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Navigating SDG 8 in the decarbonizing landscape of emerging economies: a case study of Indonesia

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Abstract
The Sustainable Development Goal 8, "Decent Work and Economic Growth," (SDG8) has crucial significance for developing nations as they grapple with the dual challenges of fostering economic growth and addressing climate change, as they are often hindered by financial constraints in advancing low-carbon transitions. Centered on SDG 8, particularly in developing countries, this paper takes Indonesia as a case study to delineate challenges and propose insights for an optimal green growth strategy. Challenges encompass fostering enduring, inclusive, and sustainable economic growth while meeting the heightened demand for electricity arising from economic priorities and strategies. The Government of Indonesia envisions low-carbon transition activities that create a substantial and dynamic workforce while preserving natural resources and the environment. The government wishes to leverage international green finance opportunities to mobilize economically stimulating capital while concurrently strengthening domestic investment capacities for future needs. In conclusion, this paper not only analyzes current challenges but also outlines prospective pathways to achieve sustainability.

Introduction

The 2030 Agenda, established in 2015 by United Nations member states, envisions a more sustainable world to be achieved by 2030. Sustainable Development Goal 8 (SDG 8), centered on decent work and economic growth, holds particular significance for developing countries navigating the dual challenges of pursuing economic growth and addressing climate change [1].

Low-carbon transitions have demonstrated synergies with air quality, human health, energy security, biodiversity, and ocean health priorities, while also presenting tradeoffs with goals related to food security and energy access [2–4]. Additionally, limiting climate change to no more than 1.5 °C above preindustrial levels has benefits that far exceed the costs, with estimated returns at least four to five times the size of required investments in the energy system until 2050 [5]. Nevertheless, research indicates that achieving decent life standards in emerging Asian and African economies may result in additional CO_2 emissions, particularly in the indicators of mobility and electricity under decent life standards [6]. Similarly, while economic growth promoted by SDG 8 can generate new jobs, it also drives unsustainable patterns of resource use [7].

This paper focuses on SDG 8, especially in developing countries. Indonesia, a prominent emerging market economy in Southeast Asia, will be used as a case study that exemplifies these challenges and provides an opportunity to develop an optimal green growth strategy for

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future use. In Indonesia's attempt to balance sustainable development and economic growth, numerous challenges emerge, demanding concerted efforts and strategic solutions. One of the most pressing issues is satisfying a heightened demand for electricity, in part driven by government strategies to spur economic growth. Meeting this demand in isolated regions is a challenge well suited for renewable energy (RE) [8]. Renewables also emerge as a strategy to keep up with the energy needs of value-added industrial parks without compromising on sustainability commitments or attractiveness for sustainability-minded investors. Meanwhile, the government-led exploration of low-carbon transition activities offers immense potential to promote a youthful and vibrant future workforce in renewable energy supply chains, notably battery manufacturing, solar photovoltaic (PV) production, and biomass feedstock. However, Indonesia must navigate challenges such as unsustainable mining practices, land-use competition, and regulatory barriers to realize the benefits. The country's ambitious environmental and economic goals necessitate major overhauls of energy infrastructure, scaling up renewable energy projects, and strengthening a weak domestic capital market. However, the current regulatory, technical, and policy environment is not optimized for realizing the available international, private, and domestic financing opportunities. It is imperative that Indonesia closes the gap between realized investment and financing goals to keep its climate commitments within reach and remain focused on fostering domestic capital markets to reduce international dependence in the future.

Table 1 JETP overview

Country	Date	Amount (USD billion)	Status	Challenges
South Africa	Nov 2021	8.5	JETP Implementation Plan approved in December 2023	Delays of coal-fired power plant (CFPP) closures due to ongoing electricity crisis [9].
Indonesia	Nov 2022	20	Comprehensive Investment and Policy Plan released November 2023, Captive Power Study launched May 2024	Filling public finance gap, lack of authority to navigate JETP and RE development capacity at the provincial and district/municipality level [10].
Vietnam	Dec 2022	15.5	Resource Mobilization Plan (RMP) released December 2023	Filling public finance gap, ensuring involvement of NGOs due to political complications [11].
Senegal	June 2023	2.5	No other major documents released as of May 2024	Navigating the use of natural gas as a transition fuel [12].

The just transition partnership

The Just Energy Transition Partnership (JETP) is a collaborative initiative designed to support traditionally coal-dependent emerging economies in their transition to sustainable energy sources. Beyond the energy transition, it emphasizes social and economic impacts, ensuring that the transition is equitable and inclusive. The JETP provides financial assistance, technical expertise, and policy support from multinational actors, NGOs, banks, and research organizations, among others. The first JETP was announced in South Africa in 2021, and JETPs in Indonesia, Vietnam, and Senegal have followed (Table 1). As a central framework for Indonesia's energy transition, it will be referred to extensively in this discussion of green growth opportunities, challenges, and pathways.

Challenge 1: Foster enduring, inclusive, and sustainable economic growth in line with climate commitments while addressing the heightened demand for electricity stemming from economic priorities and strategies

Indonesia's population growth, expanding infrastructure, and economic stimulus initiatives have all contributed to a rapid surge in energy demand. Indonesia's Comprehensive Investment and Policy Plan (CIPP) for Indonesia's JETP estimates an annual growth rate of 6.4% in on-grid electricity consumption between 2022 and 2030 [13], in contrast to the 0.8% figure from advanced economies [14]. Extensive literature highlights a positive correlation between electricity consumption and economic growth, suggesting a promising outlook for Indonesia [15]. However, the heightened energy demand is straining Indonesia's already fragile power grid and distribution channels [13]. Some of the uptick in electricity consumption can be attributed to the growth of in-house small-medium enterprises (SMEs), which comprise 60% of the national GDP, and the emergence of industrial parks specializing in value-added production [16]. Despite their economic importance, these sectors face challenges in meeting their energy needs through the existing grid. Consequently, effectively addressing the surge in electricity demand in a reliable and cost-effective way is imperative for the continued well-being of Indonesia's residents, commercial enterprises, and industries.

