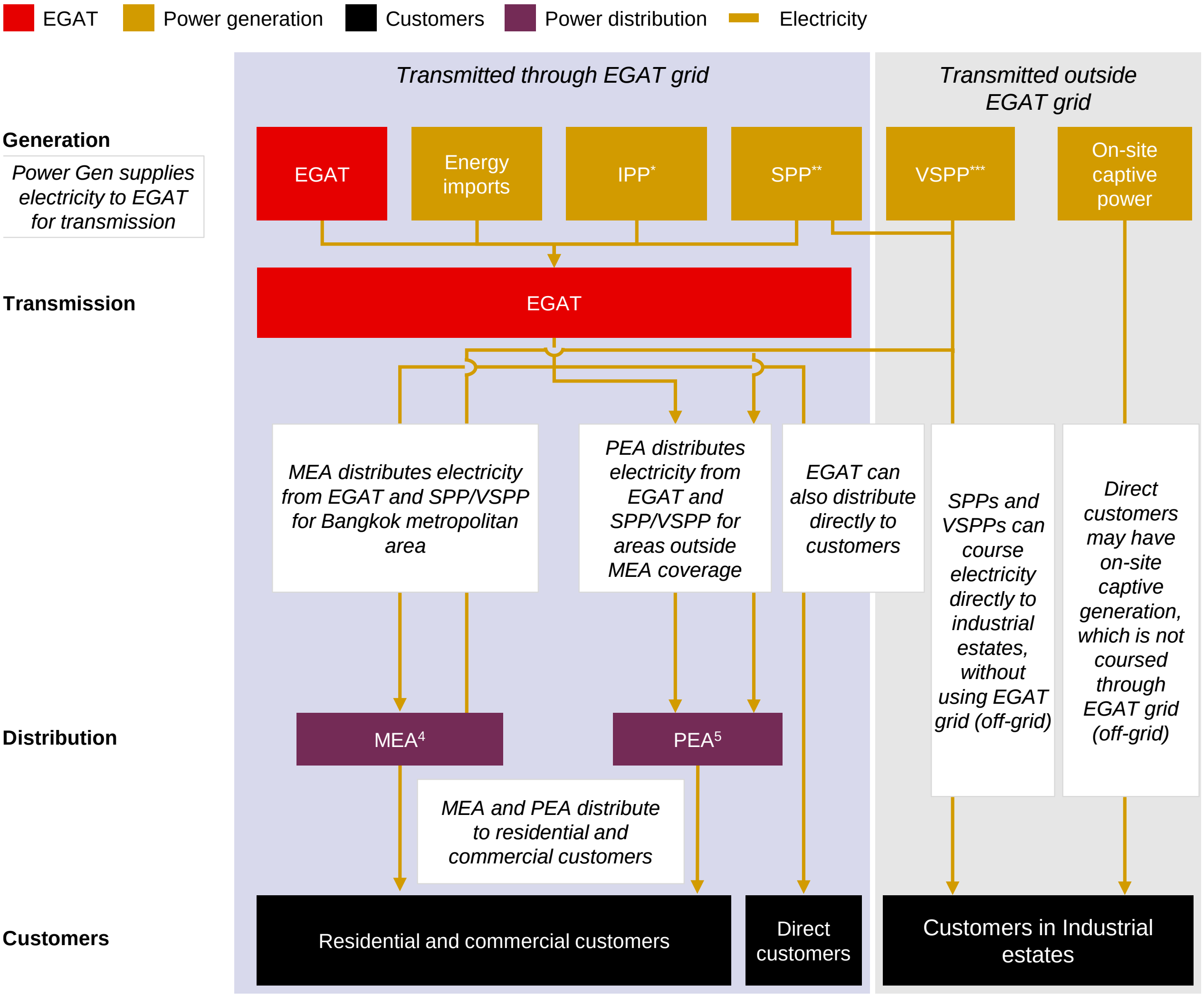
[309] Information provided by EPPO, EPPO, as of November 2023.

[310] Information provided by EPPO, EPPO, as of November 2023.

Exhibit 70: Thailand power sector, structure, and participants



* IPP = independent power producer
** SPP = small power producer
*** VSPP = very small power producer
**** MEA = Metropolitan Electricity Authority
***** PEA = Provincial Electricity Authority

4.1.2.2. Generation

In Thailand, the power generation sector is open to both EGAT and IPPs. In 2022, about 32% of the country's total contracted power capacity came from EGAT, followed closely by 31% from large IPPs, those with capacity of more than 90 MW, 17% from small IPPs, 10 to 90 MW capacity, 8% from very small IPPs, less than 10 MW capacity, and from 12% neighboring countries. Some of the largest IPPs in Thailand include RATCH Group PCL, the Electricity Generating PCL (EGCO), and GULF Energy Development PCL. EGAT is a major shareholder in two of these companies, holding 45% of RATCH and 25% of EGCO, both at the end of 2022.[311]

4.1.2.3. Transmission and distribution

EGAT owns and manages Thailand's network of high-voltage transmission lines and substations (**Exhibit 71**). As of August 2023, the grid comprised 39,054 circuit km of lines with specifications of 69 kV, 115 kV, 132 kV, 230 kV, 300 kV, and 500 kV, 237 substations, and 137,632 megavolt-amperes (MVA) of transformer capacity.[312] The majority of electricity in Thailand is transmitted through the grid.

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[311] EGAT Sustainability Report 2022," EGAT, 2023, "Annual Report 2022," EGAT, June 23, 2023.
[312] "Transmission System September 2023," EGAT, https://www.egat.co.th/home/en/statistics-transmission-latest/.

EGAT is the sole purchaser of electricity from power generation companies, except for a small share of off-grid procurement, such as for industrial estates and captive generation, and from very small IPPs, which can sell directly to MEA or PEA.

Exhibit 71: Existing grid infrastructure in Thailand[313]

Electricity distribution is managed primarily by MEA and PEA, with MEA responsible for the three metropolitan provinces of Bangkok, Samut Prakan, and Nonthaburi, and PEA serving the remaining 74 provinces.[314] These electricity authorities ensure that urban centers and more remote regions receive electricity with tariffs in line with the nation's energy policies. Both MEA and PEA operate adjacent businesses, such as power system installations, inspection and maintenance services, and electrical equipment sales and rentals. EGAT, MEA, and PEA are also responsible for investment decisions, planning, and upgrades of their respective networks.

In Thailand's enhanced single-buyer model, TPA on the national grid managed by EGAT is not permitted, but it is being considered in potential regulatory reform. TPA would allow IPPs and other private entities to use existing TnD infrastructure. By introducing TPA, Thailand would increase competition within its electricity market, which may help lower electricity prices and enhance service quality. TPA could also accelerate the development of RES, as developers could distribute directly to users wanting renewable energy.

In 2022, the ERC issued the Notification Re: Criteria and Guidelines on Preparation of the TPA Code for the Electricity Network Systems.[315] The notification required EGAT, MEA, and PEA to issue TPA codes, a

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[313] "Map of Thai electricity grid," Global Energy Network Institute, accessed September 18, 2023.

[314] "Annual Report 2021 Provincial Electricity Authority," PEA, 2021, Link.

[315] "Significant milestone to achieve toward enhancing competition through liberalization of the Thai electricity market," Norton Rose Fulbright, March 2021, Link.

prerequisite to greater access to electricity TnD by private companies. EGAT also conducted public hearings in 2022 for its TPA code drafts.[316]

4.1.2.4. Retail

Customers in Thailand purchase electricity from MEA or PEA, depending on their location. MEA serves roughly 4 million residential and commercial customers,[317] and PEA supplies more than 20 million residential and commercial customers in a service area covering 99% of the land area of Thailand.[318] While most users contract through MEA or PEA, a number of industrial parks and large customers source electricity outside the national grid. Distinct tariffs will apply depending on end consumption and type of customer.

4.1.2.5. Electricity pricing mechanisms

Two pricing models encompass Thailand's electricity market, 1) the retail pricing tariff used by MEA and PEA to charge general customers, and 2) the IPP electricity tariffs used for contracts with EGAT.

1) **Retail electricity tariffs** between customers and MEA and PEA comprise two components. The electricity base charge, which covers fixed costs related to generation, TnD, and expected variable costs.[319] The variable costs fall under the Automatic Adjustment Mechanism (Ft) charge, which fluctuates based on factors including fuel costs, electricity purchases, and government policies like FIT. The electricity base charge is typically revised every three to five years,[320] while the Ft rate is reviewed and adjusted by the ERC every four months.[321]
2) **IPP electricity tariffs** are contracted between IPPs and EGAT and set through competitive auctions. Guided by capacities set by the PDP, the government opens tenders for energy companies to submit bids. Once awarded, PPAs with EGAT are signed. PPAs prices are guided by the FIT scheme (see Sidebar).

4.1.3. Energy policy landscape

Various entities and agencies are involved in setting energy policy in Thailand, as well as providing regulatory oversight for power sector decarbonization.

As the primary governing body for Thailand's energy sector, the MOE sets the country's overarching energy policies and strategies. The MOE oversees numerous sub-agencies, including the Energy Policy and Planning Office (EPPO) and the Department of Alternative Energy Development and Efficiency (DEDE). EPPO is responsible for national energy policies and plans and oversees writing the PDP, the country's master road map for the long-term development of the power sector. PDP 2018 covers the period from 2018 to 2037 and is expected to be updated with additional allocations for RES capacity. DEDE is responsible for alternative energy planning codified through the AEDP, which contains national plans to expand alternative energy, such as renewables and waste-to-energy.

Established in 2007, ERC operates as an independent regulatory body overseeing energy regulations and operations, with tasks including issuing licenses, setting tariffs, and providing provision and safety standards. The ERC oversees retail power tariffs, ensuring prices are justified and reflect true energy costs, and helps set FIT tariffs and new renewables quotas. The ERC also oversees licenses for electricity business operations, ensuring compliance with regulatory standards.

The National Energy Policy Council (NEC), chaired by the prime minister and including different cabinet members and other senior officials, offers strategic direction for Thailand's energy sector and serves as a forum to discuss recommendations for national energy policies and overall management and development plans with the Thai cabinet.

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[316] ""รับฟังความคิดเห็น (ร่าง) ข้อกำหนดการเปิดใช้ระบบโครงข่ายไฟฟ้าให้แก่บุคคลที่สาม (Third Party Access Code: TPA Code) ของการไฟฟ้าฝ่ายผลิตแห่งประเทศไทย Listen to opinions on (draft) regulations for opening up the electrical network system to third parties (Third-Party Access Code: TPA Code) of the Electricity Generating Authority of Thailand," EGAT, accessed September 18, 2023.

[317] "Thailand will use smart grid to predict outages," GOVINSIDER, accessed September 18, 2023, Link.

[318] "Annual Report 2021 Provincial Electricity Authority," PEA, 2021, Link.

[319] "Thailand renewable grid integration assessment," IEA, October 2018.

[320] เอกสารเผยแพร่ การกำหนดค่า Ft ในแต่ละงวด "Published document: Determination of Ft value in each period," ERC, accessed September 18, 2023.

[321] "อัตราค่าไฟฟ้าโดยอัตโนมัติ (Ft) Automatic electricity tariff (Ft)," ERC, accessed September 18, 2023, Link.

Sidebar: FIT for RES production

FIT guarantees RES producers a set price for the energy they supply to the grid, aiming to attract investments and provide revenue stability. In Thailand, the ERC oversees the FIT system, which uses an auction-based approach where developers submit bids with project details and credentials. There are restrictions on foreign ownership in this process, with a maximum of 49% foreign shareholding and no more than half of the shareholders being foreign entities.

Thailand introduced a FIT program in 2007, offering an adder or premium over wholesale prices for RES. The measure sparked significant growth in RES energy production, from 2.2 GW in 2011 to 7.3 GW in 2017.[322] In 2022, a new FIT scheme for 5.2 GW of renewable energy projects was established, including ground-mounted solar, solar with battery storage, wind, and biogas, with staggered launch dates from 2024 to 2030.[323] The 2022 auction saw 175 companies selected.[324] Overwhelming demand of 17 GW in this auction prompted a second phase of the auction in 2023 with a 3.6 GW target capacity, maintaining the same tariffs as the 2022 auction.

As of 2022, FIT rates ranged from about THB 2.1 (USD 0.06) per kWh to THB 2.8 (USD 0.08),[325] with an additional FIT premium of THB 0.50 (USD 0.01) per kWh for projects in the southern border provinces of Yala, Pattani, and Narathiwat, as well as the Chana, Thepha, Saba Yoi and Na Thawi districts in Songkhla.

Table 4: FIT rates and support periods of different types of RES

Type	FIT rate (THB/kWh)	Support period
Biogas (wastewater/waste)	2.0724 (USD 0.0576)	20 years
Wind	3.1014 (USD 0.0862)	25 years
Ground-mounted Solar	2.1679 (USD 0.0602)	25 years
Ground-mounted Solar + BESS (>10-90 MW)	2.8331 (USD 0.0787)	25 years

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[322] "Extended Annual Review Report, Chaiyaphum Wind Farm Company Limited Subyai Wind Power Project (Thailand)," ADB, June 2020.

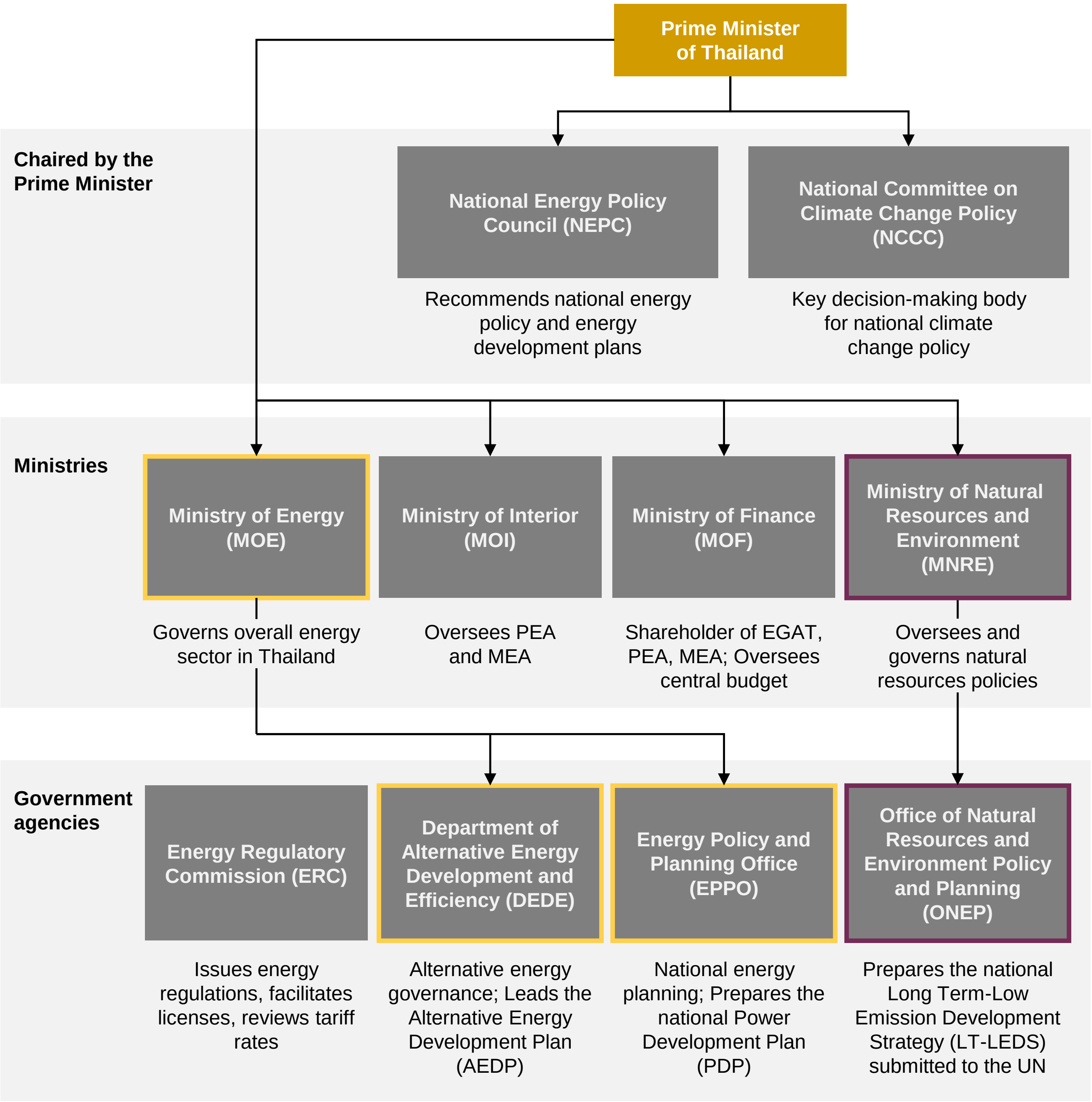
[323] "โครงการรับซื้อไฟฟ้า (Electricity purchase project)" Energy Regulatory Commission, accessed September 18, 2023

[324] "Thailand selects 175 firms for renewable energy scheme," RECCESSARY, April 26, 2023, Link.

[325] "การจัดหาไฟฟ้าจากพลังงานหมุนเวียนในรูปแบบ Feed-in Tariff (FiT) ปี 2565 - 2573 สำหรับกลุ่มไม่มีต้นทุนเชื้อเพลิง (Procurement of electricity from renewable energy in the form of Feed-in Tariff (FIT) for 2022 - 2030 for groups with no fuel costs," ERC, September 30, 2022, Link.

Other government agencies that have a role in governing clean energy in Thailand include the National Committee on Climate Change Policy (NCCC), which serves as the core decision-making body for national climate change policy; the Office of Natural Resources and Environment Policy and Planning (ONEP), which sits under the Ministry of Natural Resources and Environment (MNRE) and is charged with formulating policies affecting Thailand's natural resources, as well as preparing the LT-LEDS, which is submitted to the United Nations; the Ministry of Finance (MOF); and Ministry of the Interior (MOI), which plays a role in governing EGAT, MEA, and PEA.

Exhibit 72: Central clean energy policymakers in Thailand



Chaired by the Prime Minister

Prime Minister of Thailand

National Energy Policy Council (NEPC)
Recommends national energy policy and energy development plans

National Committee on Climate Change Policy (NCCC)
Key decision-making body for national climate change policy

Ministries

Ministry of Energy (MOE)
Governs overall energy sector in Thailand

Ministry of Interior (MOI)
Oversees PEA and MEA

Ministry of Finance (MOF)
Shareholder of EGAT, PEA, MEA; Oversees central budget

Ministry of Natural Resources and Environment (MNRE)
Oversees and governs natural resources policies

Government agencies

Energy Regulatory Commission (ERC)
Issues energy regulations, facilitates licenses, reviews tariff rates

Department of Alternative Energy Development and Efficiency (DEDE)
Alternative energy governance; Leads the Alternative Energy Development Plan (AEDP)

Energy Policy and Planning Office (EPPO)
National energy planning; Prepares the national Power Development Plan (PDP)

Office of Natural Resources and Environment Policy and Planning (ONEP)
Prepares the national Long Term-Low Emission Development Strategy (LT-LEDS) submitted to the UN

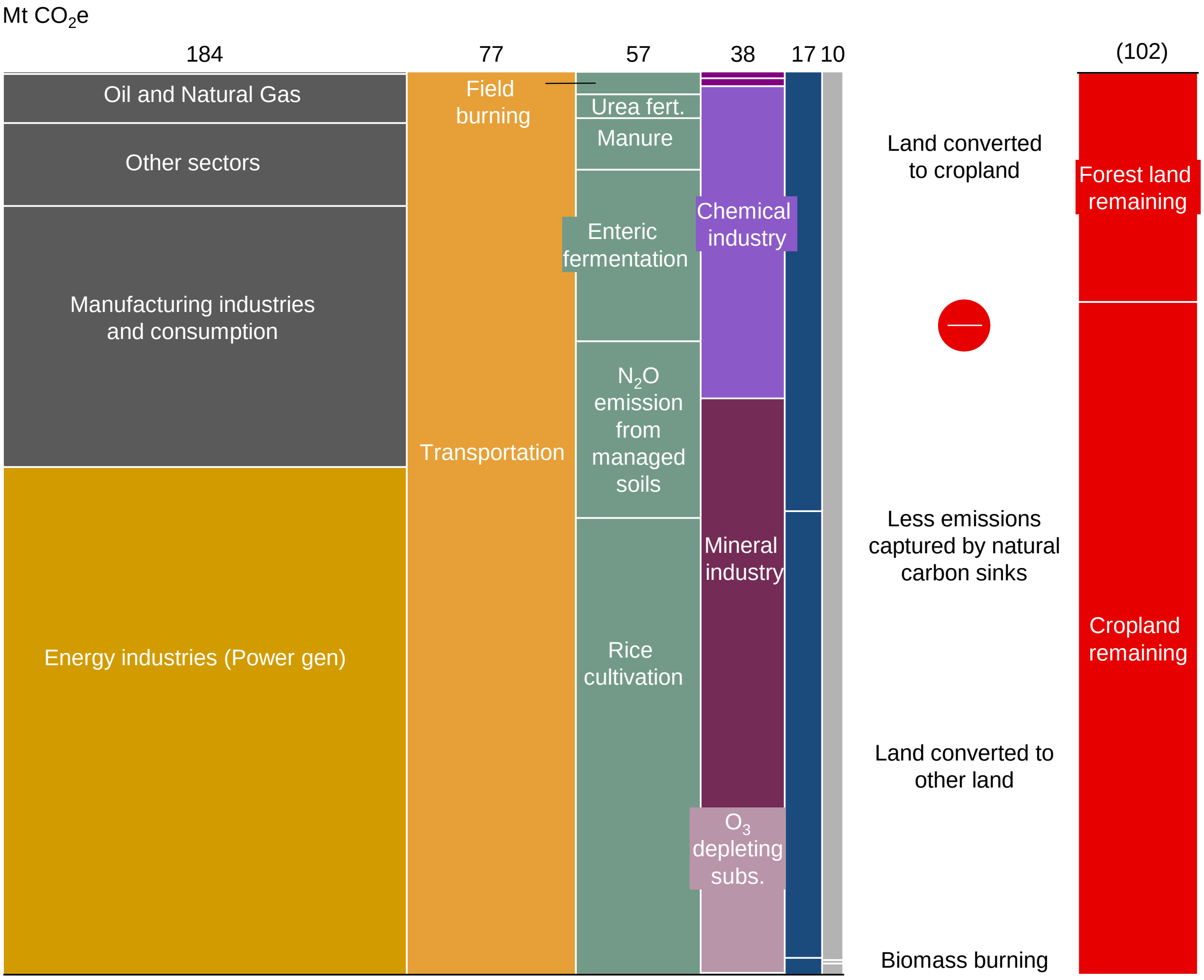
4.2. Momentum towards energy transition

Thailand has made significant progress in scaling its energy assets and developing its energy market to keep up with economic growth to date. However, the future of Thailand's energy sector relies not only on its capacity to expand and meet domestic demand, but also in ensuring a sustainable energy transition towards net zero.

4.2.1. National commitments

As per the latest Thailand National Inventory, submitted to the United Nations in 2022, energy sector, including power generation, had the largest share in Thailand's total emissions at 27% in 2019.[326] This underscores the role of power sector in Thailand's decarbonization strategy.

Exhibit 73: 2019 Thailand emissions by sector[327]



In the 2018 PDP, which pre-dated the national commitments in 2021, energy capacity is expected to increase by roughly 29 GW between 2018 and 2037, with the RES share rising from 20% to 36% over the same period. Total grey energy capacity from unabated sources is expected to remain consistent over the period. The next iteration of the PDP is likely to include a more ambitious RES target since the 2022 LT-LEDS already targets a RES share of 68% by 2040.[328]

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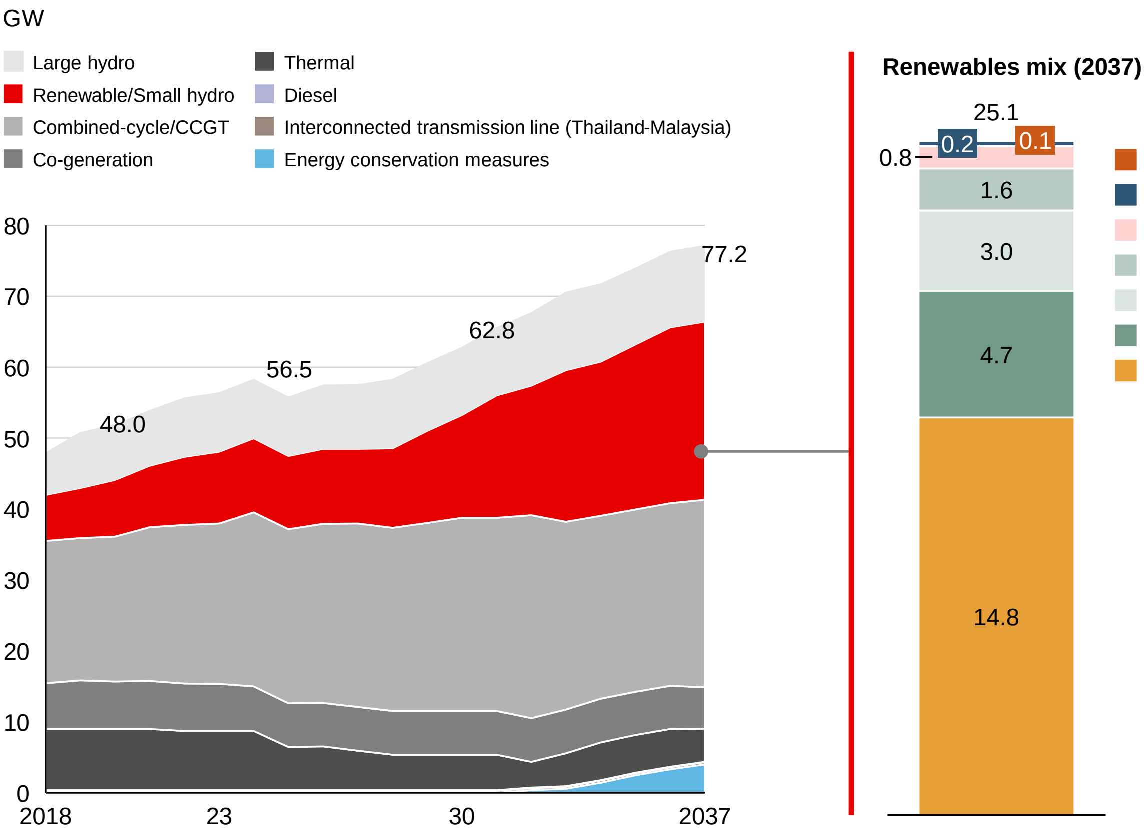
[326] "National inventory submissions 2022," UNFCCC, accessed September 18, 2023.

[327] Ibid.

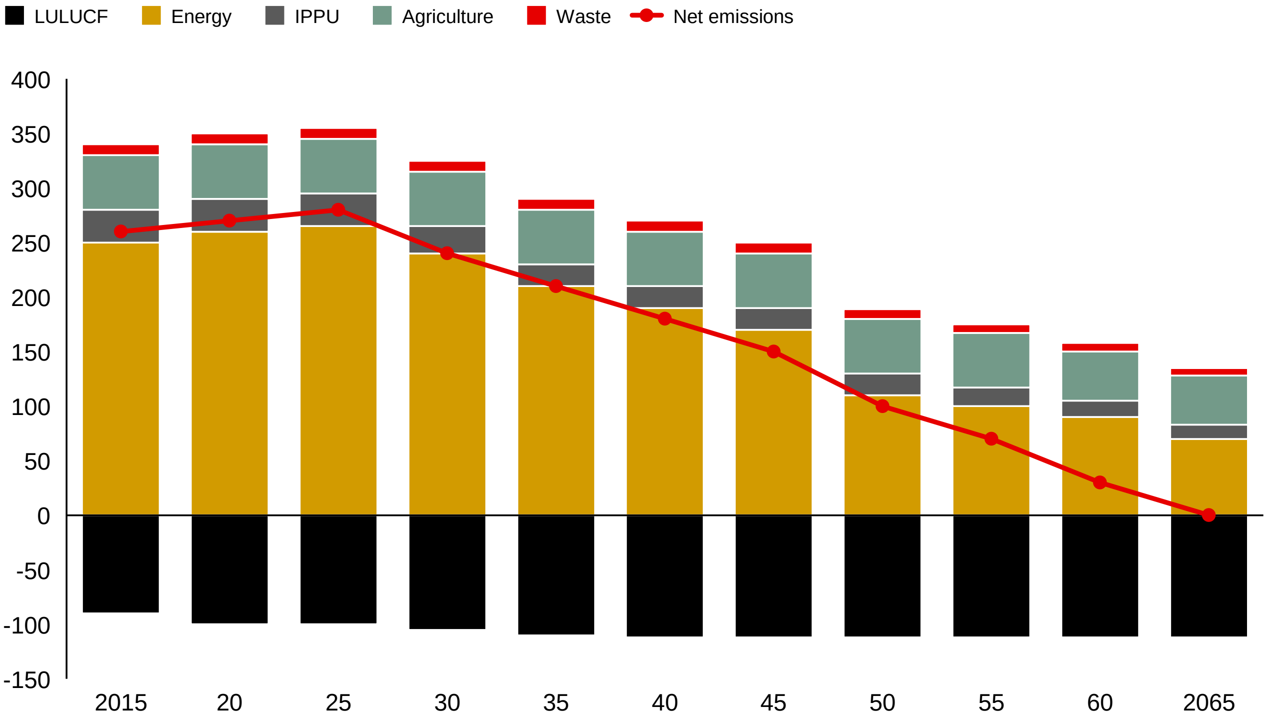
[328] LT-LEDS is published by the Office of Natural Resources and Environmental Policy and Planning under the Ministry of Natural Resources and Environment, whereas the PDP is published by the Energy Policy and Planning Office under the Ministry of Energy.

Exhibit 74: Thailand forecasted power capacity by energy source, 2018-2037[329]



The 2022 LT-LEDS expects that the energy sector, including electricity generation contributes to the largest share of GHG reduction towards Thailand's 2065 GHG net zero target.

Exhibit 75: GHG emissions/removals by sector in Thailand, 2015-2065[330]



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[329] "Thailand's Power Development Plan (PDP) 2018-2037," Thailand Ministry of Energy and Water Resources, 2019.

[330] "Thailand's long-term low greenhouse gas emission development strategy (revised version)," Ministry of Natural Resources and Environment, Thailand, November 2022. LULUCF = land use, land-use change, and forestry; IPPU = industrial processes and product use.

4.2.2. Public and private sector initiatives

Both the public and private sectors are critical to decarbonizing Thailand's power sector. Public bodies provide regulatory frameworks and guidelines, set national aspirations and targets, and enable access to financing when project economics are challenging. The private sector brings project execution expertise and can help lower overall costs to expand decarbonization technologies as capabilities and operations grow.

Public sector

Public-sector stakeholders comprise three core groups: energy policymakers, financial regulators, and public finance providers.

Energy policy makers (e.g., MOE, EPPO, ERC): The MOE actively seeks ways to shape Thai policy to promote decarbonization. In January 2023, MOE and Japan's METI began talks on energy policies of both countries as they pursue carbon neutrality by 2050.[331] Multiple MOUs with Japanese companies were signed as a result of this dialogue.

The EPPO is updating the PDP, which would then be submitted to the NEPC for approval.

In 2022 and 2023, the ERC offered the Regulation for Procurement of Renewable Energy under the FIT Scheme for 2024 to 2030,[332] which set the guidelines, tariffs, and quotas for prospective energy companies to participate in Thailand's upcoming renewables auctions.

The ERC has also explored new channels for customers to purchase renewables by offering the private sector greater participation in the Thai energy market. For instance, the ERC launched its Sandbox program, designed to test new energy efficiency mechanisms in limited geography for a set time to gain operational insights and other lessons before national implementation. Projects being tested under Sandbox fall into five categories: 1) peer-to-peer energy trading; 2) new service rates and business models; 3) electric vehicle, 4) electric vehicle charging stations, 5) BESS; microgrids; and 6) supply and load aggregators.[333] In 2022, phase two of the Sandbox program was launched, focused more on green innovation and green regulation. These included platforms or innovations for the sale and purchase of RES, carbon credits, RECs, smart grids and new forms of PPAs, including virtual PPAs and sleeved PPAs. Sleeved PPAs, such as utility green tariffs, refer to an off-site PPA in which an energy service provider takes over various processes.[334] Recently, the ERC has also held multiple rounds of public hearings concerning TPA codes for the national grid.[335]

Financial regulators (e.g., MOF, the Bank of Thailand, the Securities and Exchange Commission (SEC) and others): While not directly involved in the energy sector, financial regulators help create an enabling environment for decarbonization technologies.

