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Advancing Low-Carbon Industry Transition: Decarbonizing Industrial Captive Generation in Indonesia

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EXECUTIVE SUMMARY

Indonesia is attempting to transition its energy system from coal while ensuring reliable and affordable electricity. The international community, for example, the Just Energy Transition Partnership (JETP) and bilateral Memoranda of Understanding (MOU), have offered financial and technical support for Indonesia's clean energy transition, but investment plans leave crucial gaps in terms of phase-out and replacement of existing captive coal power plants. These facilities contribute significantly to national greenhouse gas emissions and are predominantly found in the metals and mining industries, sectors in which Indonesia is expected to grow in the future. Due to the complexity of these industrial processes and grid accessibility issues, reducing carbon emissions is also more complex than decarbonizing other sectors of the economy. Presidential Regulation 11/2/2022 (PerPres 112/22) has set a benchmark, committing to end new coal power plants and requiring captive industrial parks to reduce carbon emissions by 35% within 10 years of operation. However, many questions remain about how these targets will be achieved.

Industrial park firms are interested in decarbonizing their industrial parks by exploring various available options, including energy efficiency, on-site renewable options or more commonly referred to as captive renewables, grid imports through grid connection, and others. However, they face regulatory challenges imposed by federal and state governments, a lack of direct incentives to undertake costly upgrades, unclear industry standards, and uncertain financing streams. Coordinating grid connection options with *Perusahaan Listrik Negara* (PLN) in certain areas could be cost-effective, but these present large coordination problems among PLN's grid and generation development, international actors, local governments, and industrial park owners and tenants.

This report assesses options for reducing carbon emissions in Indonesia's captive power facilities, considering plant-level options and grid upgrades, with a specific emphasis on who owns these facilities and identifying viable strategies to support and implement these upgrades.

Key findings:

- Electricity use in these industrial facilities can be partially decarbonized, achieving 35% of industrial power generation from cleaner options.
- Grid connection of industrial parks requires upgrading the bulk transmission infrastructure by up to 16% nationwide to accommodate the additional electricity demand from industrial parks.
- Allowing industrial parks to both build captive renewable energy and connect to the grid is a cost-effective solution compared to a coal-only scenario.
- Captive coal plants are still important for heat-intensive industries like nickel and aluminum smelters and remain in the mix through 2035.
- Industrial park upgrades are very sensitive to grid electricity tariffs and coal prices, affecting the percentage of renewable energy options.

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LIST OF ABBREVIATIONS

BAU Business As Usual.

CCUS carbon capture utilization and sequestration.

CHP combined heat and power.

CIPP Comprehensive Investment and Policy Plan.

CO_2 carbon dioxide.

EV electric vehicle.

G7 Group of Seven.

GW Gigawatts.

IPP Independent Power Producers.

JETP Just Energy Transition Partnership.

MEMR Ministry of Energy and Mineral Resources.

MOU MOU Memorandum of Understanding.

MW Megawatts.

NDC Nationally Determined Contribution.

PerPres 112/22 Presidential Regulation 112/2022.

PLN *Perindustrian Listrik Negara*.

PSN *Proyek Strategik Nasional* or National Strategic Project.

PV photovoltaic.

RUED *Rencana Usaha Energi Daerah* or Provincial Energy Plan.

RUEN *Rancangan Usaha Energi Nasional* or National Energy Plan.

RUPTL *Rencana Usaha Penyediaan Tenaga Listrik Negara* or National Electricity Business Plan.

SMR small modular reactors.

LIST OF FIGURES

1 INTRODUCTION

Indonesia is committed to ambitious climate and clean energy targets, aiming for net-zero emissions by 2060 under multiple policy and investment agreements. Despite these national efforts, a significant and growing challenge persists in Indonesia's decarbonization strategy concerning industrial captive coal power plants. The inherent complexity of these industrial processes, coupled with issues like remote locations and limited grid access, often renders carbon emissions reduction in this sector more costly and technically demanding than in other parts of the economy. Industrial firms operating these captive power systems face regulatory hurdles in decarbonizing their power generation. The development of these industrial parks is also a cornerstone of economic policy which provides jobs, value-added exports, and infrastructure in remote areas[1,2].

Decarbonizing this sector involves exploring a range of technological and infrastructural solutions, primarily through the deployment of on-site renewable energy solutions (including solar, wind, geothermal, and battery storage) and the option of connecting these industrial facilities to the national grid to import cleaner power. Prior policy efforts and research initiatives, such as the JETP and PerPres 112/22, have predominantly focused on the state utility PLN's grid-connected coal power plants[3–5]. Consequently, the off-grid power sector has, until recently, received less dedicated attention within Indonesia's broader coal generation reduction strategies, creating a systemic oversight and a regulatory blind spot where a significant and rapidly growing segment of the power sector operates largely unaddressed by central national climate strategies. Similar reports have contributed significantly to this issue by identifying potential decarbonization measures for these industrial parks and local and foreign stakeholders that are relevant for this issue, but there exists a lack of facility-level cost-optimal pathways in terms of on-site renewables and grid connection [6–11].

This report aims to address this critical gap by comprehensively assessing the viable options for reducing carbon emissions in Indonesia's captive power facilities. Building on existing literature, this report considers both plant-level decarbonization strategies and the necessity of grid upgrades, utilizing a co-optimization model to identify the best strategy for each industrial facility. Specifically, the report evaluates various decarbonization pathways, quantifies the associated financial requirements, and examines the policy alignment necessary to facilitate the transition of industrial captive generation in Indonesia. The findings presented herein are intended to contribute to the development of a more coherent and effective national energy transition strategy, ensuring that emissions from the captive power sector are integrated into Indonesia's broader climate commitments. It also aims to inform the industrial facility owners on the next steps for moving away from captive coal generation.

The report is structured as follows: Section 2 outlines the current political scenario in Indonesia regarding decarbonization and energy transition. Section 3 provides a detailed overview of Indonesia's captive power landscape, including its growth, sectoral distribution, and the unique barriers to its decarbonization. Section 4 presents the methodology employed in this analysis, and Section 5 details the key findings from the scenario modeling, outlining the implications for decarbonization pathways, financing, and policy needs. Section 6 offers a comprehensive discussion of these findings, while Section 7 proposes actionable policy recommendations at national, regional, and international levels. Finally, Section 8 concludes the report by summarizing key contributions and outlining future research directions.

2 INDONESIA'S POLICIES ON DECARBONIZATION OF CAPTIVE COAL POWER PLANTS

Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience aims to achieve net-zero emissions by 2060 or earlier[12]. In the shorter term, the nation's enhanced Nationally Determined Contribution (NDC) seeks to reduce greenhouse gas emissions by 31.89% below Business As Usual (BAU) by 2030 (unconditionally), or up to 43.20% with adequate international support[12]. To realize these objectives, Indonesia has established specific energy targets, notably requiring 23% of its energy to be derived from new and renewable sources by 2025[12,13], with additional growth in renewable energy anticipated through 2050. These commitments underscore Indonesia's determination to transition from fossil fuels while ensuring sustained economic growth and energy security. Moreover, President Prabowo has also announced highly ambitious renewable energy targets, including deploying 100 GW of solar PV with 320 GWh of battery storage and achieving 100% renewable power within the next 10 years while phasing out coal within 15 years[14,15].

2.1 Restricting Coal Power: Presidential Regulation No.112/2022

A major policy step towards Indonesia's climate goals was the issuance of PerPres 112/22 on the Acceleration of Renewable Energy Development[5]. Article 3 of this regulation essentially bans the construction of new coal-fired power plants, except under strict conditions, and establishes a road map for phasing out existing coal power by 2050[5]. This marked the "beginning of the green industry era," as officials described it, aligning the power sector with the net-zero 2060 target[16]. The rule prohibits any new coal power plant projects unless they meet all of the following criteria:

- Already included in the 2021-2030 *Rencana Usaha Penyediaan Tenaga Listrik Negara* or National Electricity Business Plan (RUPTL) by PLN.
- Integrated with industrial facilities and aimed at increasing the added value of domestic natural resources (i.e. captive power for industry).
- Designated as a *Proyek Strategik Nasional* or National Strategic Project (PSN) by the government.
- Committed to emissions reduction, where the plant must cut its CO_2 emissions by at least 35% within ten years of operations through measures like technology upgrades, carbon offsets, and/or co-firing with renewables.
- Operates only up to 2050 at the latest, aligning with the national coal phase-out deadline

By limiting new coal plants to these exceptional cases, PerPres 112/22 seeks to prevent unchecked expansion of coal power while Indonesia scales up renewable generation. It also calls for developing a roadmap to accelerate the retirement of existing coal plants (including those owned by the state utility PLN and Independent Power Producers (IPP)), reflecting Indonesia's commitment to reduce power sector emissions in line with its climate targets.

2.2 Just Energy Transition Partnership (JETP) with G7 Countries

In addition to domestic policies, Indonesia has partnered with international donors to facilitate a more expedited transition away from coal. In November 2022, Indonesia, in collaboration with a coalition of G7 countries and other partners, announced JETP, which represented a historic agreement aimed at mobilizing USD 20 billion in financing for Indonesia's clean energy transition[3]. Under the JETP, Indonesia has pledged to pursue a more ambitious trajectory in its power sector, which includes:

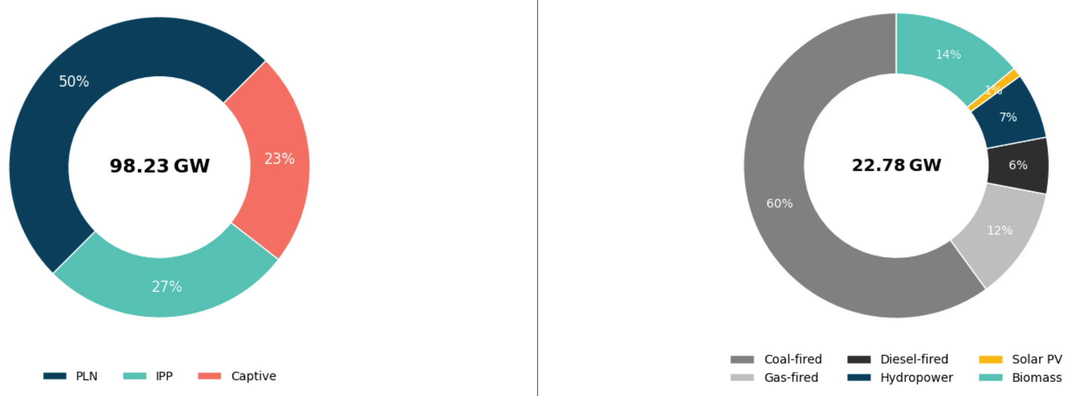
- Capping power sector emissions at 290 million tons of CO_2 by 2030

- Increasing the proportion of renewable energy to at least 34% of electricity generation by the year 2030
- Accelerated phase-out of selected coal power plants
- Achieve net-zero economy-wide emissions by 2050, which is a decade ahead of the national net-zero commitment set for 2060.

This partnership is designed to facilitate the expedited phase-out of coal-fired power plants and to accelerate investments in cleaner energy alternatives. The Comprehensive Investment and Policy Plan (CIPP), released by the JETP secretariat in November 2023, has identified priority areas, including financing the early retirement of coal power units and the expansion of the electric grid[4]. For instance, approximately 14,000 kilometers of new transmission lines and other grid enhancements, estimated to cost USD 19.7 billion, are planned to facilitate the integration of large-scale renewable energy sources[4]. In conjunction with the substantial deployment of renewable energy, exceeding 56 GW of new renewables by 2030 under the CIPP, these initiatives aim to place Indonesia on a lower-carbon trajectory while ensuring energy reliability. Consequently, the JETP strengthens Indonesia's domestic efforts by providing financial and technical assistance for the transition away from coal and the expansion of clean energy, which includes critical improvements to grid infrastructure to support the new renewable energy generation.

3 INDONESIA'S CAPTIVE COAL POWER LANDSCAPE

Despite these initiatives, a significant gap persists in Indonesia's coal transition strategy concerning the treatment of captive coal power plants. Indonesia has experienced a rapid increase in captive power plants, defined as generators installed in a factory or an industrial park for the facility's energy needs. These generators can be on-grid (connected to the grid for power exports) or off-grid (no power exports) but in Indonesia, these generators are mostly off-grid. Captive plants have emerged as a substantial component of the nation's power mix, particularly in the form of coal-fired units that cater to energy-intensive mining and smelting operations.



(a) **Power capacity share by different owners**

(b) **Technology share of captive generators**

Figure 3.1: Power capacity share in Indonesia[17]

Captive power constitutes approximately one quarter of Indonesia's power generation capacity (Fig. 3.1). Nearly 15 GW of captive coal-fired capacity is already operational, representing almost 25% of the country's coal power fleet (Fig. 3.1a)[17,18]. Moreover, more than 10 GW of additional captive coal projects are under development, anticipated to become operational in the forthcoming years[17,18]. The off-grid generation segment has expanded nearly eightfold from 2015 to 2025, demonstrating a cumulative annual growth rate of 26%, which significantly outpaces growth within the main grid power sector.

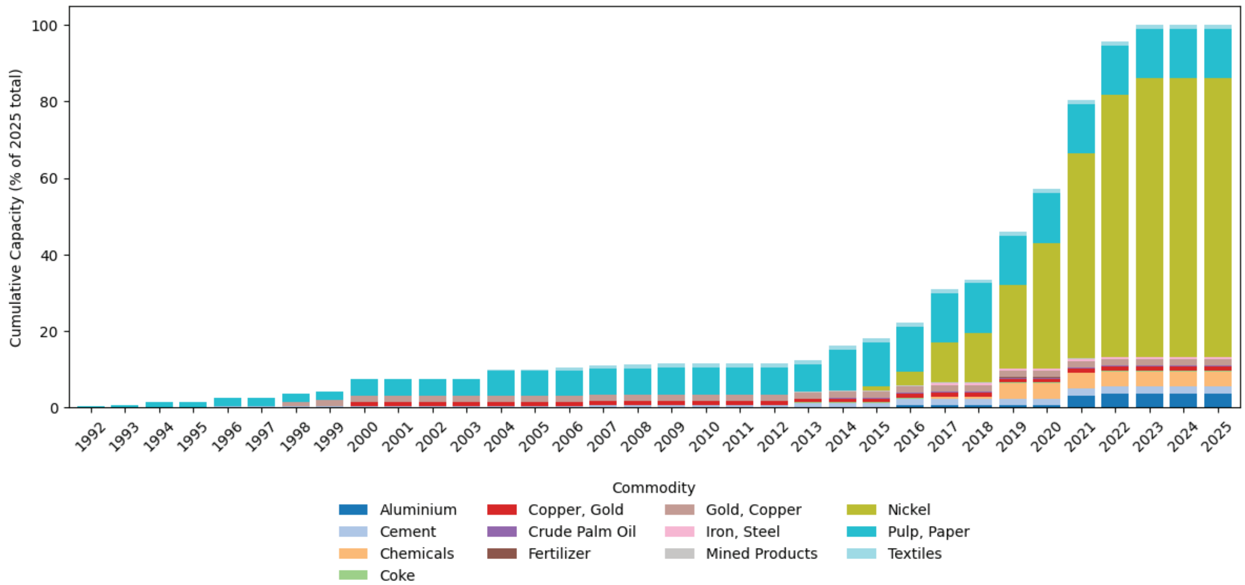


Figure 3.2: Capacities of captive coal generators within industrial facilities. Each bar indicates the captive coal capacity for each commodity for each year from 1995 to 2025[17].