Indonesia's Master Plan of National Industry Development (RIPIN) 2015–2035 outlines short-term economic priorities and strategies, serving as a roadmap for industrial and infrastructural expansion. At its core, RIPIN emphasizes the designation of industrial parks, which offer essential infrastructure to attract investment, foster industrialization, generate employment, and stimulate positive spillover into the surrounding community. Many of the new ventures within industrial parks are a response to another RIPIN growth strategy—the prioritization of downstream sectors that create higher value-added exports, especially in critical minerals crucial in the production of renewable energy technologies, such as nickel, cobalt, and aluminum [17]. The distribution of nickel and coal mines across Indonesia can be seen in Fig. 1.

Indonesia's nickel reserves are concentrated in the eastern region, with the Sulawesi, Maluku, and Papua provinces containing a significant amount of the nation's nickel reserves and downstreaming industries like smelting and refining [18]. Some individuals report that nickel mining and smelting operations have brought direct employment, increased revenue for surrounding businesses, and better standards of living for their families [19]. Additionally, adding nickel mining capacity in Indonesia is essential to domestic electric vehicle (EV) battery production, a market that is expected to generate GDP growth and value-added jobs [20, 21]. While the macroeconomic benefits of the nickel industry are numerous, nickel mining has also raised numerous environmental, human rights, and health concerns [22]. One study finds that after the fifth year of the construction phase of nickel smelting operations in Central Sulawesi, Southeast Sulawesi and North Maluku, negative effects on the region's environmental and public health begin to outweigh positive GDP growth [18]. Workers have held numerous protests over safety concerns following deaths and injuries at smelters, as well as land degradation and unfair labor practices [23–25]. Nickel mines and their related industries can both help and hurt the communities in which they are sited, making them a contentious issue at the local and national level.

After the 2020 nationwide ban on exporting raw nickel ores, nickel export values more than tripled by 2022 [26]. To solidify Indonesia's position in the global renewable energy supply chain, the government of Indonesia (GOI) has expanded the ban to include bauxite, with plans to include gold and tin shortly. These policies have driven increased refining, smelting, and mineral processing activities, which are responsible for a major portion of energy consumption along the mining supply chain and industrial activity in general [27].

A drawback of these industrial parks, predominately sited in underdeveloped eastern regions, is the lack of affordable grid connectivity [13]. Companies resort to