In 2021, a working group on Sustainable Finance, comprising the Fiscal Policy Office, the Bank of Thailand, the SEC, the Office of Insurance Commission, and the Stock Exchange of Thailand, developed Thailand's national sustainable finance policies. The group recommended five strategic initiatives: 1) develop a practical taxonomy, 2) improve the data environment, 3) implement effective incentives, 4) create demand-led products and services, and 5) building human capital.

Following this plan, the Thailand Taxonomy Board, which includes the Bank of Thailand, the ONEP, and the SEC, issued the national taxonomy. Known as the Phase I document, the 2023 taxonomy covers the energy and transportation sectors and defines what constitutes environmentally sustainable investments in Thailand.

In 2023, the MOF was also exploring the possibility of implementing a carbon tax in Thailand, designed to encourage RES use and to reduce GHG emissions by 30%.[336] Studies around levying carbon taxes in Thailand have begun.

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[331] "The 5th Japan-Thailand energy policy dialogue held," METI, January 17, 2023, Link.

[332] "The Energy Regulatory Commission of Thailand (ERC) sets out to promote low-carbon economy with new regulations on the procurement of renewable energy," In-House Community, November 9, 2022, Link.

[333] "Regulatory design for disruptive technologies in the power sector: Examples from the U.S. and implications for Thailand," USAID, April 30, 2021.

[334] "Thailand's energy transition: ERC sandbox phase 2 for green innovation and green regulation now rolled out," David Beckstead, Panupan Udomsuvannakul and Prang Prakobvaitayakij, Lexology, June 17, 2022, Link.

[335] "Significant milestone to achieve toward enhancing competition through liberalization of the Thai electricity market," Norton Rose Fulbright, March 2022, Link.

[336] "Thailand plans to impose a carbon tax in energy, transport and industry," Enerdata, April 13, 2023, Link.

Public finance providers (e.g., MDBs): Public finance providers have supported early decarbonization projects in Thailand to improve their broader bankability with corporate banks.

For example, when utility-scale solar was introduced in Thailand, IFC supported Solar Power Company Group (SPCG)'s initial project development in 2010 through blended finance. IFC orchestrated an USD 8 million loan with USD 4 million in concessional financing from the Clean Technology Fund (CTF), which allowed SPCG to raise capital from other local banks and expand its operations.[337]

As renewables projects reach mainstream bankability, such blended financing can be used to accelerate horizon technologies, including CCUS, hydrogen co-firing, and other initiatives.

Private sector

Private-sector stakeholders comprise three core groups: power sector players, power purchasers, and financiers.

Power sector players (e.g., EGAT, EGCO, and RATCH): Many Thai power companies are actively realigning their strategies with the country's decarbonization ambitions. For example, EGAT has announced plans to reduce emissions by 20% to 25% from its 2018 baseline by 2030 and to achieve carbon neutrality by 2050.[338] Other players, including GULF, RATCH, EGCO, Glow Energy, and B.Grimm Power, have also set decarbonization targets. Some of the major power sector players, EGAT, EGCO, and RATCH, will be highlighted at the end of this section.

Thai power companies aim to achieve these aspirations through new RES projects. In the 2022 auction of 5.2 GW new renewables capacity, 175 companies were selected, and among the largest winners were GULF, with 28 projects of more than 2 GW capacity; Absolute Clean Energy, 18 projects of 112 MW capacity; Thai Solar Energy PLC, eight projects of 100 MW capacity; and BCPG of the Bangchak Group, five projects of 12 MW capacity.[339]

Solar remains the largest source of new renewables projects. In 2023, EGAT announced plans to build 10 GW of floating solar farms at its nine hydropower plants by 2037. The first EGAT solar farm to go online was a 45 MW plant at Sirindhorn dam, Ubon Ratchathani, which was built by a consortium including B.Grimm and Energy China and began operations in November 2021. EGAT is also preparing to construct a second farm with 24 MW of capacity at the Ubol Ratana dam, Khon Kaen, alongside floating solar farms at seven other dams.[340]

SPCG has developed 36 solar farms in Thailand with a total capacity of 260 MW.[341] The solar farms are located across 10 provinces, with one in the central region and nine in the northeastern region.

Smaller power companies have also expanded their renewables assets. In 2023, Super Energy Corporation opened a hybrid on-ground solar farm in the eastern province of Sa Kaeo.[342] The 16 MW site features a solar farm and an energy system to supply continuous electricity.

Power purchasers: In Thailand, options for power purchasers (e.g., corporations, industrial clusters, industrial associations) to procure RES are limited currently to captive generation and purchasing RECs. Captive generation is costly and requires significant scale and available land, putting it out of reach for some buyers. Despite being supported by robust back-end platforms and international guidelines, which ensure proper documentation, proper fund flows, and avoidance of double counting, RECs are not perceived as "direct" acquisition and do not directly contribute to the development of new RES.

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[337] "How Thailand's solar power visionary built an industry with a boost from IFC," Climate Investment Funds, November 25, 2014.

[338] "EGAT Sustainability Report 2022," EGAT, 2023

[339] "Thailand's state grid to ink 5.2GW renewable deals in Q3," Alex Morgan, Thaiger, May 24, 2023.

[340] "Solar energy market in Thailand," Rated Power, January 5, 2022.

[341] "Annual information display form/Annual report 2022 (Form 56-1 One Report)," SPCG Public Company Limited, 2022.

[342] "Sa Kaeo solar farm launched," Yuthana Praiwan, Bangkok Post, January 23, 2023.

Exhibit 76: Options to purchase RES in Thailand

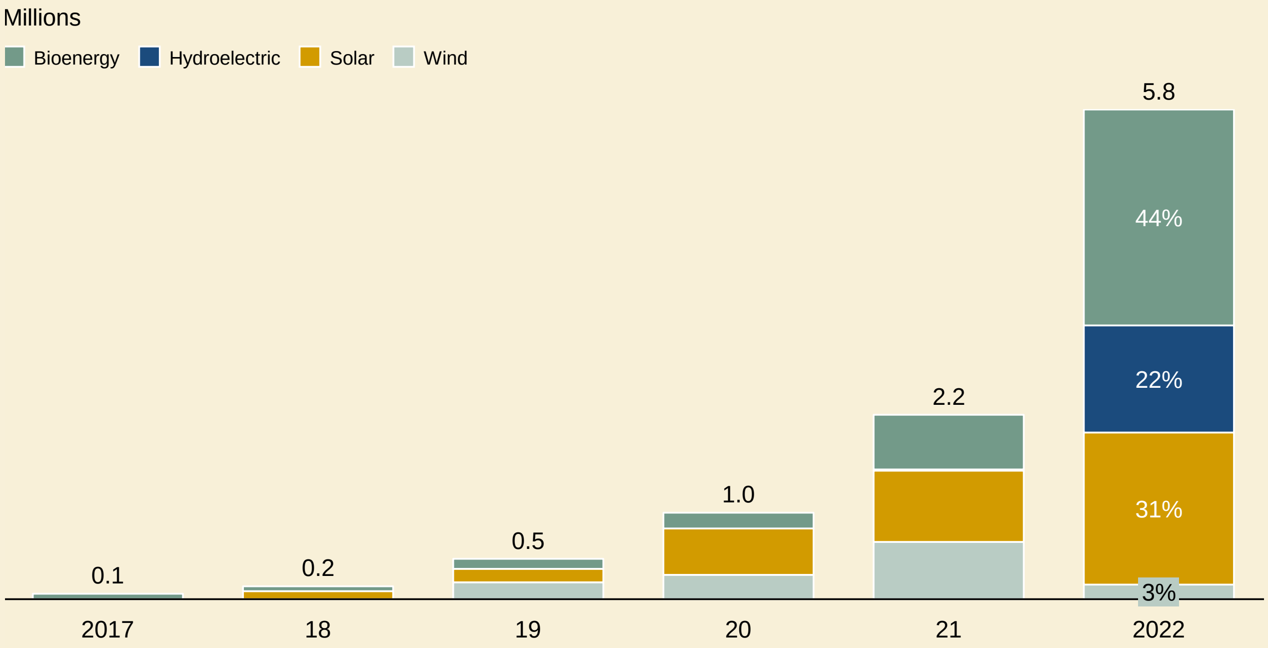
✓ = Fully allowed ◌ = Discussions underway ⊗ = Few/No discussions

Acceptability	Options to purchase RES				Status in Thailand
High	**Captive generation** *(Direct investment in production for self-consumption)*	**Customer**	Directly owns/leases	**RES asset**	✓ **Available today**
	Corporate PPA	**Customer**	Direct contracts to guarantee supply of RES (physically or virtually)	**Power generator**	◌ **Ongoing discussion on TPA and direct PPA**
	Green tariffs *(Green procurement from utilities)*	**Customer**	RES purchase product offered by utilities	**Utility**	◌ **Utility Green Tariff (UGT) underway**
Low	**Renewable Energy Certificates** *(Unbundled Energy Attribute Certificates)*	**Customer**	Purchases REC, which represents 1 MWh of RES	**Issuing body**	✓ **Available today**

Sidebar: RECs in Thailand

RECs in Thailand can be sourced through either I-RECs issued by EGAT or TIGRs issued by IPPs. Both are global platforms that track and impose standards for the issuances and purchases of RECs in countries that do not have national REC platforms. In Thailand, I-RECs are more common than TIGRs, and EGAT serves as the local I-REC issuer. The number of I-RECs issued in Thailand doubled every year between 2017 and 2022, reaching 5.8 million issued in 2022, representing 5.8 TWh of RES.

Exhibit 77: I-RECs issued in Thailand, 2017-22[343]



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343 "Thailand – 2023 Market Statistics," I-REC standard, accessed November 9, 2023, https://www.irecstandard.org/thailand/.

TPA is being explored to allow end-customers to enter contracts with power providers and procure RES directly through physical or virtual PPAs. These contracts would enable direct procurement of RES, potentially up to the level of the full capacity of the generator. Moreover, UGTs are special pricing schemes that allow residential and commercial customers to buy RES by paying a distinct tariff to a power sector player. In 2023, a potential UGT framework for Thailand was under public consultation. Tentative pricing for UGTs would be based on the standard electricity tariff plus a premium comprising the market price of RECs and a fee for administrative and operating costs. Initiatives are also underway to pilot UGTs that cover select buyers procuring renewable energy at green tariffs from EGAT.

In 2023, Western Digital and Nestle Thailand separately announced partnerships with both EGAT and INNOPOWER to buy renewable energy under a special UGT.[344] This program is one of many under the ERC Phase two Sandbox.

Thailand also has a local RE100 association. Companies part of RE100, a global initiative of corporations that pledge to move towards using RES exclusively, include 113 corporate members with operations in Thailand. Those with Thai operations require 1.8 TWh of electricity supply annually, of which only 439 GWh has been procured through RES.[345] The Thai RE100 association strives to enhance industry capabilities and enable the transition to new industries powered by clean energy.[346] Founding and current members include some of Thailand's largest companies and manufacturers, such as PTT, Central Group, Denso, and Toyota, and power sector players, such as Super Energy, GULF, and EGAT.[347]

Financiers: Sustainable finance is becoming a higher priority for Thai banks, driven by their own sustainability targets. Many banks in Thailand have announced decarbonization plans as well as initiatives to support for customers such as the Bank of Ayudhya (Krungsri) as outlined in the sidebar below.

A large volume of sustainable financing in Thailand is being raised for the energy sector. For example, energy companies have been active in the domestic green bond market. In 2018, B. Grimm Power issued its maiden green bonds, the first climate bonds in Thailand, with the proceeds going to RES projects.[348] Many energy companies, such as Energy Absolute PCL and RATCH, have followed suit.[349] These transactions involve some of the country's largest and most prominent investment banks, signaling strong support from the banking sector in underwriting sustainable finance.

Major power sector players such as EGAT, RATCH, and EGCO have been leaders in pursuing new decarbonization solutions for the sector, not only for their Thai portfolios, but also for their assets abroad. We will cast a spotlight on these major power companies below.

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[344] "WESTERN DIGITAL, EGAT, and INNOPOWER join forces to pilot green energy use under Thailand's Utility Green Tariff Initiative," EGAT, May 12, 2023, Link; "Nestlé, EGAT, and INNOPOWER join forces to pilot green energy use in food industry, aiming for proactive GHG emissions reduction," EGAT, February 8, 2023, Link.

[345] "RE100 annual disclosure report 2022," RE100, January 2023, Link.

[346] "Objectives," RE100, accessed September 18, 2023, Link.

[347] "Member of RE100 Thailand Club," RE100, accessed September 18, 2023. Link.

[348] "Green finance trends and opportunities in Thailand," RE Global, January 29, 2022, Link.

[349] "ADB, Energy Absolute Sign Green Loan for Renewable Energy and Electric Vehicle Charging Network," ADB, February 11, 2021, Link.

Sidebar: Bank of Ayudhya (Krungsri) sustainability initiatives

A member of MUFG
a global financial group

Krungsri, one of MUFG's Partner Banks, has announced plans to decarbonize its operations by 2030, and decarbonize its financial services by 2050. Other sustainability-related strategic priorities include phasing out exposure to coal-fired power plants within a decade, enhancing financial disclosure policies regarding financed emissions and reduction targets, and growing its social and sustainable finance portfolio THB 50–100 billion (USD 1.4 billion to USD 2.8 billion) by 2030.[350]

Krungsri's Social and Sustainable Finance portfolio in 2022 was THB 155 billion growing by THB 44 billion from 2021.[351] Krungsri has participated in green bond deals with top companies, such as PTT,[352] and in 2023, issued its own green bond in 2023.[353]

Krungsri has also supported the energy sector decarbonization by financing technologically innovation projects. This includes a project finance deal with Super Solar Hybrid Co., Ltd. (SSH), a subsidiary of Super Energy Corporation Public Co., Ltd. (SUPER). With financing support from Krungsri, SSH operates a solar hybrid power project in Aranya Prathlet, Sa Kaeo province. The project represents the country's first solar hybrid project, which combines a solar farm with an energy storage system to enable continuous electricity supply. This technology has enabled SSH to supply commercial electricity to EGAT under a hybrid firm PPA of 16 MW, resulting in steadier supply of electricity. Usually, renewable power contracts in Thailand are not "firm" because of the RES intermittency. The SSH solar hybrid project is a milestone towards adding more stable renewable sources for energy security of Thailand.

Krungsri also has an initiative to support consumers in power sector carbonization through Home for Cash (H4C) loan that can be used for installing solar rooftops. In the H4C loan, the borrower uses home equity as collateral and has ~30 years of payment time. The loan can be used to finance major expenses such as solar panels, other home improvement, etc.[354]

Social and sustainable finance category		Krungsri's loan portfolio in 2022, THB billions
Environmental	Underwriting: Green Bond	14
	Green Loan	3
	Loan to Renewable Energy Business	9
	Other Loans	0
Social	Underwriting: Social Bond	7
	Loan from WSME Bond	20
	Social Loan	24
Sustainability	Loan to Regional Development Projects	9
	Underwriting: Sustainability Bond	44
	Underwriting: Sustainability-linked Bond	11
	Sustainability Loan	3
	Sustainability-linked Loan	7
	Investment	3
Total		**155**

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[350] "Krungsri declares Carbon Neutrality Vision committing to decarbonize its own operations by 2030, aligning with Thailand's COP26 pledge of carbon neutrality by 2050," Krungsri, December 27, 2021, https://www.krungsri.com/en/newsandactivities/krungsri-banking-news/krungsri-carbon-neutrality-declaration.

[351] "Sustainability Report 2022," Bank of Ayudhya, 2023.

[352] "Krungsri jointly offers PTT green bonds, world's first CBI-certified offering for financing forest conservation projects," Bank of Ayudhya, July 17, 2020, https://www.krungsri.com/en/esg/esg-news/news-activities/ptt-green-bonds.

[353] "IFC Subscribes to First Green and Blue Bond Issued by Krungsri, Supporting Thailand's Climate Goals," Bank of Ayudhya, June 15, 2023, https://www.krungsri.com/en/newsandactivities/krungsri-banking-news/ifc-first-green-and-blue-bond-issued-by-krungsri.

[354] Information provided by Bank of Ayudhya, November 2023.

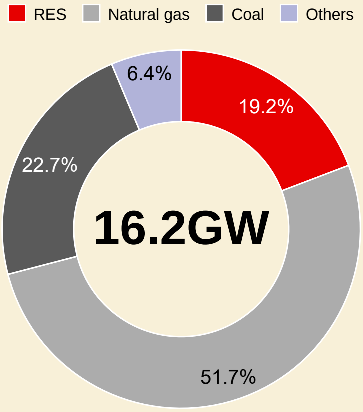
Spotlight on select power sector players

EGAT
Power for Thai Happiness

Company profile[355]

- **FY 2022 revenue:** THB 800 billion (USD 22 billion)
- **Market share:** EGAT owns about 34% of Thailand's electricity generation capacity

Total installed capacity of EGAT by generation type (as of September 2023)[356]



GHG emissions (2022)[357]

- **Scope 1:** 33.4 million tonnes of CO_2e
- **Scope 2:** 0.01 million tonnes of CO_2e
- **Scope 3:** 64.8 million tonnes of CO_2e (includes electricity purchase for sale)

Carbon intensity (scope 1):[358]
0.5 tonnes of CO_2e per MWh

Shareholder information[359]

Ministry of Finance (Thailand): 100%

Goals and commitments[360]

- **2030:** GHG emission reduction by 30% of base year (2021)
- **2050:** Carbon neutrality

Established in 1969, EGAT is a state-owned enterprise under the supervision of both the MOE and MOF. EGAT is responsible for generating, acquiring, and supplying electricity to MEA, PEA, legal power users, and neighboring countries, such as Laos and Malaysia. EGAT also provides other power-related activities and services, including operations and maintenance, and engineering and construction consultancy.

Decarbonization strategies[361]

EGAT participates in moving Thailand towards carbon neutrality by 2050 and net zero GHG by 2065 under its "Triple S" strategy: sources transformation, sink co-creation, and support measures mechanism.

1) **Sources transformation:** Build new renewables, grid modernization, and expand BESS and hydrogen energy storage system (HESS).
2) **Sink co-creation:** Increase carbon absorption through reforestation initiatives and deploying CCUS in power assets.
3) **Support measures mechanism:** Deploy initiatives such as energy efficiency projects, carbon offsets, Bio-Circular-Green (BCG) Economy promotion.

Excerpts of decarbonization efforts

As the preeminent state-owned power utility, EGAT is involved in multiple decarbonization initiatives. EGAT is pursuing plans to increase RES build and RES enablers across the full spectrum technologies, primarily in solar. EGAT is also exploring new generation decarbonization technologies such as carbon capture and hydrogen storage, in partnership with established multinational technology providers.[362]

Additionally, EGAT has played a significant role facilitating the "Sandbox" pilot programs for policy regime initiatives such as UGT, and peer-to-peer energy trading. Moreover, in 2022, EGAT announced support for the SolarPlus peer-to-peer energy trading platform, which makes it easier for residential solar-rooftop owners to monetize excess energy. In 2023, Western Digital and Nestle Thailand separately announced partnerships with both EGAT and INNOPOWER to buy renewable energy under a special UGT.[363]

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[355] "Annual Report 2022," EGAT, June 23, 2023; "EGAT overview," EGAT, December 2021.
[356] "System Installed Generating Capacity," EGAT, September 2023, https://www.egat.co.th/home/en/statistics-all-latest/.
[357] "EGAT Sustainability Report 2022," EGAT, 2023.
[358] Ibid.
[359] "Annual Report 2022," EGAT, June 23, 2023.
[360] "EGAT Sustainability Report 2022," EGAT, 2023, Ibid.
[361] "EGAT promotes "Neutral Life" to tackle climate change, moving toward Carbon Neutrality," EGAT, June 6, 2023.
[362] "Annual Report 2022," EGAT, June 23, 2023.
[363] "WESTERN DIGITAL, EGAT, and INNOPOWER Join Forces to Pilot Green Energy Use under Thailand's Utility Green Tariff Initiative," EGAT, May 12, 2023, Link; "Nestlé, EGAT, and INNOPOWER join forces to pilot green energy use in food industry, aiming for proactive GHG emissions reduction," EGAT, February 8, 2023, Link.

EGAT decarbonization levers[364]

RES: After building a 45 MW hydro-floating solar hybrid pilot at Sirindhorn Dam, which began commercial operations in 2021, EGAT plans to develop similar projects from 2023 to 2037 at nine other dams in Thailand. The projects have about 2.7 GW of capacity among them, which could increase to 10 GW.[365]

Grid upgrade: EGAT has also launched initiatives, such as grid modernization, to increase the flexibility and efficiency of its power plants and to help expand RES. EGAT announced the establishment of the Renewable Energy Forecast Center (REFC) in 2021, and the Demand Response Control Center (DRCC) in 2023.[366] The REFC forecasts renewables generation to be incorporated in power supply planning of non-renewable sources, while the DRCC acts as a control center to help balance consumption. EGAT has installed three BESS stations with a total capacity of over 37 MW.[367]

Carbon capture: EGAT is studying applications of CCUS technology with plans to retrofit existing power plants and store 3.5 million to 7 million tonnes of CO_2 by 2045.[368] In 2023, EGAT signed an MOU with Shell to collaborate on clean energy technologies, including CCUS and hydrogen.[369]

Hydrogen: In 2023, EGAT announced a partnership with five Japanese companies – Mitsui O.S.K. Lines, Mitsubishi Thailand, Chiyoda Corporation, TTCL, and IHI Corporation – to develop full-cycle clean hydrogen and clean ammonia, biofuels, and BESS.[370] EGAT wants to generate 66 TWh of electricity from hydrogen by 2050.[371] In 2019, EGAT also signed a collaboration agreement with electrolyzer manufacturer Enapter to explore the potential for green hydrogen.[372]

Others: Since 2016, EGAT has executed multiple electric vehicle R&D projects with organizations in Thailand in line with its support measures mechanism. The partnerships have included the Electric Vehicle Kit & Blueprint project with Thailand's National Electronics and Computer Technology Center (NECTEC), an electric bus retrofitting project with the Bangkok Mass Transit Authority (BMTA), and an electric shuttle boat development with Kasetsart University.[373] EGAT has also developed the EGAT E-Bike, an electric motorcycle and ventured into other products and services related to electric vehicles.[374]

EGAT is also exploring other clean energy technologies. The company launched a pilot focused on biomass co-firing in 2022 in Units 12 and 13 of the Mae Moh Power Plant.[375] EGAT steers the Participatory One-Million-Rai Reforestation Project to reforest 16,000 hectares a year from 2022 through 2031, which is expected to absorb 1.2 million tonnes of CO_2 annually.[376]

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[364] "Sustainability Report 2022", EGAT, 2023; "Overcome energy crisis: Annual report 2022," EGAT, June 2023.

[365] "Thailand planning massive floating solar power plants on hydropower dam reservoirs," Renewable Energy World, March 5, 2019, https://www.renewableenergyworld.com/baseload/hydropower/thailand-planning-massive-floating-solar-power-plants-on-hydropower-dam-reservoirs/#gref.

[366] "EGAT opens Renewable Energy Forecast Center and Demand Response Control Center, to enhance stability of Thailand's power system and support clean energy trend," EGAT, August 24, 2023, https://www.egat.co.th/home/en/20230824e/.

[367] "EGAT Sustainability Report 2022," EGAT, 2023.

[368] "EGAT aims for EGAT Carbon Neutrality in 2050 with Triple S Strategy, including 1-million-rai reforestation project, to build carbon-free society for Thais," EGAT, October 26, 2021, https://www.egat.co.th/home/en/20211026e2-pre/.

[369] "Shell and EGAT jointly study clean energy and carbon capture technologies to reduce carbon emissions," EGAT, March 13, 2023, https://www.egat.co.th/home/en/20230313e/.

[370] "EGAT Joins Hands With 5 Japanese Companies To Study And Develop Clean Hydrogen And Ammonia," Pooja Chandak, SolarQuarter, March 14, 2023, https://solarquarter.com/2023/03/14/egat-joins-hands-with-5-japanese-companies-to-study-and-develop-clean-hydrogen-and-ammonia/.

[371] "EGAT aims for EGAT Carbon Neutrality in 2050 with Triple S Strategy, including 1-million-rai reforestation project, to build carbon-free society for Thais," EGAT, October 26, 2021, https://www.egat.co.th/home/en/20211026e2-pre/.

[372] "EGAT Signs Agreement with Enapter to Advance Hydrogen Production in Thailand," FuelCellsWorks , August 14, 2019, https://fuelcellsworks.com/news/egat-signs-agreement-with-enapter-to-advance-hydrogen-production-in-thailand/.

[373] "EV Innovation," EGAT, accessed November 2, 2023, https://www.egat.co.th/home/en/ev-innovation/.

[374] "Thailand Post – EGAT join hands to test 'EGAT E-Bike' advancing toward green postal service of the future," EGAT, August 30, 2022, https://www.egat.co.th/home/en/20220830e/.

[375] "Deputy PM and Minister of Energy hastens the study of CCS in Mae Moh Mine, moving toward Carbon Neutrality by 2050 concretely," EGAT, LinkedIn, November 14, 2022, https://www.linkedin.com/pulse/deputy-pm-minister-energy-hastens-study-/.

[376] "EGAT keeps planting forests to expand green area in Krabi Province and promote community engagement in ecosystem restoration," EGAT, July 13, 2023, https://www.egat.co.th/home/en/20230713e/.

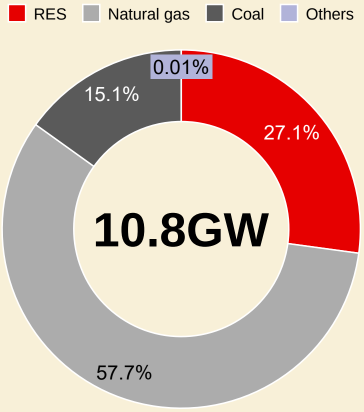
Spotlight on select power sector players

RATCH GROUP

Company profile[377]

- **FY2022 revenue:** THB 82 billion (USD 2.3 billion)
- **Market share:** RATCH owns about 20% of Thailand's electricity generation capacity

Total installed capacity of RATCH by generation type (as of September 2023)[378]



GHG emissions (2022)[379]

- **Scope 1:** 8.5 million tonnes of CO_2e
- **Scope 2:** 0.03 million tonnes of CO_2e
- **Scope 3:** 3.0 million tonnes of CO_2e

Carbon intensity (scope 1):[380]

0.1 tonnes of CO_2e per MWh

Shareholder information[381]

- EGAT: 45%
- EGAT Saving and Credit Cooperative Limited: 5.4%
- Thai NVDR Company Limited (Trust account) (Thailand): 5.4%
- Social Security Office (Thailand): 4.7%
- Others: 39.6%

Goals and commitments[382]

- **2025:** RES comprise 25% of total capacity
- **2030:** RES comprise 30% of total capacity; emissions per kWh reduced by 15% from the base year 2023
- **2035:** RES comprises 40% of total capacity
- **2050:** Carbon neutrality

Founded in 2000, RATCH Group is a leading energy and infrastructure company and strives to become a leading value-oriented energy and infrastructure company in Asia. The group generates and sells electricity in Australia, Indonesia, Japan, Laos, Vietnam, the Philippines, and Thailand. It also invests in RES projects and energy-related businesses.

Decarbonization strategies

RATCH's Climate Change Strategy, the document guiding its approach to sustainability, focuses on two components:

1) **GHG emissions reduction**
- Production efficiency enhancement: Remove pre-combustion GHG and reduce fossil fuel use.
- Diversification into green businesses: Expand renewable energy capacity and invest more in non-power businesses.
- Carbon offsetting and trading: Implementation of REC and natural capture from forest.

2) **Internal and external collaboration**
- Extended networking with external organizations: Seek collaboration with stakeholders—suppliers and customers – in promoting emission reduction and resource recycling.
- Operational improvements through internal climate management: Supervise climate change coping actions, consider rewarding employees at all levels for their climate actions, integrate the climate risk-assessment process with the enterprise risk-assessment process, set internal carbon pricing to define the monetary value of per-unit internal combustion.

Excerpts of decarbonization efforts

RATCH intends to continue to scale its RES portfolio, notably in offshore markets. RATCH intends to scale renewables significantly over the next decade, to comprise 25% of portfolio by 2025 and 40% of portfolio by 2035. RATCH's acquisition of Nexif's 1.5 GW renewables portfolio is a major leap in this direction. Nexif Energy is an energy company focused on power generation assets in South Asia, Southeast Asia, and Australia, and serves as a platform for RATCH to scale new projects internationally.[383] RATCH has also announced plans to explore next-generation technologies – hydrogen and ammonia as

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[377] "Company background," RATCH, accessed Sep. 2023; "Moving toward sustainable future," RATCH, 2022, Nov.2023.
[378] "Power Business," RATCH, September 2023, Link.
[379] Information provided by RATCH; "Sustainability Report 2022," RATCH, March 2023.
[380] Information provided by RATCH.
[381] "Major shareholders," RATCH, as of September 4, 2023, Link.
[382] "Climate Strategy," RATCH, accessed September 2023, Link.
[383] Information provided by RATCH; "Sustainability Report 2022," RATCH, March 2023.

fuel, CCUS, and green hydrogen production. As of 2023, green hydrogen feasibility studies are ongoing with pilot project planned in Australia.[384]

RATCH decarbonization levers

RES: As of September 2023, RATCH had equity installed capacity of 10.8 GW, of which about 27% comes from RES.[385] New renewables projects, such as Lincoln Gap 1&2 wind farms in Australia, Coc San, and Song Giang two hydroelectric power plants, and Ecowin wind power plant in Vietnam have been opened.[386]

RATCH has a strong pipeline of offshore RES projects spanning Australia, Indonesia, Japan, Laos, the Philippines, and Vietnam. Recent examples of RES projects include the acquisition of Nexif Energy's 1.5 GW RES portfolio, valued at about USD 600 million, which includes the 464 MW wind farms and battery project in South Australia, hydropower and wind projects in Vietnam, and solar projects in the Philippines.[387]

CCUS and hydrogen: RATCH has announced a planned expansion into green businesses such as hydrogen fuel, ammonia, and fuel cells. At the same time, the company is exploring investing in CCUS, as well as opportunities in green hydrogen production in Australia, Europe, and Japan, with a pilot being considered in Australia.[388]

Carbon offsetting and trading: RATCH participates in the Thailand Voluntary Emission Reduction Program (T-VER) in the forestation and green areas categories and the energy efficiency and renewable energy categories. Specifically, RATCH, in collaboration with the Royal Forestry Department and the Department of Marine and Coastal Resources, has developed two afforestation projects under the Thailand Greenhouse Gas Management T-VER scheme to certify 10-year carbon credits. RATCH has also signed an MOU with Mae Fah Luang Foundation on the Community Forest Carbon Credits Management for Sustainable Development Project. RATCH targets forest carbon removal by 1% of total emission in Thailand in 2030.[389]

Others: RATCH collaborated with EGAT and EGCO under INNOPOWER to study electric vehicles and charging stations. RATCH has implemented a community energy project to share knowledge on energy/fuel reduction to 500 households in Yang Hak sub-district, Pak Tho district, Ratchaburi province since 2020. Moreover, RATCH has engaged in significant afforestation efforts, covering 1,865 hectares as of 2023.[390]

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[384] "Analyst Meeting 2022 Year End," RATCH, March 3, 2023, Link.

[385] "RATCH Group announced a 29.7 MW ECOWIN wind farm in Vietnam Commencing commercial operation to Vietnam Electricity under 20-year PPA," RATCH, October 2, 2023, https://www.ratch.co.th/en/updates/company-news/1088/ratch-group-announced-a-297-mw-ecowin-wind-farm-in-vietnam-commencing-commercial-operation-to-vietnam-electricity-under-20-year-ppa.

[386] "Analyst Meeting 1Q2023," RATCH, May 26, 2023, https://ratch.listedcompany.com/misc/PRESN/20230526-ratch-am-1q2023.pdf; "RATCH Group announced a 29.7 MW ECOWIN wind farm in Vietnam Commencing commercial operation to Vietnam Electricity under 20-year PPA," RATCH, October 2, 2023, https://www.ratch.co.th/en/updates/company-news/1088/ratch-group-announced-a-297-mw-ecowin-wind-farm-in-vietnam-commencing-commercial-operation-to-vietnam-electricity-under-20-year-ppa.