The proliferation of captive coal plants is closely associated with Indonesia's mineral downstreaming initiative. Since 2019, the captive coal capacity has tripled from 5.5 GW to 16.6 GW (Fig. 4), now comprising over 130 plants of 30 MW or greater each, to accommodate a surge of new metal smelters[17,19]. It is estimated that 70-80% of this newly established captive capacity has been constructed exclusively to power nickel, cobalt, and aluminum processing facilities, which play a pivotal role in the electric vehicle (EV) and renewable energy supply chains[20].

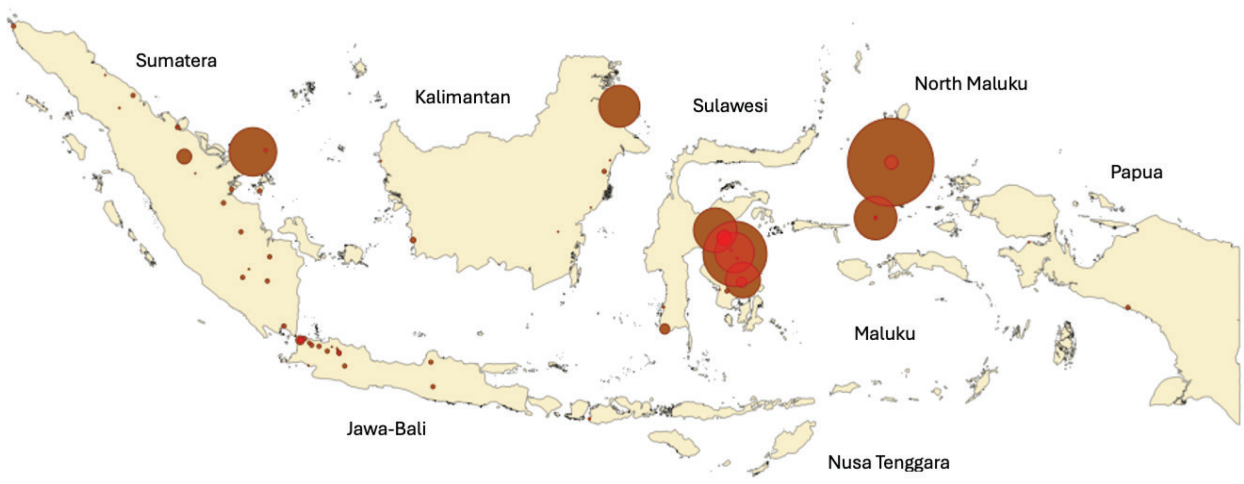


Figure 3.3: Industrial facilities with coal captive generators located across Indonesia[17]. The size of the circles indicates the size of the capacity in each of the facilities.

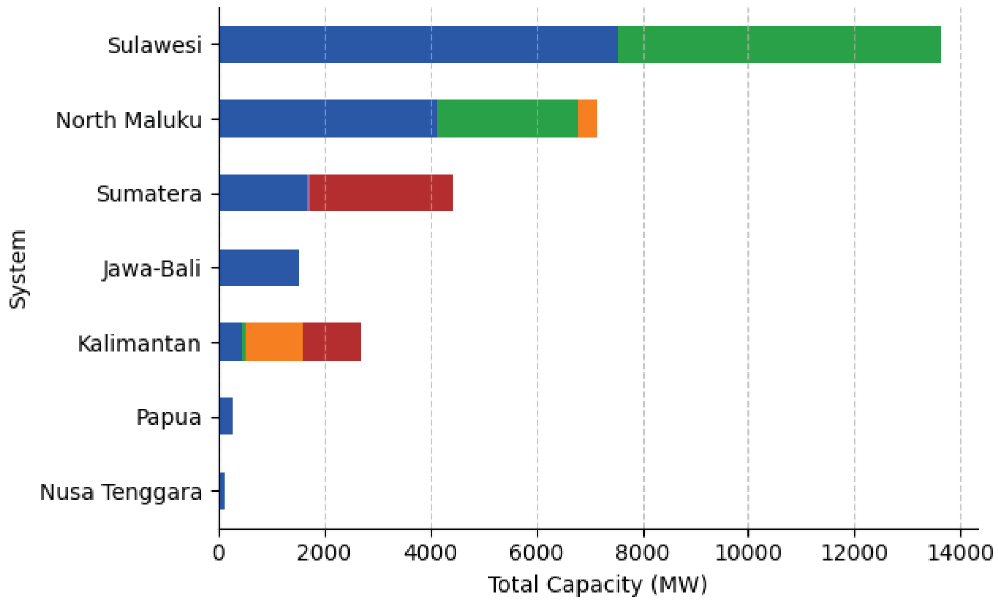


Figure 3.4: Distribution of coal captive generators across different systems

Captive coal plants are located predominantly in Indonesia's resource-rich but remote regions (Fig. 3.3, 3.4). The islands of Sulawesi and North Maluku account for the majority of the captive coal capacity (approximately 7 GW and 4 GW, respectively), which host extensive nickel smelter complexes[17,19]. These areas are characterized by limited grid infrastructure[21], which drives industries to develop their own coal power facilities on site. Such regional clustering generates coordination challenges for any transition away from captive coal.

3.1 Industrial and Geopolitical Significance

The dominance of captive coal in Indonesia's industrial sector carries broad industrial and geopolitical implications. The first and foremost is the role of nickel, a critical mineral for lithium-ion batteries and clean energy technologies. Indonesia is the world's largest nickel producer, supplying approximately 40-50% of the global nickel supply[22]. This gives Indonesia a central position in global clean energy supply chains, as nickel from its smelters ends up in EV batteries, stainless steel, and other low-carbon technology components[20].

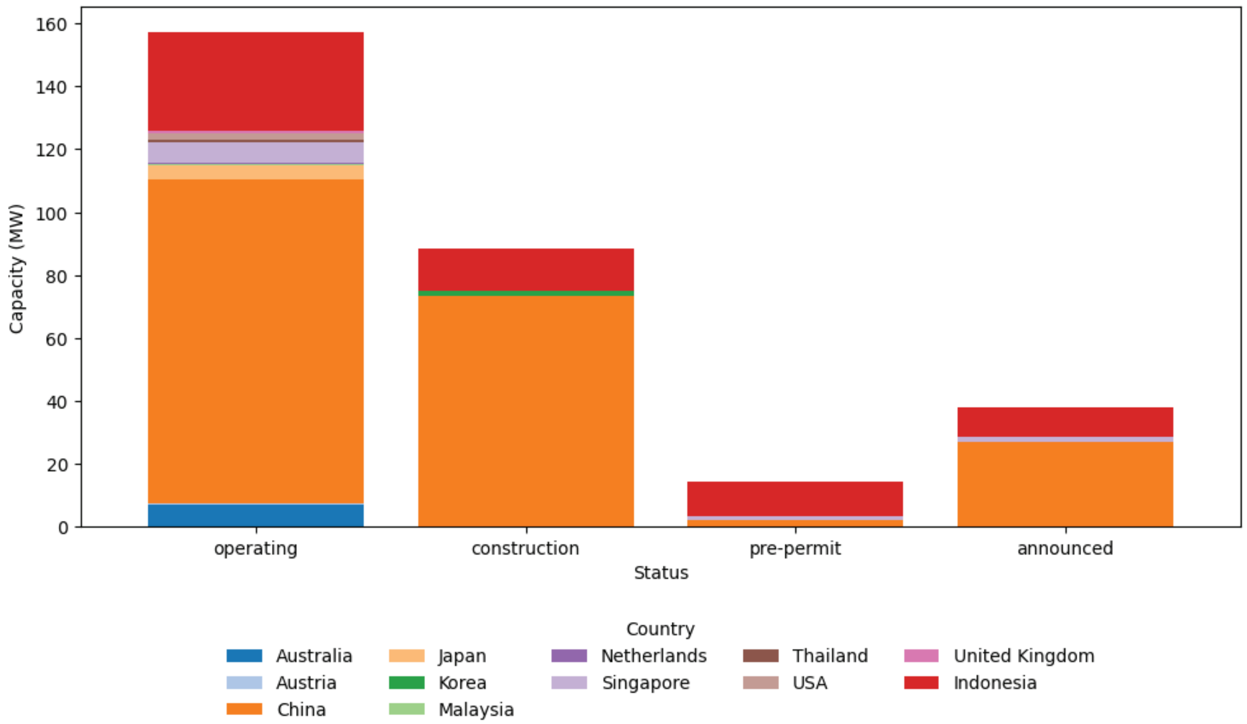


Figure 3.5: Countries that own or lease industrial facilities with captive generators[17]

Among other countries, Chinese firms have a dominant presence in Indonesia's nickel processing industry (Fig. (3.5). More than 81% of the existing and planned captive coal capacity in Indonesia involves Chinese investors or owners[10,17,18]. Major Chinese nickel and steel companies (e.g. Tsingshan, Jinchuan) finance or own dozens of captive power plants to satisfy the energy needs for their smelters[17,18]. Decarbonization of these captive plants is not just a domestic issue, but also intersects with international climate finance and trade (e.g. pressure on Indonesian nickel to be clean from EV manufacturers abroad[23,24]). The captive coal plants in Indonesia are at the nexus of its economic growth ambitions and the global push for cleaner supply chains, implicating both national policy and international partnerships in any solution.

3.2 Technical Barriers to Decarbonizing Captive Coal Power Plants

Transitioning Indonesia's captive industrial energy demand away from coal is challenging due to several unique barriers compared to grid-connected facilities.

3.2.1 Stable levels and diverse energy requirements

The industries served by captive plants (nickel smelters, steel mills, etc.) are highly energy-intensive and operate around the clock[25]. They require a reliable, continuous power supply to maintain complex electro-metallurgical processes[26]. Power interruptions or variability can disrupt production and damage equipment. This makes it difficult for these operations to replace coal plants with intermittent renewable sources without massive storage or backup systems. Current renewable energy sources, such as solar PV and wind generation, are insufficient alone to reliably satisfy the continuous baseload demand of a nickel smelting facility, which may require several hundred megawatts of uninterrupted power. Moreover, some smelting processes require high temperature heat or use coal directly as a reductant, further complicating replacement with clean energy[27]. These technical demands create an inherent reliance on coal's steady output unless alternatives can match it.

3.2.2 Remote locations and weak grid connectivity

Many captive coal facilities are located in remote mining areas or on islands (e.g., Sulawesi, North Maluku), where the main PLN grid is underdeveloped or absent[10,21]. The main Jawa-Bali grid has limited reach in these outer islands, and local grids lack the capacity to meet large industrial loads[21]. It also means that there is currently little infrastructure to deliver external (bulk grid) clean electricity to these sites. Upgrading transmission networks to reach distant smelter parks is costly and logistically complex, given Indonesia's archipelagic geography. Until grid connectivity improves, industries have few options other than on-site self-generation, which currently means coal.

4 DECARBONIZING INDUSTRIAL CAPTIVE GENERATION IN INDONESIA

4.1 Research Objective

The primary objective of this report is to investigate how Indonesian industries with captive coal generators can decarbonize their electricity supply in alignment with national clean energy objectives. The focus is on near-to mid-term solutions (through 2035) for industrial power systems that operate independently of the PLN's grid.

This report compares two main decarbonization pathways: on-site renewable energy solutions (solar, wind, geothermal, and battery storage) and grid connection, to identify the optimal mix that maximizes clean energy adoption cost-effectively by 2035. Short- to medium-term solutions are emphasized due to the strategic timing within industrial investment cycles, and compliance with PerPres 112/22, which mandates a 35% emission reduction within ten years for captive coal generators.

4.2 Methodology

Building on previous studies and reports on captive power decarbonization in Indonesia, this report seeks to implement power systems modeling tools to simulate the operation of industrial facilities in parallel with the grid. The analysis uses an optimization model for the simulation and uses co-optimization techniques where each industrial facility is assumed to be an islanded system and has a grid connection that allows it to import power from the grid. Concurrently, the main PLN grid is optimized along with these facilities to study the implications of grid connection to the main grid. These are tied together in the model with the same objective function that has both industrial and grid components and minimizes the total system cost. Figure 4.1 summarizes the complete methodology, and Figure 4.2 shows the systems studied.

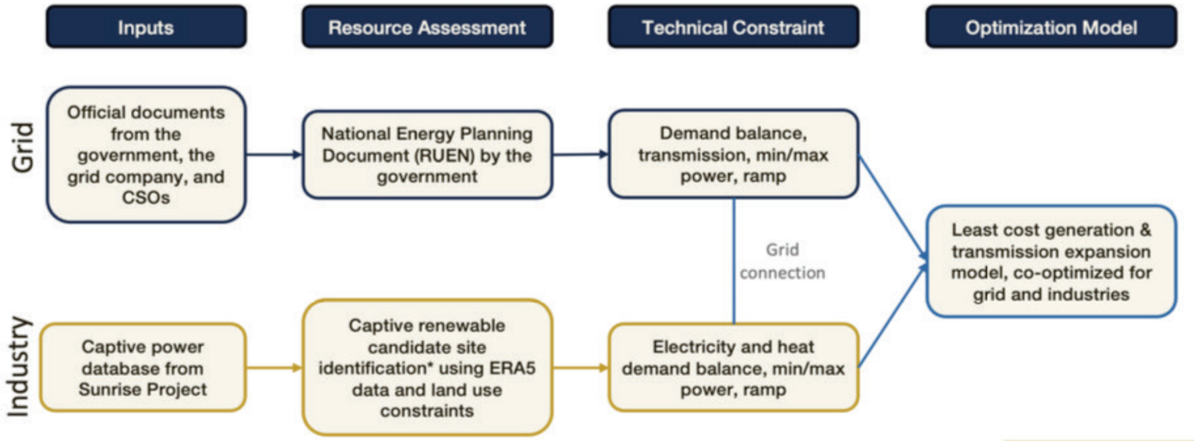


Figure 4.1: Overview of methodology. The top row indicates steps for grid modeling and the bottom row indicates industrial facility modeling.