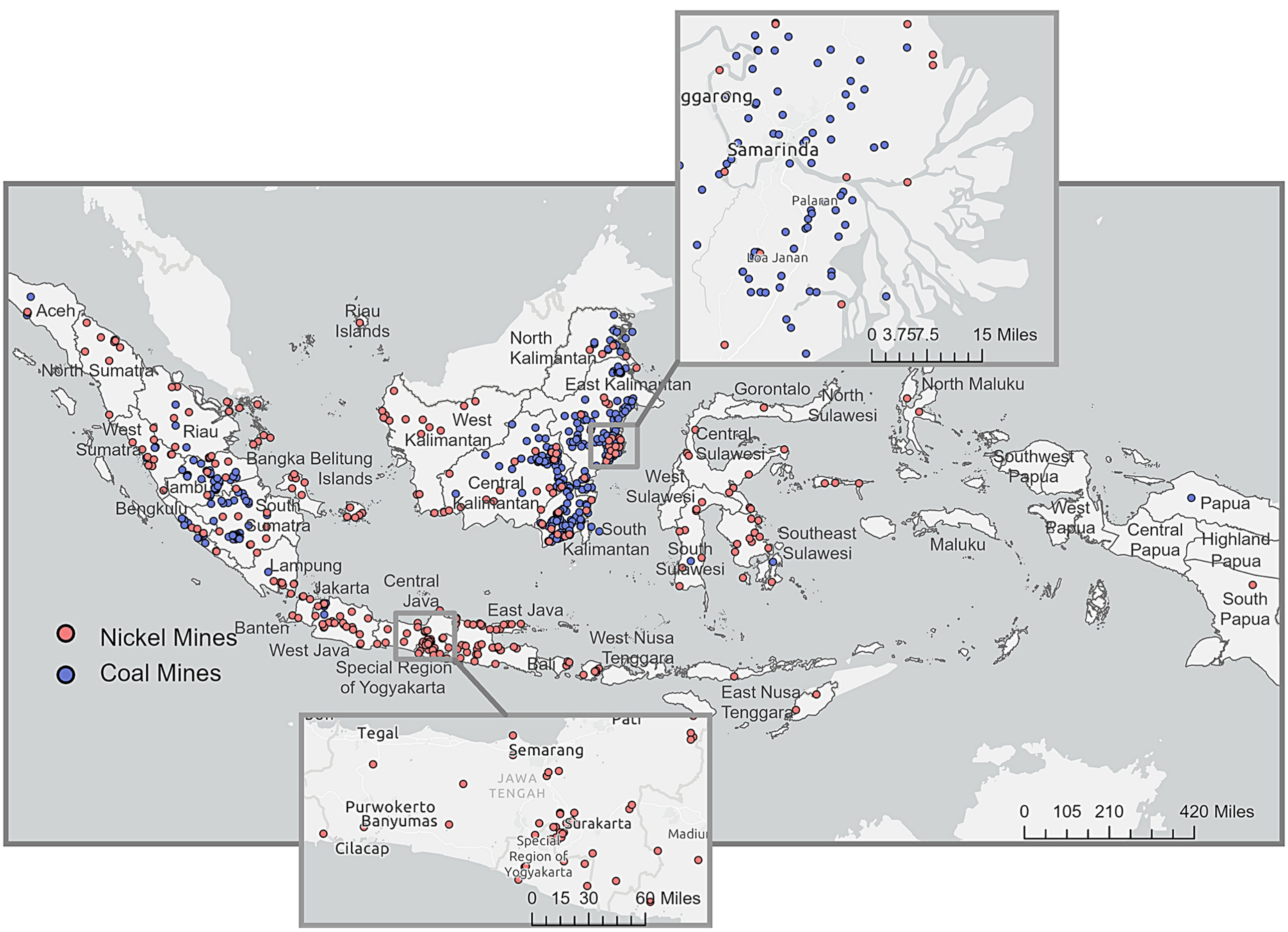

Fig. 1 Location of nickel and coal mines

off-grid (or captive) coal power for their plants, leading to a national trend in which a quarter of currently operating coal capacity and half of the proposed capacity additions are for captive use [26, 28]. By designating them as "national strategic projects," Indonesia has exempted captive plants from the country's 2022 moratorium on new coal plants [13]. The location of these captive coal plants, along with the nickel mines that some of them serve, can be seen in Fig. 2. Additionally, the profitability of the coal fired power plant industry—and the widespread involvement of political and economic elites in the industry—buttresses strong incentives to protect business interests and risks regulatory capture [29]. Maintaining and expanding captive coal to meet growing industrial needs faces its own challenges, however, including investor reluctance due to risk and uncertainty, and difficulties securing funding due to coal exclusion policies at many major global financial institutions [28]. Additionally, given its large, new coal fleet, Indonesia, among other Southeast Asian countries, faces a disproportionately large risk of stranded coal assets under both 1.5 °C and 2.0 °C scenarios. Conversely, in the face of moratoriums on international CFPP financing, Indonesia could see one of the largest reductions in stranded asset risk [30].There is a recognized gap in off-grid coal power research and analysis, and the potential for decarbonization and/or connection to the grid requires greater attention, especially since the expansion of captive power risks locking in emissions unaccounted for in national decarbonization plans. A 2023 Ministry of Energy and Mineral Resources (MEMR) analysis has suggested connecting 26 plants to the grid to remove 10 million tons of CO_2 emissions annually, providing a potential pathway for captive coal capacity reduction. [13]. However, the success of economically and environmentally aspirational carbon-reduction projects, like connecting captive coal and providing clean energy to industrial parks, depends on meeting investment targets.

The push to reduce Indonesia's reliance on coal provokes consideration of how coal-producing communities will be impacted. Literature points to the manifold consequences of closing CFPP in areas that are dependent on the coal industry for direct employment, local government revenue, secondary commercial activity, and sociocultural identity [31]. In East Kalimantan, one of the regions that would be hardest hit by the energy transition, coal industries employ around 11% of the population and coal royalties support 46% of local government revenue [32]. Transitioning individuals to jobs in renewable energy industries is complicated by skill mismatch

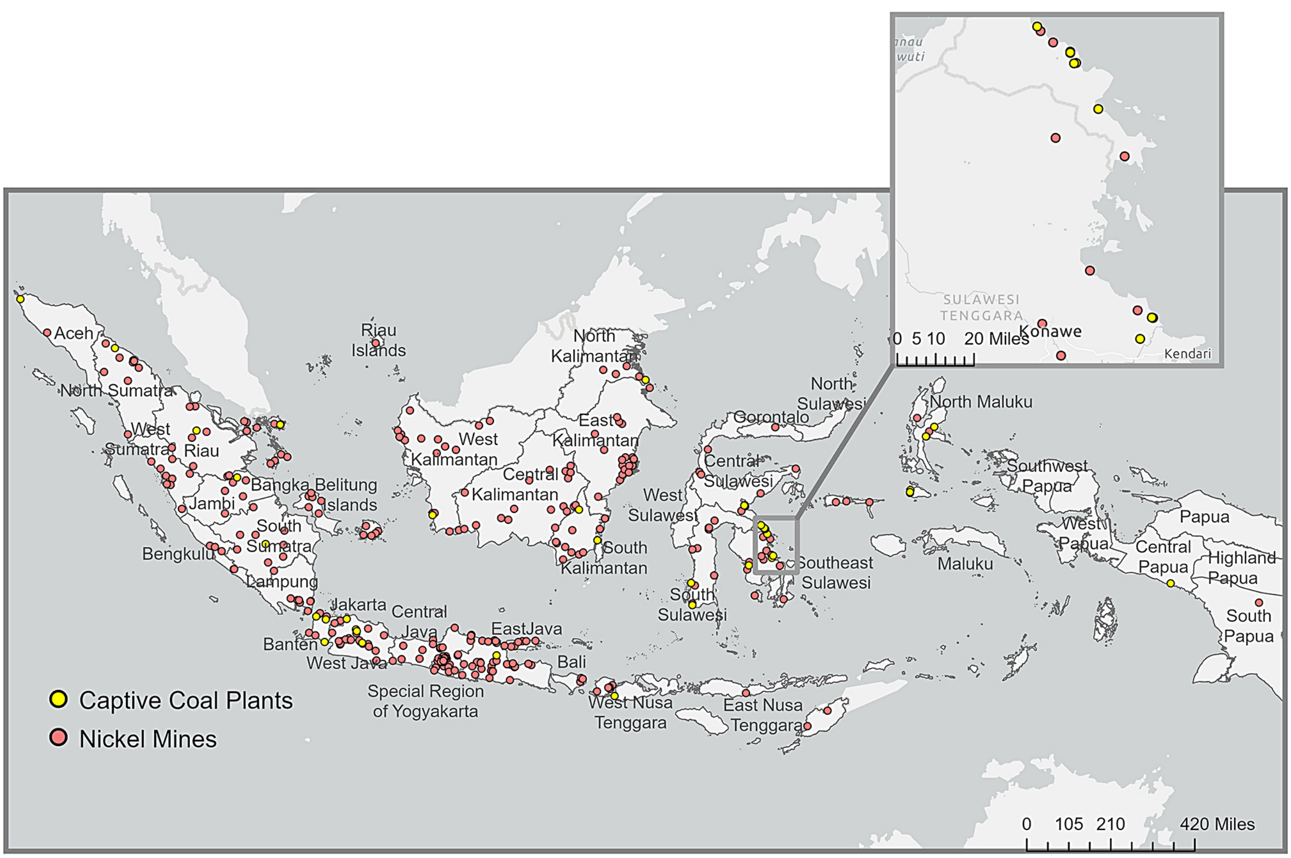

Fig. 2 Location of nickel mines and captive coal-fired power plants. Data source for the captive coal plants can be find at cgsindustrialparks.org