[387] "RATCH Group injected USD 605 Mn Acquiring Nexif and Denham's asset portfolio, Accelerating to hit 10,000MW target and renewable portfolio, Moving forwards joint venture with Nexif to continue pipelined projects and future potentiality," RATCH, August 17, 2022, https://www.ratch.co.th/en/updates/company-news/944/ratch-group-injected-usd605-million-acquiring-nexif-and-denhams-asset-portfolio-accelerating-to-hit-10000mw-target-and-renewable-portfolio-moving-forwards-joint-venture-with-nexif-to-continue-pipelined-projects-and-future-potentiality.

[388] "Analyst Meeting 2022 Year End," RATCH, March 3, 2023, https://ratch.listedcompany.com/misc/PRESN/20230303-ratch-am-4q2022.pdf.

[389] Information provided by RATCH, November 2023.

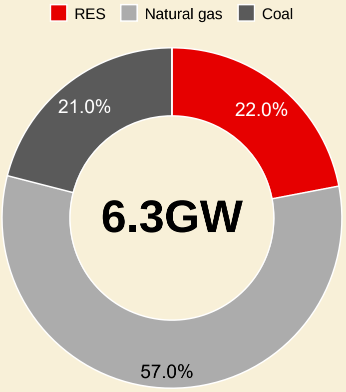
[390] Information provided by RATCH, November 2023.

Spotlight on select power sector players

Company profile[391]

- **FY2022 revenue:** THB 67 billion (USD 1.9 billion)
- **Market share:** EGCO owns about 6% of Thailand's electricity generation capacity.

Total installed capacity of EGCO total capacity by generation type[392] (as of August 2023)



GHG emissions (2022)[393]

- **Scope 1:** 6.2 million tonnes of CO_2e
- **Scope 2:** 0.009 million tonnes of CO_2e
- **Scope 3:** 0.004 million tonnes of CO_2e

Carbon intensity (Scope 1): 0.25 ton of CO_2e per MWh

Shareholder information[394]

- EGAT: 25.4%
- TEPDIA Generating B.V. (Thailand): 24%
- Thai NVDR Company Limited (Trust account) (Thailand): 7.2%
- EGAT Saving and Credit Cooperative Limited (Thailand): 5.3%
- Social Security Office (Thailand): 4.4%
- Others: 33.9%

Goals and commitments[395]

- **2030:** Reduce carbon intensity by 10% compared to the 2020 baseline, and increase the share of renewable energy to 30% of the total capacity
- **2040:** Carbon neutrality
- **2050:** Net zero

Established in 1992, EGCO was the first major IPP in Thailand. The company and its subsidiaries generate and sell electricity to the public sector and industrial users in Thailand, as well as in Australia, Indonesia, Laos, the Philippines, South Korea, Taiwan, and the United States. EGCO focuses on developing power projects that have either long-term or short-term PPAs, both in Thailand and in other markets.

Decarbonization strategies[396]

EGCO's latest carbon neutral road map comprises three phases. In August 2023, the roadmap was revised to reflect an accelerated target of carbon neutrality by 2040 and net zero by 2050.

Phase one (Present-2030): Readiness building

- Reduce carbon emissions intensity by 10%
- Increase RE portfolio to 30%
- Engage in capacity-building and collaboration with potential partners to explore the Hydrogen value chain, hydrogen/ammonia co-firing and CCUS

Phase two (2030-2040): Carbon Neutral

- Expand green energy capacity
- Target 100% clean fuel
- Expand CCUS retrofit
- Seek opportunities in Hydrogen value chain
- Measure, offset and report

Phase three (2040-2050): Net Zero

- Expand green energy capacity
- Target 100% hydrogen fuel
- Achieve 100% CCUS retrofit
- Expand hydrogen value chain

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391 "Energy for sustainable future: Annual report 2022," EGCO, February 2023.

392 "Analyst Presentation, Q2/2023," EGCO, August 28, 2023.

393 "Performance Data 2019-2022," EGCO, accessed November 2, 2023, https://sustainability.egco.com/en/reporting-center/performance-data.

394 "Major shareholders," EGCO, as of March 15, 2023, https://investor.egco.com/misc/company_snapshot/20230531-egco-company-snapshot-3m2023-en.pdf.

395 "Energy for sustainable future: Annual report 2022," EGCO, February 2023.

396 "Climate Strategy and Market Opportunities Overview," EGCO, accessed November 2, 2023, Link.

Excerpts of decarbonization efforts[397]

EGCO's equity investment in APEX Clean Energy in the US is a core part of EGCO's Net Zero strategy. As of 2023, APEX has 242 renewables projects in development with a total of 53.8 GW of capacity.

In the medium- to long-term, EGCO plans to explore next generation power technologies, including the use of hydrogen. EGCO has ongoing studies with regard deploying hydrogen for low-carbon power generation, hydrogen supply chain related businesses, and the potential of its Boco Rock Wind Farm in Australia for green hydrogen purposes.

In 2023, EGCO also signed an MOU with JERA Asia Pte. Ltd., a subsidiary of Japanese power generation company JERA Co., Inc.[398] in Singapore, in shaping its carbon neutral road map with the inclusion of hydrogen, ammonia, and CCUS technologies. This also includes feasibility studies with regard ammonia co-firing in EGCO's BLCP plant and potentially other locations, and further studies on the potential for CCUS in Thailand.

EGCO decarbonization levers

RES: EGCO is pursuing new RES projects domestically and abroad. In 2022, EGCO took full ownership of Chaiyaphum Wind Farm and Theppana Wind Farm power plants in Chaiyaphum province and started commercial operations of the Nam Theun one hydropower plant in Laos.

Outside Southeast Asia, the company invested in APEX Clean Energy Holdings, a US renewables company, in 2021. In 2023, APEX had 242 clean energy projects in the pipeline totaling more than 53 GW spanning utility-scale wind, utility-scale solar, distributed energy, and standalone storage. In 2020, EGCO acquired a 25% stake in Yunlin Holdings, which is developing a 640 MW offshore wind project in Taiwan.[399]

CCUS: Given its sizeable portfolio of natural gas projects, as part of Phase one of its carbon neutral road map, EGCO had begun studying the potential for CCUS. EGCO signed an MOU with JERA Asia Pte. Ltd. in 2023 to study and explore opportunities to implement CCUS in Thailand. A Joint Study Agreement has been signed, and a feasibility study is planned to be carried out during the third and fourth quarters of 2023. The focus of the CCUS study will be centered on the Khanom four power plant from a technical perspective.[400]

Hydrogen and ammonia:[401] In 2023, EGCO signed an MOU with Bangkok Industrial Gas to study the potential deployment of power generated from hydrogen and fuel cells. In 2023, EGCO also signed an MOUs with Diamond Generating Asia, a wholly-owned subsidiary of Mitsubishi Corporation, to study the potential business opportunities across the hydrogen value chain and with JERA Asia Pte. Ltd. to conduct feasibility studies on ammonia and hydrogen co-firing.

Overseas, the company implemented a hydrogen blending initiative at Linden Cogen, a 172 MW natural gas-fueled thermal cogeneration plant in the US state of New Jersey. The initiative reduced overall annual CO_2 emissions by 10%. The company is also co-developing a 25 MW hydrogen fuel power plant with EGAT and Bloom Energy. In the Philippines, EGCO is partnering with DOOSAN to carry out feasibility study on ammonia co-firing, exploring the technical services for ammonia co-firing station at Quezon power plant.

Others: EGCO is also exploring opportunities in electric vehicles. EGCO conducted a joint study with EGAT and RATCH on the electric vehicles and charging stations in 2021. Electric vehicle ecosystems are a focus of the clean energy MOU the three companies signed with Saudi Arabia's Ministry of Investment.[402]

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[397] "Energy for sustainable future: Annual report 2022," EGCO, February 2023; "EGCO Group plans investment in the second half of 2023 - New goal set to achieve Net Zero by 2050," EGCO, August 2023; "EGCO banking on investment in Apex," Energy Central News, September 7, 2023, Link.

[398] "EGCO Group Joins Forces with JERA Asia to Develop Carbon Neutral Roadmap on the Usage of Hydrogen, Ammonia, and CCUS," EGCO, January 13, 2023, Link.

[399] "EGCO Group Completed Acquisition of 25% Stake in Taiwan's Offshore Wind Farm Project," ECGO, April 17, 2020, Link.

[400] "EGCO Group Joins Forces with JERA Asia to Develop Carbon Neutral Roadmap on the Usage of Hydrogen, Ammonia, and CCUS", EGCO, January 13, 2023, Link.

[401] "EGCO Group and BIG to study power generative from hydrogen and fuel cells aiming to support sustainable low-carbon society," EGCO, July 12, 2023; "EGCO Group Announces Successful Completion of Hydrogen Blending Commissioning at Linden Cogen Unit 6, USA," ECGO, June 26, 2023, Link; "EGCO Group, Quezon Power and Doosan to Jointly Study Ammonia Co-firing at Quezon Power Plant in Luzon," ECGO, February 6, 2023.

[402] "EGAT Group and Saudi Arabia's Ministry of Investment signs MOU on clean energy," EGAT, November 21, 2022, Link.

4.3. Bankability assessment matrix for Thailand

Thailand has a strong national imperative to decarbonize the power sector. Public and private sector actors have driven significant progress in moving towards this goal. Multiple decarbonization measures are available for the power sector, of which a subset is most applicable for Thailand given its unique power characteristics. To identify the underlying challenges and lay out potential unlocks to accelerate the transition, we assessed the announced decarbonization levers to identify the hurdles to building scale. In this section, we will provide an overview of the prioritized decarbonization levers and highlight the major challenges and potential solutions to each. In addition, we will offer a matrix across technical feasibility and commercial feasibility to gauge the scalability of these levers which we saw in Section 1.

4.3.1. Scope of decarbonization levers

In this analysis, core decarbonization levers are prioritized for assessment considering Thailand's natural endowment, current energy mix, public and private sector decarbonization targets, and required capital. Central investment themes identified were:

1) **Solar:** Among other RES, solar is projected to take the largest share of renewables growth because of a favorable natural endowment, accessible costs, and general ease of execution. Solar comprises the majority of the recent renewables FIT auctions. In 2022, 65% of the 5.2 GW quota was for solar, and for the 2023 auction, 72% is for solar.[403] Considering land constraints, EGAT is also evaluating significant investments in floating solar power.[404]

2) **Grid upgrade and battery storage:** Ensuring a robust grid infrastructure and energy storage systems are critical to maximize the potential of solar energy. Thailand's approach to energy storage has been to require energy storage alongside solar panels during FIT tenders. In 2023, the 1.0 GW of the total 4.9 GW FIT quota was allocated to solar farms with bundled energy storage. Initiatives are also underway to ensure the grid is sufficiently capable of handling and adjusting for energy volatility from renewables, such as through the opening of the REFC by EGAT in 2023.[405]

3) **Hydrogen co-firing, CCUS:** Under the 2018-2037 PDP, natural gas capacity is expected to remain relatively flat in the medium term. With plants remaining in operation, decarbonizing natural gas generation will be important. Thailand is exploring options to introduce hydrogen co-firing and eventually converting plants to fully hydrogen fueled as well as apply CCUS to natural gas-fired power plant.

We have excluded some options:

- **Other RES:** According to the 2018 PDP, solar will comprise 72% of total RES capacity additions from 2018 to 2037, with the remainder split across other renewable type. While the ERC has issued quotas for wind and biogas capacity in recent FIT auctions, overall renewables growth will still be primarily be driven by solar power. Hydropower in the PDP refers primarily to continued imports from Laos, which is beyond the country focus of this paper. Wind is also excluded because of low technical potential as projected by IEA.

- **Nuclear:** While nuclear power has been explored as a potential solution for Thailand, particularly the long-planned 20 MW nuclear facility in Nakhon Nayok, it remains uncertain whether the country will pursue nuclear projects at scale. Nuclear small modular reactors were contemplated for Thailand in 2022, with technology from the United States,[406] but execution hurdles exist, such as need for developing local talent, negative public perceptions, and regulatory readiness. Plans for nuclear capacity were included in old iterations of the national PDP but were removed in the 2018 version.[407]

- **MPO:** Thailand's fossil fuel-fired power plants are dominated by natural gas. Since natural gas is widely considered to be a transition technology because of its lower emission profile and its ability to support the introduction of variable RES, phasing out the young fleet of natural gas-fired power plants is unlikely to be the most economical route to decarbonization. Echoing this consideration, current power plans do not foresee the early phaseout of Thailand's fossil fuel-fired power plants.

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[403] "Huge renewable scheme up for auction," Bangkok Post, March 10, 2023, Link.

[404] "Annual Report 2022," EGAT, June 23, 2023.

[405] "EGAT opens Renewable Energy Forecast Center and Demand Response Control Center, to enhance stability of Thailand's power system and support clean energy trend," EGAT, August 24, 2023, https://www.egat.co.th/home/en/20230824e/.

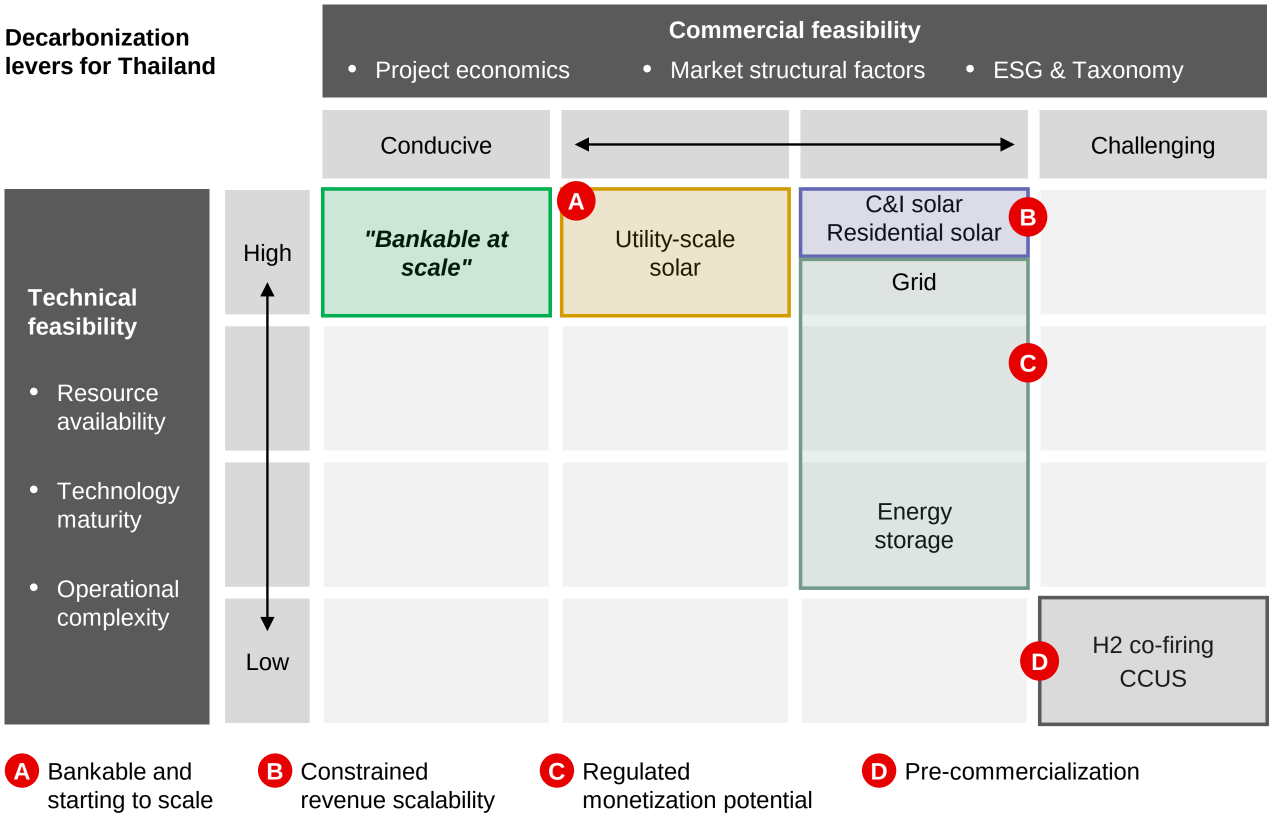
[406] "US to help Thailand develop small nuclear reactors," Bangkok Post, November 19, 2022, https://www.bangkokpost.com/thailand/general/2441459/us-to-help-thailand-develop-small-nuclear-reactors.

[407] "Thailand's Long and Bumpy Road to Nuclear Energy Adoption," Tita Sanglee, The Diplomat, March 22, 2023, https://thediplomat.com/2023/03/thailands-long-and-bumpy-road-to-nuclear-energy-adoption/.

4.3.2. Bankability assessment

For each decarbonization lever in Thailand, we applied our methodology to assess current bankability across commercial feasibility and technical feasibility. Based on our assessment, we see four key categories of decarbonization levers for Thailand: A) bankable and starting to scale, B) constrained revenue scalability, C) regulated monetization potential, and D) pre-commercialization (**Exhibit 78**).

Exhibit 78: Decarbonization lever assessment matrix – Thailand



Category A: Bankable and starting to scale

"Bankable and starting to scale" includes established measures with positive project economics, but expansion is constrained by market structural factors (such as grid constraints to absorb intermittency). In Thailand, this category focuses on utility-scale solar. Utility-scale solar power is a very mature technology that has achieved mainstream adaptation globally and in Thailand. Its prevalence is evidence of its bankability: In the 2022 renewables FIT auction, the 2.4 GW tender for on-ground solar farm projects and the 1 GW tender for on-ground solar with energy storage were all issued.[408] In addition, the auction was significantly oversubscribed, showing the desire of IPPs to participate.

However, well-paced development of utility-scale solar project is important as the intermittency brought about from RES generation must be carefully managed by investing in smart grid upgrades at the same time.

Category B: Constrained revenue scalability

"Constrained revenue scalability" consists of decentralized mature levers that have less attractive project economics and market structural factors. This includes captive C&I solar and residential solar, which are commonly referred to as Independent Power Supply (IPS) in Thailand. Although the technology is mature, expansion in Thailand is constrained primarily due to concerns around the grid stability caused by decentralized RES intermittency and bi-directional flow of power. This physical constraint is managed under regulations over C&I and residential solar projects. For example, a 10~15% ceiling on captive solar capacity is imposed. This cap limits the energy cost savings potential and can be perceived as unfavorable by investors.

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408 "Huge renewable scheme up for auction," Bangkok Post, March 10, 2023, Link.

The price formula applied to the excess electricity sold back to the grid can potentially also reduce the appeal of investment. For residential customers, Thailand allows customers to sell back to the grid at a rate of THB 2.20 (USD 0.06) per kWh,[409] a meaningful discount to the retail electricity rates, which can range from THB 2.35 to 5.80 (USD 0.07 to 0.16) per kWh for residential customers.[410]

Category C: Regulated monetization potential

"Regulated monetization potential" includes established levers with structural constraints to generating profit because electricity tariffs are regulated, and it is difficult to pass costs on to customers. Such measures include grid upgrade and energy storage to accommodate greater levels of power supply variability, a factor in expanded RES, which generate power at different levels depending on time of the day and weather.

The government has offered clear direction and planning for a national grid upgrade to ease not only the transition to RES, but also the introduction of electric vehicles. In 2021, the Thai government announced 17 grid projects requiring funding of at least THB 240 billion (USD 6.7 billion) over the next decade.[411] But passing these costs on to customers could be difficult as energy cost affordability must be preserved as a protection to the vulnerable population as well as maintaining the economic competitiveness of energy intense industries, particularly when the overall economy is experiencing downturn.

Energy storage is a less mature technology with few available projects, especially on a large scale. Without a clear market structure that rewards flexibility contributions, for example AS, the revenue potential of energy storage projects is reduced. These projects only earn income through the electricity they supply to the grid, often requiring pairing with renewable power plants, which limits the project scope, size, and contribution.

Category D: Pre-commercialization

"Pre-commercialization" represents nascent technology that have not been technically proven at scale and also face commercial challenges, particularly CCUS and hydrogen co-firing for Thailand.

Hydrogen co-firing is challenging from a technological and execution standpoint. Multiple strategic issues have yet to be resolved surrounding feedstock supply chains, the required retrofits to existing natural gas-fired assets, the necessary transport and storage infrastructure, and the significant volumes required. Green hydrogen is many times more expensive than natural gas to produce, and a significant supply is not yet available.

While carbon capture technology has been used for decades in the oil and gas industry, case studies of retrofitting CCUS in natural gas-fired power generation is only starting to emerge (IEA assigns TRL of eight indicating commercial demonstration stage). Operational challenges such as the transport of captured GHG and its sequestration, often in depleted gas fields, are still being addressed for the Thai market. Even were these challenges resolved, very high capital expenses associated with CCUS, coupled with the absence of meaningful carbon pricing, make the technology economically challenging.

Securing financing for technologies that are still maturing is also a potential challenge. Traditional financiers prefer proven technologies with lower risks and stable cash flows when providing capital, but nascent technology require capital before reaching that status. Expanding the deployment of decarbonization measures depends on continued technology maturity, as well as improved project economics as capital and operating expenses fall and carbon pricing develops further. Yet early financing must be provided for pilot testing and small-scale projects to allow for larger projects to follow.

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[409] "Government puts household 'net energy metering' plan on hold," Pattaya Mail, July 13, 2023, https://www.pattayamail.com/thailandnews/government-puts-household-net-energy-metering-plan-on-hold-435833.

[410] "Utility Costs," Thailand Board of Investment, June 30, 2023, Link.

[411] "Thailand launches 10-year 240 billion baht power grid investment plan," Seetao, August 19, 2021, https://www.seetao.com/details/105229.html.

4.4. Decarbonization lever deep dive

With reference to the bankability matrix, our analysis explored in depth the challenges and potential solutions for each priority decarbonization levers to provide a more holistic and detailed view on the Thailand market.

4.4.1. Utility-scale solar

Category A: Bankable and starting to scale

Exhibit 79: Summary of challenges and unlock ideas, utility-scale solar in Thailand

Ratings: 1 2 3 4 ⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	N/A	N/A	
Commercial feasibility	2	**Market structural factors** • Grid constraint to absorb the intermittency requires paced growth	• **Coordinate grid and RES development** through integrated planning • **Stimulating RES demand from companies** with willingness to pay green premium to support grid upgrade project cash flow	EP F

As proved by the fact that FIT tender has been significantly oversubscribed, utility-scale solar exhibits favorable technical and commercial feasibility. The main constraint to achieving rollout at scale is the grid's ability to absorb the intermittency from solar generation. Investments in smart-grid upgrades and grid expansion must proceed hand-in-hand with the expansion in utility-scale solar capacity.

4.4.1.1. Lever description and overview

Description

Utility-scale solar refers to a large scale (often defined as larger than 1 MW) solar power plants. Unlike C&I solar projects that supply power directly to corporate organizations and industrial plants, utility-scale solar projects are built primarily to serve utility companies to generate electricity to the power grid.

Growth potential

Thailand has untapped potential for solar energy. IRENA estimates that the country possesses 3.5 terawatts (TW) of solar potential.[412] The solar irradiation potential is relatively higher in the northeastern and central regions. On the other hand, in 2020, Thailand had 2.8 GW of installed solar capacity,[413] mostly in ground-mounted systems. The annual grid-connected systems installation in 2020 was 144 MW. Rooftop solar panels for commercial users dominated the sector, with 127 MW of installed capacity. In addition, there were 13 MW of floating solar power systems and 3.7 MW of ground-mounted systems installed in 2020.[414] Because of potential land-use conflicts with agricultural areas, the country is increasingly adopting solar floating technologies in place of land-based solar.

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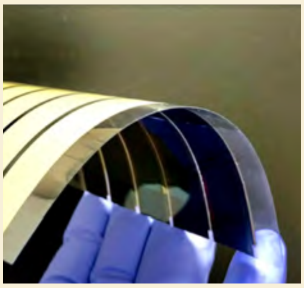
412 "Renewable energy outlook for ASEAN: Towards a regional energy transition (2nd edition)," IRENA, September 2022.
413 " Energy profile, Thailand," IRENA. Reached 3.0GW in 2022.
414 "National survey report of PV power applications in Thailand 2021," Photovoltaic Power Systems Programme, September 2022.

Exhibit 80: Solar potential in Thailand[415]

Sidebar: Emerging perovskite solar cell technology



Emerging technologies can potentially open alternative strategies for overcoming land-use constraints. For example, a potential solution is provided by film-type perovskite solar cells, which use a hybrid inorganic-organic material as the light harvesting active layer. Unlike rigid silicon panels, film-type perovskite cells can be made light and flexible, which enables installation on exterior walls of building and other places that are inaccessible for traditional silicon solar cells. However, this technology is still at a nascent stage (a technological readiness level around four to five),[416] and research effort is going to address hurdles such as the material's inherent instability in moisture.

Industrial players have already taken initiative to explore of opportunities presented by the film-type perovskite PV technology. For example, in 2023, Sekisui Chemical engaged in a joint study with Sekisui Jushi Corporation to pilot building-integrated perovskite installations, with a focus on ensuring the device's capability to withstand wind loads while retaining stable generation performance. In October 2023, this initiative culminated in Japan's first permanent installation of film-type perovskite solar cells on building's exterior walls at the Dojima Kanden Building, where the Osaka headquarters of both companies are located.[417] Meanwhile, companies spanning diverse sectors, such as Panasonic, Sharp, and Toyota, are delving into R&D projects for higher-efficiency perovskite cells, creating momentum for pushing this technology closer towards commercialization.[418]

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[415] Global Solar Atlas, Thailand, accessed November 2, 2023, https://globalsolaratlas.info/map.

[416] "ETP Clean Energy Technology Guide," IEA, last updated September 2023.

[417] "Japan's First Mounting of Perovskite Solar Cells on Exterior Walls of Building – Renovation of Osaka Head Office," SEKISUI CHEMICAL, October 5, 2023, Link.

[418] "Panasonic Holdings Corporation to Start the World's First* Long-term Implementation Demonstration Project for the Building Integrated Perovskite Photovoltaics Glass in the Fujisawa Sustainable Smart Town," Panasonic, August 31, 2023; "Sharp," accessed November 2023; "Enecoat, Toyota develop perovskite solar cells for vehicle-integrated applications," pv magazine, July 3, 2023.

Stakeholder initiatives

EGAT plans to increase solar capacity to about 15 GW by 2037.[419] Thailand has introduced an FIT scheme for renewables, under which, each type of renewable energy is allocated with a capacity addition quota. The quota for solar will range from 190 MW to 490 MW per year from 2024 to 2030 with a 25-year FIT of THB 2.17 (USD 0.06) per kWh).[420] Systems with combined solar and storage would have a quota of 100 MW per year from 2024 to 2027, increasing to 200 MW from 2028 to 2030. Solar is the largest quota share of 2022-2030 quota program, representing 3.4 GW of the total 4.8 GW. The 25-year FIT for these systems would be THB 2.83 (USD 0.08) per kWh. With quota limitations, only a few projects would be expected to come online each year.

Recent FIT tenders have been oversubscribed, attracting more interest than the capacity offered. In 2024, plans for eight projects - three small IPPs and five very small IPPs - have been commissioned, totaling 195 MW. In 2025, plans for 16 projects—five small IPPs and eleven very small IPPs—have been commissioned, with a combined capacity of 292 MW.[421]

The oversubscription of FIT quotas comes from lower costs for solar PV technology and widening profit margins in recent years. The LCOE for utility-scale solar projects in Thailand was reported to be THB 1.83 (USD 0.05) per kWh for 2022.[422] Compared to the FIT rate of THB 2.17 (USD 0.06) per kWh, this presents a sufficient profit margin for IPPs engaged in utility-scale solar projects.

The country also has ambitious plans to develop floating solar. EGAT expects to install 16 floating solar farms with 2.7 GW of combined capacity. The first floating solar farm, a 720,000 square-meter plant in Ubon Ratchathani, went into service in 2021.[423] SPCG and PEA ENCOM International Company, a subsidiary of PEA, are expected to secure state approval to build 23 solar farms in the Eastern Economic Corridor (EEC).[424]

4.4.1.2. Challenges and potential solutions

Grid constraints to absorb the intermittency requires paced growth [commercial feasibility – market structural factors]

A roadblock that affects utility-scale solar development is the ability of current power system to manage solar power intermittency. Although Thailand's generation fleet appears relatively flexible, considering the significant gas-fired power and moderate share of installed capacity of renewables (6% for domestic hydropower and 6% for solar PV in 2021).[425] However, to utilize the existing flexibility reserve efficiently, upgrading the grid system (through smart-grid development, for example) may be needed. Though Thailand currently boasts a robust grid infrastructure with a well-connected and reliable transmission network, digitalization through smart-grid application will enable better use of existing assets with more-granular control of both supply and demand. As the development of solar power plants advances further, the country may also need to expand the physical grid network to further develop the connection between high irradiation regions (such as the northeast) and the demand center (such as Bangkok). In doing so, Thailand can benefit from integrated grid-expansion planning, RES development, and the broader economy (for example, transportation, including EV infrastructure) to leverage the maximum potential of existing flexibility and minimize investment.

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[419] "Thailand enters an age of renewable energy production and sustainable manufacturing," Bangkok Bank Innohub, March 2, 2023, Link.

[420] "Thailand introduces FIT scheme for solar, storage," Beatriz Santos, PV Magazine, October 31, 2022, Link.

[421] "Announcement from the Energy Regulatory Commission, Commission regarding the list of applicants for electricity production that have been selected. According to the regulations of the Energy Regulatory commission concerning the procurement of electricity from renewable energy in the form of Feed-in Tariff (FiT) 1982-2030 for groups with no fuel costs, 2022," Energy Regulatory Commission of Thailand, April 2023.

[422] "APAC system value analysis Thailand 2022," World Economic Forum in collaboration with Accenture, September 2022.

[423] "Huge floating solar farm puts Thailand on track towards carbon neutrality," Euronews, March 11, 2022, https://www.euronews.com/green/2022/03/11/huge-floating-solar-farm-sets-thailand-on-track-towards-carbon-neutrality; Thailand planning massive floating solar power plants on hydropower dam reservoirs; https://www.renewableenergyworld.com/baseload/hydropower/thailand-planning-massive-floating-solar-power-plants-on-hydropower-dam-reservoirs/#gref.

[424] "SPCG set to win approval for 23 solar farms in EEC," Yuthana Praiwan, Bangkok Post, June 13, 2022, https://www.bangkokpost.com/business/2325243/spcg-set-to-win-approval-for-23-solar-farms-in-eec.

[425] "Partner Country Series – Thailand Renewable Grid Integration Assessment," IEA, October 2018.

Currently, EGAT is taking initiative in integrated planning, following the blueprint laid out in its reports Master plan for smart grid network system development in Thailand 2015-2036[426] and Grid modernization of TnD plan for 2018 to 2037.[427] To address the intermittency challenge, EGAT established the REFC in 2021, and the DRCC in 2023. Additionally, EGAT is visiting the innovative concept of using a virtual power plant as a control center, which would allow various types of renewable-energy power plants to be brought together to complement each other's stability. These ambitious innovations, however, call for long-term efforts to be realized through paced growth.

