Ambition to Action

INITIATING A FAIR AND INCLUSIVE ENERGY TRANSITION IN INDONESIA

AN ANALYSIS OF THE CASE FOR PHASING OUT COAL-BASED POWER GENERATION AT SURALAYA

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Authors: Xander van Tilburg, Harry Fearnehough, Tessa Schiefer, and Himsar Ambarita

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KEY FINDINGS

The Indonesian Government plans to replace 3.4GW of coal units at Suralaya with new grid-connected solar PV capacity in the Java-Bali grid. This paper is our analysis of this plan, where we present potential impacts across development indicators (SDGs), and identify barriers and enablers. We also make suggestions on steps different stakeholders could take to make this plan a reality and how they can contribute to an inclusive push for the clean energy transition in Indonesia.

There are significant positive impacts of the switch from coal, and solar PV can be a driver for greater prosperity and an inclusive clean energy transition. However, results are time-bound: the faster the replacement, and the earlier it starts, the larger the benefits.

- Reduction of local air pollution can avoid 15,000 premature deaths *(SDG 3 – Good Health and Well-being).*
- Over 100,000 direct jobs and USD 10-16bn in investments can drive domestic growth *(SDG 8 - Decent Work and Economic Growth)*.
- 270 Mt of GHG emission reduction points the way to taking ambitious climate action *(SDG 13 – Climate Action)*.

The phase-out of Indonesia's entire 35 GW fleet of coal plants is a critical part of Indonesia's transition towards zero emissions power generation. This analysis provides a starting point, an impression of the size and direction of the potential impacts that lie ahead under such a transition.

Our analysis suggests that full replacement of Suralaya in four years is possible, but also that a lack of concerted effort could delay this switch by 7-10 years. Some barriers are relatively easy to address, while others are more difficult to overcome. Key improvements are needed in spatial planning and streamlining of permitting, a predictable medium-term pathway for clean energy to replace fossil. Establishing stable policies to back large investments in capacity and manufacturing are also needed. Key stakeholders will need to each play their part. Government; the State electricity company, PLN; and banks will have to move pro-actively, in coordination, and without delay. This will ensure households and businesses can participate in the clean energy transition.

Indonesia does not need to do this alone. International support for climate action is an essential part of the Paris Agreement and has recently been re-emphasized in the Glasgow Climate Pact. However, it needs to be a true and long-term collaboration where domestic efforts to drive down Indonesia's emissions are matched with external assistance. It is unlikely that international support to scale up climate action will materialise independent of domestic efforts to accelerate the energy transition. For example, there will be little enthusiasm for 'buying out' an old coal plant if there is a risk that a new one is built in its place.

Significant and long-lasting international support for the Indonesian energy transition is most likely to succeed if the following five items are addressed simultaneously:

1. Create favourable policy conditions and establish credible clean energy targets.
2. Negotiate an exit strategy for coal.
3. Address pre-existing (legacy) weaknesses and vulnerabilities in the energy system.
4. Strengthen international climate pledges to signal ambition and commitment.
5. Establish a framework for continued dialogue and discovery

As one of the world's largest emitters, it is critical that Indonesia initiates a fair and inclusive energy transition, without delay, in a manner that addresses the twin aims of prosperous, sustainable economic development and ambitious climate action.

TEMUAN UTAMA

Makalah ini menguraikan analisis kami tentang rencana pemerintah Indonesia untuk mengganti pembangkit batubara 3,4GW di Suralaya dengan energi surya PV yang terhubung ke jaringan Jawa-Bali. Kami menyajikan dampak potensial terhadap seluruh indikator pembangunan berkelanjutan (SDGs), mengidentifikasi hambatan dan faktor pendukung, dan memberikan saran tentang langkah-langkah yang dapat diambil oleh berbagai pemangku kepentingan untuk mewujudkannya dan berkontribusi pada dorongan inklusif untuk transisi energi bersih di Indonesia.

Kami menemukan dampak positif yang signifikan dari peralihan dari batu bara ke surya PV dapat menjadi pendorong kemakmuran yang lebih besar dan transisi energi bersih yang inklusif, tetapi hasilnya tergantung waktu: semakin cepat penggantian, dan semakin dini dimulai, semakin besar manfaatnya.