and the geographical distance between coal and renewable energy resources: lower-skilled mining workers may require up to 2 years of training to become employed in solar jobs (the most comparable renewable employment opportunity to coal), and while 90% of Indonesia's coal is located in the provinces of East Kalimantan, South Kalimantan, and South Sumatra, the highest technical potential for solar PV is in Bali, Nusa Teggara, and Java [33]. However, these challenges are counteracted by the long-term employment benefits brought by a transition to renewables—the JETP CIPP estimates that solar generates 2.5 more jobs per gigawatt-hour (GWh) than coal, a multiplier that is even higher in the hydropower and geothermal industries. Additionally, studies of Indonesian coal-communities find that only a fraction of coal-derived government revenue trickles down to the community level [32, 34]. At its outset, the Joint Statement on Indonesia's JETP acknowledges the localized impact of CFPP retirement on certain sectors, regions, and groups, especially women, youth and vulnerable populations, and the importance of targeted mitigation efforts. Two out of the three Just Transition programmatic intervention approaches outlined in the CIPP mention supporting coal-based communities by ensuring fair and adequate compensation, enhancing social protections, strengthening safeguards, and supporting human capital development for groups impacted by reduced domestic coal use. However, while the Institute for Essential Services Reform estimates that USD 2.4 billion is needed to justly transition workers out of the coal industry, the JETP CIPP sets aside just USD 350 million in designated Just Transition funds [13, 35]. Additionally the technical assistance and "other" grants relevant to the re-skilling and compensation of workers are also the least available funding mechanism in the JETP CIPP [35]. Achieving improved outcomes for all Indonesians via the energy transition means prioritizing strong Just Transition policies and financial allocation.

Challenge 2: GOI's vision for a low-carbon transition that generates a sizable and vibrant workforce while safeguarding natural resources and the surrounding environment

The renewable energy technology sector is rapidly expanding and generating a fast-growing and potentially profitable market in the wake of national pledges to decarbonize and embrace the energy transition. With rich reserves of critical minerals, a large and young workforce, and extensive tropical land, Indonesia is poised to become a leader in battery manufacturing, solar PV production, and biomass feedstock production [13, 36]. The GOI has strategically prioritized the development of low-carbon transition activities, focusing on the renewable energy supply chain and value-added production industries. This development would not only address employment gaps resulting from coal sector disinvestment, but also aim to transition the economy away from a predominantly low-wage, low-skill workforce, offering valuable training and employment opportunities to Indonesia's youth (SDG target 8.6). However, despite the favorable natural provisions and the government's stated intentions, underperformance in the green industry, green jobs, and green trade remains a major challenge in Indonesia's pathway to green growth, with the economy yet to demonstrate its ability to decouple growth from emissions and uphold environmental integrity [37].

Batteries are set to drive more than 60% of clean energy technology by 2050 globally and are crucial to EV production and the energy transition via battery energy storage systems (BESS). Indonesia is the world's largest supplier and second-largest processor of nickel, a mineral whose high energy density makes nickel manganese cobalt oxide (NMC) the preferred composition for lithium-ion batteries. NMC had a market share of 60% as of 2022 [38]. A value-added analysis found that the EV battery industry could increase GDP by approximately $21 billion and add more than 42,000 jobs [21]. To position itself as the Association of Southeast Asian Nations (ASEAN)'s lithium-ion battery production hub, Indonesia aims to reach a capacity of 140 GWh by 2040. Meeting this target requires a substantial increase in nickel production, escalating from 0.8 million tons (Mt) in 2019 to 4 Mt by 2050, primarily to support the domestic car and motorcycle fleet [36]. Presidential Regulation No. 55/2019 further underscores the commitment to fostering domestic production and deployment of battery EVs, introducing measures such as a minimum Domestic Component Level for new vehicles, manufacturing incentives, and infrastructure provisions [39].

Indonesian manufacturers have turned to the high-pressure acid leach (HPAL) process to produce the purity levels required of battery-grade nickel. However, this capital-intensive method often fails to reach design capacity, leading manufacturers to resort to cost-cutting measures such as deep sea tailings disposal (DSTD), a toxic waste offloading method that is cheap and convenient but environmentally damaging [40]. While public outcry has curtailed the prevalence of DSTD due to its environmental harm, finding economically viable and sustainable alternatives remains a major challenge for the nickel processing industry [41]. Moreover, the massive uptick in nickel extraction and production is depleting existing reserves and new exploration in Indonesia's carbon-sequestering forests is causing deforestation. This expansion has resulted in the displacement of indigenous communities, posing challenges to their livelihoods and land rights [22, 40]. The projected growth of Indonesia's battery industry underscores the need to develop sustainable mining and production methods. These methods must be implemented to ensure that communities hosting production do not bear the negative externalities of resource extraction and that the benefits of economic growth are equitably distributed.

Emissions reductions will largely come from switching to low-carbon power and increasing energy efficiency. The majority of abatement will come from co-firing biomass in captive coal-fired power plants and building onsite renewable energy capacity, especially solar [42]. Twenty-one industrial parks have already adopted or planned to adopt onsite solar, showing promise in this area [43]. In 2020, the United Nations Industrial Development Organization (UNIDO) partnered with the GOI to create the Global Eco-Industrial Parks Program (GEIPP), which assists industrial parks in efficient resource management, pollution reduction, and sustainable development [44]. Existing programs such as GEIPP and eco-industrial parks can serve as an example and framework for the reproduction of sustainable industrial practices throughout Indonesia. Given the highly toxic and leachable properties of nickel mining, supervised and responsible waste disposal and management techniques are essential. Some potential pathways to a reduced environmental footprint include exploring nascent waste valorization and metal recovery options, combined with increasing transparency and strengthening oversight [45–47].