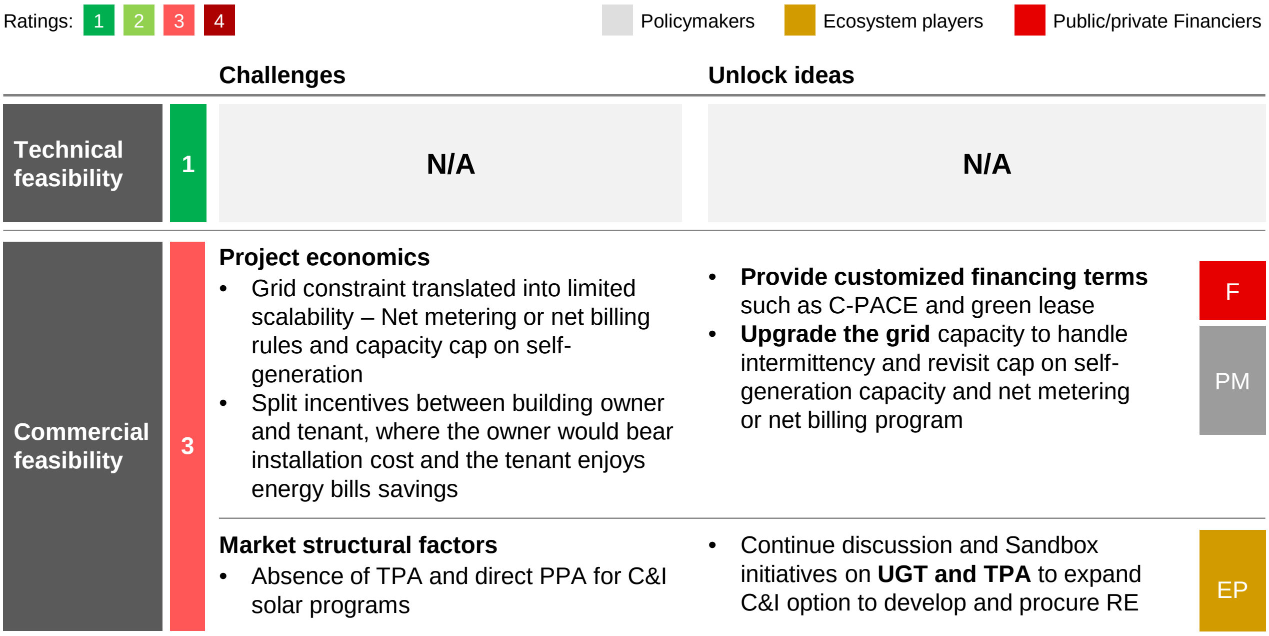
An additional challenge that naturally follows from the need for grid upgrades is difficulty with financing. Investments in grid upgrades are difficult due to the issue that cost cannot be easily passed on in these projects. Since this is an aspect that merits an in-depth discussion, we dedicate a separation section (4.4.4.) to address it in more detail.

To supplement a lack of cash flow for grid upgrade projects, one potential approach is stimulating RES demand from companies with a high willingness to pay green premiums. Specifically, this may call for the introduction of more-flexible contract mechanisms such as UGT or direct PPA. As highlighted in Section 4.2.2., UGT is already being piloted in Thailand, and EGAT is playing a significant role in helping facilitate the "Sandbox" pilot program for this pricing policy.[428]

4.4.2. Commercial and industrial solar

Category B: Constrained revenue scalability

Exhibit 81: Summary of challenges and unlock ideas, C&I solar in Thailand



Ratings: 1 2 3 4 | Policymakers | Ecosystem players | Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	N/A	N/A	
Commercial feasibility	3	**Project economics** • Grid constraint translated into limited scalability – Net metering or net billing rules and capacity cap on self-generation • Split incentives between building owner and tenant, where the owner would bear installation cost and the tenant enjoys energy bills savings	• **Provide customized financing terms** such as C-PACE and green lease • **Upgrade the grid** capacity to handle intermittency and revisit cap on self-generation capacity and net metering or net billing program	F PM
		Market structural factors • Absence of TPA and direct PPA for C&I solar programs	• Continue discussion and Sandbox initiatives on **UGT and TPA** to expand C&I option to develop and procure RE	EP

C&I solar power is technically feasible but faces commercial obstacles. Due to the concerns arising from the intermittency inherent to solar generation that is decentralized across multiple C&I locations, self-generation is capped and net metering or net billing programs for C&I segment are yet to be implemented. Therefore, the full monetization potential cannot be realized. Moreover, misalignment of interests between building owners and the tenants poses a challenge for faster expansion. Finally, without TPA and direct PPA scheme, the scalability of C&I solar project is physically confined within the land availability of the property.

To promote expansion of C&I solar power, investment into smart grid upgrade is required to enable net metering or net billing and increase the allowable capacity for self-generated solar energy. As being explored as potential change in market structure through the sandbox by EGAT, allowing more direct purchasing of renewables through UGT could open potential for growth. Meanwhile, financial institutions could also support by offering tailored financing solutions to address conflicting incentives.

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[426] "แผนแม่บทการพัฒนา ระบบโครงข่ายสมาร์ทกริดของประเทศไทย พ.ศ. 2558-2579 Thailand: Master plan for smart grid network system development in Thailand 2015-2036," Thailand Ministry of Energy, 2015, https://policy.asiapacificenergy.org/node/4348.

[427] "แผนปรับปรุงระบบส่งและระบบจำหน่าย ให้มีความทันสมัยรองรับเทคโนโลยีระบบไฟฟ้าในอนาคต (Grid Modernization of Transmission and Distribution," EGAT, Provincial Electricity Authority, Metropolitan Electricity Authority, May 20, 2020, Link.

[428] "WESTERN DIGITAL, EGAT, and INNOPOWER Join Forces to Pilot Green Energy Use under Thailand's Utility Green Tariff Initiative," EGAT, May 12, 2023, Link.

4.4.2.1. Lever description and overview

Description

C&I solar is a distributed solar solution where commercial and industrial customers procure power from a solar power plant outside of the general utility tariff (e.g., captive demand). C&I solar power applications would include those between 20 kW to 300 kW in capacity which could generate electricity sufficient for isolated facilities, such as office buildings, small food-processing plants, or electric vehicle charging stations. For needs greater than 300 kW, large numbers of rooftop and ground-mounted solar panels could provide power for, for example, manufacturing plants or large-scale data centers.

Growth potential

The current capacity of C&I solar power in Thailand is modest but there is investment potential due to the ample irradiation condition. In 2018, total installed capacity of C&I solar stood at slightly more than 80 MW, which was divided among 96 projects under MEA totaling 36 MW across and 73 projects under PEA with 47 MW. Most of these projects fall within the range of 250 kWp to 1 MWp. This capacity is still quite insignificant compared to the overall cumulative installed capacity of all types of solar power plants, which reached 3.1 GW by 2022.[429]

Stakeholder initiatives

The Thai government has not set specific targets for expansion of C&I solar power, but it has published a plan to bring all types of solar projects from the 2018 capacity of around 80 MW to 15 GW by 2037.

A few C&I businesses in Thailand have installed off-grid solar projects, for instance:

- Cleantech Solar and Osotspa Company signed a PPA in 2020 for a 3 MW solar rooftop project.[430]
- AMR Asia and Sacred Heart Group Schools signed a PPA in 2023 for a 2 MW solar rooftop project.[431]
- Molten Energy signed PPAs with Constant Energy and Shizen Energy in 2023 for a 999 kW solar rooftop project.[432]

4.4.2.2. Challenges and potential solutions

Grid constraint translated into limited scalability
[commercial feasibility – project economics]

The current TnD system in Thailand faces limitations to support decentralized C&I solar. Due to the concerns arising from the intermittency of solar generation, the capacity for self-generation is capped and the net metering or net billing program for C&I has not yet been implemented. For connections to distribution networks, PEA and MEA have set a ceiling of 15% of the distribution transformation's capacity to minimize the risk of interfering with power quality for other customers.[433]

Moreover, the current grid flexibility does not support a regulatory environment in which C&I users can participate in net metering or net billing. Net metering enables households or businesses to sell any surplus electricity, often generated through excess captive solar generation, back to the national grid at the retail rate. Net billing compensates at the lesser of the retail or wholesale rate, namely, to allow the power sector player to recover TnD costs. Without either a net metering or net billing program, potential revenue streams to the C&I customer are not generated beyond savings from direct consumption.

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[429] "Southeast Asia Solar Energy Market Size & Share Analysis - Growth Trends & Forecasts (2023 - 2028)," Mordor Intelligence, accessed November 2, 2023, https://www.mordorintelligence.com/industry-reports/southeast-asia-solar-energy-market.

[430] "Osotspa, Thailand's leading consumer products manufacturer and distributor, partners with Cleantech Solar to install rooftop PV systems to build sustainable future," Cleantech Solar, October 28, 2020, Link.

[431] "AMR จรดปากกาเซ็น PPA ไฟฟ้าโซลาร์รูฟท็อป '3 โรงเรียนพระหฤทัย' ขายไฟ 2 เมกะวัตต์ 20 ปี ชี้เป้าปี 66 มาแน่ 100 เมกะวัตต์ (AMR puts pen to paper and signs a PP)A for rooftop solar power at '3 Sacred Heart Schools', selling 2 megawatts of electricity for 20 years, with a 2023 target of 100 megawatts," AMR Asia, March 20, 2023, Link.

[432] "Shizen Energy and Constant Energy sign PPA with Molten Corporation subsidiary for 999kWp project," Shizen Energy Group, June 6, 2023, Link.

[433] "Renewable Energy Outlook: Thailand," IRENA, November 2017.

In 2023, MOE decided to postpone the rollout of a net metering program, providing three reasons for doing so:

1) **Regulatory issues:** Regulations prohibit households from offsetting excess electricity with suppliers, and tax base exemptions are needed to determine the value-added tax for these transactions.
2) **Technical considerations:** The variable nature of solar-generated electricity can create grid imbalances, posing risks of device damage and efficiency reduction. Transitioning to digital meters is also challenging.
3) **Economic considerations:** Electricity prices from utilities vary with fuel costs, placing financial burden on consumers because the added cost of purchasing solar power would be passed through the electricity tariff.

To effectively address these challenges, a series of incremental upgrades to the grid system is essential, as this is fundamentally the reason for current regulatory constraints (a more in-depth discussion on grid development can be found in Section 4.4.4). In parallel, regulators and distribution system operators (DSOs) could adopt a phased approach, progressively increasing capacity limits to facilitate the step-by-step integration of distributed solar energy into the grid. Concurrently, there is a pressing need for fresh regulatory guidelines that focus on open access and sustainable grid connections. Such guidelines could foster a deeper integration of renewable-energy-based distributed generation. It could be valuable to clearly define rules related to topics such as the allowable size of connections or wheeling, necessary equipment installations, and operational standards. These guidelines can provide a clear roadmap for industrial stakeholders, especially in a policy environment that is anticipating a rise in renewable-energy utilization through open access avenues as opposed to the single-buyer approach. Additionally, it might be prudent to consider equitable wheeling and connection charges, especially given the varied grid user profiles: traditional consumers buying from utilities, entities utilizing TPA for grid wheeling, and prosumers who generate and consume their own energy. As these users tap into the same grid infrastructure, there is a need for an equitable cost distribution. This might entail reasonable connection fees for prosumers, reflecting their balanced interaction with the grid.

Absence of TPA and direct PPA for C&I solar programs [commercial feasibility – market structural factors]

The single buyer model in Thailand limits customers' potential for project developments to either contract with EGAT, MEA, or PEA or build captive, off-grid solar plants. Building off-grid plants is further impacted by the C&I customer's own development capabilities, scalability, land and resource availability.

The current initiative led by EGAT and ERC on the UGT is one way to unlock C&I demand under the single buyer model. Under the ERC Phase two Sandbox, Western Digital and Nestle Thailand separately announced partnerships with EGAT and INNOPOWER to buy RES under the UGT scheme.[434] The scheme enables C&I customers to purchase renewables energy from a specific project by combining REC. When fully implemented, this will allow C&I customers to develop solar projects across the country and reclaim the energy produced for its own consumption.

To facilitate faster adoption of C&I solar, regulatory changes allowing TPA and direct PPAs can be explored to can unlock access to third party developers with C&I demand. This can be explored alongside required grid expansions and net metering or net billing programs, and referred in Section 5.3 on financial solutions observed in other markets.

Split incentive between owner and tenant hinders project economics [commercial feasibility – project economics]

In some cases, with separate building owners and tenants, incentives differ. The owners make the decision whether to install solar panels, but the tenants receive the direct financial benefits. Known as a split incentive, this mismatch dissuades owners from solar adoption and commonly requires financing mechanisms to shift installation costs to tenants. This, in turn, complicates financing contracts for rooftop solar on commercial properties, for the financing contracts are entered into by the owners, while the repayment is supported either by the tenants' monthly rent payments or other methods, such as property tax, depending on the specific

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[434] "WESTERN DIGITAL, EGAT, and INNOPOWER Join Forces to Pilot Green Energy Use under Thailand's Utility Green Tariff Initiative," EGAT, May 12, 2023, Link; "Nestlé, EGAT, and INNOPOWER join forces to pilot green energy use in food industry, aiming for proactive GHG emissions reduction," EGAT, February 8, 2023, Link.

financing terms. Also, the credit rating of building owners does not reflect the ability of the tenants to pay back the loans, complicating the borrowing process further.

Financial institutions could help unlock the complexity around capital availability by accelerating financing for C&I solar projects. Particularly by using innovative financing terms, financial institutions could address the split incentives. Some options could include C-PACE and green leases. C-PACE covers up to 100% of project costs at fixed interest rates with terms up to 25 years. This non-recourse financing is secured by the property and repaid via a special assessment on property taxes and is therefore transferable upon sale. The second solution, green leases, lays a foundation for the owner to recoup a portion of the utility savings from solar, in addition to the tax benefits and incentive income. Similar to existing cost-recovery clauses, green lease language details a path for landlords to be compensated for the utility savings that their asset provides to the tenant. In both solutions, the cost of installing rooftop solar systems is passed on from the owner to the tenant, so that the owner would have economic incentive to choose clean energy solutions.

4.4.3. Residential Solar

Category B: Constrained revenue scalability

Exhibit 82: Summary of challenges and unlock ideas, residential solar in Thailand

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	**N/A**	**N/A**	
Commercial feasibility	3	**Project economics** • Grid constraint translated into limited scalability – net metering or net billing rules and capacity cap on self-generation • Small ticket size and credit risk leading to limited project economics	• **Upgrade the grid capacity to handle intermittency** and revisit cap on self-generation capacity and net metering or net billing program • Financial institutions could **address credit risk by providing innovative lending products** such as monthly leases, PPA payments, or securitization	PM F

Residential solar technology is also well-established and faces similar challenge to C&I solar. Residential solar is held back by the absence of a net metering or net billing program and cap on self-generated solar energy, which keep homeowners from getting the full benefits of these systems. Furthermore, expanding residential solar projects are also slowed by the cost, which are beyond the budget of some customers, and hurdles to financing small-scale projects.

To fully unlock the potential of residential solar power, policymakers could accelerate the introduction of a net metering or net billing program in a controlled phase. EGAT and DSOs could also consider reviewing capacity constraints, taking into account improvements in grid capacity. In addition, IPPs could capture the opportunity to serve as integrated solution providers, offering end-to-end services to assist customers in overcoming financial constraints.

Financial institutions could also play a vital role by offering customized lending products that address the varying credit-risk profiles of residential solar customers.

4.4.3.1. Lever description and overview

Description

Residential solar energy systems are installed for personal consumption, and usually used by homeowners to lower electricity costs and shield themselves from retail tariff increases. Most systems are between 9 and 10 kWp.

Growth potential

Residential solar market in Thailand is starting to kick-off, largely because of cost reductions. In 2018, the country had a total installed capacity of 47 MWp, with 15 MWp distributed across 2,067 projects administered by MEA and 32 MWp dispersed among 3,894 projects under PEA.[435] These residential solar systems are developed by various independent providers such as K.G. Corporation and Solar PPM Co., Ltd.

Stakeholder initiatives

The government has set a modest target for expanding residential solar. The revised 2018 PDP includes a target of 50 MW of new residential rooftop solar by 2020, with a further increase to 250 MW by 2024.[436] The PDP projects RES taking a 35% share of the country's energy mix by 2037 without specifying what portion would come from distributed solar energy sources.[437]

4.4.3.2. Challenges and potential solutions

Net metering rules and capacity cap on self-generation affects project economics [commercial feasibility – project economics]

Similar to the case of C&I solar, development of residential solar is capped by the ability of the grid infrastructure to manage the intermittency and bi-directional flow of electricity. Practically, these conditions are translated into net metering rules and cap on self-generation which affects the economic viability of project. For one, fixed rates at which customer can sell electricity to the grid are about half the rates charged for electricity. Although quite uncommon in residential solar segment, systems larger than 10 kWp are prohibited from selling back to the grid, and any excess power from these large systems is wasted. In addition, 15% capacity limits in residential solar similar to those seen on C&I solar is imposed.

The financial feasibility of residential solar systems derives from either selling excess energy back to the grid for additional income or reducing energy bills through local generation. These conditions therefore reduce the potential savings gleaned from residential solar, loading to lower demand.

As with C&I solar, residential solar would benefit if net metering or net billing is implemented without electricity sales price cap and the capacity limit was raised. Such reforms would have to weigh the burdens on the TnD grid. A phased approach could help mitigate these issues.

Small ticket size and credit risk leading to limited project economics [commercial feasibility – project economics]

Residential solar projects in Thailand also face the similar commercial feasibility challenges as seen globally. Individual projects are small, which makes financing difficult, and credit histories and income levels among prospective adopters vary considerably, requiring innovative financing solutions.

Consolidating demand across several projects could be a strong tool for increasing the commercial feasibility of residential solar. Along with conventional loans, which tend to cover one project at a time, diversified financing options, such as securitization, could be offered. For instance, Krungsri (Bank of Ayudhaya) offers a loan called Home for Cash that lets borrowers use their home equity as collateral.[438]

Real estate developers could also be active in finding solutions. Already, some are selling homes with solar panels already installed. This approach improves the bankability of solar projects because they are essentially bundled with property itself, which tend to have higher profit margins. For instance, developer Sansiri is working with Huawei Technologies, ICBC (Thai) Leasing Co., and Ion Energy Corp. to offer low-interest loans for green homes through a "SOLAR to ZERO" campaign.[439]

However, existing solutions have limited scalability and do not address the challenges of small ticket size for those not buying a home or variable customer risk. To address these issues more generally, financial institutions could provide customized lending products to suit different end-users' credit histories. Some examples include a third-party owned model with repayment structured in the form of monthly leases or PPA

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[435] "Tracking the status of electricity production from the solar energy of Thailand," Department of Alternative Energy Development and Efficiency, July 2018, http://e-lib.dede.go.th/mm-data/BibA11561.pdf.

[436] "Sector overview," in Green Yellow Rooftop Solar Project: FAST Report, ADB, April 2021, https://www.adb.org/sites/default/files/linked-documents/53283-001-so.pdf.

[437] "Thailand launches net metering scheme for residential PV," pv magazine, May 24, 2019, Link.

[438] Information provided by Krungsri.

[439] "First in Thailand – 'Sansiri' partners with 'Huawei' launches 'SOLAR to ZERO' campaign," The Nation, August 18, 2023, https://www.nationthailand.com/pr-news/more/pr-news/40030311.

payments or securitization. More details on financial solutions observed in other markets are further explored in Section 5.3.

4.4.4. Grid upgrade and expansion

Category C: Regulated monetization potential

Exhibit 83: Summary of challenges and unlock ideas, grid upgrade and expansion in Thailand

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	1	**N/A**	**N/A**	
Commercial feasibility	3	**Project economics** - Hampered project economics due to increasing demand for CAPEX investment but difficulties to pass the cost onto electricity tariff - Grid projects generate no incremental revenue	- EGAT could explore **BOT (build-operate-transfer) or BLT (build-lease-transfer) models** where the financing is handled by third-party developers - **Offer** corporate-level sustainability-linked loans **to the TSO and DSOs** - **Inject** concessional capital to lower the cost of finance **and improve project economics**	EP F

Owing to the geography of Thailand, the technical feasibility of grid development is relatively straightforward. However, commercial feasibility challenges arise from EGAT, PEA and MEA relying on timing and setting of the retail electricity tariff to recover its TnD investment cost. Retail electricity tariff pass through has been particularly challenging in the recent years given the already high energy cost amidst the global rise in fuel price. While the careful balance between allocating sufficient budget for grid investment and maintaining affordability will be continuously reviewed by the government and the utilities, financiers could play a role by developing mechanism to provide low-cost financing options. These include blending with concessional capital such as MDBs or providing sustainability-linked loans to grid investment supporting RES installation.

4.4.4.1. Lever description and overview

Description

An electrical grid is a network of power lines and substations which enable the TnD of electricity power from producers to consumers. Aging grid infrastructure and increasing demand for electricity already necessitate regular expansion and upgrades to the grid. As the share of renewables in the energy mix increases and the renewables portfolio becomes more diverse, TnD network will need to cover a wider geographic area because renewable energy projects tend to require more land than conventional generation. RES projects must also be where the relevant natural resources - water, wind, or abundant sunlight - are, which means they are often in remote areas far from demand. The resulting regional mismatch between supply and demand will require grid expansion.

Growth potential

RES, especially solar and wind, are often intermittent sources with high variations in energy output within a single day, which puts a strain on the existing grid infrastructure. To accommodate this, Thailand's grid would need to be modernized. The expansion of the distributed solar energy sector, particularly if TPA and net metering rules are revisited, would also require network upgrades. To accommodate net metering or net billing, for instance, the grid would need to undergo technical upgrades to enable bi-directional electricity flows and manage peak demand from distributed solar sources.

Additionally, grid modernization would likely include components such as smart grid infrastructure that monitors electricity consumption in real time. Such system can enable distribution automation to efficiently manage the flow of electricity, and provide demand response to adjust electricity usage during peak demand.

Stakeholder initiatives

Thailand has two main blueprints related to grid improvements: the Master Plan for Smart Grid Network System Development in Thailand (2015-2036)[440] and the Grid Modernization of Transmission and Distribution Plan (2018-2037).[441] According to both, a smart grid could give Thailand greater energy security, improved reliability, higher power availability and efficiency, and a higher share of RES.

Three main improvement streams from these two plans are presented:

1) **Grid expansion to allow more renewables** - especially mini hydro and solar projects - into the power mix, as well as the development of a renewable energy forecast center and control center.[442]

2) **Grid upgrades** to improve system reliability, power quality, and energy efficiency. To accommodate RES variability and electric vehicles, system technology upgrades would cover areas including monitoring operations and integration of the data management system.

3) **Smart-grid initiatives** would help balance supply and demand from RES generation. Smart grids use advanced technological and digital capabilities to introduce distributed and bi-directional power balancing.

EGAT has run pilots of grid measures in recent years. In 2023, it opened the REFC and the DRCC to better capacity fluctuations common with RES.[443]

4.4.4.2. Challenges and potential solutions

Challenges to recover investment by increasing the electricity tariff
[commercial feasibility – project economics]

TnD projects in Thailand could have a challenging revenue case when transferring the cost to the customers through the electricity tariff is difficult during economic downturns. EGAT, MEA, and PEA make decisions on project development based on an investment plan that outlines fixed capital and operating expense budgets covering all generation, as well as TnD. On the other hand, these entities rely on revenue generated from the electricity tariff. They must make a decision carefully balancing the competing needs to implement necessary investment while maintaining the affordability of electricity tariff.

In order to equip the grid infrastructure with the capability to manage the intermittency from RES integration, additional investment is required. In fact, Thailand has recognized the benefits of grid modernization and developed The Thailand Smart Grid Development Master Plan 2015-2036 with a cumulative investment budget of THB 199 billion (USD 5.6 billion) for 2015-2036.[444] While smart grid investments have been growing, in the recent years, electricity tariff has not increased enough to be able to fully recover the cost, due to the pressing need for consumer protection following the COVID-19 pandemic as well as soaring price of LNG following the War in Ukraine.

As the public consultation on the three different options on electricity tariff opened by ERC in July 2023 suggests,[445] the government is continuously discussing options to update the electricity tariff balancing the needs for cost recovery and maintaining affordability. Beyond tariff increase, as a potential unlock, EGAT, MEA and PEA could explore different project development models with the private sector to reduce its financial burden from the increasing investment for TnD. Opportunities include the BOT and BLT models, which shift the responsibility of financing and construction to a private company, then transfer ownership back to the public utility once the contract expires. Third-party engagement models like BOT and BLT also open a possibility to minimize the overall cost by lowering the cost of capital by involving concessional capital, such as MDBs, more flexibly at project level.

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[440] "แผนแม่บทการพัฒนา ระบบโครงข่ายสมาร์ทกริดของประเทศไทย พ.ศ. 2558-2579 (Thailand: Master plan for smart grid network system development in Thailand 2015-2036)," Thailand Ministry of Energy, 2015, https://policy.asiapacificenergy.org/node/4348.

[441] "แผนปรับปรุงระบบส่งและระบบจำหน่าย ให้มีความทันสมัยรองรับเทคโนโลยีระบบไฟฟ้าในอนาคต (Grid Modernization of Transmission and Distribution)," EGAT, Provincial Electricity Authority, Metropolitan Electricity Authority, May 20, 2020, Link.

[442] "EGAT Grid Modernization เสถียรภาพพลังงานหมุนเวียนของไทย (EGAT Grid Modernization Thailand's renewable energy stability)," Committee on Energy, Thai Chamber of Commerce, September 9, 2022, Link.

[443] "Two new EGAT centres pave the way for grid modernization," The Nation, August 24, 2023.

[444] "แผนปรับปรุงระบบส่งและระบบจำหน่าย ให้มีความทันสมัยรองรับเทคโนโลยีระบบไฟฟ้าในอนาคต (Grid Modernization of Transmission and Distribution)," EGAT, Provincial Electricity Authority, Metropolitan Electricity Authority, May 20, 2020, Link.

[445] "ERC offers 3 tariff alternatives to deal with Egat's debt from subsidies," The Nation, July 07, 2023, https://www.nationthailand.com/thailand/general/40029169.

Another unlock could be for financial institutions to design corporate-level, sustainability-linked loans for the Transmission system operator (TSO) and DSOs. The latest ASEAN transition finance taxonomy has created green tiering for TnD investments.[446] Loans for grid infrastructure development for integrating RES could be structured to highlight the purpose of the funds, opening the door to green financing with favorable terms and potentially reducing the overall cost of capital for TSOs and DSOs.

Moreover, to supplement insufficient cash flow for grid upgrade projects, one of the potential approaches is through stimulating RES demand from companies with a high willingness to pay green premiums. Specifically, this calls for the introduction of more-flexible contract mechanisms such as UGT. As highlighted in Section 4.2.2., UGT is already being piloted in Thailand, and EGAT is playing a significant role in helping facilitate "sandbox" pilots for this pricing policy.

4.4.5. Energy storage

Category C: Regulated monetization potential

Exhibit 84: Summary of challenges and unlock ideas, energy storage in Thailand

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	3	**Technology maturity** • Large-scale or long-duration battery storage is still at pre-commercialization stage	• **Inject public finance into R&D** of large-scale or long-duration battery storage systems	F
Commercial feasibility	3	**Project economics** • Net metering or net billing rules and capacity cap on self-generation affects project economics • Restricted project cash flow for standalone storage projects • Potential of cost overruns because of operational complexity for pumped hydro projects	• **Increase the self-generation capacity limit** as overcapacity and the constraint on grid flexibility is resolved • **Financially reward flexibility services provided by storage projects** e.g., offer AS • Avoid cost overruns by **building local IPPs' capabilities** in front-end engineering	PM EP

Energy storage presents technical and commercial challenges. At a large scale, for instance for utility applications, the technology is still considered to be in the pre-commercialization phase. To hasten its development, the public sector could offer financing or participate in blended-financing initiatives to speed R&D efforts.

On the commercial side, lack of clear monetization potential stymied adoption of energy storage system. Without price differentiated market or AS, energy storage projects are difficult to ensure favorable cash flows as the project can only generate additional cashflow from increased utilization ratio of the combined RES capacity. Other regulated markets (e.g., Japan) opted for a tendering mechanism for AS to reward the flexible energy sources, which could be a reference for Thailand.

4.4.5.1. Lever description and overview

Description

Energy storage is a crucial solution to address the intermittency of RES. It enables balancing intra-day variability from renewables generation, providing a more consistent energy supply, and it also allows for bulk shifting of energy from renewables generation during the day to the night, addressing the issue of negative demand during periods of low generation.

Energy storage can also help optimize renewable energy capacity. By providing additional capacity in peak periods, energy storage reduces the need to overbuild renewables to meet peak demand, increasing the utilization rate of renewable plants and reducing electricity generation costs.

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[446] "ASEAN Taxonomy for Sustainable Finance Version 2," ASEAN Taxonomy Board, June 9, 2023, https://asean.org/wp-content/uploads/2023/03/ASEAN-Taxonomy-Version-2.pdf.

Energy storage can be thermal, such as heat/cold storage; mechanical, such as pumped hydro; chemical, such as BESS; or power-to-hydrogen conversion. Considering technology maturity, cost competitiveness, and functionality, BESS and pumped hydro are the most established and promising options.

Growth potential

In the 2022 LT-LEDs Thailand set a goal of achieving 68% RES share in the country's energy mix by 2040, with solar energy being identified as the primary source. As described above, meeting such ambition requires energy storage in the backbone of the power system. On the other hand, the country's existing capacity for battery storage is limited, creating large potential for expansion. EGAT operates three battery storage projects with a total capacity of 41 MW.[447] Whereas, pumped hydro posts a larger existing capacity, with EGAT running three sites totaling 1.5 GW.[448]

Stakeholder initiatives

Under the NEPC, the government plans to add an additional 1 GW utility-scale solar plus battery storage by 2030. EGAT is also planning to expand the current storage pipeline and is conducting a feasibility study to develop six projects.[449]

Expanding pumped hydro for storage has also been highlighted as part of Thailand's smart-grid plan for 2022 to 2031. EGAT is also building an 800 MW pumped-storage hydropower plant at Chulabhorn Dam in Chaiyaphum province.[450]

4.4.5.2. Challenges and potential solutions

Large-scale battery storage remains in pre-commercialization stage [technical feasibility – technology maturity]

Large-scale or long-duration BESS still face technology constraints. For example, increasing the energy density of batteries is crucial for storing more energy in a compact space, but materials and designs are still being explored to achieve appropriate densities. Also, critical materials, such as lithium and cobalt, have dubious availability.

Public finance or blended finance for energy storage R&D could accelerate the development of large-scale, long-duration battery storage technologies. Low-interest capital expense funding at a project level is another option. Local IPPs could also collaborate with leading foreign companies on R&D, creating a two-way exchange of knowledge, expertise, and experience.

Net metering or net billing rules and capacity cap on self-generation affects project economics [commercial feasibility – project economics]

The net metering rule and cap on self-generated solar capacity covered in Section 4.4.2 and 4.4.3 soften demand growth for small-scale battery storage systems. The cap on captive solar generation, for example, limits the size of solar systems, resulting in minimal surplus electricity generation that needs to be stored for later use. The absence of a net metering or net billing program discourages energy storage as a means to capture additional revenue. Without effective financial incentives to sell surplus energy back to the grid, a core benefit in C&I and residential solar, users are less likely to install energy storage systems.

As with C&I and residential solar, battery storage would benefit if net metering or net billing were implemented without electricity sales price cap and the capacity limit was raised. Such reforms would have to weigh the burdens on the TnD grid. A phased approach could help mitigate these issues.

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[447] "BESS battery energy storage system A new dimension in EGAT's electrical system management," Energy News Center, June 23, 2023, Link.

[448] "โรงไฟฟ้าพลังน้ำแบบสูบกลับ = ระบบกักเก็บพลังงานพลังงานสะอาดเสริมความมั่นคงระบบไฟฟ้า (Pumped hydroelectric power plant = Clean energy energy storage system to enhance the stability of the electrical system)," EGAT, March 15, 2023, https://www.egat.co.th/home/art-20230315/.

[449] "Feasibility study sought for Vajiralongkorn pumped-storage project in Thailand," International Journal on Hydropower & Dams, April 28, 2023, https://www.hydropower-dams.com/news/feasibility-study-sought-for-vajiralongkorn-pumped-storage-project-in-thailand/.

[450] "54th Anniversary of EGAT to accelerate green power generation, expand Hydro-floating Solar Hybrid, support investments, and drive Thai economy toward carbon-free society," EGAT, May 2, 2023, https://www.egat.co.th/home/en/20230502e-03/.

Restricted project cash flows for standalone BESS projects [commercial feasibility – project economics]

Standalone BESS projects designed to provide flexibility are also hindered in project economics. For TSO and DSOs, same challenge on limited investment budget observed in TnD grid is also observed. For IPPs, energy storage projects are difficult to establish sufficient revenue stream without a mechanism either allowing electricity arbitrage, where electricity is sold at high tariff rates and purchased at low rates in the wholesale market, or rewarding AS, where frequency control services are compensated through combination of capacity and generation payment.

As discussed in Section 4.4.4, careful balancing of investment needs and electricity tariff affordability is required. TSO and DSOs could also offer tenders for AS to reward energy storage solutions. In some other markets, TnD companies procure ancillary capability from third-party operators. The TnD company typically pays a fixed capacity payment for the contractor to reserve a certain capacity to assist when the TnD company needs to increase or decrease power supply. These tenders are usually divided among different products depending on capacity, expected ramp-up speed, and expected response speed, adjusted to different types of technologies such as natural gas-fired power plants, batteries, pumped storage, and demand response. For example, Japanese TSOs has offered AS tenders.