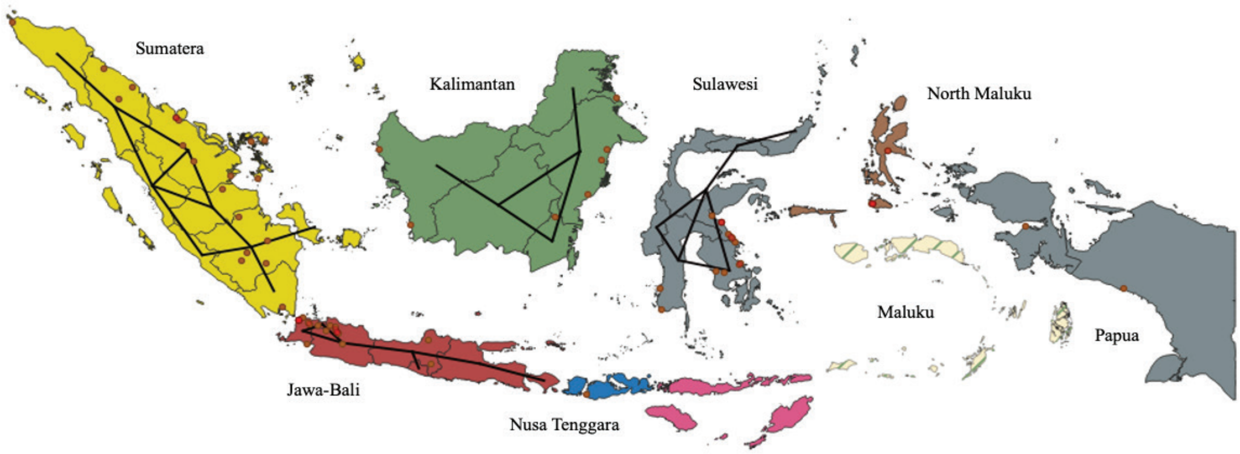


Figure 4.2: Modeled current and planned industrial facilities and existing grid transmission lines. Colors differentiate separate systems that were modeled independently of each other. All island systems are modeled except Maluku (shaded lines), where there are no known industrial facilities with captive generators.

Data Sources

Power sector data are derived from various official documents by PLN, the Ministry of Energy and Mineral Resources (MEMR), and the JETP Secretariat. Information about current and planned generators and transmission networks, along with load projections, was obtained from PLN's RUPTL 2021-2030. The demand profile was constructed based on Malaysia's Grid System Operator (GSO) load profile for the year 2023[28,29]. Fuel cost estimates and new power plant projects under the JETP agreement were obtained from JETP CIPP[30]. Coal generators are categorized into three types: grid, captive, and mine-mouth captive, and different coal price estimates are assigned to these generators. These data were supplemented with additional data from OpenStreetMap[31].

For industrial facilities, generator information was obtained from the Sunrise Project International Indonesian captive power database[17]. The load profiles were created synthetically based on existing literature on industrial processes for each commodity. Production for these industrial facilities was estimated based on historical trends, with a growth rate of 3-5%. This projection was used to shape the load profiles. Additional information can be found in the Technical Appendix. The link to the complete database used for this project is also available at Section 8.

Renewable Energy Resource Assessment

This analysis uses a renewable resource assessment evaluated by MEMR for the grid, based on *Rancangan Usaha Energi Nasional* (RUEN)[13]. This analysis also identifies candidate sites for captive renewables by conducting a resource assessment within a 10-km buffer radius of an industrial facility.

For solar and wind resource assessment, this analysis uses the geodata package, which uses ERA5 data to identify capacity factors of certain locations[32]. For geothermal resource assessment, this analysis used the Global Heat Flow Database by the International Heat Flow Commission (IHFC)[33,34]. An ordinary kriging interpolation was performed on a 500m grid, then a suitability mask was applied to retain only those areas within each park buffer exhibiting heat flow of at least 80 mW/m2[35,36].

Land use constraints were obtained from the Ministry of Environment and Forestry (KLHK) database[37]. Critical land elements like forest and residential areas were identified from this database and excluded from the assessment. Slope constraints were obtained from EarthExplorer, a database developed and maintained by the United States Geological Survey (USGS)[38].

Model

A generation and transmission capacity expansion mixed-integer linear programming (MILP) model was developed in Julia/JuMP for this report[39,40,41], building on sample optimization notebooks. Gurobi is used as the optimization engine[42,] and the high-performance computing cluster under the Triton Shared Computing Cluster, part of the San Diego Supercomputer Center, was used for computational needs[43]. See the Technical Appendix for more information on the computational setup and a reduced version for faster execution. The link to the GitHub repository that hosts the model code is available in Section 8.

Decision Variables

Investment and operational decisions for both the grid and industrial facility infrastructure were included as decision variables in this co-optimization model. New build and retired capacities of generators, storage, and transmission lines were included in the investment decisions. Commitment states of thermal units, dispatch, charging of storage units, non-served energy, flow on transmission lines, and grid imports were the key decisions made for system operations.

Constraints

The model incorporates a range of technical and policy constraints. It evaluates the investment potential for new solar, wind, geothermal, and hydro projects while ensuring zonal demand balance and accounting for transmission expansion requirements and grid imports for the industrial parks. Dispatch limits are enforced through maximum and minimum generation thresholds. Time-coupling requirements link decisions across consecutive periods, and storage operations are modeled explicitly. Thermal units are subject to unit commitment rules, including minimum up- and down-time constraints. The model also enforces clean energy constraints based on PerPres 112/22 and JETP targets[3,5].

Objective Function

The objective function aims to minimize the system's total annual cost by considering several cost components for both grid and industrial infrastructure. These include the annualized capital and fixed expenses associated with resource additions, storage units, and transmission infrastructure, as well as the variable operating costs of generators. In addition, the function incorporates penalties for non-served demand, startup costs for thermal plants, and grid connection costs. For further details, refer to the Technical Appendix.

Zonal Aggregation

Each system in Indonesia was modeled separately based on jurisdiction borders set by MEMR[13] (Fig 4.2). Then each system was further broken down, where provinces were assumed to be demand centers/zones. The Sumatera system has nine zones, the Jawa-Bali system has seven zones including the Bali island, the Kalimantan system has five zones and the Sulawesi system has six zones. Additionally, North Maluku, Maluku, Papua, and Nusa Tenggara systems were modeled as one zone each due to the lack of transmission lines[21].

Time Sampling

This model simulates eight representative weeks in a year of hourly energy system operations for both the grid and each industrial park. A k-means clustering algorithm was used to pick the representative weeks, which also includes a peak week for resource adequacy conditions. The selected weeks are outlined in the Technical Appendix.

Scenarios

This analysis is driven by two main factors that subsequently define the scenarios explored: (a) decarbonization options and (b) clean energy targets. (a) and (b) are combined to create five main scenarios.

(a) Decarbonization options. The *BAU* and *Captive* scenario assumes that the industrial facilities do not connect to the grid and continue to operate with coal generators (and build new captive renewables for *Captive*). The *Grid* scenario only allows the industrial facilities to connect to the grid and use its existing coal generation fleet, while *GridCaptive* allows the industrial park to connect to the grid, build new captive renewables, and keep the current captive coal generators.

(b) Clean energy targets. In addition to the decarbonization options, this analysis also adds the clean energy targets set by JETP and PerPres 112/22[3,5]. The JETP targets (JETP scenario) enforce maximum CO_2 emissions and minimum renewable generation from the grid while the PerPres 112/22 (35%R scenario) sets an emissions cap on the industrial facilities.

These scenarios are run in combination. The main set of scenarios are: (i) *BAU*, (ii) *BAU + JETP*, (iii) *Grid + JETP + 35%R*, (iv) *Captive + JETP + 35%R*, and (v) *GridCaptive + JETP + 35%R*.

(c) Sensitivities. A cost sensitivity analysis was performed on the *GridCaptive + JETP + 35%R*. A higher grid import price with a 21% increase[21] was tested to analyze the impacts on the system. This scenario will be referred to as *High Import Price + JETP + 35%R* for the rest of the report. Furthermore, all scenarios were examined with the emissions constraint applied only to the power generation of the captive plants. To explore the coal price sensitivity, all scenarios with a reduced coal price of $70/ton were also studied, reflecting the price cap of the domestic market obligation (DMO)[13].

5 KEY FINDINGS

5.1 The use of electricity in industrial parks can be partially decarbonized easily

Compared to the *BAU* scenario, with grid connections alone (*Grid + JETP + 35%R*), industrial facilities are able to reduce their captive generation capacity by 17.5% (Fig. 5.1). Subsequently, grid connection provides about 26.5% (Fig. 5.2), which also accounts for the clean energy share in this scenario. But the (*Grid + JETP + 35%R*) is considered infeasible due to a high amount of load shedding. In the *Captive + JETP + 35%R* scenario, coal captive capacity is reduced by 18.4% (Fig. 5.1) in the industrial facilities, with a build-out on solar and battery storage. As a result, grid connection accounts for about 34.7% of total generation in this scenario.

Introducing captive renewables and storage, along with grid connection (*GridCaptive + JETP + 35%R*), significantly reduces the capacity and generation of coal captive plants compared to the previous two scenarios. By connecting the industrial facility to the grid and adding captive renewables, the industrial facilities nationwide are able to reduce their captive generation capacity by 20.2% (Fig. 5.1). With this mix of clean energy options, about 34.5% of generation are from clean energy options (Fig. 5.2).

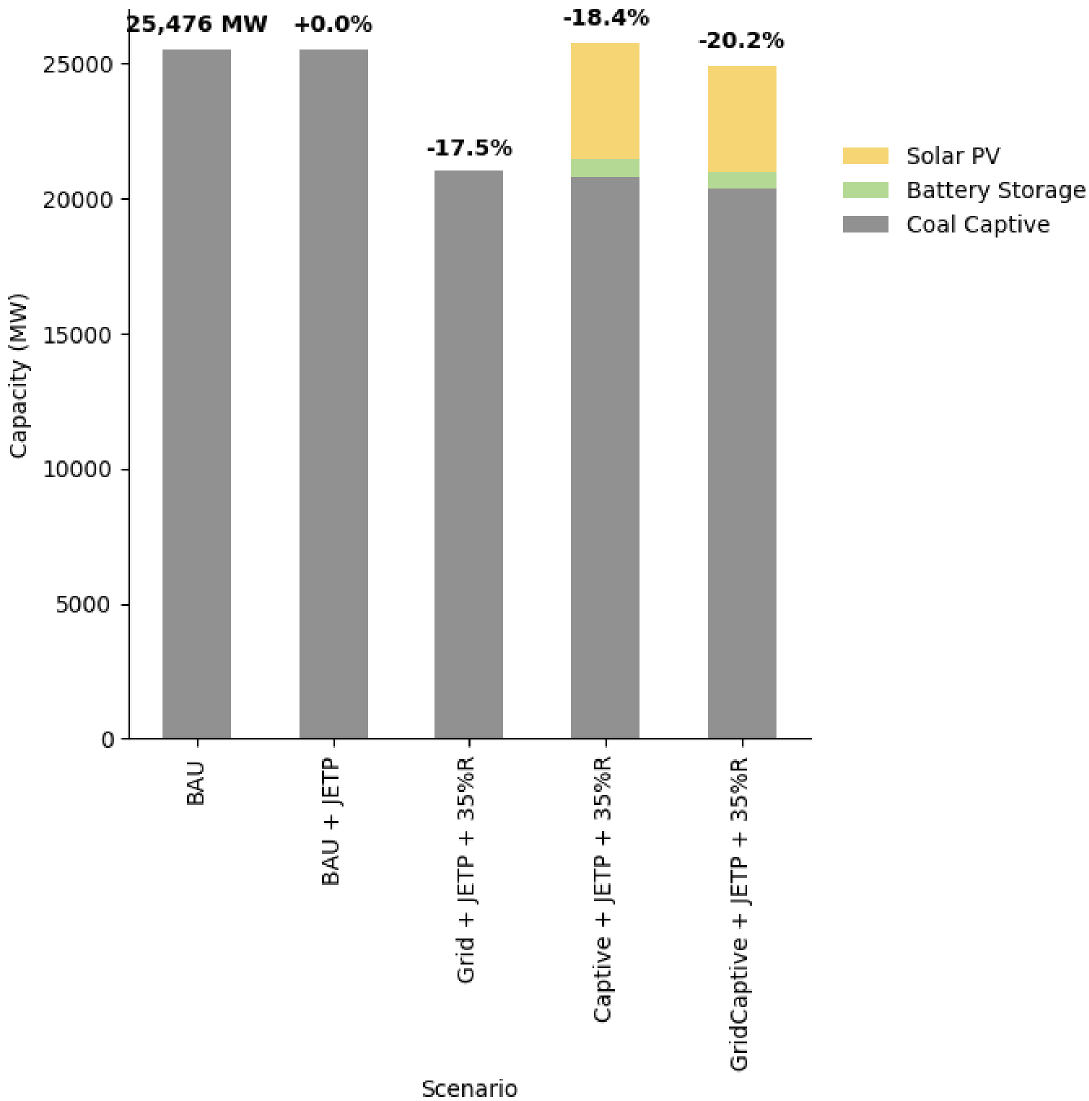


Figure 5.1: **Industrial facilities capacities for all scenarios for the year 2035.** Percentages on top of the bars indicate the decrease of total coal capacity with respect to *BAU* scenario.