Biomass plays an important role in Indonesia's energy transition plans as a clean and readily available energy source. In the 1.5 C scenario, biofuel is projected to make up 18.5% of the country's total primary energy supply by 2050, in part driven by the substitution of coal with biomass in retiring CFPPs [36, 48]. Biomass use generates operational and maintenance jobs, and the labor-intensive nature of feedstock production adds another level of employment generation [49]. The bioenergy industry is projected to contribute significantly to employment in renewables by 2030 (510,000 jobs in the Planned Energy Scenario and 1.1 million jobs under the 1.5 Scenario), and biomass projects under 10 MW have the highest profit margins of all renewable energy technologies in Java [16, 50]. However, high productivity in Indonesia's agricultural sector combined with a single digit biomass deployment rate (4%) means that large amounts of potential biomass are wasted, particularly palm oil residue and rice husks [36].

Indonesia's projected 5% growth in biofuel production from 2021 to 2027 is exclusively fueled by palm oil feedstock [51]. High yields and low production costs along with physiochemical properties similar to diesel have propelled palm oil to a dominant role in the bioenergy and biodiesel market [52]. The government intends to raise the biodiesel blend from 30% (B30) to 40% (B40) to utilize surplus biodiesel, capitalize on the decreasing price gap between biodiesel and diesel, and further reduce emissions in the transportation sector. However, B40 is not yet proven or road-tested, and several approval delays have made it unclear when B40 will be rolled out in Indonesia [16]. Furthermore, scaling up the biomass industry means facing greater land-use competition and potential expansion, and biofuel production already impacts the food and feed market in Indonesia. Mitigating these effects involves implementing productivity improvements in agriculture and livestock, as well as adopting sustainable feedstock production arrangements [53].

There is an estimated 3.5 million ha of degraded land suitable for biodiesel crops, which could offer both ecological restoration and increased fuel production amounting to 3 Petajoules of biodiesel annually. However, these relatively small and dispersed land plots hinder economies of scale [54]. Integrated landscape management, which diversifies food, feed, fiber, and fuel crops in a single plot, offers environmental, productivity, and financial benefits to famers and could provide a source for biomass feedstocks without requiring new land concessions. Similarly to planting on degraded lands, the fragmentation of energy crops inherent to this method is difficult to integrate into the current biomass supply chain [55]. Used cooking oil (UCO) provides a chemically feasible feedstock alternative to palm oil, with an estimated production potential of 651 kilotons of biodiesel per year. Indonesia currently collects roughly 1/3 of its UCO supply and exports more than half of that amount, leaving under 200 kilotons available for domestic biofuel production [56].

The transition to palm oil monocultures across southeast Asia has demonstrated financial benefits for rural farmers and promoted community-wide economic growth [57, 58]. However, the success of this shift is primarily observed in villages already integrated into a market-based economy, while communities relying on traditional subsistence agriculture experience significant losses in social, financial, and environmental well-being [59]. Moreover, economic pressures on small holder farms in Indonesia to cultivate profitable monocultures like oil palm and rubber lead to a reduction in biodiversity and the ecological value of their land [60]. Smallholders, constituting around 40% of oil palm production, have been found to degrade intact forest land at a higher rate than large companies [58]. In the case of larger companies acquiring oil palm concessions, the lack of effective land dispute resolution channels or enforcement mechanisms jeopardizes land rights, economic security, and access to traditional means of subsistence for indigenous and transmigrant groups [61].

Challenge 3: Utilizing international green finance opportunities to mobilize economically stimulating capital while also building out domestic capacity for future investment needs

A key element of SDG 8 is to strengthen the capacity of domestic financial institutions, ensuring the encouragement and expansion of access to banking, insurance, and financial services for all. Indonesia has readily acknowledged the necessity for extensive infrastructure updates to foster a healthy, adaptable economy that is prepared for a renewable energy powered future [13]. Investors are increasingly drawn to sustainable development projects and numerous green finance funds have emerged to aid developing countries in transitioning their energy systems [16, 62]. The adoption of green finance could help prevent stranded assets, modernize infrastructure, and ultimately cultivate a more resilient economy [13, 63]. A breakdown of the funding mechanisms, investment focus areas, and sources the JETP's current public funding pool can be found in Figs. 3 and 4, including both International Partners Group (IPG) and Energy Transition Mechanism (ETM) funding. While JETP's CIPP focuses on leveraging public finance to catalyze private investment in Indonesia's energy transition, various regulatory, financial, and technical barriers pose challenges to closing the investment gap.

One of the major complications in financing Indonesia's transition lies in the reliance on the state-owned utility monopoly, PLN, to manage the energy transmission and distribution sector. Financing new energy capacity relies on PLN's balance sheet, government subsidies, and concessional funds. Encouraging robust private sector involvement in project funding could diversify the financial base of energy transition projects within the grid. However, a lack of clear tariff accountability, private sector regulation, and project transparency has proven to be a major barrier [64]. Additionally, the presence of long-term inflexible Power Purchase Agreements (PPAs) between Independent Power Producers (IPPs) and PLN featuring take-or-pay obligations have enabled