Potential of cost overruns because of operational complexity for pumped hydro projects [commercial feasibility – project economics]

Because of high capital expense needs and operational complexity, pumped hydro energy storage projects risk of cost overruns, especially from land acquisition costs, delays in obtaining permits and geo-technical engineering and construction.

Building better front-end engineering capabilities within local IPPs could reduce cost overruns by improving overall project execution and cost management. In addition, the public sector could inaugurate initiatives to build domestic capabilities, such as knowledge exchanges with international stakeholders.

4.4.6. Hydrogen co-firing

Category E: Pre-commercialization

Exhibit 85: Summary of challenges and unlock ideas, hydrogen co-firing in Thailand

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	4	**Operational complexity** • Production of green hydrogen is a nascent technology and its supply chain is yet to be developed	• **Continued feasibility studies** through pilot projects • Setting national hydrogen strategy • **Provide public finance support** for supply chain development or creation of **hydrogen hub**	EP PM
Commercial feasibility	4	**Project economics** • Green hydrogen is significantly more expensive than natural gas but does not produce additional revenue • Potential financing difficulties before commercialization at scale	• **Public finance support tailored to different stages** of technology and project development (e.g., grants for R&D, tax incentives, guarantee of loss for initial commercial projects)	F

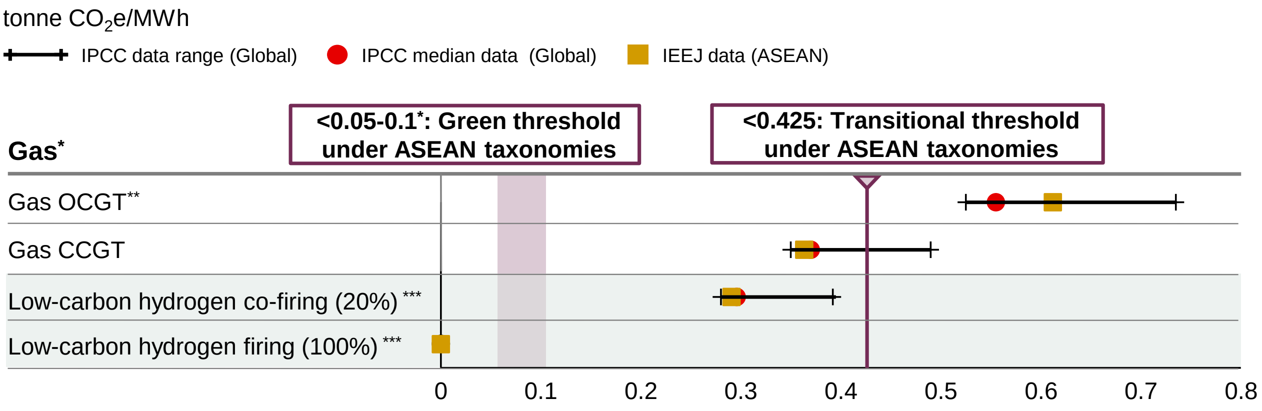
Hydrogen co-firing blends low-carbon hydrogen with natural gas combustion and can help decarbonize Thailand's power plants. Expanding hydrogen co-firing at this moment remains challenging because of high operational complexity and low commercial feasibility. Since hydrogen co-firing is a nascent technology, these challenges are likely to remain into the next decade as production capacity is built and capital expenses drop. Thailand could still prepare for the future deployment for hydrogen co-firing by gaining practical experience through pilots and feasibility studies, creating a conducive regulatory and policy regime, notably in carbon pricing, and setting a clean national strategy that provides clarity for energy companies and investors.

4.4.6.1. Lever description and overview

Description

Hydrogen is a versatile energy carrier with significant potential in many clean-energy applications. Among the properties that make hydrogen attractive: its energy density by weight is almost triple that of gasoline and, as a distinct element, hydrogen does not emit CO_2 during combustion. It is worth noting that the emission impact of hydrogen-co-firing can also depend on the different blending rate between the low carbon fuels and the fossil fuels. Additionally, the interpretation of those emission levels vary by country/region due to differences in taxonomy. For example, under the ASEAN taxonomy, 20% hydrogen co-firing is considered transitional but not green, while only 100% hydrogen fueled firing process can be considered green.

Exhibit 86: Estimated emission after co-combustion[451]



* Direct emissions for power generation only; other lifecycle emissions not included; IPCC data for 2018; IEEJ data for 2017.
** Emissions for OCGT are estimated based on CCGT emissions and the efficiency of OCGT over CCGT.
*** Emissions for co-firing of low-carbon fuels are estimated based on the co-firing ratios and the base emissions in respective Coal or Gas CCGT.

Along with reduced emissions, another advantage of hydrogen co-firing is the minimal retrofitting needed to add hydrogen into natural gas combustion at a power plant. Many natural gas turbines can readily accommodate hydrogen blending. The US Environmental Protection Agency has found that the most prevalent turbine models in operation can incorporate at least 30% hydrogen co-firing, with future models able to incorporate pure hydrogen combustion.[452]

Growth potential

Hydrogen-gas co-firing could serve Thailand's fleet of gas-fired power plants, which holds by far the highest share of contribution of electricity production in the country (64% in 2022). Hydrogen could be viewed as relatively economical compared to other low carbon co-firing feedstock (such as ammonia), due to its lower production cost and carrier-agonistic nature.

Stakeholder initiatives

Many companies in Thailand have announced plans to explore hydrogen production and co-firing. EGAT has plans to explore using green hydrogen in its Lamtakong Wind Turbine Project Phase two and expects to pilot 5% hydrogen co-firing between 2031 and 2040.[453] EGCO has completed hydrogen blending pilots at its Linden Cogeneration Unit 6 in the United States.[454] In 2023, EGCO signed an MOUs with Diamond Generating Asia, a wholly owned subsidiary of Mitsubishi Corporation, to study the potential business opportunities across the hydrogen value chain and with JERA Asia Pte. Ltd. to conduct feasibility studies on ammonia and hydrogen co-firing. One of the potential opportunities is green hydrogen production at EGCO's Boco Rock Wind Farm in Australia.[455]

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[451] "Annex III Technology-specific cost and performance parameters," IEEJ, IPCC, 2018.
[452] "Hydrogen in Combustion Turbine Electric Generating Units Technical Support Document," U.S. Environmental Protection Agency, 2023.
[453] "EGAT continues to develop hydrogen technologies and energy storage systems," EGAT, August 9, 2023, Link.
[454] "EGCO Group Announces Successful Completion of Hydrogen Blending Commissioning at Linden Cogen Unit 6, USA," ECGO, June 26, 2023, https://www.egco.com/en/news-update/2023/linden-h2-blending.
[455] "EGCO Group Joins Forces with DGA to Study and Develop Hydrogen Value-Chain Related Business and Renewable Energy in Australia," EGCO, July 20, 2023, https://www.egco.com/en/news-update/2023/egco-mou-dga.

4.4.6.2. Challenges and potential solutions

Nascent technology and supply chain [technical feasibility – operational complexity]

While hydrogen generates no CO_2 emissions during combustion, traditional production methods are energy-intensive and upstream emissions can offset benefits from hydrogen co-firing. To serve as a decarbonization lever, hydrogen need to be produced through low-carbon green methods. Green hydrogen is produced via electrolysis (a process that splits water into hydrogen and oxygen) in RES-powered facilities. However, this production method is still in a nascent stage, with a TRL around five to six.

Due to the technological nascency, the supply of green hydrogen and logistic infrastructure also awaits to be developed. Currently, strategic questions remain open in Thailand regarding the green hydrogen supply chain, such as whether to pursue large-scale domestic production or focus on a supply import infrastructure. Additionally, dedicated hydrogen transport systems are needed to connect prospective production sites with gas power plants. While hydrogen gas can be transported through existing natural gas infrastructure, multiple issues await to be addressed, including material embrittlement from the dissolution of hydrogen into pipelines, managing the potential of leaks during transport, and building more robust hydrogen compression technology. Different analyses suggest after a maximum mix of 12% to 20% hydrogen is reached during transport, major capital investment would be needed to upgrade pipelines.

Considering the technological nascency, pilot programs and feasibility studies could serve as a starting point for encouraging further development. Testing in a limited setting would help prepare for broader deployment, which meshes with early efforts in Thailand to explore potential domestic green hydrogen production. PTT Group is investing USD 7 billion in a partnership with Saudi Arabia ACWA Power for green hydrogen production[456]. Pilots can also help energy companies build operational experience, validate technological feasibility, assess the compatibilities of existing infrastructure, and gain a sense of the costs to expand.

Meanwhile, the development of supply chain can benefit from a clear national strategy or roadmap and public-finance support. A clear national strategy or roadmap can serve to signal demand and clarify government aspiration for hydrogen production and co-firing. This can in turn offer assurance and guidance for prospective investors, allowing them to make more informed decisions on hydrogen development. As a reference, in Japan the 2023 Hydrogen Strategy provides guidance on national plans to expand hydrogen efforts, including regulatory frameworks and subsidies to support growth.

High production costs with no incremental revenues [commercial feasibility - project economics]

Due to the technical feasibility challenge discussed above, green hydrogen exhibits significantly higher costs compared to fossil fuels. As the technology matures, green hydrogen has been forecasted to see a significant price drop in production cost. By 2030, the cost of green hydrogen is projected to decrease by as much as 50%, and it can potentially become lower than that of blue hydrogen by 2050. However, green hydrogen is unlikely to be cost-competitive with natural gas unless the carbon cost is factored in. Since co-firing hydrogen does not generate additional revenue on its own, mechanisms like public finance support (e.g., price differential compensation) or a carbon-pricing system can be needed for making the economics viable.

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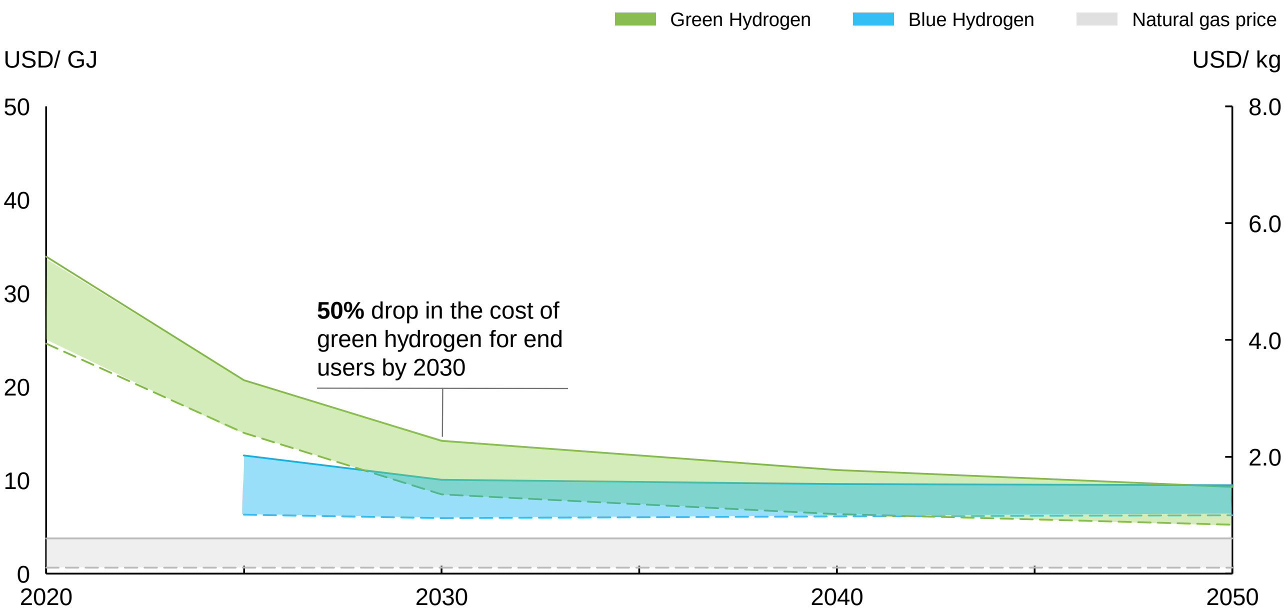
[456] “Japanese government will fund carbon-capture studies in Thailand,” Asia News Network July 7, 2023, Link.“Thailand's PTT to invest USD 7bn in green hydrogen with Saudi firm,” Apornrath Phoonphongphiphat, Nikkei Asia, April 11, 2023, Link.

Exhibit 87: Projected global production cost of hydrogen, compared with that of natural gas[457]

Price Forecast for Hydrogen



Project economics may improve through technology maturity and scale; however, commercial finance will encounter difficulties supporting projects in the early stages. Pipeline upgrades and new compression equipment, for example, are expensive, and difficulties in funding these capital expenditures could delay expansion. In other markets, different models of public-finance support targeting different stages of technological development have been explored to mobilize commercial finance. At the initial pre-commercialization phase, grants could be the viable option as R&D projects are not intended to generate positive cash flows. In Japan, the Green Innovation Fund was introduced in 2021, and it provides grants to early-stage technologies contributing to the green transformation. At the initial stage of commercialization, public-finance support has been leveraged to provide first-loss guarantees or bolster cash flows. For example, the Inflation Reduction Act in the United States provides tax incentives for hydrogen projects to improve commercial viability. In Japan, the government is considering providing support to close the gap between hydrogen and other conventional fuels.[458] Additionally, creating a hydrogen hub can also be beneficial as it enhances economic efficiency by physically bringing supply and demand facilities together. As an example, the US Department of Energy selected seven regional clean hydrogen hubs that will receive USD 7 billion of Bipartisan Infrastructure Law funding.[459]

At the private-sector level, long-term purchase commitments from off-takers could mitigate market risk. As an analogy, historically project financing for LNG projects has been supported by linking long-term take-or-pay contracts with off-takers such as power and gas companies.

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[457] "The clean hydrogen opportunity for hydrocarbon-rich countries," McKinsey, November 23, 2022, Link; The value shown for natural gas price is based on SDS 2030.

[458] "Overview of Basic Hydrogen Strategy," METI Japan, June 2023.

[459] "Biden-Harris Administration announces regional clean hydrogen hubs to drive clean Manufacturing and jobs," DoE, October 2023.

4.4.7. Carbon capture, utilization, and storage

Category E: Pre-commercialization

Exhibit 88: Summary of challenges and unlock ideas, CCUS in Thailand

Ratings: 1 2 3 4

⬜ Policymakers 🟨 Ecosystem players 🟥 Public/private Financiers

		Challenges	Unlock ideas	
Technical feasibility	4	**Operational complexity** • General knowledge and understanding of CCUS operations at scale still being developed • Transport and storage uncertainties, i.e., identifying storage sites require several years and trial and error; concerns regarding potential leaks	• **Build knowledge and capabilities early by continuing CCUS pilots** with CCUS technology providers to test technology feasibility and accumulate learnings, and **working with O&G players** to identify potential sinks, and potentially partner on O&G CCUS projects	EP
Commercial feasibility	4	**Project economics** • High cost to capture and store carbon, with limited opportunity to generate incremental revenue • Potential financing hurdles as financiers lack full understanding of project risks due to absence of precedent transactions	• **Develop carbon pricing** environment to enable economic feasibility by continuing plans to launch new carbon tax • **Public finance support tailored to different stages** of technology and project development (e.g., grants for R&D, tax incentives, guarantee of loss for initial commercial projects)	PM F
		Market structural factors • Regulatory ambiguity regard national strategy and lack of overarching legal framework	• **Provide regulatory** clarity by setting national CCUS strategy and implement legal framework for CCUS	PM

CCUS is another way to decarbonize Thailand's existing natural gas-fired fleet. Though deployed for decades in the oil and gas industry, CCUS is relatively new for power plants and faces operational challenges, questions around transport and storage feasibility, and the need for significant capital investment. With a power plant portfolio fueled largely by natural gas rather than coal, Thailand intends to retain its energy mix through the long term. This approach gives CCUS a greater priority, along with hydrogen co-firing, in decarbonizing the power sector.

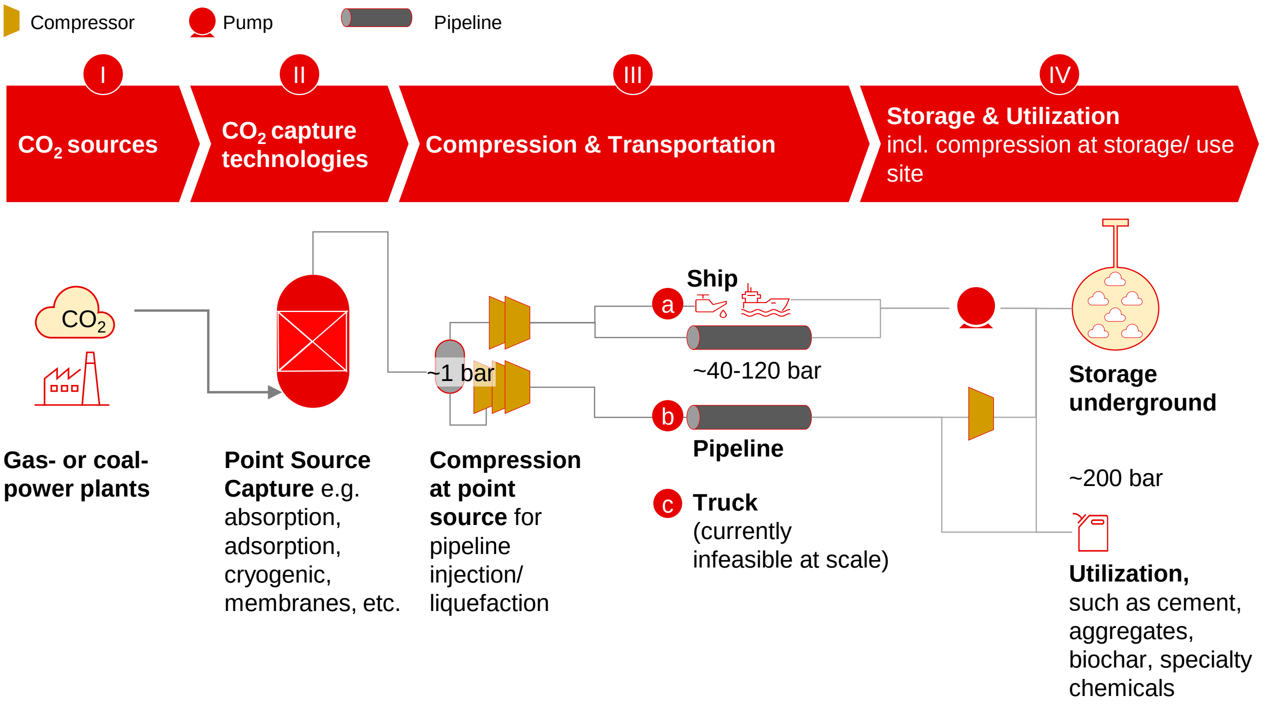
Thai energy companies could continue to gain practical knowledge through pilots and feasibility studies. Carbon pricing and other financial incentives, such as blended finance, could also help alleviate costs. And an overarching regulatory framework for CCUS would clarify responsibilities and accountabilities for CCUS project development.

4.4.7.1. Lever description and overview

Description

CCUS entails capturing carbon to prevent its release into the atmosphere, and the subsequent use or storage of this captured carbon. In power generation, CCUS begins with the combustion of coal or natural gas, which emit flue gasses containing CO_2 that would pass through carbon capture equipment – solvents, membranes, or other technologies – that would isolate the CO_2. The CO_2 is then compressed and transported for storage or use. Because of its efficacy in controlling CO_2 emissions, CCUS could decarbonize coal- and natural gas-fired power plants not slated for early phaseout.

Exhibit 89: CCUS process flow



Growth potential

CCUS can potentially play a role in decarbonizing Thailand’s fossil fuel plants, in particular the natural gas assets. Natural gas holds the largest share in Thailand’s energy mix, contributing to about 64% of electricity generation in 2022. Additionally, the country’s domestic gas fields can potentially serve as storage sites for the captured CO_2.

Stakeholder initiatives

In March 2023, 23 CCUS projects were underway in Thailand, comprising 10 feasibility studies and 13 pilots. Nine of these pilots centered on exploration and production, three on the power sector, and one on cement manufacturing.[460] For the power sector, the 2022 LT-LEDS mentions greater deployment by 2040. More specifics on the national strategy for CCUS are being crafted as further studies are conducted.

By 2023, PTT Exploration and Production, a subsidiary of PTT, had made the largest investments in CCUS. For example, it has allocated USD 300 million to develop Thailand's first CCUS facility at Arthit gas field[461] and is evaluating the CCUS hub model to offset investment by generating returns from nearby companies that want to store their carbon. Building broad national capabilities even outside power sector helps deployment, offering power producers an option to join CCUS hubs rather than building their own end-to-end infrastructure.

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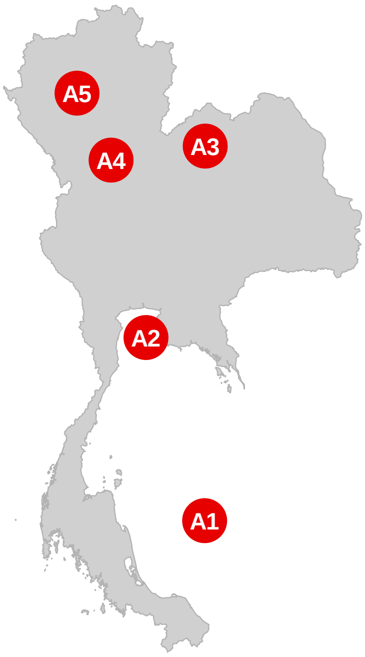
[460] “Thailand’s CCUS Policy and Development,” Ministry of Energy, Thailand, March 24, 2023, Link.

[461] “PTTEP allocates $300m for CCS facility,” Bangkok Post, July 22, 2022, Link.

Exhibit 90: CCUS pilot projects in Thailand as of 2023



A1 **1. CCS:** Arthit Project – PTTEP
2. CCS: A18 - MTJA

A2 **3. CCS:** North GOT CCS - DMF
4. CCU: Methanol Production – BLCP
5. CCU: Ammonia Co-firing – BLCP
6. Carbon Capture and Purification – PTT Group Industry

A3 **7. CCS:** Phu Horm Pilot Project – PTTEP
8. CCS: Nam Phong Power Plant - EGAT

A4 **9. CCS:** S1 Pilot Project - PTTEP
10. CCS: Syngas and Hydrocarbon Chemical - SCG

A5 **11. CCS:** Artificial Carbonate: Mae Moh Fired Power Plant – EGAT
12. CCS: Mae Moh Project
13. CCS: Lampang Project Coal – (DMF, EGAT, PTTEP and DED take in charge project No. 2 and 3)

4.4.7.2. Challenges and potential solutions

High cost to capture and store carbon with no incremental revenue [commercial feasibility – project economics]

The most significant challenge is the high capital requirements with no accompanying revenue streams to offset investments. Carbon capture technology has yet to achieve economies of scale. These systems are generally tailor-made for specific projects, and a workable modular that could be produced at scale has yet to be designed. A 2021 analysis estimated that retrofitting CCUS onto a 560 MW natural gas-fired power plant in the United States would cost between USD 399 million to USD 666 million or USD 34 to USD 155 per tonne of CO_2 captured (**Exhibit 91**). For comparison, carbon credits for a tonne of CO_2 in Thailand have averaged roughly THB 108 (USD 3).[462]

Exhibit 91: Required CAPEX for carbon capture technology

Facility type	**Reference plant size**	**Capacity Utilization, %**	**CO_2 Volume Captured** (tonne/year)	**Capital Cost Low-High** (USD millions)	**Unit Capital Cost 20-Year Life Low-High** (USD/tonne)
Coal Power plants	550 MW net	85	3,089,000	891-1485	33-55
		55	1,999,000		54-91
		85	1,272,000		89-149
Natural Gas Power plants	560 MW net	35	1,279,000	399-666	34-58
		85	827,000		57-95
		35	527,000		92-155

Because Thailand's energy mix is skewed towards natural gas, CCUS deployment would be more expensive than in country with heavier reliance on coal. This is because coal has higher CO_2 emissions than natural

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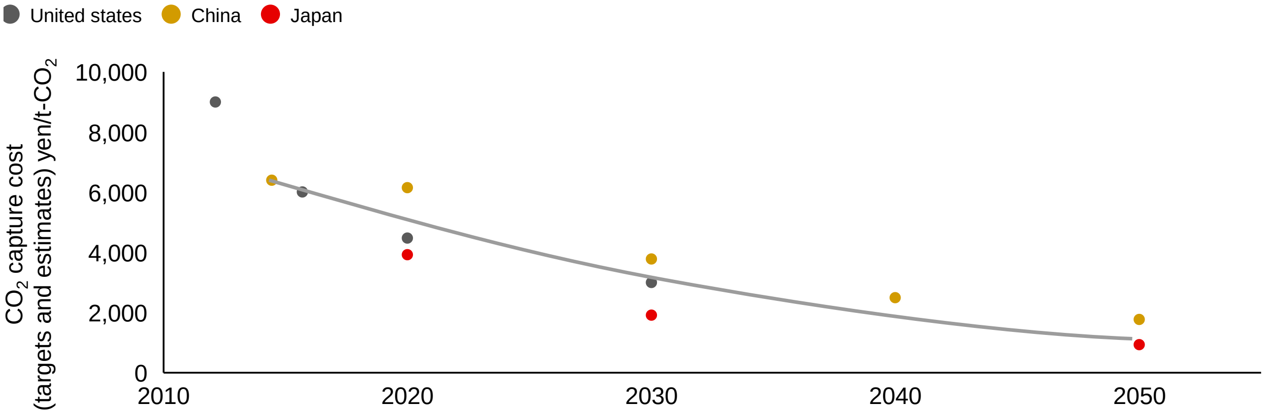
[462] "Carbon Credits for Sustainable Development," The Nation Thailand, March 31, 2023, Link.

gas, making CCUS more cost effective towards coal-fired power plants. One study estimated it would cost about USD 47 per tonne of CO_2e captured from coal emissions and USD 76 per tonne from natural gas power emissions. IEA has shown that CCUS costs have fallen and are expected to continue to do so. METI in Japan has forecast that CCUS costs will drop by roughly a third by 2050.

Exhibit 92: Carbon capture costs outlook 2010-2050[463]



The high CAPEX brings little to no opportunity to earn incremental revenue from the captured CO_2. Sequestration - storing captured CO_2 in depleted sinks, such as oil and gas wells or saline aquifers - is the primary way to store large volumes of captured CO_2, but has no revenue component.

Few commercially scalable uses for the captured CO_2 are available, undermining the value of CO_2 as a commodity. Potential uses may be found in construction materials and fuels, yet the cost of producing these products from CO_2 is generally too high to be considered commercially attractive.

To mitigate the cost of CCUS, Thailand could continue towards levying a carbon tax, which would create pressure to invest in decarbonization. Introducing carbon taxes could accelerate the development of CCUS by creating incentives in the medium to the long term.

Thailand's Board of Investment has granted petrochemical producers that implement CCUS technologies income tax exemptions for eight years,[464] and further incentives using government grants, import duty exemptions, tax deductions, and others could also be considered to push CCUS deployment in the power sector.

Execution uncertainties surrounding storage and transport [technical feasibility – operational complexity]

Thailand faces the same concerns as other countries around transporting and storing captured CO_2, including the risk of leaks and the difficulty in finding appropriate storage sites. Early studies in Thailand have identified a potential capacity to store 2.7 gigatonnes of CO_2 in depleted reservoirs in five areas: North Malay Basin, Kra Basin, West Kra Basin, Sinphuhorm and Namphong fields, and Phitsanulok Basin.[465] The feasibility of specific locations requires further study, including addressing questions on which transport modes--pipeline, land, or sea—would be appropriate.

Thai energy companies could expand their pilot programs to gather knowledge ahead of greater deployment of CCUS technologies, taking advantage of ongoing momentum. For example, the Japanese government has pledged THB 1.6 billion (USD 46.9 million) for CCUS studies in Thailand. CCUS pilots would allow companies gather operational expertise that can help them address risks early. Pilots also send positive signals that movement towards CCUS is underway. Power sector players could also work with oil and gas companies to identify potential transport and storage solutions and even form partnerships CCUS projects.

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[463] "What is CCUS technology?," Ministry of Economy, Trade and Industry (METI), accessed September 18, 2023. The data is based on materials first presented by the GI Promotion Council Working Group, Link.

[464] "Thailand BOI Approves Measures to Support Carbon Reduction," Bangkok Post, September 6, 2021, Link.

[465] "Thailand's CCUS Policy and Development," Ministry of Energy, Thailand, March 24, 2023, Link.

Potential financing hurdles for mainstream financiers [commercial feasibility – project economics]

As with other nascent technology, the first large projects face financing hurdles from traditional lenders that may not understand the technology or desire some precedent to be comfortable with these transactions. Financing is also hindered because CCUS projects are not coupled with revenue streams. Cost pressure from carbon taxes could also impact bankability and constrain financing.

Different models of public-finance support targeting different stages of technological development could help facilitate CCUS deployment. At the initial pre-commercialization phase, grants (such as the Green Innovation Fund introduced in Japan) could be a potential option, considering that R&D projects are not intended to generate positive cash flows. Upon reaching the initial stage of commercialization, public-finance support can potentially be leveraged to provide first-loss guarantees or bolster cash flows for CCUS projects.

Regulatory ambiguity surrounding national strategy and lack of overarching legal framework [commercial feasibility - market structural factors]

Although CCUS is mentioned in government plans, a complete national strategy for CCUS has yet to be published. Regulators are drafting a national strategy for CCUS that would help clarify plans to expand the technology and identify opportunities for private investors to participate.

In addition, no regulatory framework specifically for CCUS projects in Thailand has been announced. The deficiency creates ambiguity for project developers considering end-to-end project development, such as around long-term liabilities and responsibilities for any leakages, roles, and responsibilities for monitoring stored CO_2, standards and criteria for site selection and transport, and processes and requirements for securing necessary permits and approvals.

Thailand could continue to develop of a national strategy for CCUS to provide direction for ecosystem players and financiers. It could also implement a national legal framework providing additional clarity around definitions, roles and responsibilities, process and requirements, long-term liabilities, and other factors. Many countries have established CCUS regulatory frameworks, including Canada, Indonesia, the United Kingdom, and the United States. These efforts could be used as guides as Thailand crafts its own.

4.5. Summary

Thailand has made significant progress in guiding its energy sector towards a path to decarbonization, from setting more ambitious renewables targets to implementing systematic pilots of innovative power structures, such as the ERC Sandbox program. Thailand has also made efforts to stay ahead of the curve, exploring opportunities through early pilots and feasibility studies in nascent technology. National energy planning has also been pivotal, and Thailand is preparing to update its PDP. However, as with most transitioning economies in most markets, challenges remain in deploying core decarbonization measures broadly, requiring joint efforts from energy and financial regulators, as well as power sector players and financiers.

- **Policy enabler - Energy policymaker:** Thai energy policymakers have driven national planning to decarbonize the power sector and explored new clean energy solutions for power suppliers and power purchasers. Energy policymakers could continue these efforts across four main fronts. The first would be to continue to provide clarity on the national energy plan, coupled with the necessary regulatory frameworks. Apart from the PDP, national plans focused on nascent technology, such as CCUS and hydrogen, and regulatory frameworks governing these technologies could help prepare the country to quickly adopt these technologies as costs decline. Second, they could address operational constraints expanding RES, such as restrictions on captive demand. Third, energy policymakers could accelerate the pipeline of innovative pilots and ideas towards broad implementation. Given the large volume of new ideas being tested, regulators may need to ensure the successful ones make the transition from pilot to practice. Among the many initiatives, direct PPA and UGT could help hasten RES procurement.[466] And finally, public finance could continue be to a major catalyst to power sector decarbonization, including measures like tax incentives, direct

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[466] See Appendix 7.1 for case studies from other markets on direct PPA and TPA and auction mechanisms.

grants, and subsidies.[467] Public finance can help accelerate development of nascent technology, by supporting early pilots and feasibility studies and helping to expand their use.