- Pengurangan polusi udara dapat menghindari 15.000 kematian dini (SDG 3)
- Lebih dari 100.000 lapangan kerja langsung dan investasi USD 10-16 miliar dapat mendorong pertumbuhan (SDG 8)
- Pengurangan emisi GRK sebesar 270 Mt menunjukkan aksi iklim yang ambisius (SDG 13)

Analisis pada laporan ini menunjukkan titik awal, perkiraan tentang ukuran dan arah dari dampak potensial yang akan diperoleh kemudian, sebagai usaha mengganti seluruh pembangkit 35 GW yang saat ini sedang beroperasi sebagai bagian dari usaha menuju pembangkit dengan emisi nol.

Analisis kami menunjukkan bahwa penggantian penuh Pembangkit Suralaya dalam kurun waktu 4 tahun adalah mungkin, tetapi karena kurangnya upaya bersama dapat menunda penggantian ini sekitar 7-10 tahun. Beberapa hambatan relatif mudah diatasi, sementara yang lain lebih sulit diatasi. Perbaikan utama diperlukan dalam perencanaan tata ruang dan perampingan perizinan, jalur jangka menengah yang dapat diprediksi untuk energi bersih sebagai pengganti fosil, dan menetapkan kebijakan yang stabil untuk mendukung investasi besar dalam kapasitas dan bidang manufaktur. Pemangku kepentingan utama perlu memainkan peran mereka masing-masing: Pemerintah; Perusahaan Listrik Negara; dan bank harus bergerak secara proaktif, terkoordinasi, dan tanpa penundaan, sehingga rumah tangga dan bisnis dapat berpartisipasi dalam transisi energi bersih tersebut.

Indonesia tidak perlu melakukan ini sendirian: dukungan internasional untuk aksi iklim adalah bagian penting dari Perjanjian Paris yang baru-baru ini ditekankan kembali dalam Pakta Iklim Glasgow. Tapi itu perlu kolaborasi yang benar dan jangka panjang di mana upaya domestik untuk menurunkan emisi Indonesia diimbangi dengan bantuan eksternal. Dukungan internasional untuk meningkatkan aksi iklim tidak akan mungkin terwujud tanpa adanya upaya domestik untuk mempercepat transisi energi. Misalnya, akan ada sedikit antusiasme untuk 'membeli' pembangkit listrik batu bara lama jika ada risiko bahwa pembangkit baru akan dibangun di tempatnya.

Dukungan internasional yang signifikan dan berjangka lama untuk transisi energi Indonesia kemungkinan besar akan berhasil jika lima tema berikut ditangani secara bersamaan:

1. Menciptakan kondisi kebijakan yang menguntungkan dan menetapkan target energi bersih.
2. Negosiasikan strategi keluar dari batubara.
3. Mengatasi kelemahan dan kerentanan yang sudah ada (warisan) dalam sistem energi.
4. Memperkuat janji iklim internasional untuk menandakan ambisi dan komitmen.
5. Tetapkan kerangka kerja untuk dialog dan penemuan lanjutan

Sebagai salah satu penghasil emisi terbesar di dunia, sangat penting bagi Indonesia untuk memulai transisi energi yang adil dan inklusif tanpa penundaan dengan cara yang sesuai dengan tujuan ganda yaitu pembangunan ekonomi yang sejahtera, berkelanjutan, dan aksi iklim yang ambisius.

CONTENTS

1 INTRODUCTION

Indonesia is on the verge of accelerating its clean energy transition. The need to shift to an efficient, clean energy system is driven by the demand to provide enough reliable and affordable energy for economic development and growth, while drastically reducing greenhouse gas emissions and local air pollutants.

In the past two decades, coal has become increasingly important for Indonesia, both as an export commodity and to drive much of its current and planned power production capacity.[1] However, the greenhouse gas emissions associated with the use of coal have a devastating effect on the world we live in. Scientific consensus points to an urgent need to dramatically reduce global emissions to avoid catastrophic and irreversible damage from global warming. In fact, the threat of continued global warming from burning fossil fuels is so acute, that most of the remaining coal will need to stay in the ground, and the energy sector will need to turn to renewable sources without delay. As a signatory to the 2015 Paris Agreement and the 2021 Glasgow Climate Pact, Indonesia is part of the global effort to drastically reduce emissions and commits to strong and swift action according to its "highest possible ambition". Fortunately, Indonesia has an abundance of renewable resources, more than enough to effectively switch to an energy system that is built predominantly around geothermal energy, solar photovoltaic, and hydropower.