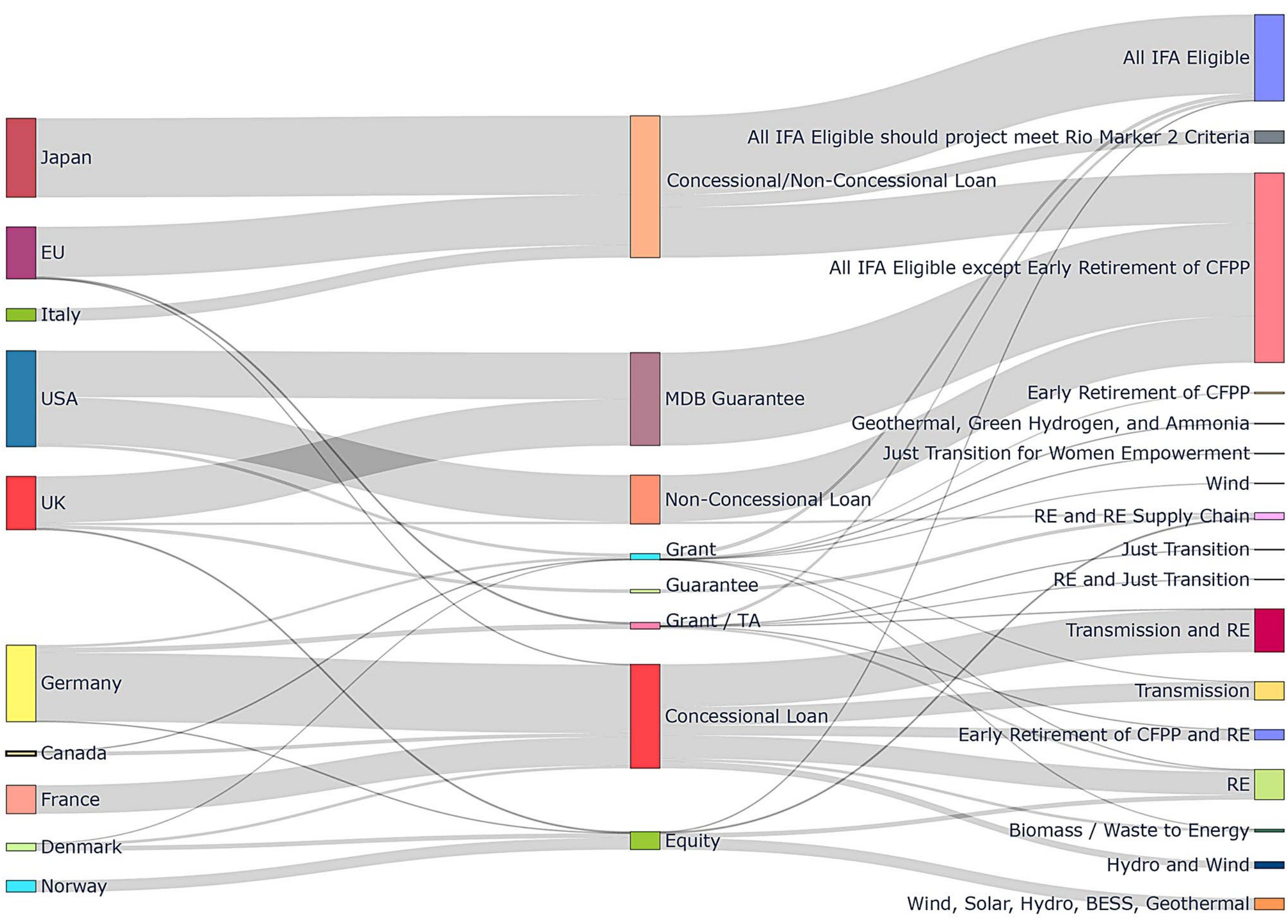

Fig. 3 International Partners Group (IPG) Funding. *Note* This diagram shows funding flows from a total IPG pool of USD $ 9073.55 million. Two funding projects from France and one from the EU were presented as a range of USD $100–200 0–300, and 2–3 million, respectively. These ranges have been represented in the figure using the midpoint. USD $167 million in funding from Germany has not yet been officially committed to the GOI via common processes