- **Policy enabler - Financial regulator:** Financial regulators help create an enabling environment for project economics and fundraising by easing efforts such as green and transition financing. For example, the central bank could provide low-cost capital to banks to mobilize green financing at favorable rates.[468] Financial regulators could also continue to assess plans for a carbon tax in Thailand, which would improve project economics across all decarbonization levers.
- **Ecosystem enabler - Power sector players:** EGAT, MEA, and PEA, through their own operations and their partnerships and programs, have signaled strong support for decarbonizing the power sector. Alongside other power companies in Thailand, these three could continue to make progress towards their decarbonization targets. They could also play roles in shaping the broader Thai power sector. The possibilities include adjusting grid management operations to absorb greater distributed generation by revisiting restrictions on captive demand, supporting the implementation of direct PPA and TPA, and exploring ways to implement BOT and BLT schemes to attract a broader set of investors.
- **Ecosystem enabler – Power purchasers:** Purchasers could also play central roles in accelerating RES expansion. Through continued RES procurement, for instance by direct investment in power self-generation and RECs, as well as eventually direct PPAs and UGT, purchasers could support the financing needed to expand decarbonization measures.
- **Financing enabler:** For bankable opportunities within the decarbonization levers, financiers could continue to provide lending and other financial services. Financiers could also go beyond transitional financing and explore other solutions that could lower financing costs and improve project economics.[469] In particular, blended finance mechanisms involving foreign government and MDBs could provide low-cost funding to high-ticket projects with cash-flow constraints, such as grid upgrades, utility-scale energy storage, and CCUS.

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[467] See Appendix 7.2 for case studies on Japan's Green Innovation Fund.

[468] See Appendix 7.4 for a case study on Bank of Japan efforts.

[469] See Section 5.3 for a US case on aggregation and securitization of a distributed solar project.

5. MUFG's contribution to the power sector decarbonization

As we have described, decarbonizing the power sectors in Indonesia and Thailand would make a powerful contribution to net zero ambitions in those countries, Southeast Asia, and globally. But alongside its significant potential, challenges prevent widespread adoption. Although progress has been notable and innovations across public and private efforts are commendable, more is needed to mobilize financing through a concerted effort.

While financiers like MUFG play a critical role in funding efforts, their extensive industry network and sector expertise can be formidable in spurring action. MUFG aspires to support the transition not only as a financier, but also by engaging and connecting with different real economy players. This section describes solutions MUFG proposes to accelerate power sector decarbonization.

Beyond our existing business activities, including a suite of transition finance products,[470] customer engagement, and advisory work, we are targeting three efforts:

A) **Stimulate the Green Economy through demand orchestration:** Leverage MUFG's network and capabilities to stimulate real economy actions and enable the realization of decarbonization measures.

B) **Mobilize capital at scale through blended finance:** Provide blended finance solutions as an option for some decarbonization levers that are inherently non-bankable, including nascent technology and grid and storage infrastructure.

C) **Bring proven financing solutions to unlock additional value:** Provide financing solutions that could enhance the commercial feasibility of decarbonization measures.

Exhibit 93: Solutions pursued by MUFG enabled by existing business activities

A	B	C
Stimulate the Green Economy through demand orchestration	**Mobilize capital at scale through blended finance**	**Bring proven financing solutions to unlock additional value**
Renewable Energy Alliance and related ecosystem to stimulate demand for RES development at scale	**Blended finance platform** focusing on near bankable projects, including non-commercial technologies and emerging markets	**Bring financing and securitization solutions** that have been successful in other regions to unlock additional value and improve bankability for all stakeholders in Asia

Provide our suite of Green and Transition Finance Products

Customer engagement to support their transitions

5.1. Stimulate the Green Economy through demand orchestration: Renewable Energy Alliance (REAL)

MUFG can leverage its broad client network and knowledge of the power markets gained through its vast deal portfolio to help overcome broader structural issues that prevent accelerated power sector decarbonization. Across the range of RES sourcing options, excluding captive power, companies in Indonesia and Thailand currently have access to RECs today. However, RECs are not perceived as a firm commitment because they can be bought only as need arises without establishing any long-term purchasing agreement. More direct sourcing with clearer element of additionality is currently being explored but not fully implemented (e.g., Thai's Utility Green Tariff Sandbox and PLN's contract with Amazon[471]) in these two countries today.

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[470] "MUFG Sustainability Report 2022," Mitsubishi UFJ Financial Group. September 2022.

[471] "To supply Amazon's needs, PLN builds four PLTS with a total capacity of 210 MW (Pasok Kebutuhan Amazon, PLN Bangun Empat PLTS Berkapasitas Total 210 MW)," Dunia Energi, November 14, 2022, https://www.dunia-energi.com/pasok-kebutuhan-amazon-pln-bangun-empat-plts-berkapasitas-total-210-mw/.

As such, market structures still provide limited opportunities for users to provide demand signals into supply investment decisions, which, when positive, could lead to new renewables generation.

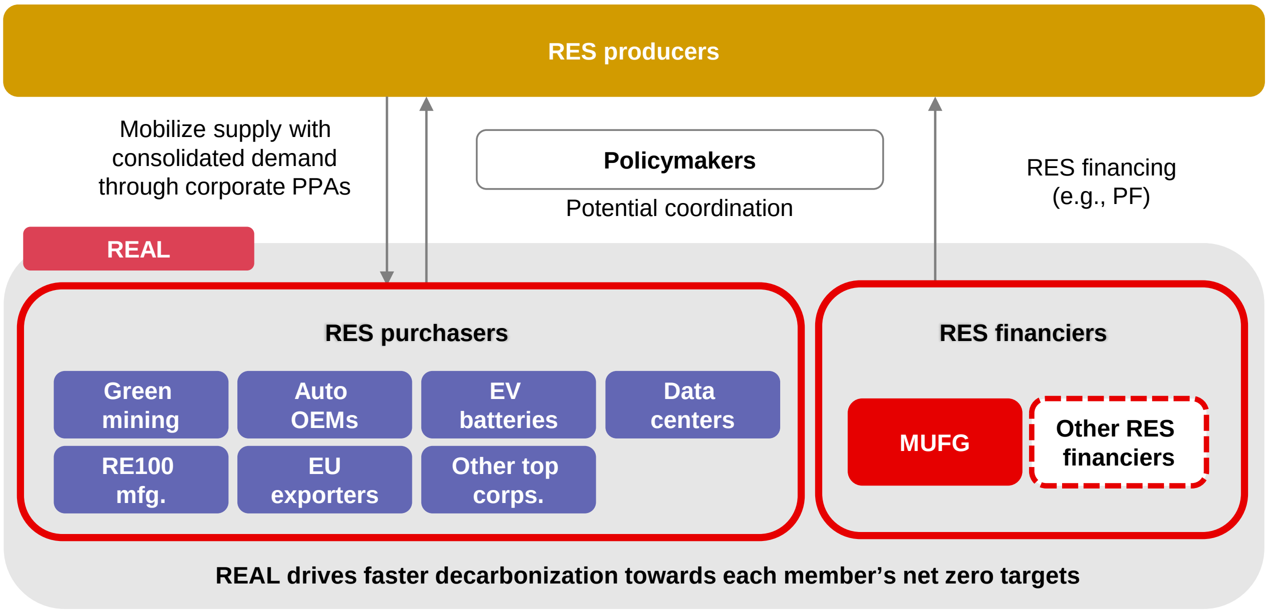
MUFG is keen to explore the viability of high-quality sourcing such as corporate PPAs while supporting RES investments by producers. One way is through an initiative that consolidates renewables demand and champions more direct procurement structures that could help accelerate new RES supply.

5.1.1. Concept summary

REAL, an initiative being explored by MUFG, strives to accelerate the development of new sources of renewable energy in Indonesia and Thailand, two of the bank's core markets in Southeast Asia.

Members of the initiative would be corporations that have set commitments for decarbonization and firmly intend to deliver on those commitments but are constrained by inadequate supply channels. As a global financial institution with broad sector expertise from an industry-leading track record of closing landmark project finance deals in energy, alongside deep ties from its client network across Asia, including Indonesia and Thailand, MUFG can support REAL by connecting demand for renewables to energy providers – power utilities – and potentially supporting financing for new renewables development (**Exhibit 94**).

Exhibit 94: REAL concept ecosystem (Illustrative)



5.1.2. Value proposition

REAL strives to bring new renewable energy into the grid faster by addressing some of the challenges we have identified. REAL can improve project certainty by signaling offtake volume and price from prospective buyers. It can also help discover the true magnitude of demand for renewables, as well as customer willingness to pay potential for green price premiums.

REAL aims to expand RES use even amid the overcapacity in the market. One approach would be to expand electricity demand by inviting new industrial facilities and accelerating development of an environment for competitive RES procurement. Even for existing electricity demand in the country, REAL can facilitate more secured replacement with retiring fossil fuel power plants or support the retirement through additional revenue from green premium.

For renewables purchasers, REAL can offer several benefits. It can help companies accelerate their RES efforts by potentially increasing options for procuring renewables. Additionally, REAL could serve as a unified platform to promote policy discussions on renewable procurement options, such as RECs and corporate PPAs. And finally, REAL can serve as a platform for companies to signal firm commitments to RES and reinforce their credibility as an advocate for RES in partnership with multinational organizations.

5.1.3. Potential participants

Four groups of companies could be candidates to participate in this initiative:

1) **Companies part of RE100 with manufacturing sites in Indonesia and/or Thailand:** Companies with factories in Thailand and/or Indonesia that are part of the RE100 initiative that have pledged to move towards using RES exclusively. As of 2022, RE100 lists 113 member companies in Thailand, which collectively consumed 1.8 TWh of electricity in 2022, but procured only 439 GWh from RES, and 96 members in Indonesia, which consumed 1.5 TWh of electricity in 2022, but only procured only 432 GWh from RES.[472] Such procurement gaps highlight unmet demand in these two markets.
2) **Companies in sectors affected by Carbon Border Adjustment Mechanism (CBAM):**[473] Companies that export to the European Union and are affected by CBAM. The new CBAM rules impose charges on imported goods based on their carbon content, providing an incentive to decarbonize operations for companies that export goods to the bloc in the sectors covered by CBAM. Global companies with supply chain spanning across countries could be affected. For example, steel manufacturer with export to EU.
3) **Companies in sectors where customers have high willingness to pay green premiums:** Manufacturers and producers across a range of industries with a distinct and valuable customer segment that is willing to pay premium prices for environmentally friendly offerings, such as companies that produce materials used in clean energy technologies, high-end electrical appliances, and green-conscious furniture.
4) **Companies among the largest in the countries with firm sustainability commitments:** Top local corporations in Thailand and Indonesia that have set their own decarbonization aspirations.

REAL can have meaningful impact in the power sectors in Indonesia and Thailand, and MUFG will continue to engage with the stakeholders to implement this idea.

5.2. Mobilize capital at scale through blended finance

Blended finance is gaining traction as a solution to mobilize commercial capital and reset the risk-reward balance in decarbonization projects to increase the likelihood they will be efficiently financed. In addition to sophisticated transactional work, structured around public sector credit enhancement instruments, MUFG proposes to develop an innovative blended finance platform taking a portfolio approach combined with securitization solution. The proposed scheme aims to upscale the impact of blended finance by orienting the origination process through a portfolio approach as well as expanding the investor base to secondary market through securitization.

5.2.1. Blended finance as a solution

Blended finance enables public and philanthropic capital to play a catalytic role in the mobilization of commercial finance in developmental- and climate-relevant projects. Convergence, a global network for blended finance under WEF and the Organization for Economic Co-operation and Development (OECD), defines blended finance as a structuring approach that allows organizations with different objectives to invest alongside each other while achieving their own objectives, for instance financial return, social impact, or a blend of both.

Convergence also defines four archetypes for blended finance:

1) **Concessional capital:** Public or philanthropic investors provide funds on below-market terms within the capital structure to lower the overall cost of capital or to provide an additional layer of protection to private investors.
2) **Guarantee/risk insurance:** Public or philanthropic investors provide credit enhancement through guarantees or insurance on below-market terms.
3) **Technical assistance funds:** A grant-funded facility can be utilized pre- or post-investment to strengthen commercial viability and development impact.

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[472] "RE100 annual disclosure report 2022," RE100, January 2023, Link.

[473] "Carbon Border Adjustment Mechanism," European Commission. https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en.

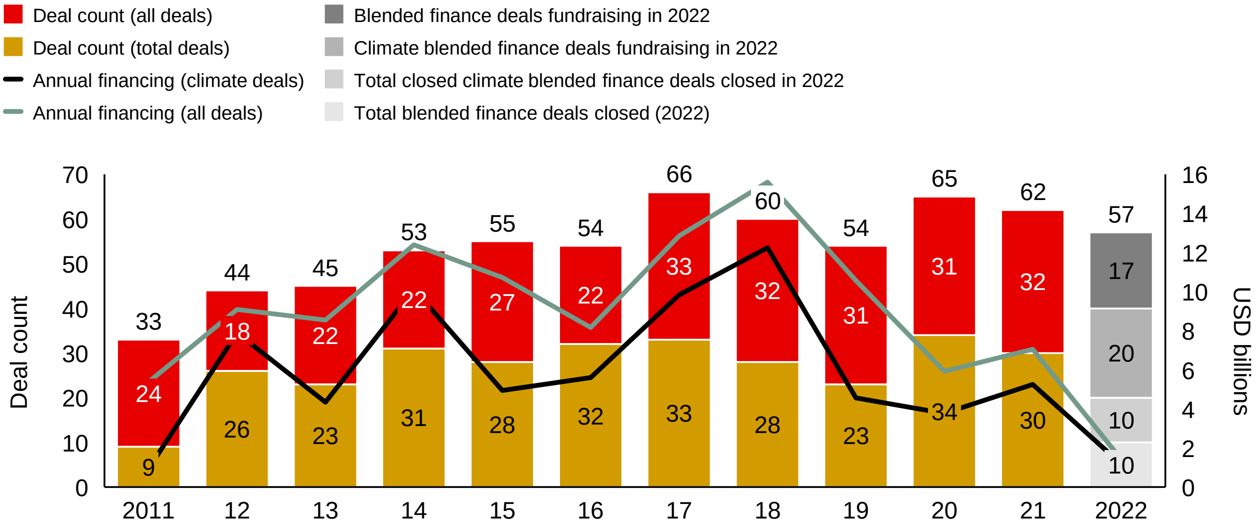
4) **Design-stage grants:** Transaction design in preparation for grant funding.

The main investment barriers for private investors addressed by blended finance are the high perceived and real risks and poor returns for the risk relative to comparable investments. If this risk-return balance can be reset to address the requirements of commercial capital, it can create investable opportunities, in particular in developing countries, that can accelerate development impact.

5.2.2. Current state of blended finance

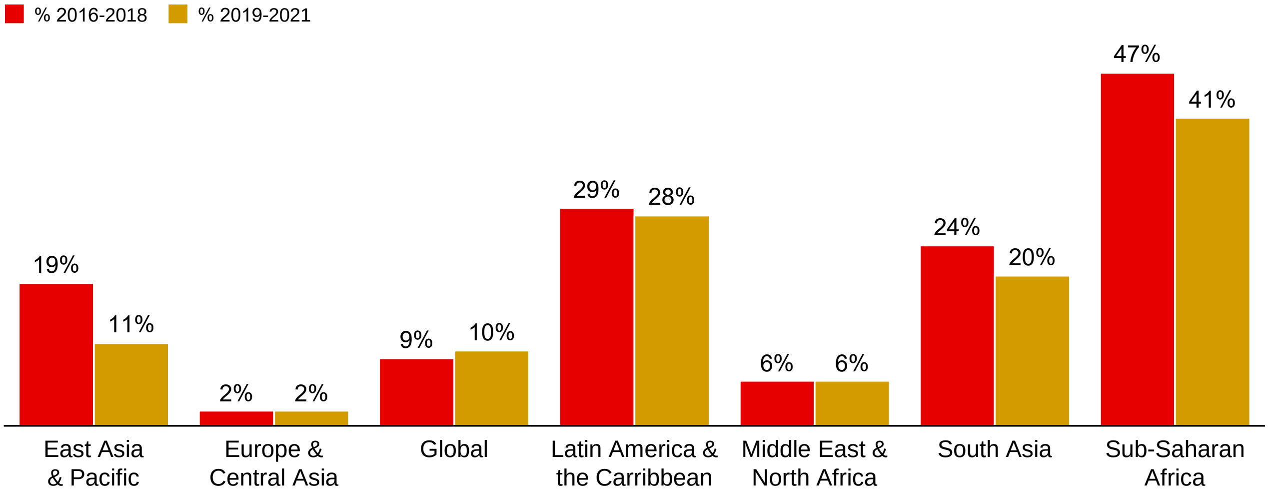
Convergence has reported that from 2011 to 2022, the blended finance market completed 56 deals a year on average, totaling an average of USD 11 billion in financing a year.

Exhibit 95: Overall blended climate finance market relative to the overall market (2011-September 2022)[474]



Blended finance has been concentrated in Sub-Saharan Africa, Latin America, and the Caribbean, and the geographic spread has not changed significantly since 2016.

Exhibit 96: Proportion of climate blended finance deals by regional breakdown, 2016-2021[475]



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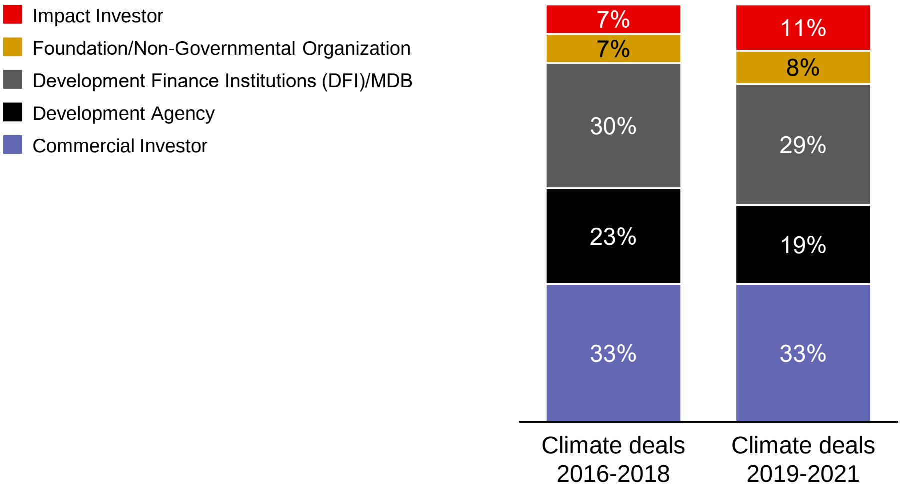
[474] "The State of Blended Finance 2022: Climate Edition," Convergence Blended Finance, 2022, Link.
[475] Ibid.

Aggregate financing levels in the climate blended finance market have declined in recent years, with the exception of adaptation blended finance. Between 2019 and 2021, USD 14 billion was invested into blended climate transactions, compared to USD 37 billion between 2016 and 2018, softening partly because of the COVID-19 pandemic. Convergence conducted a survey to its membership in its 2022 report on blended finance to understand the barriers to more strategic participation in climate blended finance deals – leading barrier identified was the lack of bankable investment opportunities with appropriate risk-adjusted returns (65% of responses), followed by a lack of coherent and standardized taxonomy on low-carbon and green investing (31% of responses), the lack of tools to measure and report climate impact (27% of responses), and liquidity constraints in emerging markets (27% of responses).[476]

Other hurdles to expand blended finance participation include: agile and scalable project formation, operational and administrative complexity that can exacerbate implementation challenges,[477] limited outreach to a broader set of investor-types,[478] and inadequate data, information, and common frameworks and understandings.[479]

Investor commitments have remained steady from 2016 to 2021, with the largest proportion of investments coming from commercial investors.

Exhibit 97: Proportion of commitments to climate blended finance deals by investor type, 2016-2021[480]



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[476] "The State of Blended Finance 2022: Climate Edition," Convergence Blended Finance, 2022, Link.

[477] Implementation and capacity challenges can impede blended finance flows reaching scale in developing countries. Implementation challenges can include administrative burden to negotiate right structure, including contract terms and conditions, and lengthy negotiation timelines; risk and return sharing across stakeholders and sectors; knowledge and talent base to select and risk-manage transactions.

[478] Risk and return of a blended finance project is currently customer designed taking factors such as nature of the project economics, component of different investors (e.g., concessional vs, commercial) and the negotiation among stakeholders. Hence, typically a blended finance project can only attract specific type of investors that matches the specific risk-return profile limiting the ability to source capital from diverse set of investors.

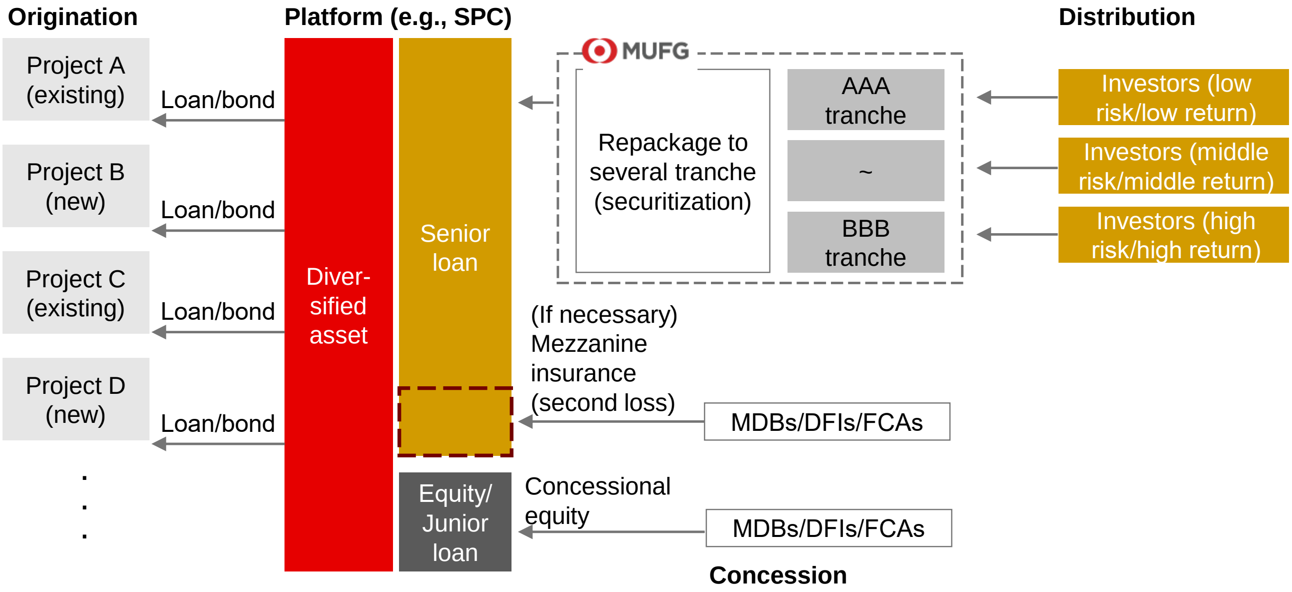
[479] Data and information: Availability and transparency of data and information, including on project pipelines and via common reporting standards, related to blended finance transactions. One impact of the lack of transparency is its limiting visibility on funding supply, thereby creating a potential artificial imbalance between funding demand and funding supply. Frameworks and common understandings: Blended finance policy and practitioner frameworks, e.g., around quantification of risk hurdles, measurability and verifiability of benefit and impact of transactions, and demonstration of additionality – supported by consistent standards and their implementation – on how developing countries can engage more effectively in attracting, deploying and scaling blended finance.

[480] "The State of Blended Finance 2022: Climate Edition," Convergence Blended Finance, 2022, Link.

5.2.3. MUFG's proposed blended finance platform

To facilitate the uptake of blended finance, MUFG proposes a portfolio approach using a blended finance platform vehicle combined with securitization capabilities. This approach and vehicle would address common challenges observed in blended finance, such as agile and scalable project formation and expanded outreach to a broad set of investors in the secondary market.

Exhibit 98: Blended Finance Platform Mechanism



The platform will be composed of concessional equity or junior loan provided by MDBs, DFIs, FCAs combined with senior loan by private sector capital such as MUFG. By incorporating concessional capital to credit enhance the vehicle, the platform will enable the creation of a pool of investable assets through the reduction of project and country risk, and lowering the cost of financing relative to pure market opportunities.

The proposed platform incorporates two features: portfolio structure and securitization. Firstly, the pooled capital will be invested into a set of near-bankable projects that meet pre-determined criteria and investment themes. This is different to a project-based approach where the transaction is structured at a single project level. The portfolio approach is advantageous as it does not require hefty structuring negotiation among multiple stakeholders every time a project arises, which has been a common challenge to implement blended finance deals. The portfolio approach also enables risk diversification for private investors.

Secondly, through the platform, MUFG will also provide a securitization solution where MUFG's own share of senior loan is repackaged to several tranches with differing risk-return profile and distributed to different types of investors. This approach will broaden the approachable investor pool by enabling the platform to access the investors active in the secondary market.

5.2.4. MUFG's unique position today

MUFG continues to be a recognized, leading player deeply engaged in blended finance.[481] Despite a decline in the amount of financing from commercial banks into climate blended finance from 2016 to 2021, MUFG is the most frequent commercial investor in climate blended finance by number of commitments during this period, primarily through project finance.[482]

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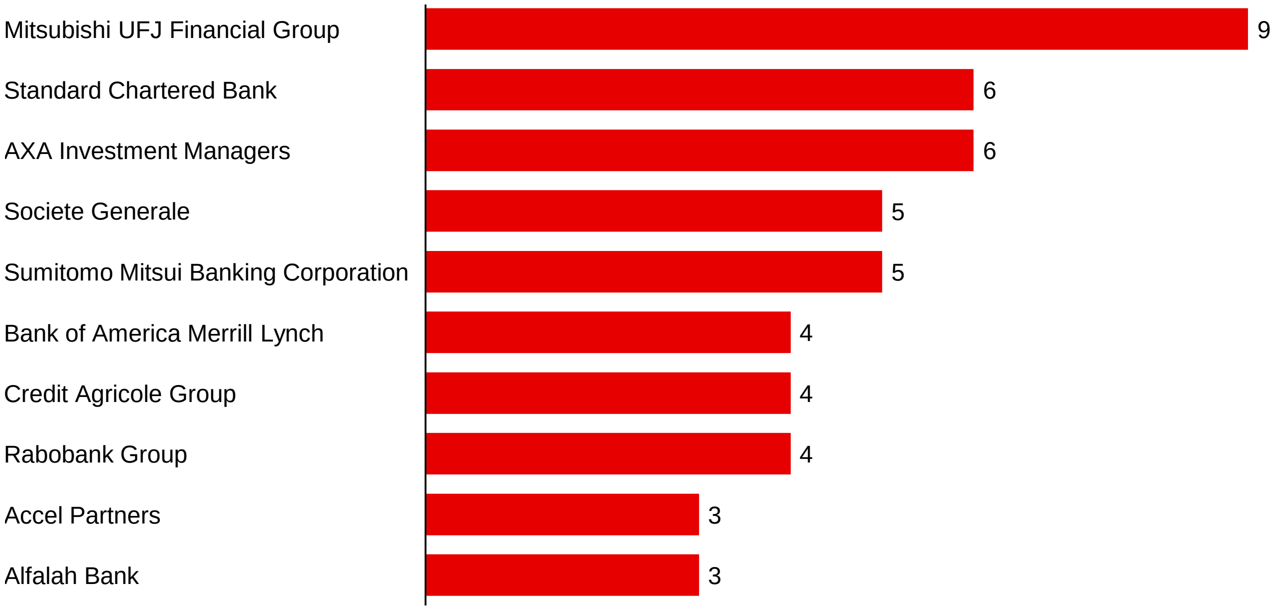
[481] "Convergence memberships," Convergence Blended Finance, accessed November 2, 2023, Link.
[482] "The State of Blended Finance 2022: Climate Edition," Convergence Blended Finance, 2022, Link.

Exhibit 99: Most frequent commercial investors in climate blended finance by number of commitments, 2016-2021[483]



As an example, in 2023, MUFG and Nippon Export and Investment Insurance Co. (NEXI) announced a partnership to promote blended finance for decarbonization in Asia. The MOU confirmed an agreement to cooperate in the establishment of a financing scheme using blended finance to make possible an effective energy transition approach in Asia. Other initiatives consistent with objectives of the Japanese government-led Asia Zero Emission Community (AZEC) and Asia Energy Transition Initiative (AETI) have also been considered.

MUFG will continue to use its partner bank network – Bank of Ayudhya (Krungsri) in Thailand, Bank Danamon in Indonesia, Security Bank Corporation in the Philippines, and Vietin Bank in Vietnam – to advance its sustainability agenda. Examples of sustainability efforts from these partners include Krungsri's decarbonization pledge aligned with Thailand's COP26 Carbon Neutrality declaration and its recent USD 400 million green and blue bond issuance.

5.2.5. MUFG initiative GAIA

Purpose of GAIA

MUFG is already leading the implementation of an innovative blended finance platform, GAIA, which is a quasi-sovereign debt platform to finance both climate adaption and mitigation projects in selected emerging markets. By combining public and private capital, GAIA will deliver scalable climate finance to high impact and demonstratable efficacy projects at a market clearing financial return.

Structure of GAIA

GAIA is structured as a Limited Partnership and its capital structure is drawn from the typical blended finance archetype that have been deployed globally. The concessional capital is provided in form of equity and whilst the commercial capital comes in the form of Senior Debt.

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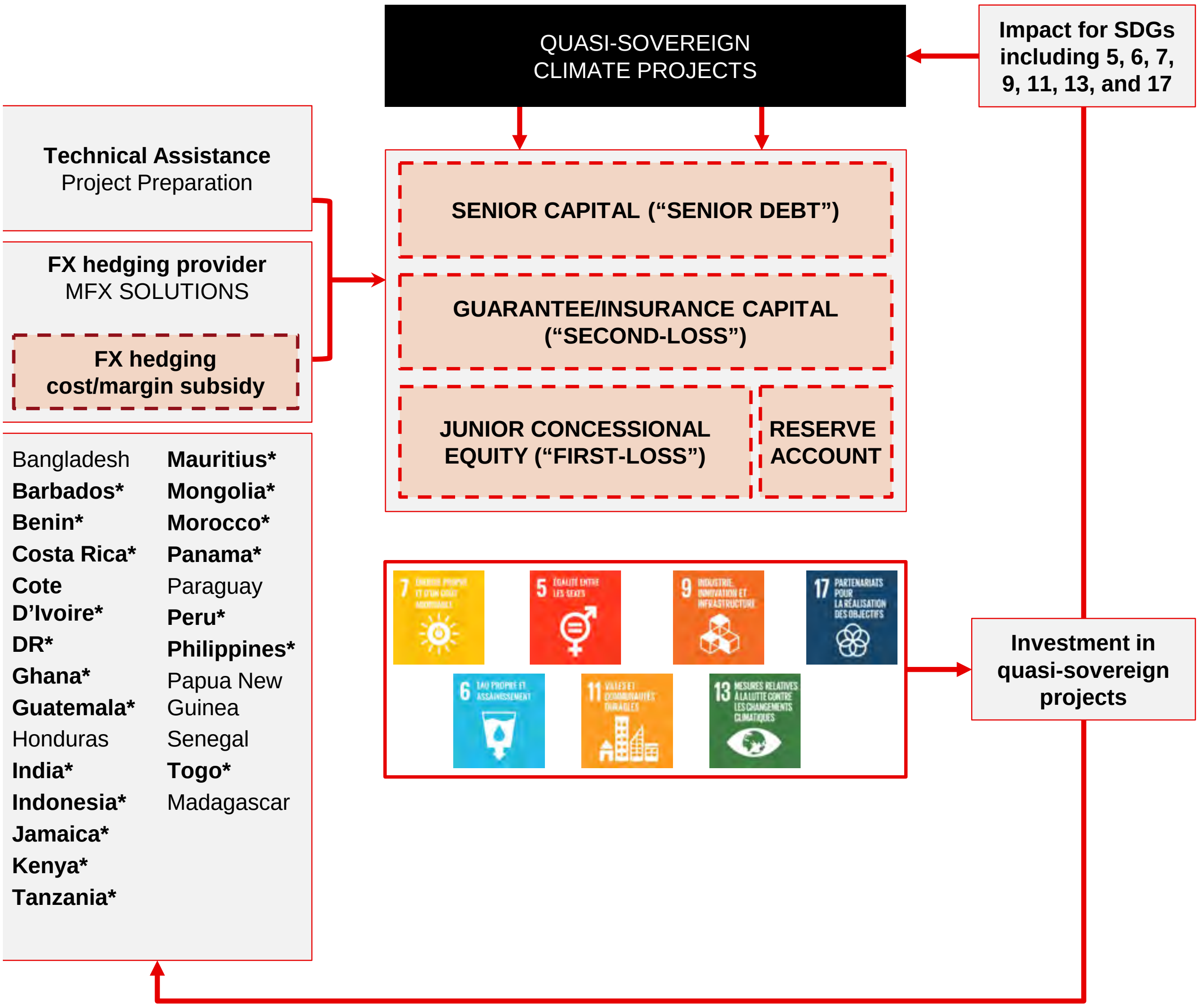
483 "The State of Blended Finance 2022: Climate Edition," Convergence Blended Finance, 2022, Link.