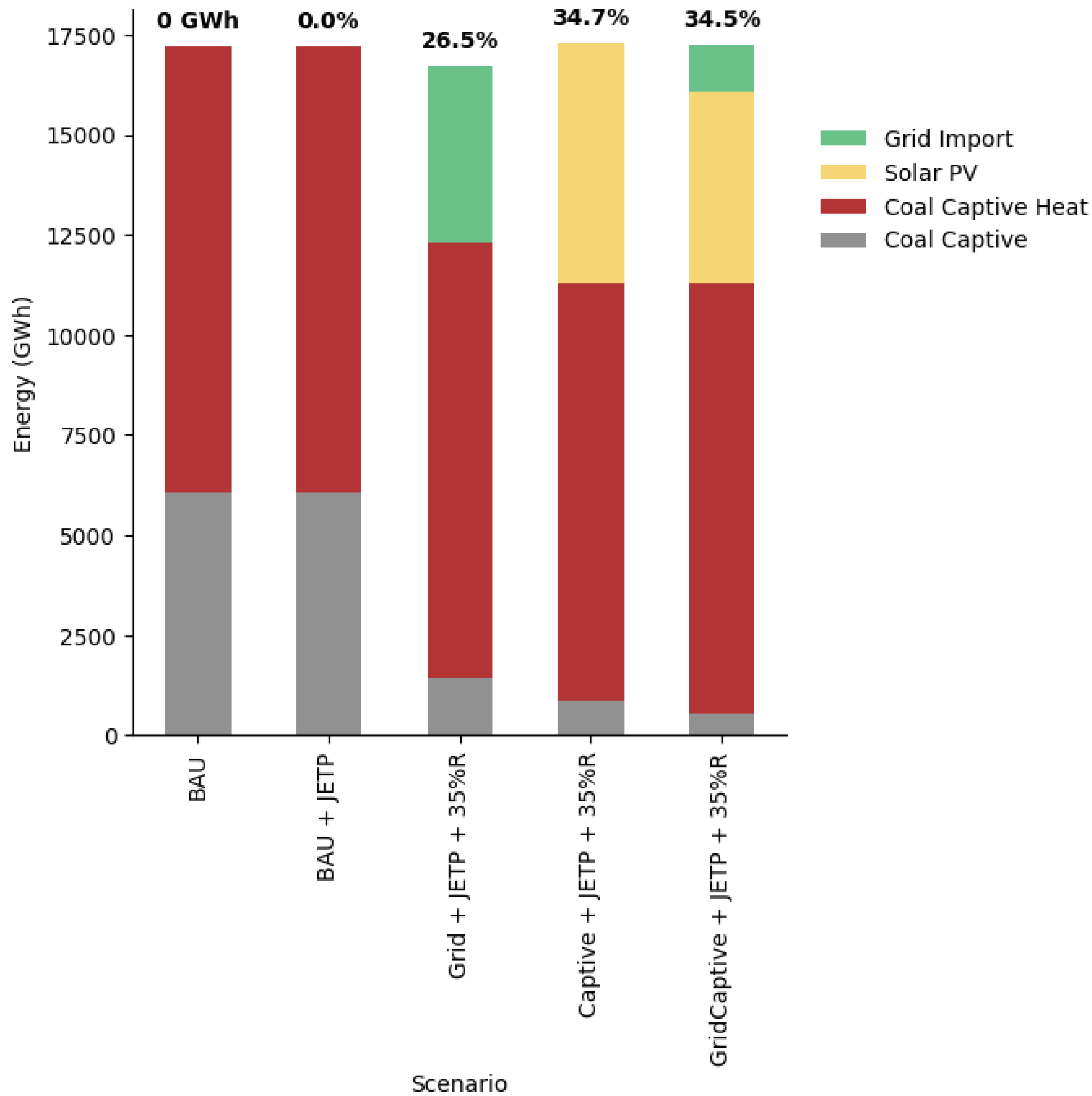


Figure 5.2: **Industrial facilities power and heat generation mix with grid imports for all scenarios for the year 2035.** **Percentages and values on top of the bars indicate renewable generation with respect to total generation.**

5.2 Industrial grid connections increase the total generation and transmission capacity in main power system

In terms of the installed capacity for the main grid, the *Grid + JETP + 35%R* scenario spurs a 8.4% capacity expansion: solar capacity grows by over 1 GW, pumped storage and gas generators are scaled up to provide flexibility, with coal contracting slightly. The *Captive + JETP + 35%R* scenario, which relies solely on on-site renewables, achieves a 0.8% capacity rise, again led by solar but without broader diversification seen under full grid reforms, similar to *BAU + JETP* scenario. By contrast, the *GridCaptive + JETP + 35%R* scenario yields a 1.5% increase over the baseline. This uptick is by modest additions of roughly 200-300 MW each of solar and hydropower plants, while coal, gas, and large hydropower capacities remain essentially unchanged.

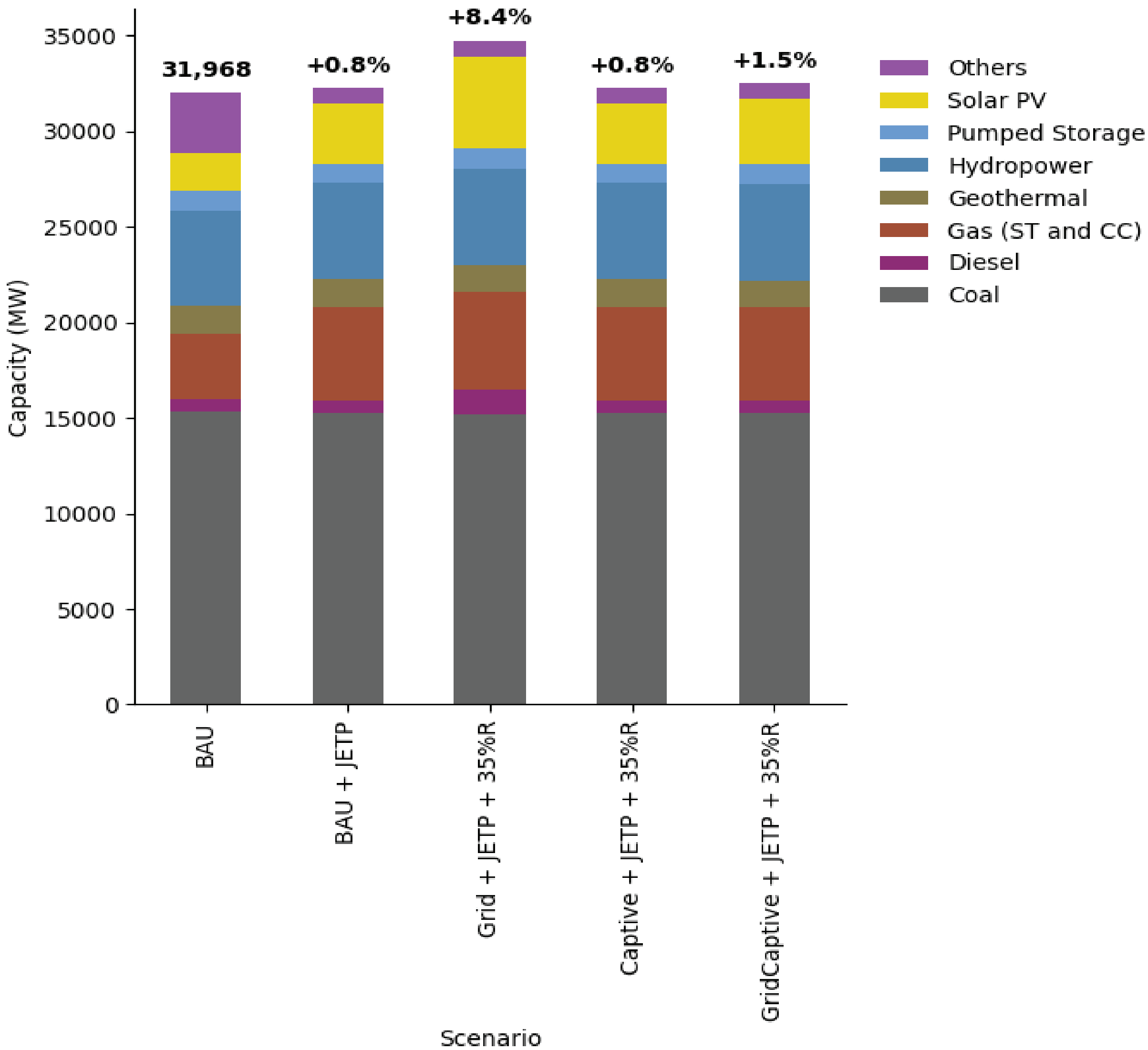


Figure 5.3: Nationwide installed grid capacities for all scenarios in the year 2035. Percentages indicate the increase in total installed capacities relative to the *BAU* scenario.

A similar pattern emerges in the annual generation too (Fig. 5.4). In the *Grid + BAU + 35%R* scenario, generation climbs by 9.4%, with significant shifts from coal to solar and hydropower, reflecting the added dispatch requirements to meet the industrial parks demand. The *Captive + BAU + 35%R* case delivers a negligible 0.1% generation boost. Under the *GridCaptive + BAU + 35%R* scenario, total output increases by 3.5%, as small gains in solar and hydropower are offset by the dominance of coal in dispatch. Overall, these results show that connecting the industrial parks to the grid and allowing them to build their own captive renewables does not trigger significant changes in system infrastructure or generation mix, whereas comprehensive grid-level reforms are required if the industrial parks were only to connect to the grid.

In addition to capacity and generation shifts, *GridCaptive* and *Grid* scenarios also drive significant transmission upgrades. It is worth to note that there are required increase in transmission capacity of 5.9% in the *BAU + JETP* scenario to achieve the clean energy targets. *GridCaptive* and *Grid* scenarios require lower upgrades compared to the *BAU* scenario.

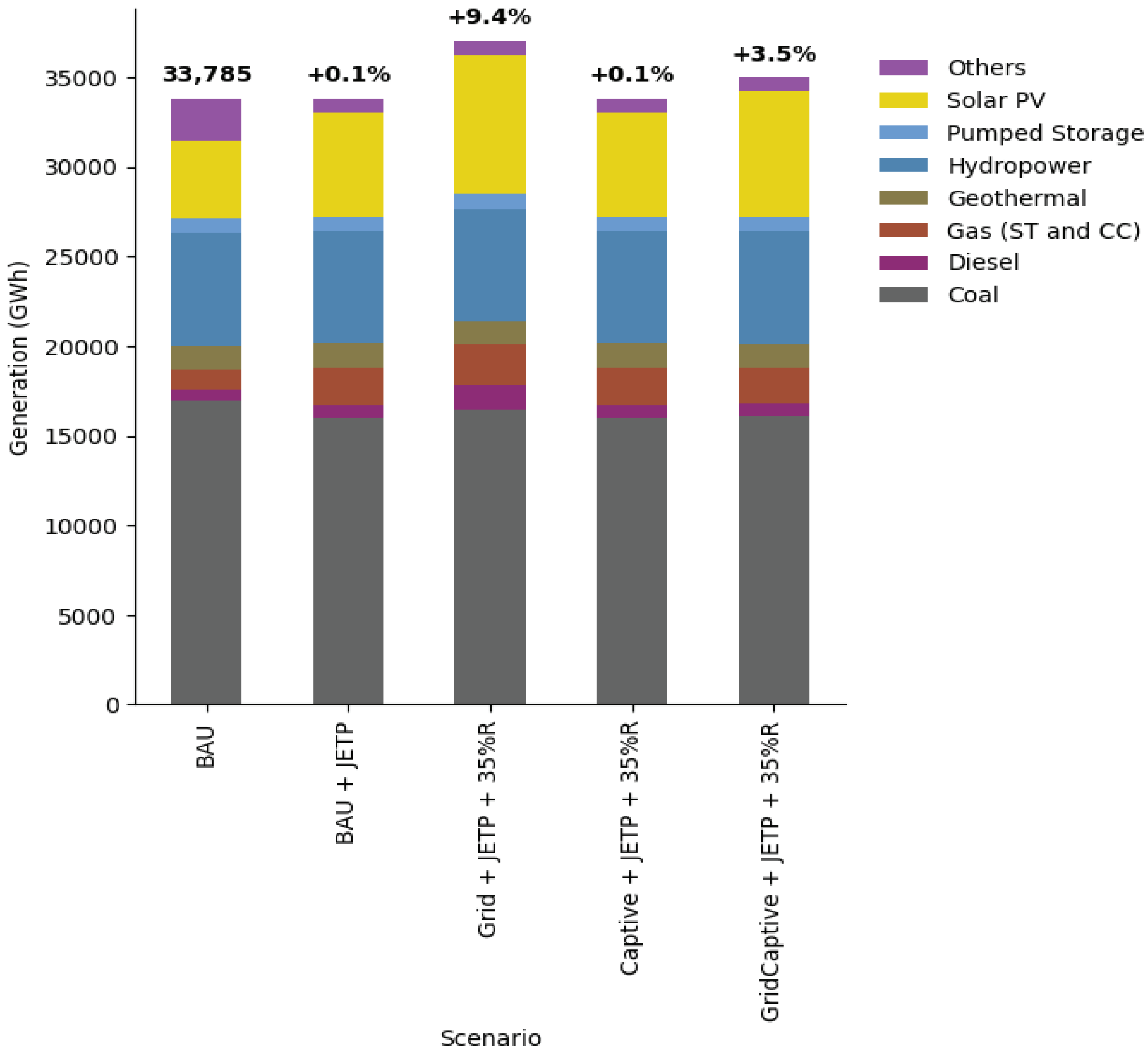
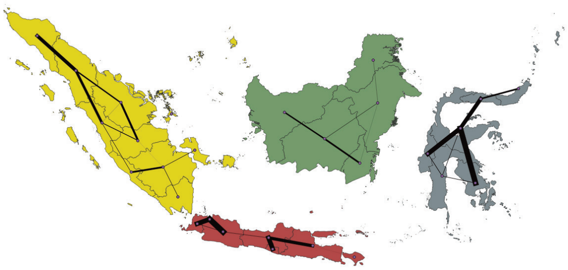
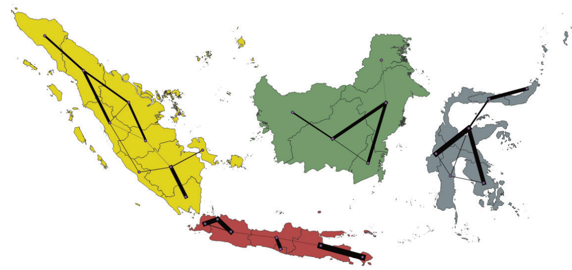


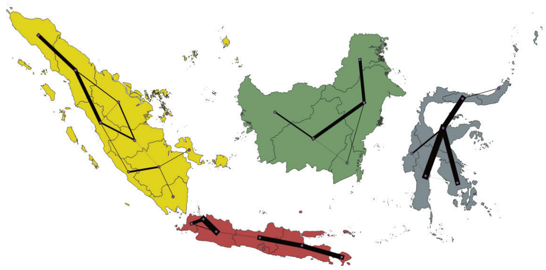
Figure 5.4: **Nationwide power system generation for all scenarios in the year 2035.** Percentages indicate the increase in total generation relative to the *BAU* scenario.