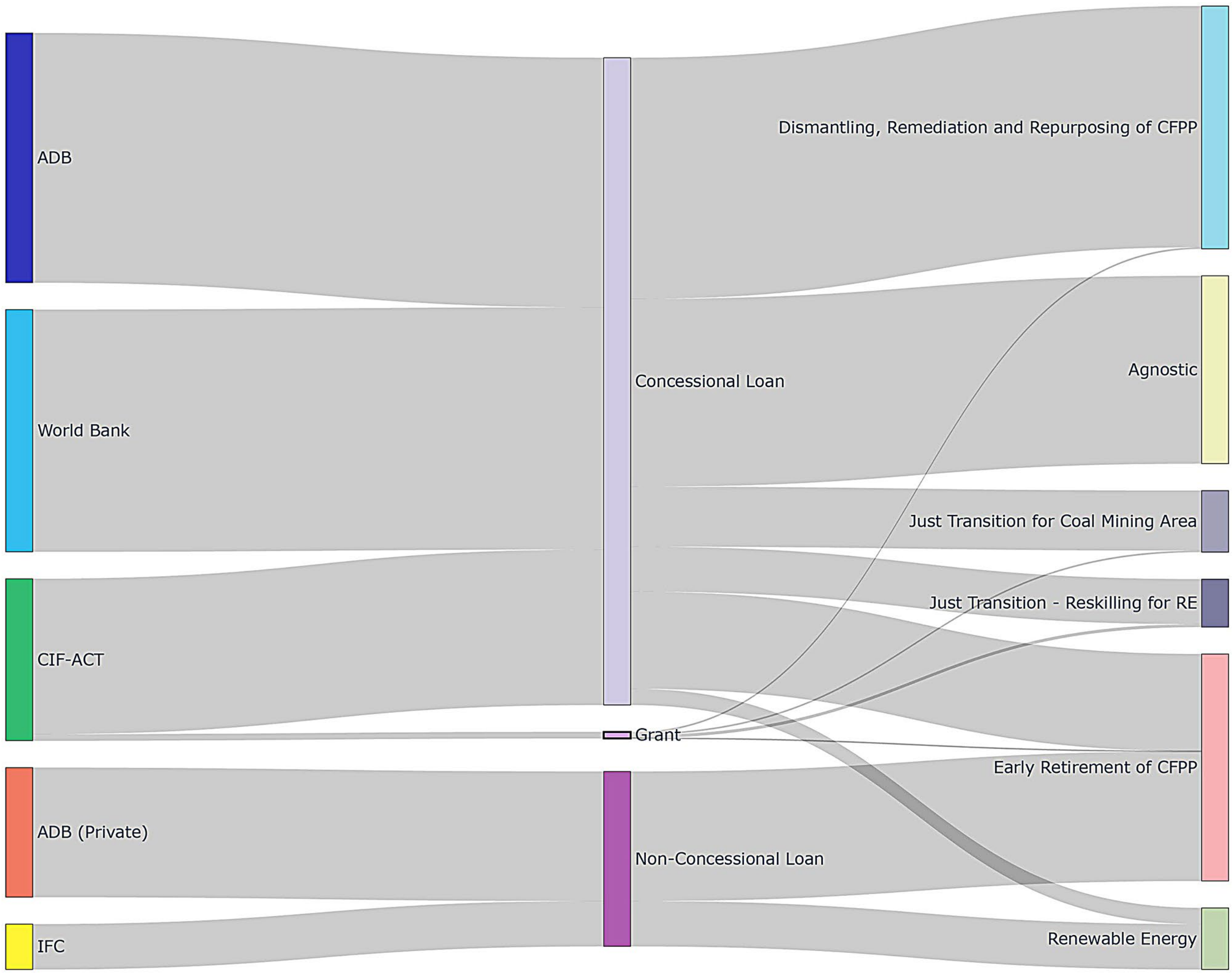

Fig. 4 Energy transition mechanism (ETM) funding. *Note* This diagram shows funding flows from a total ETM pool of USD $ 2559.0 million

coal power capacity additions and hinder the flexible use of the power grid [13, 63, 65]. Addressing these PPAs, which are unfavorable to renewable energy projects, becomes increasingly urgent given that IPPs are projected to develop 65% of all planned additional capacity according to the GOI and PLN's Electricity Business Plan 2021–2030 (RUPTL) [66]. While PLN's monopoly presence within electricity transmission and distribution does not prohibit successful relationships with private investors, it requires a tailored approach to project financing and reworking of the regulatory, contractual, and policy environment to suit public-private collaboration.

Enhancing access to climate finance is not a standalone endeavor. It requires complementary policies, regulations, training, and other support systems. An analysis of geothermal projects in Indonesia highlights that the effectiveness of climate finance hinges on its alignment with policy guidance and technical capacity building [67]. Moreover, hydro and geothermal power projects face significant exploration and development costs, and lac adequate de-risking mechanisms to attract investment [13, 67]. Scaled renewable energy projects encounter similar challenges, struggling to sustain themselves due to a scarcity of suitable human capital within domestic green finance and institutional designs that predominantly favor state-owned energy over private capital [68].

Green bonds present an opportunity to strengthen domestic financial capacity and reduce future reliance on international support (SDG target 8.A). JETP has acknowledged the need to strengthen local financial institutions' capacity to issue bonds and recognizes their invaluable working knowledge. Domestic non-bank institutions like insurance companies, pension funds, and venture capital can also contribute significantly by transforming savings into capital market products, providing an additional stream for project financing [13]. As of 2022, there were approximately 7,000 green, social, and sustainable (GSS) bonds, of which 4,000 were issued by the private sector. However, GSS bonds were almost entirely issued in foreign currency, while just 0.25%

originated from local financial institutions. While local investors express interest in green bonds, they cite challenges such as a lack of ESG development capacity, a minimal green project pipeline, and inadequate policy incentives, which impede their active participation [69]. Issuers are also unmotivated to enter the green bond market as they must foot the bill for the additional verification processes needed for green bond credentials, as well as meet separate disclosure requirements [69, 70].

Outlook and conclusion

1. Advocate for the implementation of renewable energy-based village grids in remote areas, facilitating household electricity usage to support the green economy and adhere to climate commitments.

Approximately 42% of total electricity consumption is attributed to household use, significantly surpassing the global average of 30%. This high household demand is driven in part by the prevalence of home-based SMEs, which constitute 60% of Indonesia's GDP. This underscores the importance of reliable residential access to on-grid electricity [16]. While research highlights the positive microeconomic and macroeconomic effects of household electrification, much of it focuses on grid connection, overlooking decentralized sources that could better serve poor, remote communities, particularly in Indonesia's eastern regions [71, 72]. Residential power supply in Indonesia exhibits regional disparities, with densely populated areas experiencing power supply surpluses, while less dense regions face deficits and unreliability [13]. In response, a 2011 program by the state electricity company, Perusahaan Listrik Negara (PLN) and Ministry of Energy and Mineral Resources (MEMR) introduced renewable energy-based village grids (RVGs) in regions where grid connection were cost-prohibitive, utilizing solar PV and micro-hydropower. Despite MEMR's claim of a 98.9% electrification rate in 2019, citing the rural electrification program as a success, challenges persist, with rates as low as 72% in East Nusa Tenggara and over 13% of villages unable to connect to the PLN grid [73, 74]. RVGs emerge as an effective low-carbon solution to grid unreliability, demonstrating positive impact on productivity and income generation in unconnected villages, especially for small to medium-sized enterprises [74]. While micro-hydro is the most cost-effective and biomass production has found local success, solar PV remains the most accessible option [75, 76]. However, given the risk-averse investment climate, the current solar PV market is geared towards large centralized generation facilities, creating a "missed opportunity" to stimulate economic growth and encourage wide electrical access, as well as neglecting energy justice in favor of economic outcomes [77, 78]. Addressing this, along with other challenges discussed below, requires more supportive investment policies.