Exhibit 100: GAIA platform structure



* NOL Obtained

GAIA also benefits from a strong and diverse ecosystem of specialized partners, incorporating a parallel technical assistance facility which will deploy grants for project preparation in projects aligned with GAIA eligibility criteria.

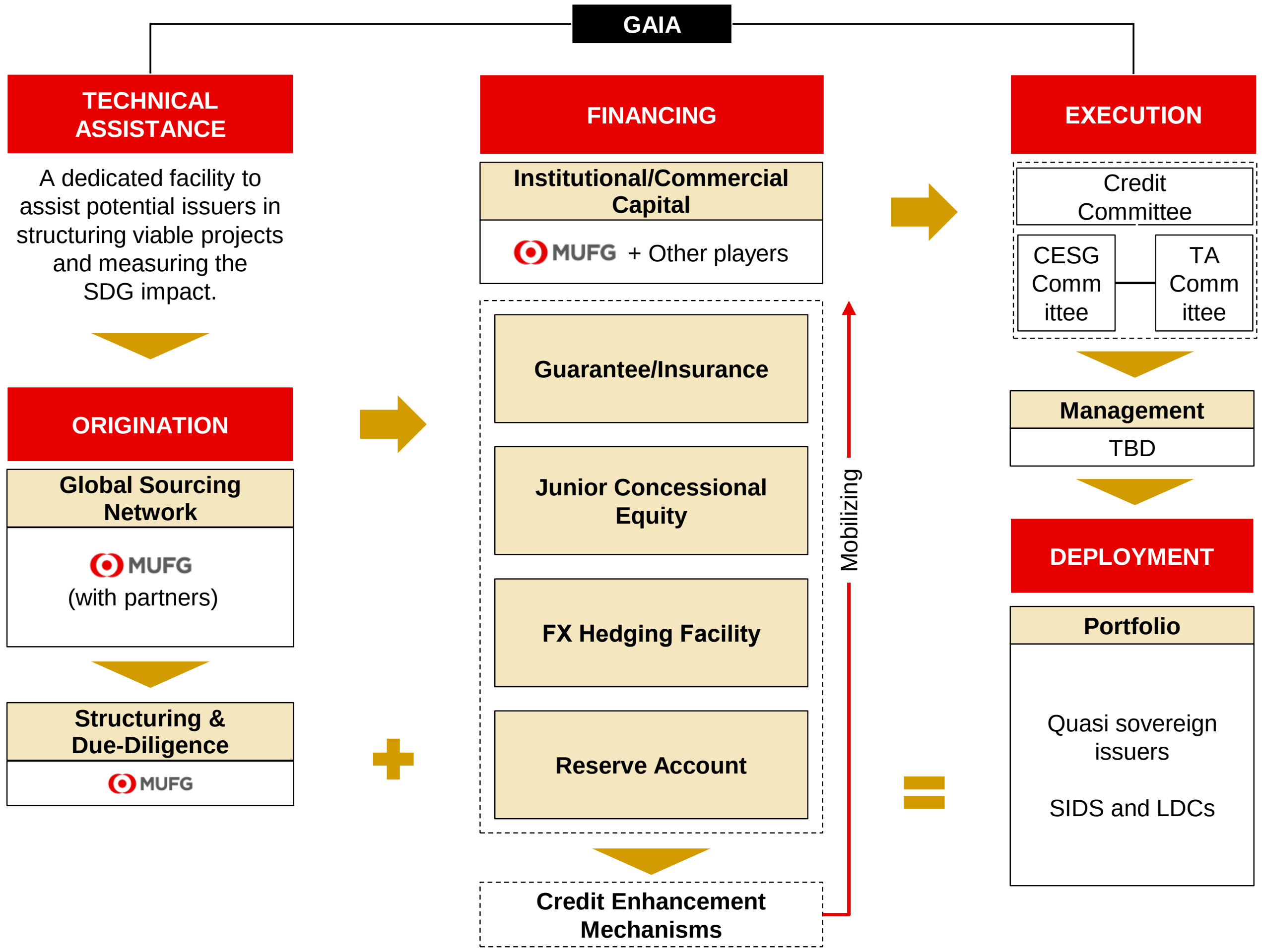
Investment thesis

GAIA creates a financial architecture allowing commercial investors to provide financing that will be additional to current market options. GAIA financing creates a new hybrid borrowing option that sits at the interface of multilateral concessional funding and pure commercial market options. It brings together aspects of both developmental and commercial capital by offering long-term illiquid loans in both hard and local currency.

While also offering borrowers technical assistance to ensure the ultimate success of the projects, GAIA's principal investment focuses on climate adaptation assets, incorporating early-stage project design, sighting, and impact measurement assistance, which marks out a singular, scalable public-private contribution to partner countries' resilience programming.

GAIA's mandate is to finance projects in climate mitigation within energy generation/access and low-emission transport segments which may also have resilience co-benefits, while privileging three adaptation results areas: health, well-being, food, and water security; infrastructure and the built environment; and ecosystems and ecosystem services. GAIA will invest a minimum of 70% of its portfolio in climate adaptation projects.

Exhibit 101: Capital deployment ecosystem



5.2.6. Way Forward

Blended finance can be useful in pushing energy transition in Asia. MUFG continues its interest in advancing this capability in collaboration with MDBs and other stakeholders. Specifically on the blended finance platform mechanism, MUFG continues to be in discussions with prospective sponsors and investors about securitization and other aspects of this mechanism.

5.3. Bring proven financing solutions to unlock additional value

Distributed solar can play a significant role in Indonesia and Thailand’s decarbonization pathways, given the potential to utilize available rooftops and land close to demand, as well as tap third-party investments in solar (e.g., households, businesses).

Nevertheless, when it comes to financing solutions, these projects face obstacles owing to relatively small ticket sizes and varying individual credit assessments. To draw insights from other markets, we will share the United States context on distributed solar, and how the regulatory and policy environment, together with MUFG’s innovative financing solutions, can support its bankability and uptake of distributed solar at scale.

5.3.1. US Market and Policy Landscape

The regulatory and market environment in the United States that enable the uptake of distributed solar are described as follows:

- Community solar legislation which allows individuals or entities to share the benefit of a single solar array, as well as how shared solar projects can be developed by solar developers. Indeed, through each state’s community solar regulation, solar developers are able to sell energy at a discount to the prevailing retail rate of customers, and public utilities must allow these solar developers to interconnect their solar projects to the grid and sell this energy to the distribution company’s customers.

- Net metering, which allows customers to offset a portion of their electricity usage from electricity generated by solar panels, is essential in allowing customers to benefit from community solar regardless of whether they are able to host solar panels on their own roof. This is especially beneficial for customers living in apartments in large cities and low to middle income households who may not be able to bear upfront installation costs of solar panels.
- Smart grid TnD system that allows bi-directional flow of the power to accommodate the distributed solar at scale.
- Regulated retail electricity price tariff, which has been largely stable and includes capital costs to maintain TnD networks.
- TPA which refers to the ability for third-party ownership of solar asset (e.g., rooftop, community) to be connected into the national grid, as well as the ability to participate in the sale of electricity (e.g., via PPA).

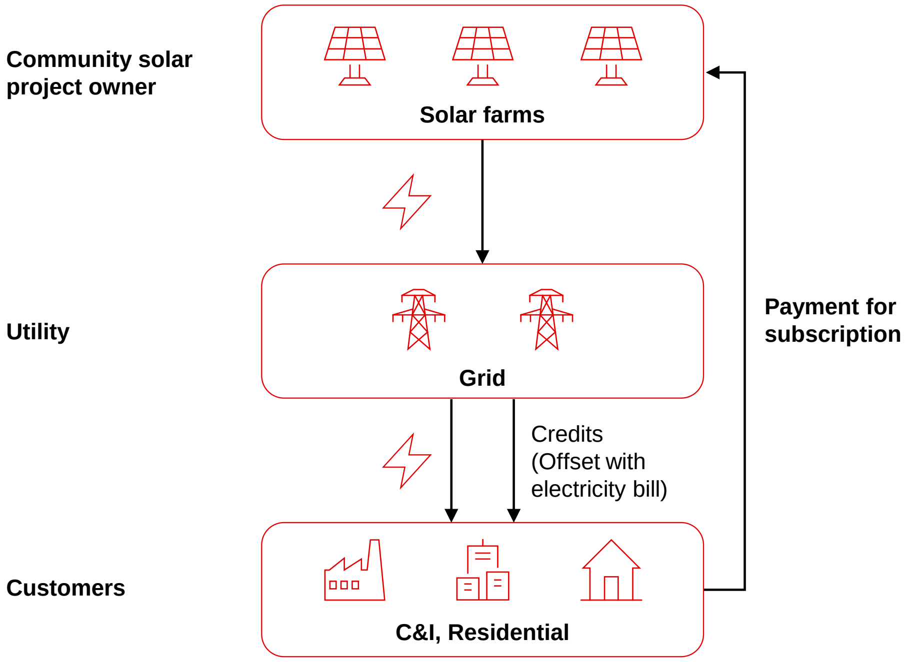
Specific to the United States as well, there exist other policies incentivizing the development such as the Federal Investment Tax Credit providing tax credit of up to 30% of solar energy system or State Renewable Portfolio Standards.

5.3.2. Community Solar Program

From the real economy perspective, third-party ownership model has emerged. In a third-party model, the ownership of the panel belongs to a third party, typically the developer and/or operator, instead of the owner of the premises. In this model, either the solar panel is leased to the premises owner, or the premises owner enters a PPA contract with the operator. This is beneficial for the premises owner as they do not need to cover the upfront investment.

Importantly, the third-party model also serves as an aggregator to provide better scale for financiers to consider financing a portfolio of small-scale distributed solar projects. One archetype of such model is the Community Solar Program which allows multiple customers such as homeowners, small businesses, or any other electricity customers to share the benefits of a single solar energy system. Each end-user pays for their own share of electricity usage, typically in the form of a monthly subscription fee but overall, their electricity bill is reduced by the net-metering credits. The monthly subscription fee acts as a PPA to provide revenue certainty for the project owner to finance the solar CAPEX with debts. From the utility's perspective, it can outsource the required CAPEX for distributed solar and redeploy its capital elsewhere, although it will not earn a rate of return for the distributed solar.

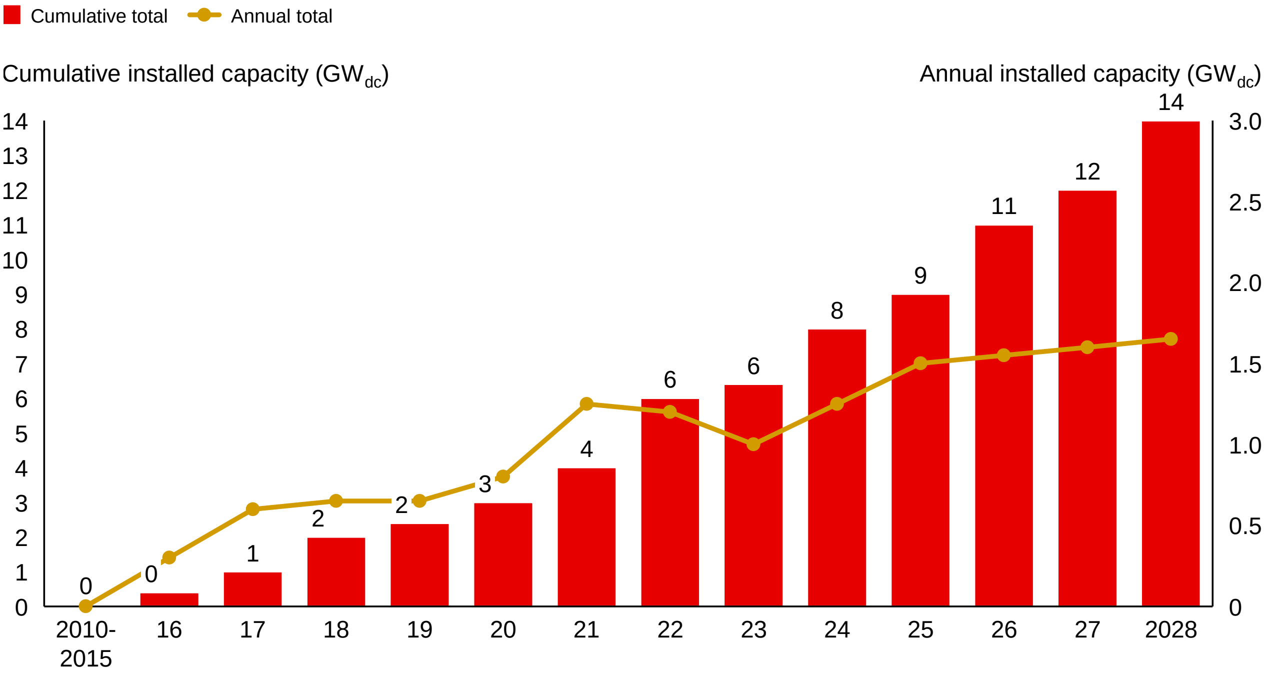
Exhibit 102: Community solar model in the United States



Community solar offers a range of social benefits that can positively impact both customers and the broader community. For instance, community solar makes solar energy accessible to a broader range of people, including renters, those with shared roofs, and individuals who cannot afford or have physical constraint to install solar panels on their own properties. It can also enhance the resilience of the local energy grid. In times of power outages or disasters, these systems can continue to generate electricity where it is directly connected to the local community. Owing to these benefits and various policy support, the community solar capacity has grown and is expected to continue growing rapidly (**Exhibit 103)**.

Community solar is one of the fastest-growing segments of the solar industry, growing from a few scattered projects in 2007 to 6 GW of installed capacity as of 2023.

Exhibit 103: Cumulative installed community solar capacity, 2010-2028[484]



Currently, there is at least one community solar project in 43 states and the District of Columbia (DC). Of those, 22 states and DC have passed ‘enabling legislation’ that encourages or mandates community solar in their jurisdictions. States with enabling legislation typically have more projects developed and subscriptions available (**Exhibit 104**).

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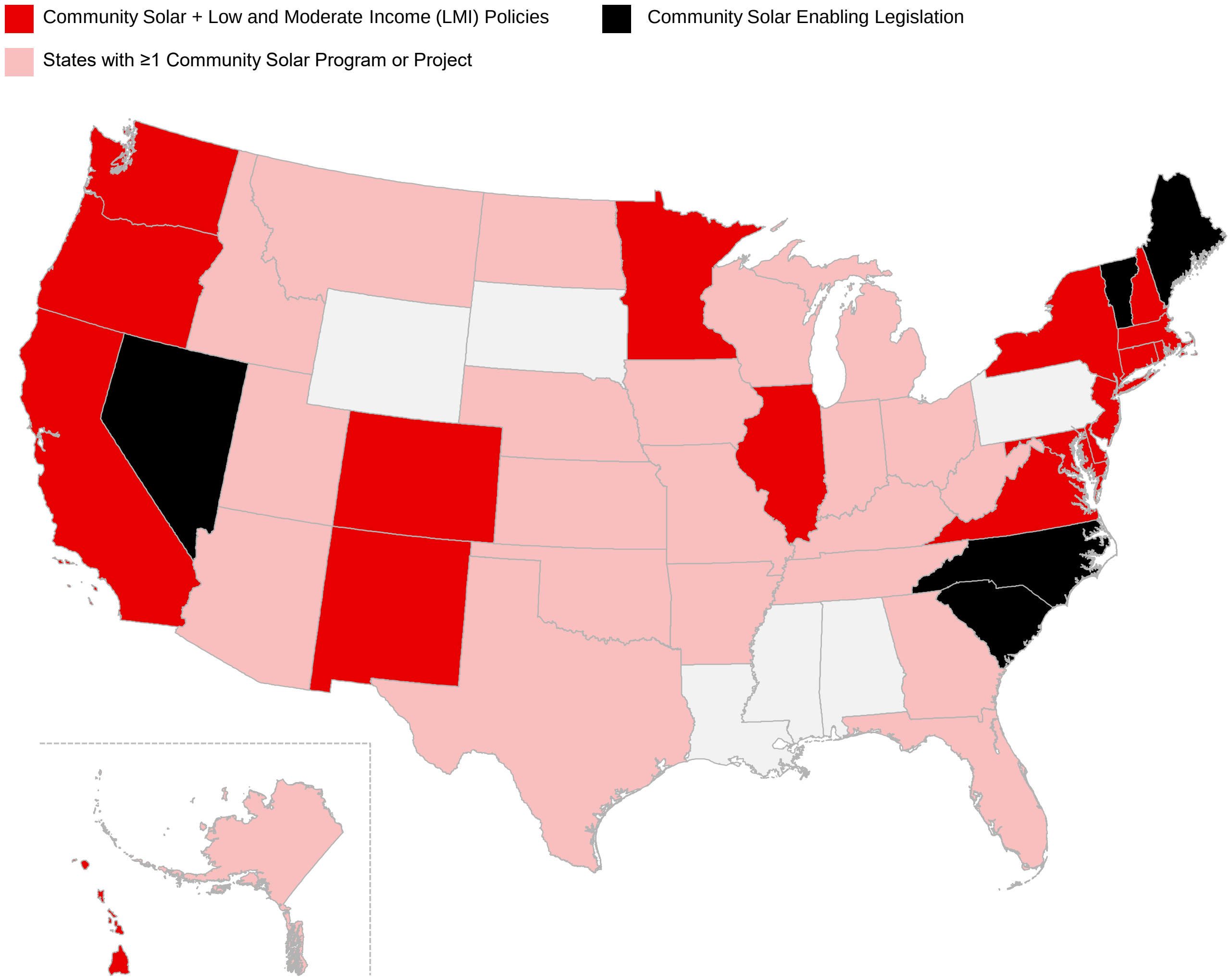
484 “Cumulative US community solar capacity expected to break 6 GW in 2023, despite interconnection and siting headwinds,” Wood Mackenzie, 3 August, 2023, Link.

Exhibit 104: Availability of Community Solar[485]



Financiers have contributed by providing innovative financial solutions. The community solar model is well suited to project finance for the following reasons:

- **Stable Cash Flows** – The power price sold by the projects to the customers is tied to stable retail prices.
- **Long Dated Cash Flows** – Community solar programs provide projects with 20-25 years' worth of visibility in terms of the power price they can charge customers.
- **Customer Value Proposition** – Customers always pay less for the energy purchased from the community solar projects than what they would have had to otherwise pay their power utility, providing a sticky and diversified offtake. Moreover, customers can cancel their subscription at any time providing them with an additional incentive to subscribe as they do not feel locked into anything.
- **Replaceability** – Due to significant higher demand than supply of community solar projects, projects can easily replace customers subscribed to the community solar project and regulation allows for an easy "swapping" or "replacement" of customers. This allows projects to be less reliant on the individual credit of residential customers. Moreover, electricity is one of the first things all households make sure they pay given its essential nature in people's everyday life.

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[485] "Community Solar Basics," Solar Energy Technologies Office, Link.

5.3.3. MUFG's Initiatives in Community Solar

MUFG has also actively contributed to the growth of distributed solar by offering various customized financing options to community solar projects in the United States.

One case study was where MUFG acted as coordinating lead arranger and joint bookrunner for a 338 MW communal solar portfolio across five US states in 2021. This facility was featured by:

- A portfolio of 338 MW DC distributed solar projects with 119 MWh energy storage capacity, comprising of 95 projects across five states. Projects are subscribed to an attractive mix of anchor off-takers (~1/3 of total revenues) and highly diversified residential and commercial customers (~2/3 of total revenues) serving up to 14,000 customers.
- A seven-year USD 408 million Mini Perm Facility, USD 32 million debt service reserve, and various project LCs.

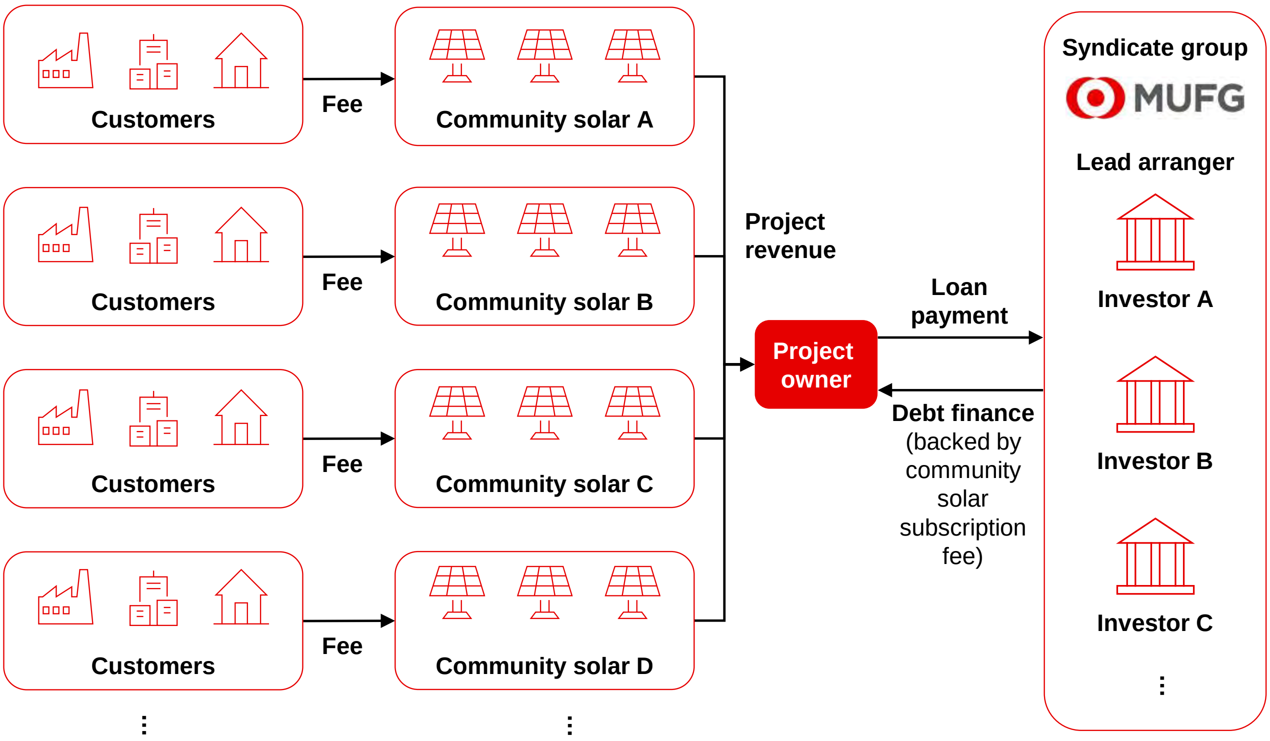
Another example was where MUFG acted as joint lead arranger, coordinating bank, and agent on two community solar projects with a total capacity of 51 MW in 2022. This facility was featured by:

- Two community solar portfolios, 32 MW in Maine and 19 MW in Illinois. The portfolio consists of six ground-mounted projects in Maine ranging from 3-7 MW, and seven projects in Illinois ranging from 1-3 MW. The projects are backed by long-term power supply contracts with large C&I customers as anchor off-takers.
- A seven-year and 10-year USD 80.6 million Back-Leverage Term Loan Facility and a USD 4.4 million Letter of Credit Facility.

There are three key aspects of these financing solutions that can provide valuable insights to the markets in Indonesia and Thailand while addressing the challenges associated with distributed solar energy sources.

1) **Portfolio aggregation:** These facilities are designed to consolidate individual customer portfolios into larger financing packages that can be subsequently offered as pooled portfolios. This also provides a diversification of asset location which is positive from a credit perspective.
2) **Less reliance on customer individual credit:** Due to the high value proposition for customers (guaranteed discount to their utility rate) and the ease with which customers can be replaced (high demand and limited supply), banks do not require individual creditworthiness evaluations. The portfolio includes a mix of anchor off-takers and a highly diversified customer base comprising of residential and commercial customers. This diversified and secure revenue stream reduces the risks associated with such projects and allows project developers to secure more favorable financing terms.
3) **Stability of cash flows:** Relatively stable cashflow as the power sale price is linked to the regulated retail price rather than shole-sale market prices.

Exhibit 105: Community solar financing scheme at scale



5.3.4. Way Forward

The financing options discussed in this section have limited presence in Indonesia and Thailand due to differences in the underlying market structure. However, as both countries explore the potential of distributed solar in their home markets, the United States context can provide insights on the enabling policy and market environment necessary for distributed solar, as well as MUFG's financing solutions to boost its adoption.

6. Closing

MUFG looks forward to participating in and leading discussions around building awareness and global efforts in decarbonization through provision of financing solutions, industry discussions, broader knowledge sharing, and other thought leadership channels.

This White Paper adds to MUFG's efforts to provide a holistic view of the challenges faced in decarbonizing the power sector in Asia by taking a closer look into five Southeast Asian countries – an overview of the situation in the Philippines, Singapore, and Vietnam and a more detailed exploration of the situations facing Indonesia and Thailand. Through our efforts, we isolated potential solutions that are relevant to a range of stakeholders – including energy policymakers, financial regulators, public finance providers, power sector players, power purchasers, and MUFG among other financiers – to overcome the decarbonization challenges across technical and commercial feasibility to promote bankability in these markets.

The coming years leading up to 2030 are pivotal. Let us work together to contribute towards progress against this challenging global problem, while finding opportunities to evolve our financial ecosystem and grow, develop, and empower our communities.

MUFG would also like to thank the information providers whose inputs have helped inform this document, including McKinsey & Company.

7. Appendix – case examples as a reference for stakeholder actions

We will use this section to outline case studies from other markets on how different stakeholder groups have been contributing to the energy transition.

7.1. Regulatory reform: TPA, DPPA

Many countries have been engaging in a series of regulatory reforms towards open access to power grids. While the footsteps of each country's reform journey vary, there are recurring themes that can serve as references for countries with currently limited TPA and direct power purchase agreement (DPPA) opportunities. According to analysis conducted by the Energy Sector Management Assistance Program (ESMAP),[486] effective regulatory reform towards open grid access often involves ensuring a separation between transmission and generation, an establishment of a neutral system operator, and a balance between open access and central planning. In this section, we will highlight these key lessons by discussing the actions other economies take and challenges they encounter.

7.1.1. Unbundling of transmission and generation

The separation between TnD facilities from generation and supply lays a fundamental ground for enabling TPA. This can be either ownership separation (legal unbundling) or clear accounts separation (functional unbundling), and the extent of the adoption of unbundling often varies across different economies. On a regulatory level, it is critical to ensure licenses issued for economic activities in the sector are highly activity-specific, separately covering transmission, distribution, supply (retail sale), generation, and, ideally, metering and billing, as illustrated by the following case examples:

- **Brazil: Legal unbundling (ownership separation)**

  Brazil introduced legislation in 1998 (Law No. 9648) that established separate contracting and pricing procedures for energy supply and grid services. Under this legislation, the suppliers of electric power are required to choose between selling energy or transporting it rather than doing both. Further, Agência Nacional de Energia Elétrica (ANEEL), the nation's regulator, was charged with regulating tariffs and establishing general conditions for contracting access and use of the TnD system. This set of regulatory reforms played an instrumental role in opening third-party access in Brazil.

- **Japan: From billing unbundling to legal unbundling**

  Japan took a stepwise journey in its regulatory reform towards unbundling transmission from generation. Japan initially introduced the unbundling of billing in 2003, in which the charge of the transmission of electricity is counted separately from the charge of electricity itself. However, the billing separation alone does not fully ensure the neutrality of the transmission entity. Therefore, based on new legislation issued in 2015, Japan took another step to adopt a complete legal unbundling scheme, effective from 2020 onward. Under this new regulation, transmission companies are no longer allowed to simultaneously engage in electricity generation or retail, thereby ensuring their neutrality towards all electricity generators and retailors.

- **United States: Functional bundling (account separation)**

  For a variety of legal, tax-related, and political reasons, the United States adopted "functional unbundling" instead of a complete ownership unbundling of transmission from generation. Under this approach, the transmission costs are strictly segregated from other costs. Further, the transmission managers were regulated by a strict code of behavior.

- **India: Challenge in case of incomplete unbundling of distribution from retailing**

  India experienced difficulties while implementing the open access provision of its Electricity Act 2023, which does not recognize supply of electricity as a licensee function separate from distribution. Under this framework, the distribution companies hold a joint license for the network service provision and retail sale of electricity. However, since the distribution company is also a retail sale licensee, its revenue will decrease if eligible consumers switch to alternative supplies. Because of this, the distribution companies were unwilling to limit their business activities to the TnD associated services and instead focused on the ability to engage in energy sales.

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[486] "International experience with open access to power grids," Energy Section Management Assistance Program (ESMAP), November 1, 2013.

- **India: Challenge in metering and billing**

  Another challenge India is encountering involves metering and billing. This is mainly caused by lack of established mechanisms in regulations for monitoring day-ahead scheduling, real-time dispatch, the carrying of weekly meter-reading instruments, or the preparation of unscheduled interchange accounts.

7.1.2. Establishment of a neutral system operator

Another common theme related to regulatory reform towards open access involves establishing an independent system operator (ISO) for grid. By establishing that the system operator is independent from generation and supply interests, conflicts of interest in dispatch decisions as well as grid-expansion planning can be avoided. Below, we will introduce two successful models of system operation utilized by other countries.

- **ISO model**

  Under the ISO model, ownership of grid assets is separate from system operations. The system operation is instead managed by a free-standing entity that is usually not-for-profit and thus has no interest other than the proper management of grid-related services. Case examples include the following:

  The United States: The ISO model emerged in the United States in the late 1990s because of Federal Energy Regulatory Commission (FERC) Order No. 888. Under this order, ISOs are required to be not-for-profit entities that do not own the transmission assets. Instead, they manage the grid and serve as a regulatory authority with powers delegated by FERC. The financial indifference of ISOs effectively ensures system operator neutrality.

  Brazil: Brazil adopted the ISO model in 1998 by creating a national grid operator, the Operator of the National Electricity System (ONS). ONS is a government agency responsible for coordinating and monitoring Brazil’s national grid, operating under the regulation of the country’s national power regulator ANEEL.

- **TSO model**

  Under a TSO model, the system operator also serves as the owner of the physical assets. Similar to the ISO model, the system operator is required to be financially disinterested in the outcome of competition among suppliers. However, unlike the ISO model, the operator in a TSO model is given financial incentives for efficient management of the TnD network. Case examples include the following:

  The United Kingdom: The England and Wales implemented the TSO model, in which National Grid, a private company, served as both the owner and the operator of the transmission system.

  Turkey: In Turkey, ownership and operation of the grid are integrated in the same single state-owned entity, the Turkish Electricity Transmission Company (TEIAS). TEIAS is responsible for the operation and maintenance of the existing TnD infrastructure and the planning of new transmission investments and facilities.

7.1.3. Balance between planning and TPA

The challenge several countries encounter during their reform towards TPA shows a need to maintain a balance between centrally directed planning and open access, as reflected by the case examples below:

- **Turkey: Challenge in insufficient grid capacity to meet the demand of generators**

  In 2021, Turkey introduced the Electricity Market Law to promote TPA. However, upon the introduction of open access, TEIAS was overwhelmed by connection requests from independent generation developers, with a total capacity twice the existing installed power. Meanwhile, more than 700 license applications were made project owners, leading TEIAS to be unable to prepare and implement a realistic investment program. This challenge can be particularly worth noting for developing countries that are experiencing rapid growth in electricity demand and a corresponding high level of investor interest in generation.

- **Brazil: Challenge in planning and long-term optimization**

  Upon allowing TPA and DPPA, a large number of additional players (such as IPPs) were introduced to the framework. The input from a variety of stakeholders became indispensable in the planning, making it more challenging process.

- **Peru: Formalization of centralized transmission planning**

  In 2006, Peru strengthened centralized planning by introducing a more inclusive organization of the system operator, the National Interconnected System Financial Operation Committee (COES). COES takes charge of identifying system expansion needs, thereby resolving disputes between transmission investors and the general public. This measure led to a marked increase in private investments in transmission and generation, suggesting that private-sector investors react positively to the predictability of a well-organized planning framework.

7.2. Public finance

There are multiple ways where the public sector could encourage the growth of clean energy technologies, such as through tax incentives, carbon pricing, grants, guarantees.