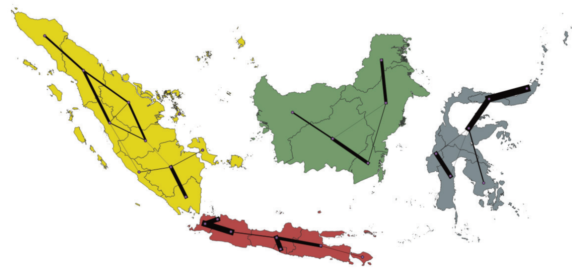
(a) *BAU* scenario



(b) *BAU* + *JETP* scenario with a 5.9% increase



(c) *Grid* + *JETP* + *35R%* scenario with a 16.7% increase



(d) *GridCaptive* + *JETP* + *35R%* scenario with a 11.2% increase

Figure 5.5: Transmission line upgrades across all scenarios for the year 2035. Only the systems with transmission lines are shown. *Captive + JETP + 35%R* scenario is not shown as it is similar to the *BAU + JETP* scenario. See Technical Appendix for detailed results.

5.3 Building captive renewables and connecting to the grid saves costs relative to a coal-only scenario.

Meeting JETP targets in the power sector alone leads to total system cost increases of 3.3% (*BAU + JETP* scenario). When considering industrial facilities, some of which face higher coal prices due to transportation costs (see Data Sources), introducing clean energy options can decrease overall system costs. By connecting these facilities to the grid (*Grid + JETP + 35%R*), total system costs go down by 6.7%. Allowing industrial facilities to provide on-site clean power reduces total system costs by 18.9%. Providing both options to industrial facilities (*GridCaptive + JETP + 35%R* scenario) drives the cost even further, achieving a 24.4% total system cost savings relative to the *BAU* scenario.

While the *GridCaptive + JETP + 35%R* scenario is the cheapest among all scenarios, CO_2 emissions are slightly elevated compared to other decarbonization scenarios due to the high carbon intensity of on-grid power. In terms of CO_2 emissions, the *Captive + JETP + 35%R* yields the lowest emissions, followed by *GridCaptive + JETP + 35%R* and *Grid + JETP + 35%R* scenarios.

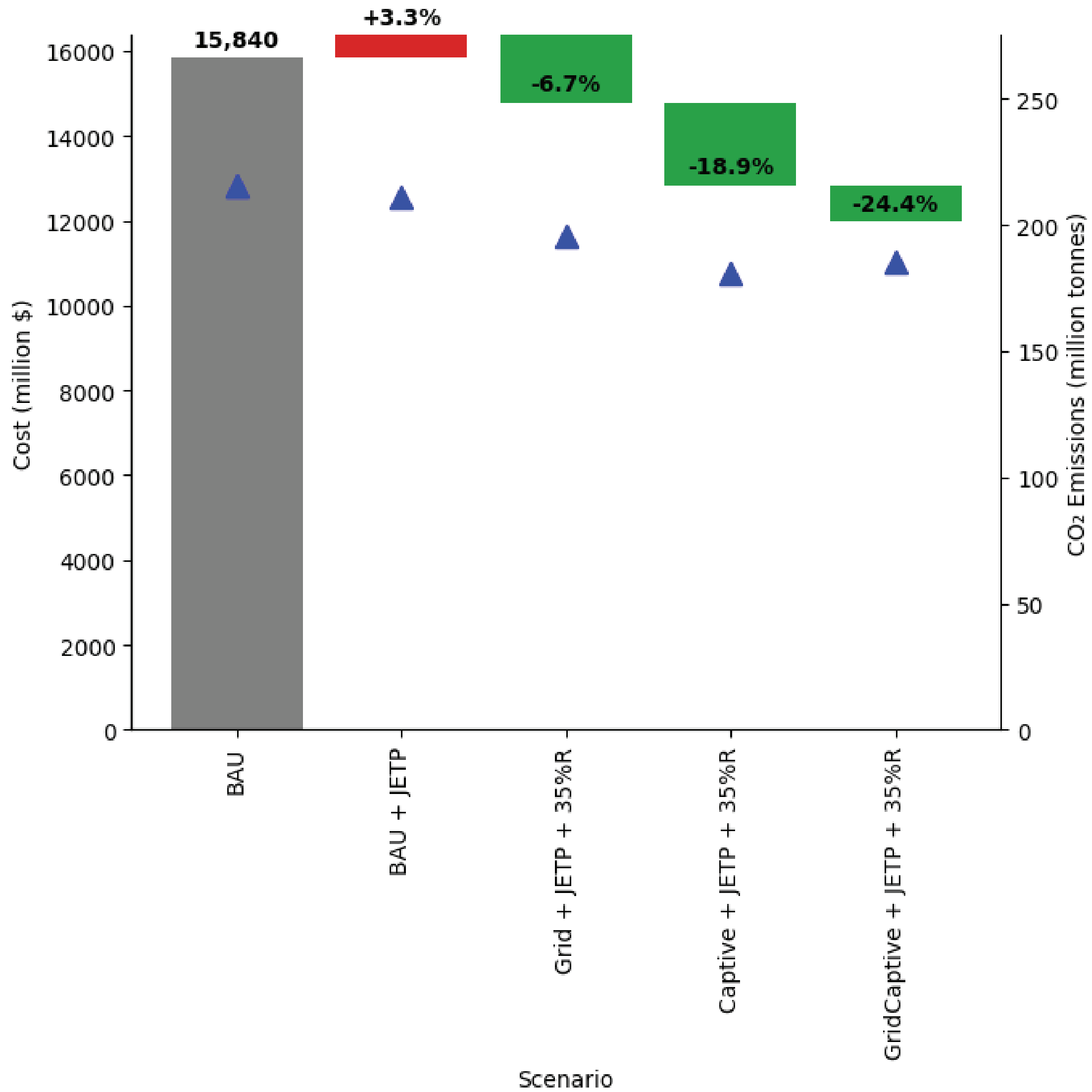


Figure 5.6: **Total system cost and corresponding CO2 emissions for power and captive industry sectors for all scenarios in the year 2035. Red bar indicates cost increases, and green bar indicates cost decreases relative to the *BAU* scenario. Percentages indicate an increase or decrease in cost relative to the *BAU* scenario.**

5.4 Coal captive plants are still prevalent in heat-intensive industries

Figure 5.7 shows the decarbonization share of industrial facilities by commodity in the *GridCaptive + JETP + 35%R* scenario, revealing a clear gradient from the low to high heat sectors. At the top, glass products (100%), wood (93.9%), and fertilizer processing (82.2%) achieve the deepest decarbonization. Midrange sectors, such as sugar refining (71.2%), crude palm oil (67.7%), petrochemicals (66.4%), gas refining (61.2%), and cement (58.9%), show that over half of their generation is decarbonized.

Further down the scale, copper & gold processing (47.9%) and iron & steel industry (46.8%) demonstrate slower progress, as these processes demand higher-grade heat and continuous steam. The nickel processing industry (22.9%) lags even more, constrained by metallurgical temperatures and large baseload requirements. Finally, aluminum smelting (8.7 %) and pulp & paper (6.5%) stand out as the hardest to decarbonize, with more than 90% of their power still supplied by captive coal.

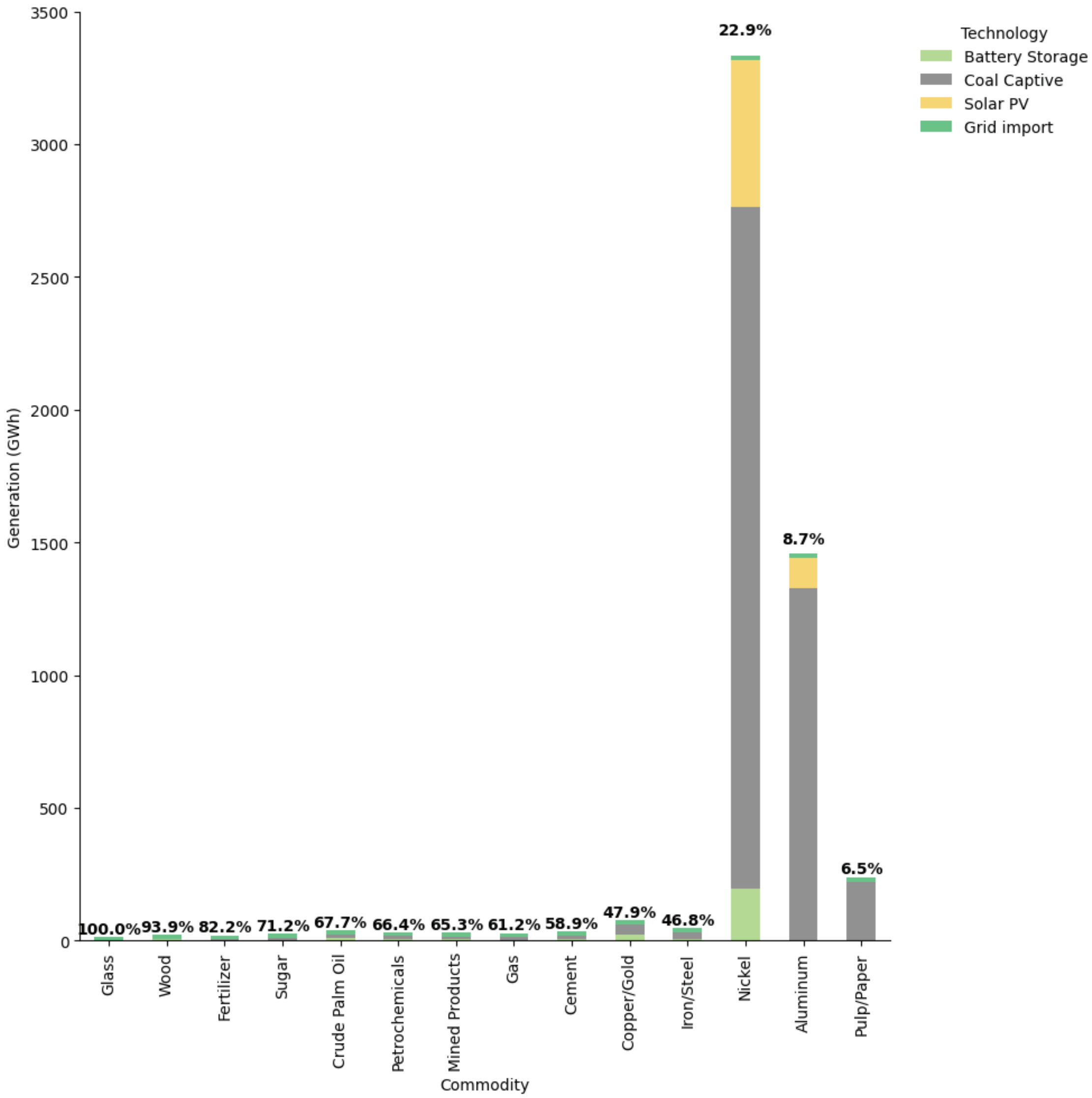


Figure 5.7: **Captive power generation for industrial facilities in the *GridCaptive + JETP + 35%R* scenario, separated by the type of commodities.** Percentages indicate the proportion of renewable generation to total generation.

5.5 Sensitivity Analysis

5.5.1 On-site solar becomes more attractive as grid import prices increase

To test the impact of rising electricity costs on industrial power sourcing, we model a scenario where grid-purchase prices increase by 21%, reflecting PLN's projected tariff adjustments of approximately 10% every five years[44]. This assumption captures how steadily rising grid tariffs could shift industrial facilities toward greater reliance on self-generation rather than imports. Raising the grid-purchase price by 21% in the *High Import Price + JETP + 35%R* scenario compared to *GridCaptive + JETP + 35%R* reduces the total grid imports from 6.6% of total generation to just 4.3% of the total generation in these industrial facilities. To respond to this, decrease, solar and coal generation increase slightly, similar to the case of *Captive + JETP + 35%*.

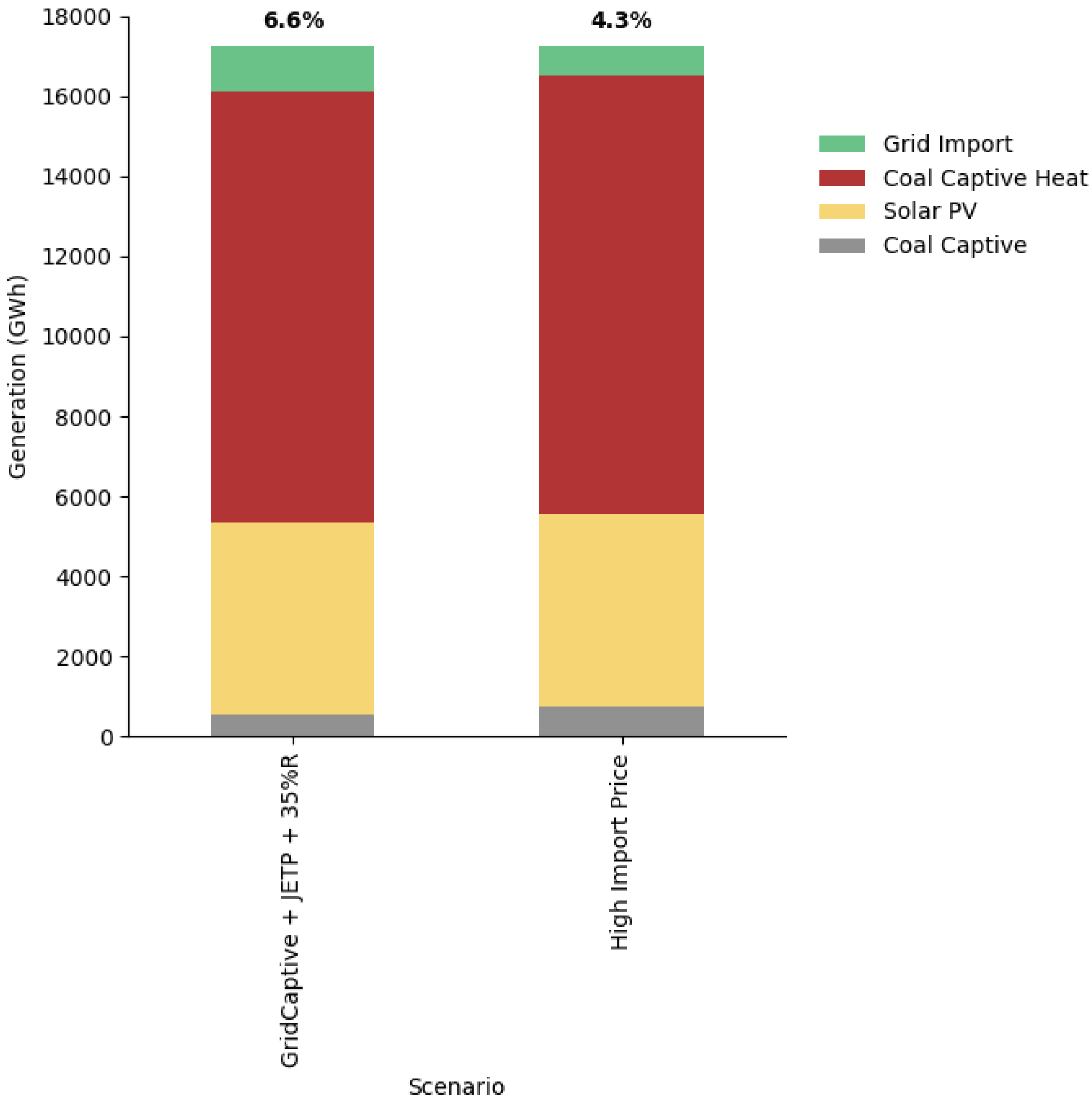


Figure 5.8: **Grid import price sensitivity.** Percentages indicate the grid imports with respect to total generation.