Shifting to renewable energy is not only an effective way to reduce greenhouse gas emissions, it also makes sense from economic and development points of view. The clean energy transition has many linkages with other sustainable development goals (SDGs). Some of these are overwhelmingly positive, for example in the realm of health improvement, while others, such as employment and energy security, involve trade-offs and depend on smart choices around implementation. Governments play an important role in safeguarding the inclusiveness and fairness of transition outcomes: their guidance on trade-offs and choices has a large bearing on which stakeholder groups stand to benefit, which may not, and who (disproportionately) bears the costs.

ABOUT THIS REPORT

This policy brief sets out our analysis of plans to replace 3.4GW of coal units at the Suralaya power plant on Java with new grid-connected solar PV, as announced by the Indonesian government. We examine a range of climate and wider socioeconomic impacts and present impacts across development indicators, linked to the SDGs, to show how changing from coal to solar PV can bring greater prosperity to Indonesia. Based on evidence from quantitative scenario modelling, analysis of the energy sector, and a series of stakeholder interviews, we identify barriers and enablers, and we provide suggestions for actions different stakeholders could make to make this a reality and contribute to an inclusive green push for solar PV.

1 Indonesia is currently the second largest coal producer in the world, after China (Statistica, 2021). This has not always been the case though: Indonesia's coal production has increased sixfold since 2001 (IEA, 2021a)

2 REPLACING COAL BY SOLAR PV

Our analysis explores the effects a rapid energy transition could have on development, through a real-world case study: replacing the large 3.4 GW Suralaya coal power plant on Java Island, with new grid-connected solar photovoltaic (PV). This case study provides a starting point, an impression of the size and direction of the potential impacts – including both opportunities and challenges – that lie ahead as the entire 33 GW fleet of coal plants currently in operation will need to be phased out in the years ahead.

In this section we give a brief description of the Suralaya power plant (2.1) and of recent developments in the global and national markets for solar PV (2.2), followed by a brief introduction to the three scenarios we use to compare our findings in the rest of this report (2.3) and some notes on the scope and limitations of our analysis (2.4).

2.1 SURALAYA IS A DIRTY POWERHOUSE …

The Suralaya power plant consists of 7 units that have been built in the period 1984-1997 (units 1-7; 3,400 MW) and one unit that came online in 2011 (unit 8; 625 MW) and is mainly used to provide backup electricity supply. There are controversial plans for a further expansion with two more units (units 9 and 10; 1,000 MW each) for which construction activities started in June 2021. For our analysis we consider the first 7 units, comprising a combined capacity of 3.4 GW. The power plant is situated in Banten province, at around 100 km from the capital Jakarta and it is operated by Indonesia Power, a subsidiary of the state-owned utility PT PLN (Persero). Suralaya power station has large open-air on-site coal storage facilities and an attached coal terminal where it receives its coal from Bukit Asam Coal Mining operations in nearby South Sumatra.

Figure 1: Suralaya power plant in Banten province, Java Island, Indonesia

The Suralaya complex supplies over half the electricity demand within a 100 km radius around Jakarta and has been dubbed 'the most polluting industrial complex in South-East Asia.'[2] In addition to being a large source of local air pollution, the plant is also a significant source of CO_2 emissions: as a subcritical pulverised coal plant converting sub-bitumous coal at around 34% efficiency it releases CO_2 emissions of around 1000 g/kWh output. As we will see in section 0, rapid phase out of the first 7 units can avoid greenhouse gas emissions equivalent to two years of total transport emissions in Indonesia.

2 Crea (2020) Transboundary Air Pollution in the Jakarta, Banten, and West Java provinces

In November 2020, Minister Arifin Tasrif announced that the Ministry of Energy and Mineral Resources (ESDM) is looking into closing the plant and replacing it with renewable energy in combination with energy storage. Despite worries about pollution and emissions, and the relative old age of the plant, shutting it down presents challenges too: Suralaya is of strategic importance to PLN because of its high capacity, attractive location close to a major demand centre, and low production costs compared to other plants.[3]