2. Maximize the use of solar PV production to cultivate a future workforce with high wages, substantial value-added contributions, and advanced skill sets.

Currently, Indonesia's job market is characterized by low-wage, low-value-added, and low-skilled labor, with more than half of all workers employed in the informal sector [50]. The development of the solar PV supply chain has the potential to create over 100,000 high-value-added jobs, with half of them being highly skilled, primarily in the equipment manufacturing sector [49, 50]. MEMR has an installed target capacity of 3.6 GW by 2025, requiring annual solar PV production of 600−120 MW. The capacity becomes even more significant under the 1.5 scenario, which necessitates 800 GW of domestically installed solar PV [36].

China currently dominates over 80% of the global solar PV supply chain due to their clear cost-advantage in labor, manufacturing, energy, and overhead. However, relying on a single location for production poses risks of supply chain disruption and vulnerability [79]. Upstream production of polysilicon, ingots, and wafers entails large investment and energy inputs, and requires economies of scale to achieve competitive per-unit pricing. In this context, Indonesia can derive substantial benefits from downstream production, particularly in cell manufacturing and module assembly, which entail low upfront costs and can operate in plants as small as 100 MW [13]. Indonesia's low electricity prices present a prime opportunity for cost-competitiveness within the ASEAN region [80]. However, this advantage might be affected by the emissions-heavy electricity sector transitioning to cleaner energy sources. Additionally, high local content requirements (LCR) intended to stimulate domestic production have led to the production of subpar units by domestic manufacturers, marked up by 40% compared to imported panels [36]. Despite this, the Ministry of Industry plans to raise LCRs further to 90% by 2025, even though there is no planned expansion of factories or technical capabilities to supply the necessary production components [80]. Presidential Regulation No. 112/2022 on the Acceleration of Renewable Energy Development for the Supply of Electric Power somewhat improved returns for developers, but LCRs remain unattractive in solar auctions and concerns about quality have rendered them generally unbankable by financial institutions [16]. Addressing LCR's challenges, alongside increased manufacturing incentives and improved access to financing instruments for factory projects, is crucial to achieving Indonesia's solar PV module industry development goals.

3. Leveraging the pivotal role of transition finance in the energy transition and identifying eligible transition activities and investment to strengthen the capacity of domestic financial institutions.

Indonesia introduced its Green Taxonomy 1.0 in January of 2022, aiming to guide investments, categorize green business activities, and bridge the financing gap. The taxonomy employs a traffic light system—red for environmentally harmful activities, yellow for transitional activities avoiding significant harm but not fully aligned with environmental goals, and green for activities aligned with national environmental objectives [81, 82]. While a positive step, the initial version lacked details on transition criteria, a framework for businesses to self-classify, specific environmental impact metrics, and integration with regional and international taxonomies like ASEAN Taxonomy V2 [16]. In response, Indonesia released Green Taxonomy 2.0 in late February 2024, addressing interoperability with regional taxonomies and allowing certain transitional activities like nickel smelting, mineral mining, and captive coal power plants. However, this leniency, without proper regulation and monitoring, poses risks to the taxonomy's credibility and may lead to the inadvertent expansion of coal capacity [81, 83]. Despite the Green Taxonomy's contribution to the green transition, urgent actions are needed to identify eligible transition activities and collaborate with international financing mechanisms to facilitate a smoother energy transition.

Navigating SDG 8 as an emerging economy while adapting to climate change and a renewable energy powered future presents both challenges and opportunities for Indonesia. Given its rich natural resources, plentiful renewable resource availability, abundant labor force, and positioning within ASEAN, Indonesia has the tools and ambition to emerge as a global and regional leader in renewable energy deployment and supply chain production. However, getting to that position requires navigating complex barriers in everything from policy to resource management to technical capacity. Updating historically weak infrastructure, navigating the international climate finance landscape, avoiding the resource extraction trap, and finding a niche to fill in supply chains or other renewable energy focused industries are common challenges for many emerging economies across the globe. Indonesia's experiences in these areas, particularly as it navigates the challenges discussed above, can potentially deliver success in achieving the vision for SDG 8 and may serve as an example for other nations on a similar growth trajectory.

Abbreviations

ASEAN	Association of Southeast Asian Nations
ADB	Asia Development Bank
B30	Biodiesel 30%
B40	Biodiesel 40%
BESS	Battery Energy Storage Systems
CFPP	Coal-fired Power Plant
CIF-ACT	Climate Investment Funds Accelerated Coal Transition
CIPP	Comprehensive Investment and Policy Plan
CO_2	Carbon Dioxide
DSTD	Deep Sea Tailings Disposal
EMT	Energy Transition Mechanism
EV	Electric Vehicle
GDP	Gross Domestic Product
GOI	Government of Indonesia
GSS	Green, Social, and Sustainability
GWh	Gigawatt-hour
HPAL	High-pressure Acid Leach
IFA	Investment Focus Area
IFC	International Finance Corporation
IPG	International Partners Group
IPP	Independent Power Producer
JETP	Just Energy Transition Partnership
LCR	Local Content Requirement
MDB	Multilateral Development Bank
MEMR	Ministry of Energy and Mineral Resources
Mt	millon ton
MW	megawatt
NMC	Nickel manganese cobalt oxide
PLN	PT Perusahaan Listrik Negara (Indonesia's state-owned electricity company)
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
RIPIN	Rencana Induk Pembangunan Industri Nasional (Master Plan of National Industry Development)
RUPTL	Rencana Usaha Penyediaan Tenaga Listrik (Electricity Supply Business Plan)
RVG	Renewable Energy-based Village-Grids
SDG	Sustainable Development Goals
SME	Small-medium Enterprise
UCO	Used Cooking Oil

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J.L is responsible for designing the original study and framing. A.R wrote the original manuscript, J.L is responsible for reviewing, editing, and supervising the original draft. N.H., T.H and Y.G. reviewed the manuscript and provide valuable comments.

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Declarations

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