5.5.2 Emissions constraint applied to power generation only is cost-effective

If the emissions reduction requirement is applied solely to electricity generation, rather than to both electricity and industrial heat, the results show that this requirement is easily achieved, provided these clean energy options are available. This is because coal is already an expensive option relative to renewable alternatives. In effect, decarbonizing electricity generation emerges as the least-cost pathway for industrial parks. The model results for cost and emissions are nearly identical to those of the emissions constraint on both the power and heat cases.

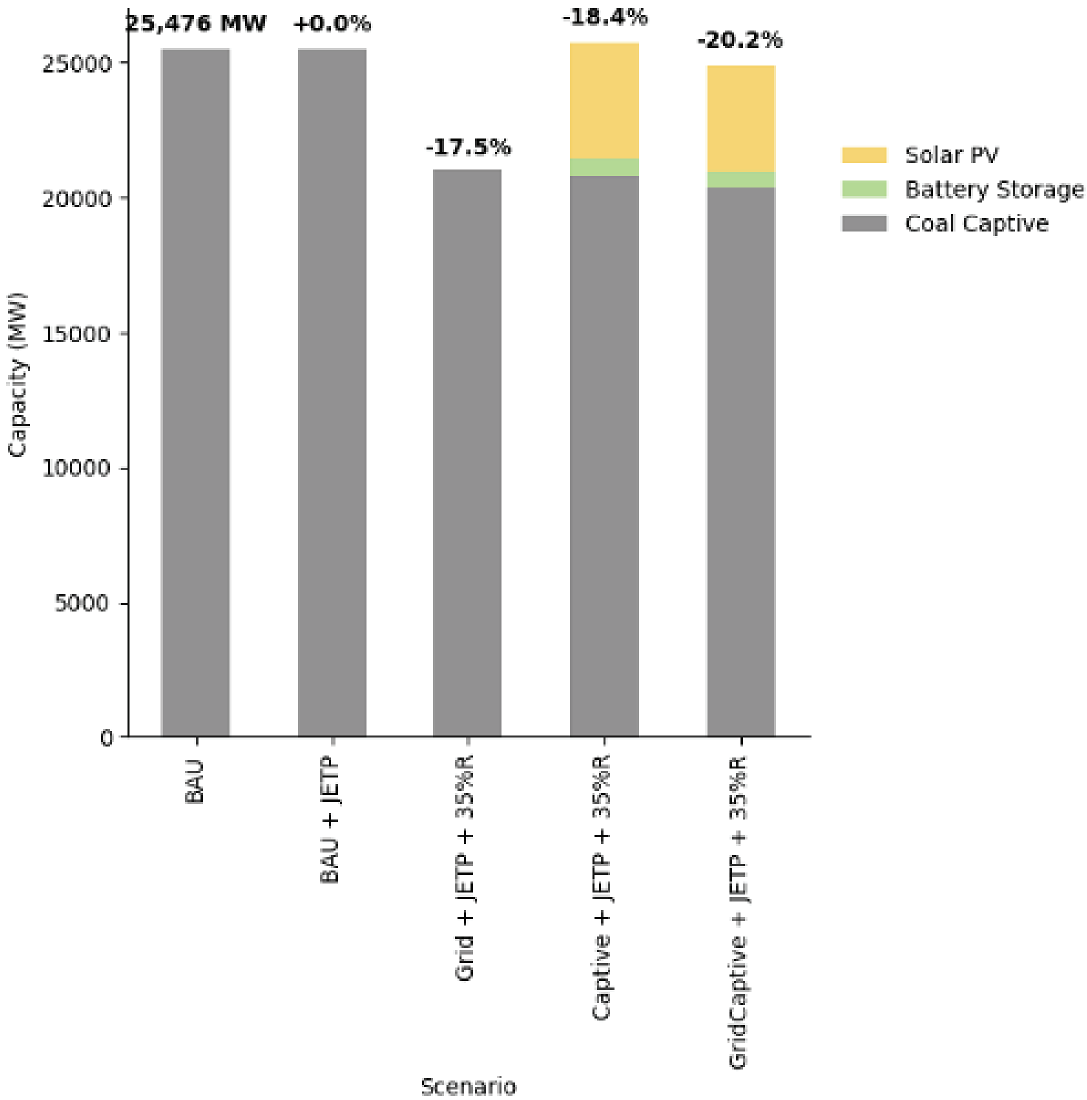


Figure 5.9: **Industrial facilities capacities for all scenarios for the year 2035 with the emissions constraint on power only.** Percentages above the bars indicate the decrease in total coal capacity compared to the *BAU* scenario.

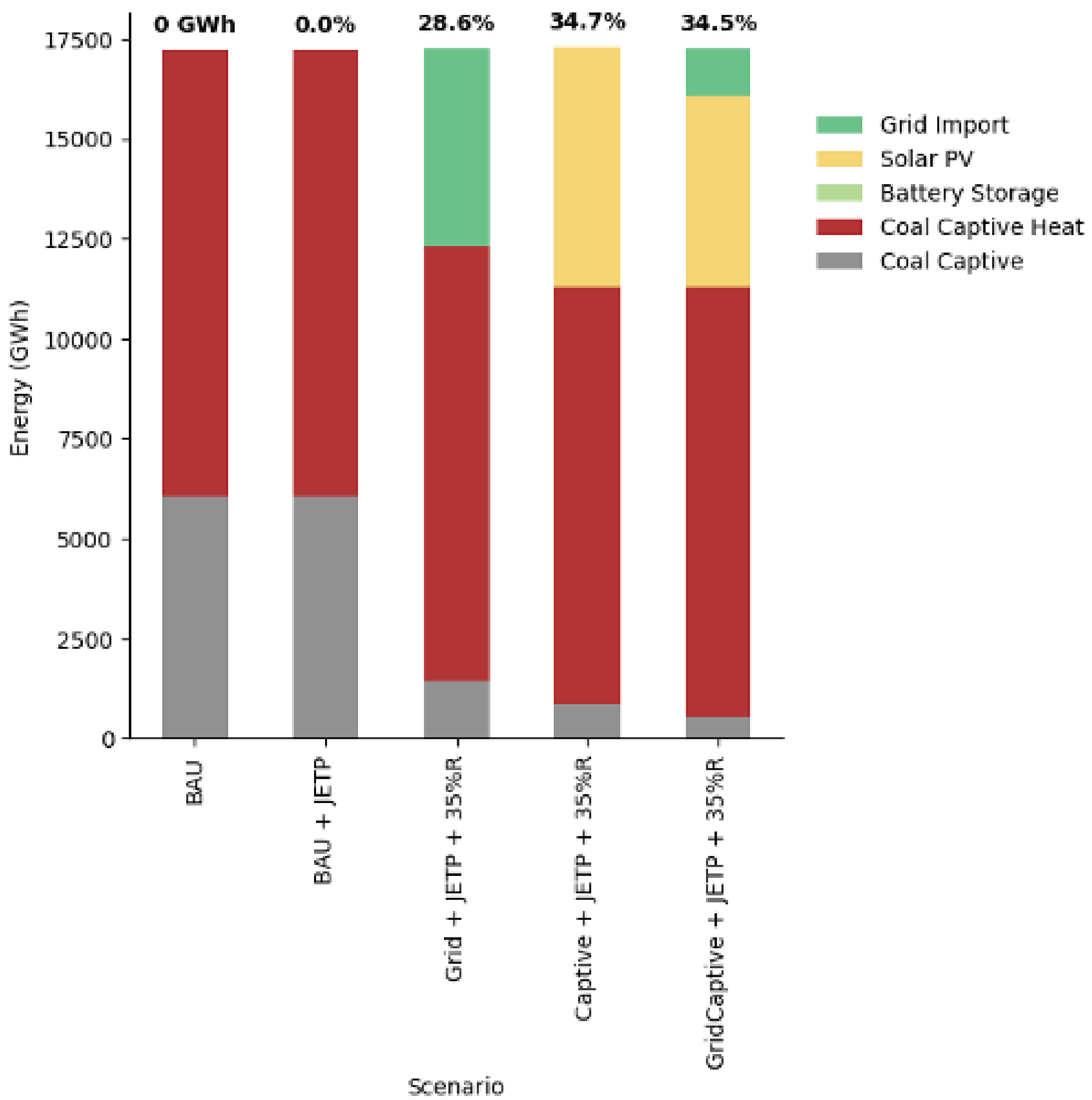


Figure 5.10: **Industrial facilities' power and heat generation mix with grid imports for all scenarios for the year 2035, with the emissions constraint on power only.** Percentages and values above the bars indicate renewable generation as a percentage of total generation.

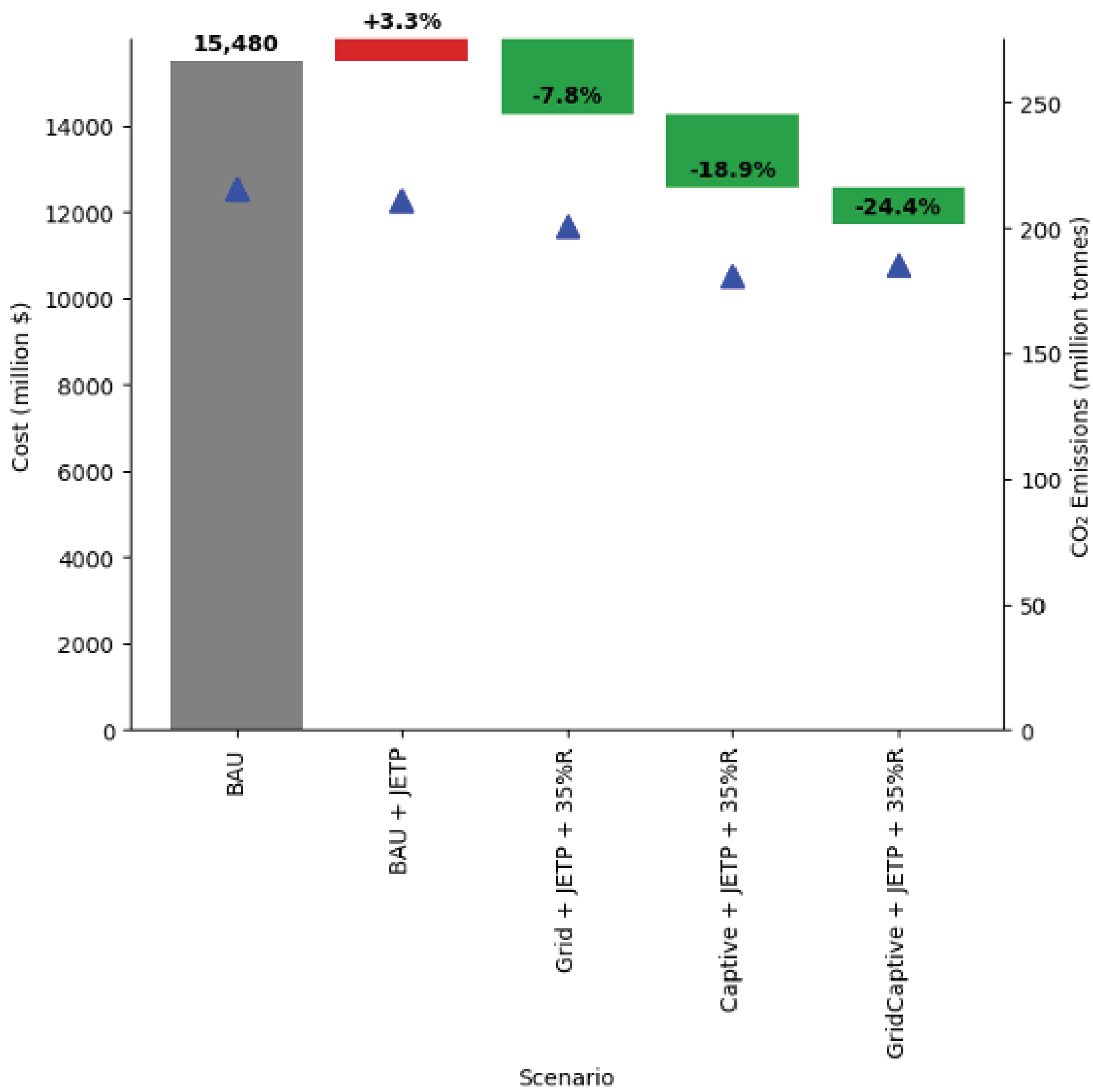


Figure 5.11: **Total system cost and corresponding CO2 emissions for power and captive industry sectors for all scenarios in the year 2035 with the emissions constraint on power only.** The red bar indicates cost increases and the green bar indicates cost decreases relative to the *BAU* scenario. Percentages indicate an increase or decrease in cost relative to the *BAU* scenario.

5.5.3 Lower coal prices for parks cut down clean energy attractiveness

This study also explores the impact of cheaper coal for captive generators, set at $70/ton, on the outcomes of decarbonization. When coal prices fall, the incentive to switch away from captive coal weakens considerably. Under this scenario, clean energy options are no longer cost-competitive beyond what is required to meet the minimum emissions reduction target. Parks, therefore, revert to maintaining larger shares of captive coal while deploying renewables only to satisfy clean energy constraints. This scenario considers the emissions constraint on power generation only.