2.2 … AND SOLAR PV IS AN ATTRACTIVE, CLEAN ALTERNATIVE

Nowadays, solar PV is among the most attractive technologies for new power plants and the global market is growing fast: the cumulative capacity has reached 700 GW with 144 GW added in 2020 alone, corresponding to a sevenfold market growth in the past 10 years. The IEA projections of paths to global net-zero emissions in 2050 show that even faster growth is needed: the market will need to grow at an average of 24% per year between 2020 and 2030 towards 630 GW additional annual capacity in 2030.[4]

Current market growth is driven mainly by economic considerations, as costs for solar PV have dropped steadily and are now on, or below, par with conventional fossil generation in many parts of the world. In Germany, for example, the current levelized cost of electricity (LCOE) for utility scale solar PV is as low as 0.03 to 0.07 USD/kWh[5] while in other places, with favourable solar irradiation, prices can go well below that for large scale projects as is the case for Abu Dhabi's winning bid of 0.0135 USD/kWh for a 2 GW solar plant.[6] Not only utilities and independent power producers choose solar PV, households and businesses too are increasingly interested in the high rates of return on investment and short payback periods associated with switching to solar PV.[7]

In contrast, in Indonesia solar PV deployment is not moving all that fast. The market is still small, and growth is modest and well behind schedule: the total installed capacity by the end of 2020 was just 0.15 GW, up from 0.12 GW in 2019.[8] Compared to the stated government ambition of 6.5 GWp in 2025 this would require a 300-fold increase in the years ahead (RUEN; ESDM, 2017). The main reasons for this tardiness are lack of an attractive policy framework for renewable energy and the government's focus on expanding coal-fired power capacity in recent years. The good news is that Indonesia has a massive solar potential, with estimates ranging from 208 GWp to 532 GWp[9] and that some hopeful initiatives are emerging, such as the 145 MW Cirata floating solar plant. This utility scale initiative is a collaboration between Masdar Solar and Indonesian partner PTPJBI with a reported LCOE of 0.058 USD/kWh.

Replacing a large coal power station such as Suralaya will require a significant amount of solar PV capacity, well beyond the current scale of the Indonesian market. While it would be a step change for Indonesia, it is not uncommon for countries to install multiple gigawatts of solar PV per year nowadays: Brazil, Netherlands, India, and Spain for example installed between 3-5 GW each in 2020. In this regard, Vietnam is especially notable for its recent ramping up of solar PV, growing from near 0 to 16 GW in two years.

3 Bisnis Indonesia (2020) PLN is still reviewing substitution plan for Suralaya with renewable energy; Kontan (2020) The Minister for ESDM visits Suralaya power plant for inspection by the end of the year
4 IEA (2021) Solar PV in Tracking Clean Energy Progress
5 Philipps and Warmuth (2021) Photovoltaics Report
6 PV Magazine (2020) Abu Dhabi's 1.5 GW tender draws world record low solar bid of $0.0135/kWh
7 BloombergNEF (2021) Realizing the Potential of Customer-Sited Solar
8 ESDM (2021) Performance and achievements 2020 and Program 2021
9 208 GWp is the potential used by ESDM (DSK, 2021), 532 GWp is based on the IRENA REMap assessment (IRENA, 2017)

2.3 THREE SCENARIOS

In order to assess the potential impacts of the coal-to-solar switch, we use three tools that were developed as part of the Ambition to Action project[10], to help policy makers with the task of identifying sustainable development impacts of climate mitigation actions and NDC ambition raising across a range of sectors and themes.

The SDG Climate Action Nexus tool (**SCAN**-tool) is used to identify a long- and shortlist of relevant impacts. It is a visual aid to help policymakers understand whether the climate actions they are considering for their NDC targets are likely to reinforce or undermine the SDGs. Based on the latest literature, it offers a high-level starting point that can be followed up by more context specific and detailed analyses.

The Air Pollution Impact Model for Electricity Supply (**AIRPOLIM-ES)** is used to investigate the health consequences associated with local air pollution from fossil fuel power plants. It is a spreadsheet-based model that uses an accessible methodology for quantifying the health impacts of emissions of particulate matter (PM2.5), NOX, and SO_2 from different sources of electricity generation and other fuel combustion (including coal-fired power). It distinguishes between mortality from four adulthood diseases whose prevalence is increased through exposure to air pollution: lung cancer, chronic obstructive pulmonary disease, ischemic heart disease, and strokes.