Financial incentive - Tax incentives

Tax incentives such as tax credits and tax breaks could incentivize renewables IPPs. The governments of advanced economies such as the US have already introduced tax incentives for renewable energy business owners, especially solar- and wind developers. Specifically, the US has implemented investment tax credits (ITC), which lets businesses deduct a certain percentage of investment costs from their taxes in addition to normal deductions for capital-asset depreciation. The country also has production tax credits (PTC), a ten-year inflation-adjusted federal income tax credit for each kWh of electricity generated by renewable or zero-carbon-emissions assets that meet its criteria (**Exhibit 106**).

Exhibit 106: Eligibility criteria for the US ITC and PTC[487]

ITC

- Energy storage
- Fuel cell
- Geothermal (heat pump and direct use)
- Combined Heat & Power
- Microturbines
- Interconnection property
- Microgrid controller

- Solar (multiple technologies)
- Municipal solid waste
- Wind (multiple technologies)
- Geothermal (electric)
- Tidal

PTC

- Biomass
- Landfill gas
- Hydroelectric
- Marine and hydrokinetic

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Credit prior to IRA	26%	22%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Credit under IRA	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	26%	22%	0%

The original versions of the ITC and the PTC had been set to expire in 2023, but the IRA of 2022 extended the ITC to 2033 and the PTC to at least 2025 (**Exhibit 106**).[488] Under the IRA, individuals would receive 30% tax credit on residential solar and energy storage for ten years. Developers would receive either a 30% ITC or a 2.6-cent per kWh PTCTC.[489] Grid-scale storage would be eligible for a 30%.[490]

Additionally, such tax incentives could also encourage the ramp-up of nascent technology. For instance, in the US, the Inflation Reduction Act provides USD 395 billion in clean energy with majority of the funding in the form of tax credits to support reduced carbon sources thus unlocking clean energy technology investment.

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[487] "Overview of Inflation Reduction Act incentives for Federal decarbonization," Federal Energy Management Program, accessed September 18, 2023, Link.

[488] "Summary of Inflation Reduction Act provisions related to renewable energy," United States Environmental Protection Agency, 2023, https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy.

[489] Ibid.

[490] "Energy Storage Fact Sheet," Joe Manchin, accessed November, 2023, Link.

The Act provides up to USD 3/kg tax credit/direct pay option to produce clean hydrogen (H_2) given its qualifications. IRA also boosts blue H_2 production through extension of tax credits for construction of carbon capture facilities through 2033, increasing tax credit for select carbon capture facilities and lowering threshold requirements for additional facilities to qualify.[491]

Financial incentive - Carbon pricing

Carbon pricing could also promote clean energy transition by disincentivizing use of carbon intensive technologies. For instance, Japan is implementing a new carbon pricing mechanism that not only penalizes carbon intensive industries but to also stimulate green growth. In 2023, METI announced the launch of a GX initiative. This program, backed by a joint public-private investment of over JPY 150 trillion (about a quarter of country's GDP) over the next 10 years, aims to achieve carbon neutrality by 2050.[492] The carbon pricing policy has three pillars: GX Economy Transition Bonds, emissions trading, and new financial measures. All three pillars are focused on increasing Japanese companies' competitiveness while producing a stable supply of energy, economic growth, and paving a path towards decarbonization.

1) **GX Economy Transition Bonds** will allow the government to provide around JPY 20 trillion to the private sector for early-stage investment, focusing on projects that would be non-bankable without support from the public sector. Government will issue bonds every fiscal year to support investment of new projects. This investment would stimulate demand for goods and services associated with the green transition.

2) **Pro-growth carbon pricing** will allow companies to trade emissions allowances based on the gaps between their emissions targets and actual emissions. Emissions trading will be fully implemented by the 2026 financial year. By the 2028 financial year, a surcharge on fossil fuel imports will be introduced based on each import's carbon emissions. The government also plans to introduce auctions for emissions allowances in the 2033 financial year, in which power companies would need to purchase allowances based on their actual emissions at auction. Carbon pricing and support for early-stage investment will facilitate the development of green technology, contributing to increased competitiveness and economic growth.

3) **New financial measures** such as loan guarantees that de-risk projects are aimed at developing domestic markets for green finance. Blended finance will also be established to pool public and private funds to finance projects that would be risky for private institutions to invest in alone.

Grants

To promote non-bankable or near-bankable technologies, such as CCUS, hydrogen co-firing, ammonia co-firing, and managed phase-out, some governments have opted to offer funding targeting R&D for emerging technologies or to fund pre-commercialization pilots (for an example, see sidebar, "Japan's Green Innovation Fund").

The EU Innovation Fund is part of the Green Deal Industrial Plan which plans to mobilize about EUR 40 billion (est. EUR 75 per tonne carbon price) between 2020-2030 for breakthrough technologies in CCUS, renewable H_2, energy storage, etc.[493] Financed by revenues from the auctioning of allowances from the EU Emissions Trading System (EU ETS), it has held three large-scale calls awarding EUR 1.1 billion, EUR 1.8 billion, and EUR 3.6 billion in grants to 7, 16, and 41 projects respectively.[494]

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[491] "Building a clean energy economy: A guidebook to the Inflation Reduction Act's investments in clean energy and climate action," The White House, January 2023, Version 2, Link; "Inflation Reduction Act: Key green and blue hydrogen and CCUS provisions," Shearman & Sterling, August 12, 2022, Link.

[492] "Japan's energy policy toward achieving GX (Part 2): Policy package toward simultaneously realizing decarbonization and economic growth," METI, May 26, 2023, Link.

[493] "What is the Innovation Fund," European Commission, accessed September 18, 2023, Link.

[494] "Innovation Fund: EU invests €3.6 billion of emissions trading revenues in innovative clean tech projects," European Commission, July 13, 2023, Link.

Sidebar: Japan's Green Innovation Fund

The Japan Green Innovation Fund is part of the METI's Green Growth Strategy Through Achieving Carbon Neutrality in 2050, announced in December 2020. The fund was set up within the New Energy and Industrial Technology Development Organization (NEDO), and will receive about JPY 2 trillion (USD 13.8 billion[495]) over ten years to facilitate public-private collaboration and to financially support R&D and implementation of green technologies.

The fund's main targets are projects that have a scale of at least JPY 20 billion (USD 138 million).[496] However, NEDO may decide to fund promising smaller-scale projects. The fund's overall measure of success is to help Japan achieve carbon neutrality and create economic gains worth JPY 190 trillion (USD 1.3 trillion)[497] by 2050.

As of September 2023, the fund has awarded a total of about JPY 1.87 trillion (USD 12.7 billion) to 19 of the 20 projects (**Exhibit 107**).[498]

Exhibit 107: Project list as of July 12, 2023[499]

🟪 Cost reduction and functionality enhancement for green energy
🟩 Transition to a hydrogen society
⬜ Transformation of major downstream industries towards electrification

Project theme
Cost reductions for offshore wind power generation
Next-generation solar cell development
Development of CO_2 reduction technology for waste treatment (in discussion)
Large-scale hydrogen supply chain establishment
Hydrogen production through water electrolysis using power from renewables
Hydrogen use in steelmaking processes
Fuel ammonia supply chain establishment
Development of technology for producing raw material for plastics using CO_2 and other sources
Development of fuel production technology using CO_2 and other sources
Development of technology for producing concrete and cement using CO_2
Development of technology to separate/capture CO_2
Development of next-generation batteries/next-generation motors
Development of in-vehicle computing and simulation technology for energy saving such as electric vehicles
Establishment of a smart mobility society
Establishment of next-generation digital infrastructure
Development of next-generation aircraft
Development of next-generation ships
Development of CO_2 reduction and absorption technology for food/agriculture, forestry and fisheries industries
Promotion of carbon recycling using CO_2 from biomanufacturing technology as a direct raw material
Decarbonization of heating process in manufacturing industry

Considering that over 90% of the initial fund has been awarded to projects, the Japanese government released an additional JPY 300 billion (USD 2 billion) for the fund in the 2022 supplementary budget and another JPY 457 billion (USD 3.1 billion) in the budget for FY2023.[500]

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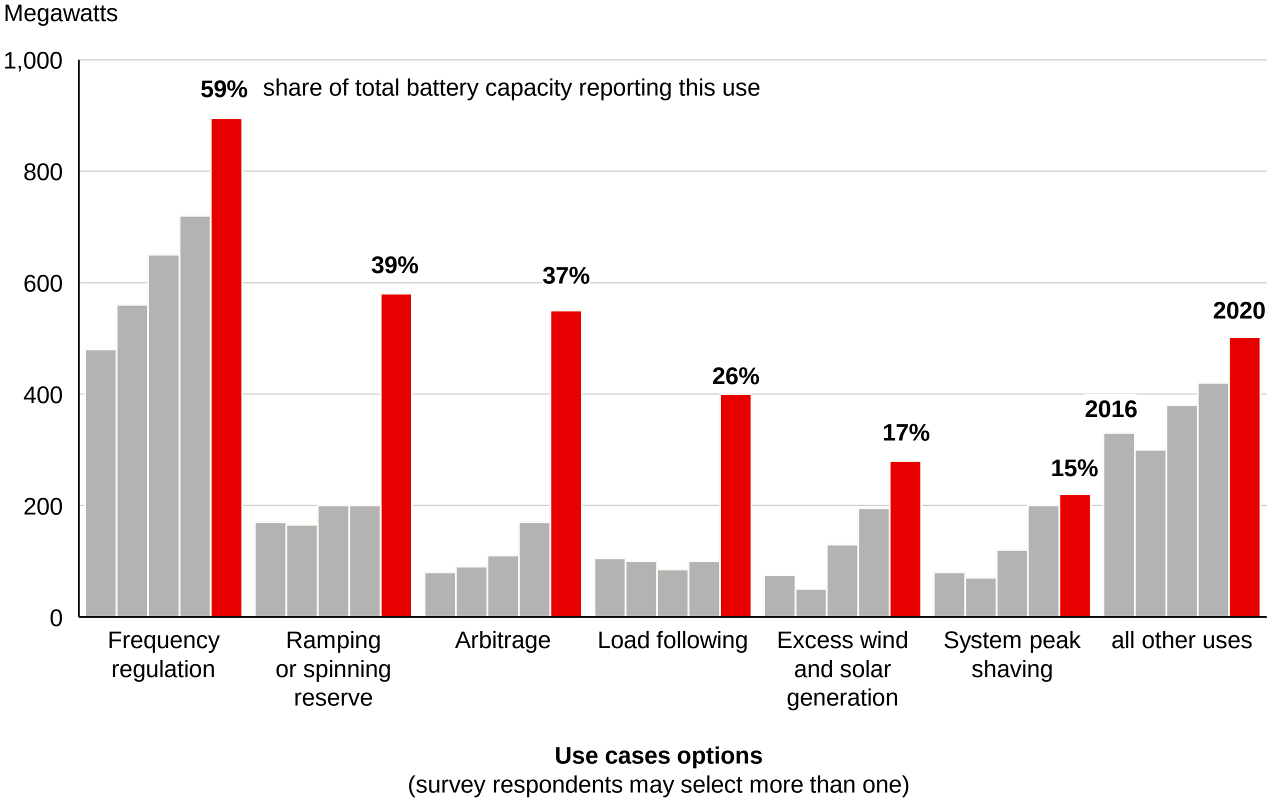
[495] JPY 2 trillion converted as of Aug 25, 2023.
[496] JPY 20 billion converted as of Aug 25, 2023.
[497] JPY 190 trillion converted as of Aug 25, 2023. Economic gains refer to ripple effect through increase in revenue or capital expenditure.
[498] "Green Innovation Fund project progress status," METI,September 11, 2023, Link.
[499] Ibid.
[500] "Regarding the future direction of the Green Innovation Fund project," METI, May 24, 2023, Link.

7.3. AS tendering

In advanced economies, liberalizing the AS market can incentivize the adoption of battery storage. AS providers support grid stability and are remunerated for their services. Examples of AS services in the US include:[501]

- Frequency control is a service that restores the frequency to the nominal operating level after any deviation occurrence due to physical imbalance between generation and demand. Deviations below the nominal operating level can lead to protective generator trips that result in a subsequent decline in system stability. Batteries are particularly well suited for frequency regulation because their output does not require any startup time and batteries can quickly absorb surges. In the US, at the end of 2020, 885 MW of battery storage capacity (59% of total utility-scale battery capacity) cited frequency response as a use case.
- Ramping or spinning reserve is a set of AS in which generators quickly respond to system disruptions, such as a sudden loss of generation or a rapid change in demand. Regions that have a relatively high proportion of electricity generation from sources such as wind and solar – whose output can fluctuate as wind speeds or cloud cover changes – tend to require resources that can respond quickly. At the end of 2020, 583 MW of battery storage capacity (39% of total) cited ramping or spinning reserve as a use case.
- Arbitrage is a strategy of buying electricity during low price periods and selling during high price periods. Battery storage supports this strategy by charging when power prices are low and discharging when prices are high. This use case increased by 390 MW from 2019 to 2020 – the greatest capacity increase among use cases. At the end of 2020, 586 MW of battery storage capacity (37% of total) was used for arbitrage.
- Load following is an operating strategy in which generators change their output to match changes in electric demand, or load. Batteries are used for load following because their output can be digitally controlled and therefore can respond to load changes with less stress than mechanical systems. Nearly 400 MW of battery storage capacity was used for load following in 2020.

Exhibit 108: Use cases for US utility-scale battery storage capacity, 2016-2020[502]



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[501] "Battery storage applications have shifted as more batteries are added to the U.S. grid," Glenn McGrath, US Energy Information Administration, November 1, 2021, Link.

[502] "Annual Electric Generator Report," U.S. Energy Information Administration, 2021.

Case Example on the Japanese AS tendering scheme

To illustrate potential pathways towards a liberalized AS market, we would like to shift the spotlight to an ‘AS tendering scheme’ introduced in Japan since 2016. This initiative enabled the gradual development of an AS system within a regionally monopolized TnD market. We will take TEPCO Power Grid as an example of the case study, but other TSOs have similar mechanisms.

Under the scheme, two major types of contracts are offered to the IPPs.[503] The Type I contract operates on a fixed-term basis, and the procurement opens every September-October prior to the fiscal year of service provision.[504] To apply for this type of contract, IPPs submit their biddings directly to the TSO, which proceed to review the entries and announce winning bidders in December. This form of contract is mainly intended for power generation companies, whose electricity generators are initially required to be located within certain operational regions to qualify for the entry. However, the regional barrier is gradually lifted to further enhance competition of the tending process. The Type II contract on the other hand, features higher level of flexibility and operates on an incremental-term basis. Applications can be made throughout the year and are coordinated with the real-time demand via an online platform. The Type II AS are intended to serve as a complementary power source used jointly with the fixed term AS power (Type I), and are mainly intended for retail electricity providers. The coexistence of multiple contract options endows an additional layer of security to the supply-demand balance, while catering to the needs of different types of IPPs in the meantime. In 2022, 250 companies were targeted for a tender including 139 retail providers and 74 generators.

A key strategy of the initiative involves categorizing the AS based on their temporal traits. Under this approach, the response time range of an AS is divided into three major categories: (a) within 5 minutes, (b) within 15 minutes, and (c) within 3 hours.[505] Such categorization is driven by the rationale that electricity demand fluctuations can be decomposed into individual components, and thus the ancillary power generators’ capacity can also be tailored to meet the specific need of each demand segment.

An implication of this categorization approach is that it allows the temporal feature to be used as a handle for matching a particular AS provider with its suitable function. For example, the nimblest AS (Category a) are assigned to meet the urgent need of frequency control, while the other two slower-responding categories mainly serve to address supply-demand imbalances. These imbalances can originate from either short-term supply/demand fluctuations (e.g., those caused by severe weather conditions or unexpected system outrage) or long-term shifts in demand (which are gradual and can be sufficiently countered by AS that reacts on longer time scales).

The operational mechanism also varies across the different AS categories and is determined by the category’s specific temporal feature as well as purpose of usage. Specifically, the AS that respond in the time frame of minutes (Category a/b) are maneuvered via dedicated online control systems to ensure timely coordination. AS supplies that are accepted into this subcategory are also required to be high spec (>5,000 kW). In contrast, power sources that reacts on the time scale of hours (Category c) are coordinated by a more rudimentary system and is subject to lower capacity requirements (>1,000 kW).[506]

Ending in 2023, the Japanese ‘AS tendering initiative’ served as a steppingstone towards a fully liberalized AS market (which is expected to open in 2024).[507] The five different products that will enter market transaction feature different temporal characteristics, reminiscent of the response time-based AS subcategories piloted during the 2016-2023 initiative.

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[503] Additional contracts have been introduced with the program’s development but are omitted for the purpose of this discussion.

[504] Based on information from the official website of Tokyo Electric Power Company (TEPCO).

[505] 61st meeting document, the Japanese Electricity and Gas Market Surveillance Commission, May 31st, 2021.

[506] 61st meeting document, the Japanese Electricity and Gas Market Surveillance Commission, May 31st, 2021.

[507] Meeting document, the Japanese Electricity and Gas Market Surveillance Commission.

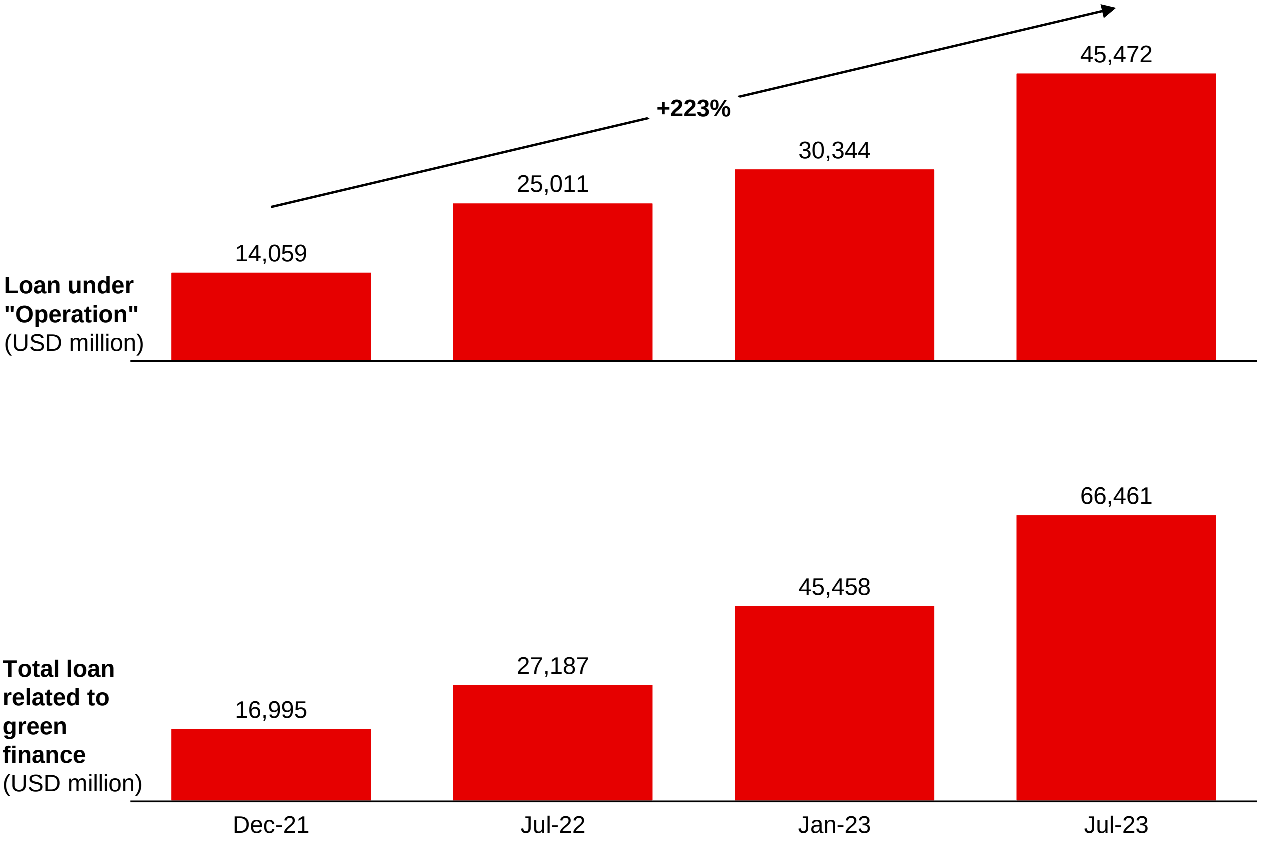
7.4. Financial incentives to FIs: Differentiated cost of capital for sustainable finance

Differentiating capital costs – increasing or decreasing interest rates on particular asset forms – could encourage the renewables uptake. Central banks in advanced economies are already issuing low-cost loans or bonds to commercial banks with a mandate to invest in sustainability linked assets, which would help renewable energy developers lower their cost of financing and retain a thicker margin.

Example: Climate Response Financing Operation

The Bank of Japan (BoJ) uses an approach called a Climate Response Financing Operation to provide zero-interest loans to banks that support initiatives geared towards decarbonization. Eligible banks must publicize their sustainability-related investment targets and actual results for their investment or loans, as well as Task Force on Climate related Financial Disclosures (TCFD) covering governance, strategy, risk management, and metrics and targets.[508] The term of the loan is usually one year, but it could be renewed. Each loan can be a green loan or bond, a sustainability-linked loan or bond, or transition finance. The program is scheduled to last until March 31, 2031. The value of loans issued has more than tripled in a year and a half (**Exhibit 109**).

Exhibit 109: Value of fundings disbursed under the Climate Response Financing Operation[509]



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508 “Outline of Transactions for Climate Response Financing Operations,” Bank of Japan, November 26, 2021, https://www.boj.or.jp/en/mopo/measures/mkt_ope/ope_x/opetori22.htm. The TCFD was created by the Financial Stability Board to increase and improve the quality of financial information related to climate.

509 “Loan Disbursement under the Funds-Supplying Operations to Support Financing for Climate Change Responses,” Bank of Japan, July 20, 2023, January 27, 2023, July 20, 2022, December 23, 2021, https://www.boj.or.jp/en/mopo/measures/mkt_ope/ope_x/index.htm. Total loan related to green finance refers to investment made towards climate change response measures by banks eligible for operation.

BoJ’s current monetary policy has a three-tier system in which different interest rates are assigned to the current reserves held by the financial institutions at the BoJ: positive interest rate (0.1%) for Basic Balances, zero interest rate for Macro Add-on Balances, and negative interest rate (minus 0.1%) for Policy-Rate Balances. Under the Climate Response Financing Operation, BoJ will add an equivalent of twice the value of green investments made by commercial banks to their respective Macro Add-on Balances. This effectively mitigates the adverse impacts these banks experience from the negative interest applied to a portion of their balances. This policy is expected to incentivize financial institutions to increase their loans to companies with green initiatives.

For example, MUFG and a syndicate of banks agreed in July 2022 to provide Nikon with a green loan to build its new environmentally friendly headquarters. The new headquarter will reduce the energy needed for air conditioning by having an exterior design with excellent solar shading and will be structured in a way that introduces natural light inside the building and promotes natural ventilation. This new building stands as a prime example of the company’s efforts to reduce GHG emissions from its operations by 46.5% relative to 2013 figures, aligning with the nation’s overarching ambition to reach net zero emissions by 2050.

List of Abbreviations

2025 PSN	2025 National Strategic Project, Indonesia
ABS	Asset backed securities, asset backed securitization
ACT	Accelerating Coal Transition
ADB	Asian Development Bank
AEDP	Alternative Energy Development Plan, Thailand
AETI	Asia Energy Transition Initiative
AIIB	Asia Infrastructure Investment Bank
ANEEL	Agência Nacional de Energia Elétrica, the National Electric Power Agency of Brazil
AS	Ancillary services
ASEAN	Association of Southeast Asian Nations
ATFSG	Asia Transition Finance Study Group
AZEC	Asia Zero Emission Community
BAPPENAS	Badan Perencanaan Pembangunan Nasional (National Development Planning Agency), Indonesia
BESS	Battery energy storage system
BCG	Bio-Circular-Green
BLT	Build-lease-transfer
BMTA	Bangkok Mass Transit Authority
BoJ	Bank of Japan
BOT	Build-operate-transfer
BPP	Biaya pokok penyediaan (average electricity generation price), Indonesia
C&I	Commercial and industrial
CAP	Corporate Assistance Program. Indonesia
CBAM	Carbon Border Adjustment Mechanisms, European Union
CCGT	Combined cycle gas turbine
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization, and storage
CDP	Carbon Disclosure Project, Indonesia
CEIA	Clean Energy Investment Accelerator
CIF	Climate Investment Funds
CIF-ACT	Climate Investment Funds-Accelerating Coal Transition
COES	National Interconnected System Financial Operation Committee
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP26	2021 United Nations Climate Change Conference
C-PACE	Commercial Property Assessed Clean Energy
CREA	The Center for Research on Energy and Clean Air
CREEI	China Renewable Energy Engineering Institute

CTF	Clean Technology Fund
DEDE	Department of Alternative Energy Development and Efficiency, Thailand
DEN	Dewan Energi Nasional (National Energy Council), Indonesia
DOE	Department of Energy, the Philippines
DPPA	Direct power purchase agreement
DPR	Dewan Perwakilan Rakyat (House of Representatives), Indonesia
DRCC	Demand Response Control Center, Thailand
DSO	Distribution system operator
ECA	Export credit agency
ECR	Effective carbon rate
EDC	Energy Development Corporation
EEC	Eastern Economic Corridor, Thailand
EGAT	Electricity Generating Authority of Thailand
EGCO	Electricity Generating PCL, Thailand
EPC	Engineering Procurement Construction
EPPO	Energy Policy and Planning Office, Thailand
EPRI	Electric Power Research Institute
ERC	Energy Regulatory Commission
ERIA	Energy Research Institute of Asia
ESDM	Kementerian Energi dan Sumber Daya Mineral (Ministry of Energy and Mineral Resources), Indonesia
ESG	Environmental, social, and governance
ETM	Energy Transition Mechanism
ESMAP	Energy Sector Management Assistance Program
EU ETS	European Union Emissions Trading System
FERC	Federal Energy Regulatory Commission
FIT	Feed-in tariffs
Ft	Automatic Adjustment Mechanism, Thailand
GDE	PT Geo Dipa Energi
GEUDP	Geothermal Energy Upstream Development Project, Indonesia
GFANZ	Glasgow Financial Alliance for Net Zero
GHG	Greenhouse gas
GJ	Gigajoule
GLGP	Geothermal Loan Guarantee Program, United States
G-PST	Global Power System Transformation Consortium
GTCC	Gas turbine combined cycle
GW	Gigawatt
GWh	Gigawatt-hour
GWp	Gigawatt peak

GX	Green transformation
HESS	Hydrogen energy storage system
H2	Hydrogen
H4C	Home for Cash, Krungsri
IBC	Indonesia Battery Corporation
IBCSD	the Indonesian Business Council for Sustainable Development
IDR	Indonesian rupiah
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IESR	Institute for Essential Service Reform, Indonesia
IFC	International Finance Corporation
INA	Indonesia Investment Authority
IPCC	Intergovernmental Panel on Climate Change
IPG	International Partners Group
IPP	Independent power producer
I-REC	International renewable energy certificate standards
IRA	Inflation Reduction Act
IRENA	International Renewable Energy Agency
IRR	Internal rate of return
ISO	Independent system operator
ITB	Institut Teknologi Bandung (Bandung Institute of Technology), Indonesia
ITC	Investment tax credit
IUPTLS	Izin Usaha Penyediaan Tenaga Listrik (captive power license, Indonesia
JETP	Just Energy Transition Partnership
JICA	Japan International Cooperation Agency
JOGMEC	Japan Organization for Metals and Energy Security
KADIN	Kamar Dagang dan Industri (Chamber of Commerce), Indonesia
KBUMN	Kementerian Badan Usaha Milik Negara (Ministry of State-Owned Enterprises), Indonesia
KEN	Kebijakan Energi Nasional (National Energy Policy), Indonesia
KEPCO	Korea Electric Power Corporation
KLHK	Kementerian Lingkungan Hidup Dan Kehutanan, (Ministry of Environment and Forestry, Indonesia
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
kWh/kWp	Kilowatt-hour per kilowatt peak
kWp	Kilowatt peak
LCOE	Levelized cost of electricity
LNG	Liquefied natural gas

LT-LEDS	Long-Term Low Emission and Development Strategies
MAS	Monetary Authority of Singapore
MDB	Multilateral development bank
MEA	Metropolitan Electricity Authority, Thailand
METI	Ministry of Economy, Trade, and Industry, Japan
MGI	McKinsey Global Institute
MHI	Mitsubishi Heavy Industries
MMBtu	One million British thermal units
MNRE	Ministry of Natural Resources and Environment, Thailand
MOE	Ministry of Energy, Thailand
MOF	Ministry of Finance, Thailand
MOI	Ministry of the Interior, Thailand
MOU	Memorandum of understanding
MPO	Managed phaseout
MRV	Measurement, reporting, and verification
MVA	Megavolt-ampere
MW	Megawatt
MWh	Megawatt-hour
MWp	Megawatt peak
NCCC	National Committee on Climate Change Policy, Thailand
NDC	Nationally determined contribution
NECTEC	National Electronics and Computer Technology Center, Thailand
NEDO	New Energy and Industrial Technology Development Organization, Japan
NEPC	National Energy Policy Council, Thailand
NEXI	Nippon Export and Investment Insurance Co.
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
NOx	Nitrogen oxides
NPV	Net present value
NREP	National Renewable Energy Program, the Philippines
NZBA	Net Zero Banking Alliance
NZE	Net-Zero Emissions scenario, International Energy Agency
OECD	Organisation for Economic Co-operation and Development
OJK	Otoritas Jasa Keuangan (Financial Services Authority), Indonesia
ONEP	Office of Natural Resources and Environment Policy and Planning, Thailand
ONS	Operator of the National Electricity System
PDP	Power Development Plan, Thailand
PDP8	National Power Development Plan, Vietnam
PEA	Provincial Electricity Authority, Thailand

PISP	Pembiayaan Infrastruktur Sektor Panas Bumi (Geothermal Sector Infrastructure Financing), Indonesia
PLN	Perusahaan Listrik Negara, Indonesia
PLN NP	PLN Nasantara Power, Indonesia
PPA	Power purchase agreement
PROPER	Company Performance Rating Assessment Program
PTC	Production tax credits
PV	Photovoltaic
R&D	Research and development
REAL	Renewable Energy Alliance
REC	Renewable energy certificate
REFC	Renewable Energy Forecast Center, Thailand
RES	Renewable energy sources
RESD	Renewable Energy Skills Development
ROI	Return on investment
ROIC	Return on invested capital
RUED	Rencana Umum Energi Daerah (Regional Energy Plans), Indonesia
RUEN	Rencana Umum Energi Nasional (National Energy Plan), Indonesia
RUKD	Rencana Umum Ketenagalistrikan Daerah (Regional Electricity Plan), Indonesia
RUKN	Rencana Umum Ketenagalistrikan Nasional (National Electricity Plan), Indonesia
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik, Indonesia
SDG	Sustainability Development Goals, United Nations
SEC	Securities and Exchange Commission, Thailand
SSH	Super Solar Hybrid Co., Ltd.
SLL	Sustainability-linked loan
SME	Small and mid-sized enterprises
SMI	PT Sarana Multi Infrastruktur
SMV	Special mission vehicle
SOE	State-owned enterprise
SOx	Sulfur oxides
SPCG	Solar Power Company Group
SPT	Sustainability Performance Targets
SPV	Special purpose vehicle
SSH	Super Solar Hybrid Co.
SUPER	Super Energy Corporation Public Co., Ltd.
TCFD	Task Force on Climate related Financial Disclosures
TEPCO	Tokyo Electric Power Co.
THB	Thai baht
TIGR	Tradable Instrument for Global Renewables

TKDN	Tingkat Komponen Dalam Negeri (local-content level), Indonesia
TnD	Transmission and distribution
TPA	Third-party access
TRL	Technology readiness level
TSO	Transmission system operator
TEIAS	Turkish Electricity Transmission Company
T-VER	Thailand Voluntary Emission Reduction Program
TW	Terawatt
TWh	Terawatt-hour
UGT	Utility Green Tariff
UNFCC	United Nations Framework on Climate Change
USD	US dollar
VA	Volt-ampere
VER	Voluntary Emission Reduction
Wp	Watt peak
WEF	World Economic Forum

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