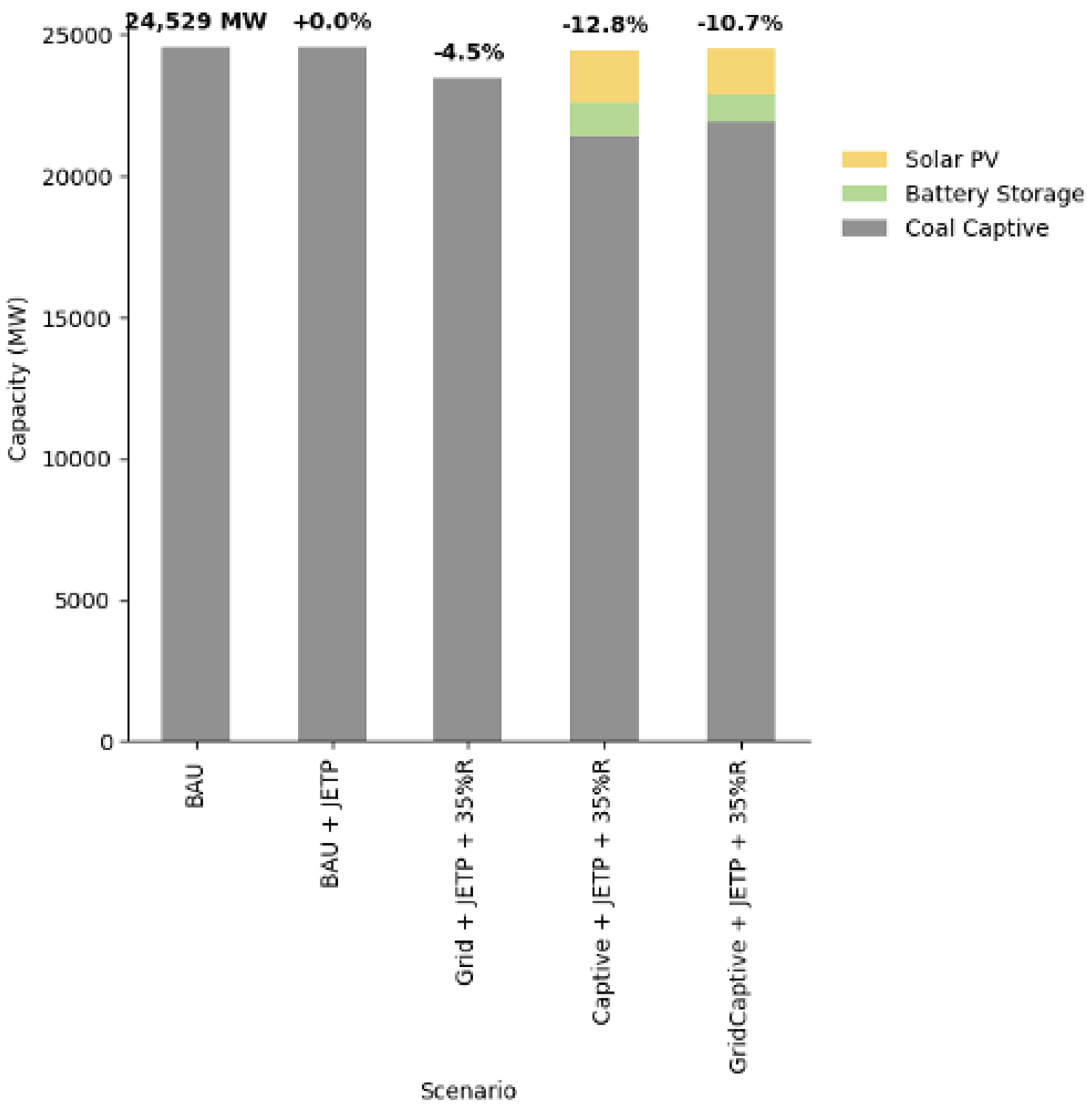


Figure 5.12: **Industrial facilities capacities for all scenarios for the year 2035 with the captive coal price of $ 70/ ton.** Percentages on top of the bars indicate the decrease in total coal capacity with respect to the *BAU* scenario.

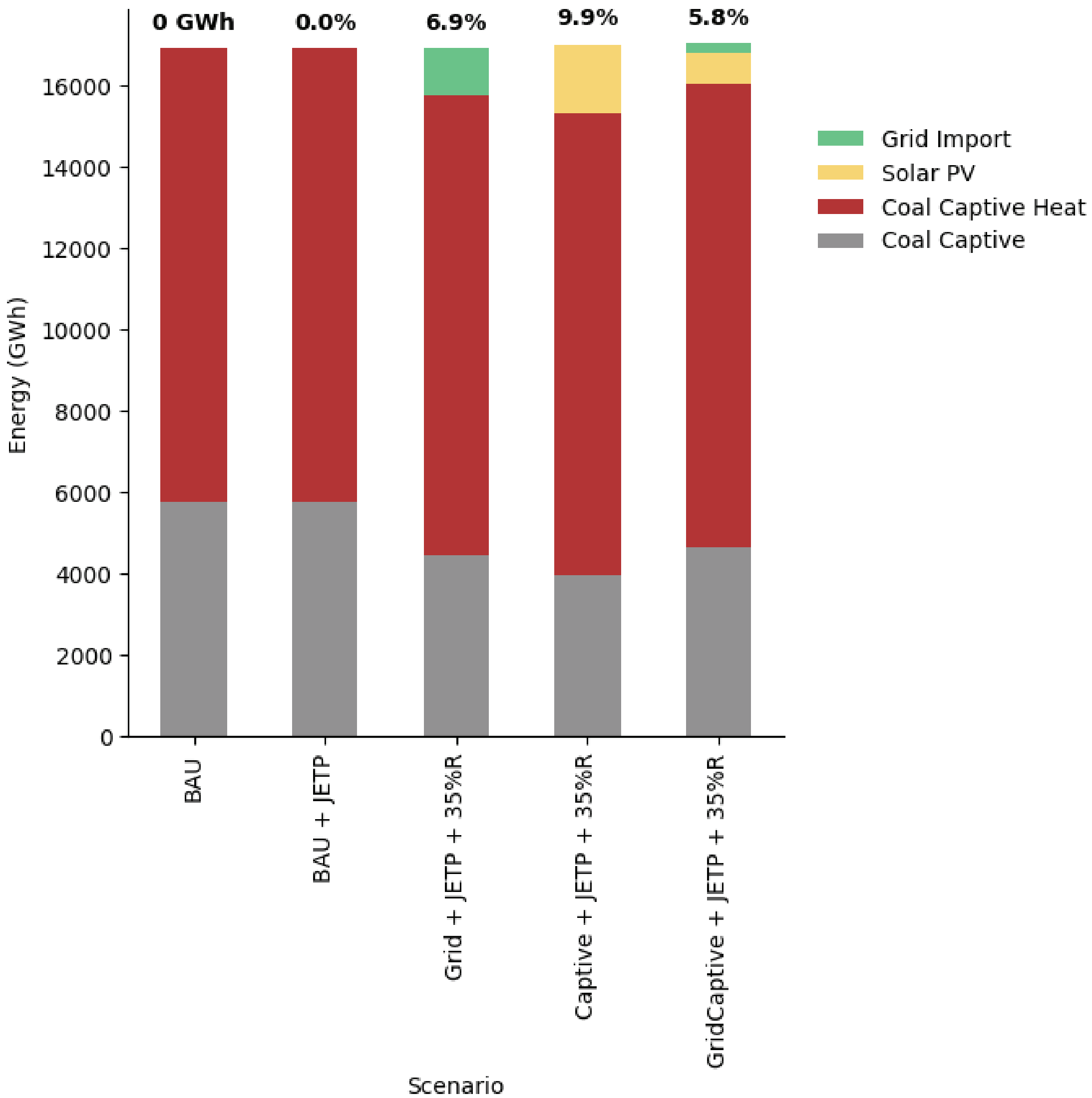


Figure 5.13: **Industrial facilities power and heat generation mix with grid imports for all scenarios for the year 2035 with the captive coal price of $ 70/ton.** Percentages and values on top of the bars indicate renewable generation with respect to total generation.

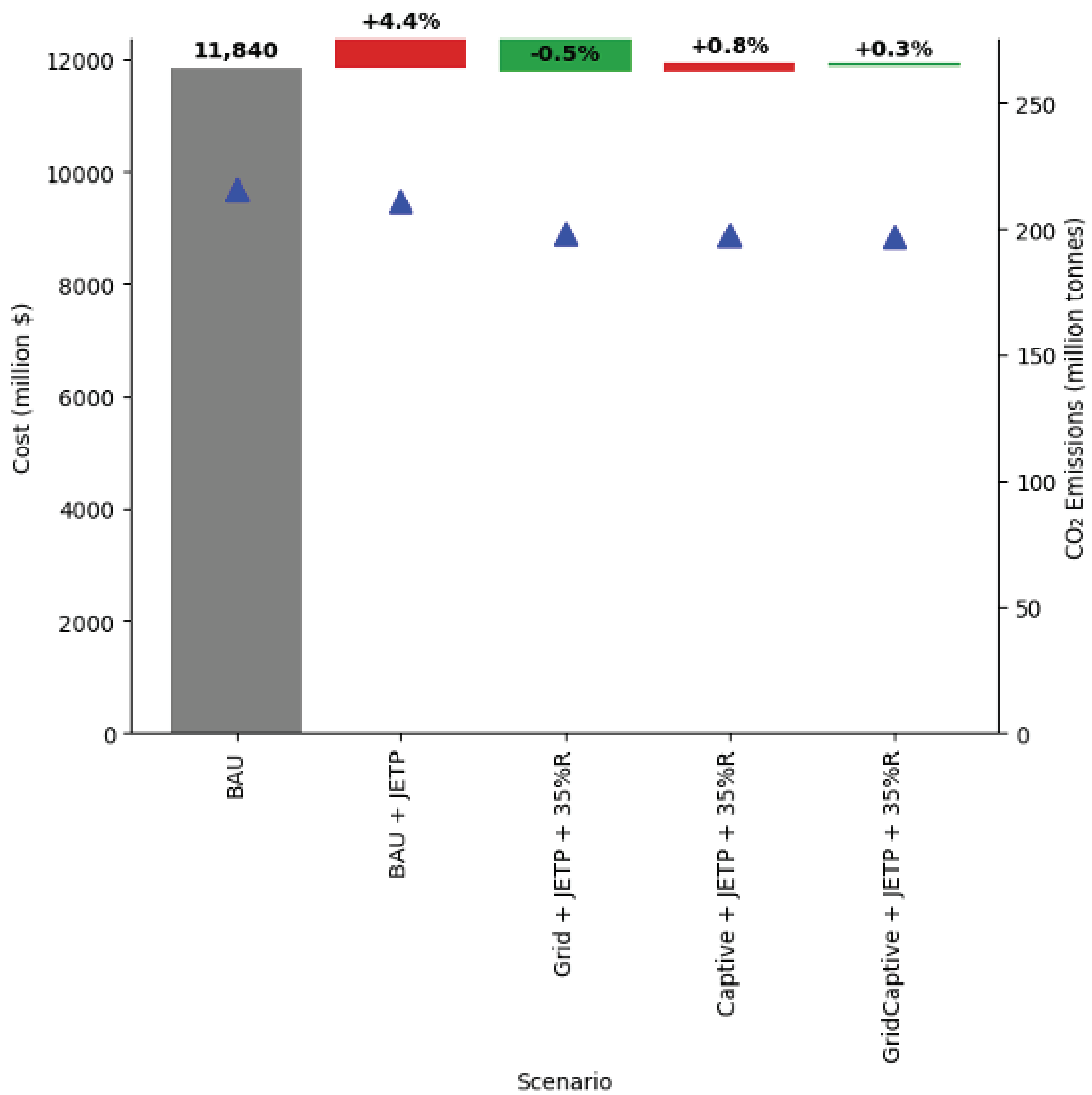


Figure 5.14: **Total system cost and corresponding CO2 emissions for power and captive industry sectors for all scenarios in the year 2035 with the captive coal price of $ 70/ton.** Red bar indicates cost increases and green bar indicates cost decreases relative to the *BAU* scenario. Percentages indicate increase or decrease of cost relative to the *BAU* scenario.

6 DISCUSSION

Electricity use within Indonesia's industrial parks can be partially decarbonized with relatively modest interventions. Under the *GridCaptive* scenario, captive coal capacity falls by 20.2% and clean sources supply 34.7% of the total generation, while the heat output of the coal units remains the same. In addition, integrating renewables and storage transforms captive coal units from rigid baseload assets into more flexible generators, allowing them to operate at lower minimum loads and ramp up or down to balance variable clean supply and on-site demand, thereby enhancing overall operational flexibility. In the *Grid* scenario, where facilities draw clean power exclusively from the grid, captive coal capacity shrinks to the lowest by 17.5% and the grid imports for 26.5% of generation, and the heat requirement decreases similarly to the *GridCaptive* scenario, indicating the flexibility of captive coal generators. The *Captive* case, relying solely on on-site options, delivers a 18.4% reduction in coal capacity, and again with the heat output holding steady.

From the grid perspective, these scenarios impose very different infrastructure requirements. Under the *GridCaptive*, the small increase in generation capacity indicates the negligible need for new infrastructure to serve connected parks. The increase in required transmission lines also indicates that the grid connection to the industrial parks requires more power imports from more resource-rich regions or provinces. Significant upgrades are required in the *Grid* scenario, indicating that if industrial parks rely only on grid imports, the infrastructure must be improved to meet the significant increase in demand.

While the *GridCaptive* scenario is the cheapest decarbonization pathway, the higher CO_2 emissions raise a fundamental question: Industrial facilities can avoid direct emissions through their on-site generators but incur indirect emissions through the grid, which are more difficult to quantify. However, this also enables coordination and streamlines decarbonization for both the grid and industrial facilities, as PLN and the government work to decarbonize the grid; industrial facilities also receive clean energy.

The commodity-level decarbonization gradient reveals that low-temperate sectors can achieve up to 100% clean capacity by 2035, while heat-intensive industries remain over 90% coal dependent. This constitutes the urgent need for targeted R&D and relevant policy instruments to promote decarbonization in hard-to-abate manufacturing, as grid and local generation infrastructure evolve in tandem.

Finally, while grid imports are an attractive way to decarbonize power generation in industrial facilities, they are also highly sensitive to tariffs. The analysis also underscores a critical vulnerability in Indonesia's industrial decarbonization pathway: the relative economics of coal versus renewables is not fixed, but heavily dependent on market prices and policy frameworks. As long as coal remains relatively costly, renewables present a cheaper alternative, driving greater clean energy uptake. However, if coal prices decline and remain low, the model demonstrates that industries will default to coal, and clean energy investments will diminish.

This study has several limitations. The load profiles used for industrial parks are synthetic, derived from sectoral demand patterns reported in the literature rather than empirical measurements from operating facilities. Consequently, the modeled demand may not fully capture the temporal variability and operational variability, such as transient peaks and unplanned outages. This study also does not consider the land acquisition costs for the captive renewable projects.

Second, all coal-fired captive units are represented as Combined Heat and Power (CHP) plants with flexible heat-to-power ratios. In practice, certain captive coal generators may operate in power-only mode or adjust heat output dynamically in response to process requirements. Hence, the assumption of flexible CHP operation may underestimate the inflexibility of these units and mischaracterize their emission profiles.

Third, the technology portfolio for industrial parks is restricted to commercially mature options (solar PV, onshore wind, geothermal, and battery storage) in alignment with the current RUEN[13]. Emerging technologies (for example, Small Modular Reactors (SMR), green hydrogen, or Carbon Capture, Utilization and Storage (CCUS) have been excluded, although their potential commercialization by 2035 could alter the cost-emissions trade-off, particularly in hard-to-abate sectors.

Fourth, the analysis assumes a uniform, linear scaling for industrial output across all parks by 2035, thereby neglecting potential variations induced by macroeconomic fluctuations, policy incentives, or international commodity price volatility. Any deviation from linear production growth would influence both electricity demand projections and the optimal allocation between on-site generation and grid-supplied electricity.

Fifth, the transmission model considers exclusively intra-regional grid reinforcements and omits the inter-regional “Indonesian Super Grid” that would link all the islands into one huge grid[45]. In reality, the decision to advance or defer such super-grid infrastructure may substantially affect regional renewable deployment strategies and the economic attractiveness of grid-sourced electricity for remote industrial clusters[45].

Finally, the present analysis is based on Indonesia’s 2021 RUPTL[21]; however, a revised 2025 RUPTL was issued in May 2025, which proposes modified capacity targets and transmission build-out schedules[46]. Incorporating these updated planning assumptions is planned for future work, as they would more accurately capture the latest renewable targets and PLN’s new projects, especially the plan to expand connections to remote industrial parks. This is expected to yield insights into how decarbonization pathways may change with project commitments from different stakeholders.

7 POLICY RECOMMENDATIONS

7.1 Stakeholders

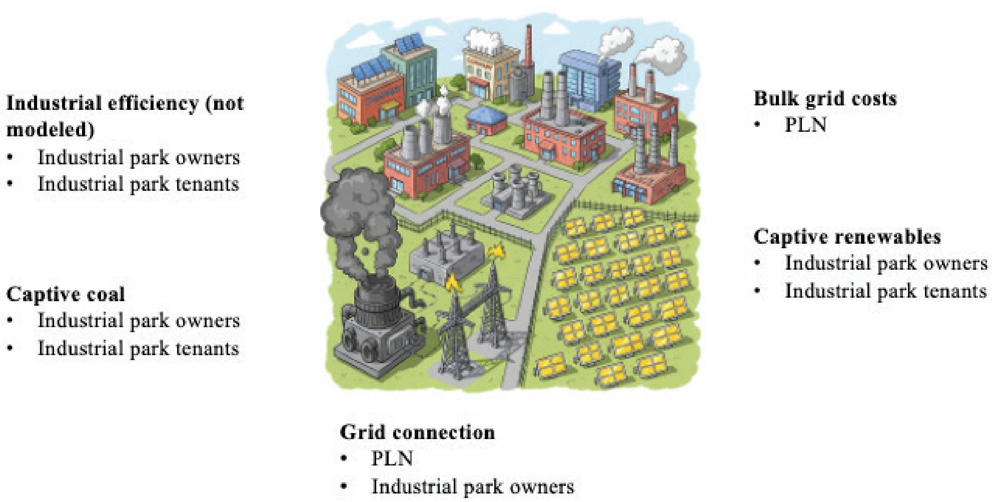


Figure 7.1: Responsible stakeholders for industrial park decarbonization. Image created with Google Gemini.

This figure illustrates the key stakeholders responsible for different components of industrial park decarbonization pathways.

- **Industrial efficiency (not modeled)**: Both industrial park owners and tenants influence energy demand through operational efficiency measures, though these are not explicitly included in the modeling for this study.
- **Captive coal**: Industrial park owners and tenants currently rely on coal-fired captive power plants, making them directly responsible for associated emissions and costs.
- **Captive renewables**: The same stakeholders are also responsible for adopting and investing in on-site renewable energy and storage solutions as alternatives to coal.
- **Grid connection**: The responsibility for grid connection is shared between PLN, which provides bulk supply infrastructure, and industrial park owners, who manage local connections.
- **Bulk grid costs**: PLN bears responsibility for setting and managing the costs of bulk electricity supply, including upgrading and maintaining generation and transmission assets required to supply the additional demand.

7.2 National Policy Recommendations

7.2.1 Complete the policy framework for coal power

While current regulations require reducing emissions from captive coal plants by 35% within ten years of operation and for coal power to be phased out by 2050, the regulatory framework for this is underdeveloped, which leads to uncertainty for investors in pursuing major upgrades. A refreshed coal power policy framework should specify further relevant coal power targets and expand upon encouraged efforts that are grounded in broad national policy priorities. This is particularly important given the significant pipeline of new captive coal projects, many of which may lock in high emissions if not aligned with the national strategy[13].

- **Clarify the scope and targets** for coal power investments and operations in the country, expanding or revising PerPres 112/22 in line with energy security and economic objectives. This could include interim targets for partial retirement, standards for retrofits with carbon capture or co-firing with biomass, and clearer eligibility criteria for continued operation of existing plants.
- For captive generation, ministry regulations should **encourage the consideration of grid connection** as a solution to achieving coal power policy goals. Grid connection can provide a pathway to displace captive coal with cleaner sources gradually, but this requires regulatory alignment so that connecting to PLN does not create additional financial burdens for industrial park operators.

7.2.2 Strengthen grid infrastructure and grid access to captive industrial parks.

Enhancing grid infrastructure constitutes an attractive part of the solution to help reduce emissions in industrial parks. The grid owner PLN, together with the government and industrial parks, will need to coordinate planning to accomplish effective grid extension and access. PLN has included some pilot grid connections to industrial parks in its latest report, signaling an increased commitment to decarbonizing industrial parks. This will also help ensure that industrial loads are integrated into broader power system planning, allowing for system-wide efficiency gains and enabling economies of scale in renewable energy deployment.

- **Strategic grid extensions** to select industrial parks in Sulawesi, North Maluku, and Kalimantan can help accommodate part of the industrial loads and should be considered in planning documents such as

RUEN and RUPTL. Prioritization could be based on parks with high growth in nickel and steel processing, which are especially under pressure from global supply chain decarbonization standards.

- Not all industrial parks are feasible to connect to the main grid. In these cases, there may be opportunities to **develop regional microgrids or islanded grids that interconnect multiple facilities** to facilitate economies of scale for cleaner energy generation. Such approaches are already under consideration in other island systems across Southeast Asia and could reduce reliance on diesel or coal back-up plants.
- Policy reforms and clarity are needed to facilitate grid extensions to remote industrial parks, including consideration of **private co-investment** in transmission to enable private investors or industrial park owners to support these. Experiences from other countries suggest that industrial users are often willing to co-finance grid access when regulatory frameworks guarantee stable returns or reliable service.
- **Bulk grid investments** are necessary alongside grid extensions to ensure power reliability and increased access to utility-scale clean energy and storage. These investments will need to be coordinated with the RUPTL and other government priorities, including Indonesia's commitments under the JETP[30].

7.2.3 Align incentives and regulations with the industrial park's green electricity use

As global supply chains increasingly demand verifiable low-carbon electricity, Indonesia must ensure that its industrial parks can access and utilize renewable energy in credible and transparent ways. Current regulatory initiatives, such as renewable energy certificates and wheeling proposals, remain at early stages and require further development to provide certainty for both industrial users and investors. On-site captive renewable energy is another solution, discussed below.

- To facilitate the ability of industrial parks to use a green electricity grid to satisfy supply chain standards, it is necessary to **develop regulatory frameworks enabling industries to procure green electricity** from off-site producers through off-taker agreements and clean energy crediting systems. Indonesia has initiated exploration into wheeling (i.e., third-party utilization of PLN's network), which is one option to help meet robust clean energy requirements[46].
- The government should ensure **a cost-reflective tariff structure** for industrial facilities for grid electricity to allow for the cheapest option to deliver clean electricity. Additionally, the government could streamline the process of building new transmission lines for industrial parks by facilitating coordination between park owners and PLN, reducing delays in project permitting and alignment with spatial planning policies.

7.3 Regional and Local Measures

7.3.1 Provincial Energy Plans (RUED) aligned with the national net-zero target

Provincial governments play an important role in translating national policies into implementable measures. However, many provincial energy plans (RUED) remain general in nature and are not yet sufficiently aligned with Indonesia's long-term net-zero target. Revising these plans to include more concrete actions would help ensure that national commitments are implemented across different regions, particularly in provinces hosting major industrial parks.

Each province should **revise its RUED** to include specific targets for reducing the use of captive coal and enhancing local renewable energy generation. These revisions could build on existing local resource availability, such as geothermal in North Sulawesi, solar in East Kalimantan, or hydropower in Papua, to diversify supply options and avoid over-reliance on imported coal. Provinces could also identify industrial parks as priority zones for renewable energy deployment to better align energy planning with industrial development strategies[47].

7.3.2 Expediting captive renewables project approvals

While Indonesia has strong renewable energy potential, renewable project developers face delays in permitting, land acquisition, and environmental clearances. These barriers are particularly pronounced for projects located near industrial parks, where land competition is high and spatial planning rules are complex. Addressing these local-level bottlenecks will be essential to accelerate the deployment of clean captive generation.

Local governments should prioritize the development of captive renewables by **speeding up the permitting and land acquisition procedures** for these projects. This may involve improving coordination between land agencies and energy offices and designating industrial energy zones where renewable and storage projects can be fast-tracked.

7.4 Foreign Stakeholder Responsibilities and Actions

Foreign investors, financiers, and owners of industrial facilities are essential players in Indonesia's captive power sector. Achieving Indonesia's energy plans requires their support, as these actors control large shares of investment flows, technology choices, and supply chain strategies. Their involvement can help to meet both economic and environmental objectives while ensuring Indonesia's industrial products remain competitive in global markets.

7.4.1 Substitute portions of captive coal power capacity for clean energy solutions

Given the large deployment and proposed pipeline of captive coal power plants, which may conflict with Indonesia's long-term coal power strategy, foreign stakeholders need to reassess the financing and construction of captive coal plants. This aligns with international commitments, including China's pledge to end overseas coal power financing and the commitment by G7 countries to end international financing for unabated coal power projects[48,49].

- Based on technical feasibility and long-term economics, foreign investors and park owners should **redirect new captive coal investments into renewable energy, battery storage, and efficient industrial processes**. Hybrid options combining solar, storage, and flexible generation can help modernize Indonesia's industrial base while enhancing energy security and resilience against fuel price volatility.
- For **existing industrial parks**, park owners should assess retrofit options to supplement energy needs from cleaner sources, including nearby captive renewable energy and grid connections coupled with renewable energy purchases.

The development of clean energy solutions also aligns with President Prabowo's pledge to build 100 GW of solar, a target that will require foreign stakeholders to play a central role by providing financing, technology transfer, and partnerships that enable both industrial parks and surrounding villages to transition to and benefit from clean energy[15].

7.4.2 Support grid infrastructure upgrades and extensions through financing and technical assistance

In order to accommodate clean grid electricity for industrial park decarbonization, our report identifies that significant **new bulk transmission and grid extension investments** would be required. Park owners can help support grid extension investments with PLN, including joint planning and co-financing. For bulk transmission upgrades, major foreign countries can help play an important role through both financing grid projects, which may face bankability problems, and technical assistance and coordination with park owners on relevant upgrades.

7.4.3 Enforce climate-aligned supply chains

Numerous multinational firms, ranging from electric vehicle battery manufacturers to end-users, have moved toward **requiring the use of low-carbon electricity** within their extended supply chains. This market pressure is already being felt, with reports indicating that Indonesia's coal-dependent industrial parks have prompted Tesla to reconsider establishing operations in the country due to misalignment with its clean energy objectives[23]. Similar pressures are expected to intensify as downstream industries, especially in EVs and aluminum, adopt stricter procurement standards.

7.4.4 Partner on technology and policy initiatives

Foreign governments and corporations should engage with Indonesia on both **knowledge sharing and policy development** pertaining to the energy transition of industrial parks. They should facilitate technology transfer through joint research initiatives, training programs, and pilot projects within Indonesian industrial hubs. Partnerships could focus on advanced technologies such as green hydrogen for industrial heat, high-efficiency smelters, and long-duration storage systems. Such cooperation may also extend to **policy guidance**, where international stakeholders can assist Indonesian regulators in designing incentives and frameworks that promote the decarbonization of captive power.

8 CONCLUSION

The analysis presented in this report underscores the critical challenge posed by the rapidly growing captive coal power sector within Indonesia's broader energy transition. Despite comprehensive national climate commitments and international partnerships, this segment has largely operated as a regulatory blind spot, contributing significantly to national greenhouse gas emissions outside the primary focus of decarbonization efforts. The rapid expansion of captive power, particularly in energy-intensive industries linked to Indonesia's mineral "downstreaming" initiative, has created a substantial parallel power system that, if unaddressed, could fundamentally undermine the nation's climate targets.

The report's scenario modeling demonstrates that while significant decarbonization of electricity use in industrial parks is feasible through hybrid (*GridCaptive*), on-site (*Captive*), and grid-only (*Grid*) solutions, these pathways entail distinct trade-offs in terms of emissions reductions, cost, and grid infrastructure requirements. The *GridCaptive* scenario, although the cheapest, incurs a higher amount of CO_2 emissions due to the grid's reliance on fossil fuel generators. In contrast, purely captive solutions offer emissions reductions at the expense of higher costs. Nevertheless, heat-intensive industries remain heavily reliant on coal due to process heat demands, indicating that a comprehensive strategy must extend beyond power generation to industrial process transformation. Furthermore, sensitivity analysis reveals that while grid electricity pricing has a strong influence on import decisions, it has a minimal impact on the internal dispatch of on-site generators, suggesting the need for multi-pronged policy approaches.

The findings emphasize the crucial role of policy alignment, robust grid infrastructure, and tailored incentives at national, regional, and international levels. The existing policy framework, including the exemption for PSNs, reflects a strategic prioritization of rapid industrial growth, creating a path dependency on coal that needs to be carefully navigated. Foreign stakeholders, particularly those with dominant investments in Indonesia's captive power sector, bear significant responsibilities. Their actions are pivotal in shifting investment towards renewables, supporting grid development, and enforcing climate-aligned supply chains, thereby contributing to Indonesia's decarbonization goals and leveraging their geopolitical influence for sustainable development.

Supplemental Information

The Technical Appendix, along with the data and the code used for this study, can be found at:
https://pwrlab.org/2025/09/30/indonesia-industry-captive-generation.html

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