The Economic Impact Model for Electricity Supply (**EIM-ES)** is used to analyse the potential economic impacts. It is a spreadsheet-based economic model used to estimate the domestic employment impacts of investments in new electricity generation capacity within a country. Direct employment creation over time is the key focus of the model (e.g. for manufacturing equipment, construction of plants, professional services, etc.). In addition, the tool calculates indirect and induced employment impacts by drawing on input-output tables for the economy.

We build our analysis and narrative around three future scenarios. These are not predictions, but rather projections of plausible and consistent technology pathways that *could* materialize. The first scenario is a coal-based baseline in which solar PV is introduced in a stepwise manner, only to replace each of the seven coal units as they reach the end of their economic lifetime (between 2030 and 2040). In the second and third scenario, this replacement is accelerated (i.e. between 2022 and 2025). Constructing the scenarios involves a number of considerations, which we briefly present here before summarising the pathways below.

How much solar PV capacity is needed? How much backup capacity is needed?

The point of departure is that in each of the scenarios, the total capacity in place should be sufficient to produce the same amount of electricity on an annual basis (i.e. 21 TWh). This means that the capacity in GW is much higher for solar PV than for coal, because the capacity factor is in the range of 15-20% for solar PV instead of 60-80% for coal plants. We also assume that the electricity needs to be available to the same customers, which means that new capacity should be connected to the Java-Bali-Madura power grid, but not that all the PV units will need to fit on or close to the physical site of the coal plant. To give a sense of scale, the Java-Bali-Madura grid generating capacity currently stands at approximately 40 GW and consists mainly of coal- and natural gas-based power stations, alongside a smaller share of geothermal and hydropower. Solar PV accounts for 0.1% of total supply today and wind power is negligible. It is the largest grid in Indonesia, serving 60% of the country's total population (followed by the smaller 8.6 GW Sumatera grid serving 22%).

10 All tools used for the analysis are available for download at https://ambitiontoaction.net/methodologies-and-tools/

Backup capacity in the form of battery or hydropower storage, or dedicated fast-response gas-power plant, can be useful to increase the flexibility of electricity supply and allow for matching of demand and supply (for example, solar PV does not generate any electricity during hours of darkness and output is temporarily limited by factors such as cloud cover). Based on the findings in our prior work[11], we have chosen *not* to include physical power storage into our scenarios because under current circumstances a variety of less costly approaches are available to effectively manage the variability of solar PV. With strategic planning and power system development, integrating higher amounts of variable renewable energy would not necessarily lead to additional investment requirements beyond the cost of normal system development. International experiences with the integration of variable renewable energy are continuously exceeding experts' expectations, with systems going well beyond a 20% share of electricity in the system in China and countries like Spain, Portugal, Germany, UK Ireland, and Uruguay

How fast *should* and *could* solar PV be phased in?

In terms of reducing greenhouse gas emissions, the urgency is clear, and the faster coal is phased out, the better. Indonesia operates a large number of coal-fired plants today and it is critical that the transition away from their use starts immediately. Further delay will not only have adverse implications for the global climate, but will likely exacerbate the economic and social challenges that Indonesia faces as part of the inevitable transition away from coal. Our analysis focuses on the start of this transition towards a complete phase-out of fossil-based power generation and we choose a four-year time window, because that will kick-start the market for solar PV to a volume (of around 5 GW per year) consistent with phasing out another 30 GW of coal power in the coming decades, as well as keeping up with growing electricity demand.

How fast solar PV could actually be phased in is hard to predict; rather than making assumptions on barriers and enablers, we selected ambitious but achievable scenarios and then sought a dialogue with expert stakeholders on what could be feasible if the barriers to rapid development are addressed, and enablers are put in place. See sections 0 and 0 for the results of this analysis.

How do positive impacts of solar PV compare to the loss of employment and economic activity in and around the phased-out coal plant?

Any transition has winners and losers because those involved in the dominant incumbent technology, that is being phased out, may not be the same companies and individuals that benefit from the social and economic opportunities that come with the new dominant technology. We look at solar PV investments and employment that emerge, as well as coal value chain investments and employment that will disappear. We deliberately choose contrasting scenarios, to allow for clear comparison of impacts across technologies, while appreciating that the reality will more likely reflect a mix of the projections we present.

11 A2A (2019c) Three Indonesian Solar Powered Futures

How do fairness and inclusiveness feature in the analysis?

Fairness and inclusiveness are important pillars on which Indonesia's development planning is based. They are at the heart of Agenda 2030[12] and feature prominently in president Joko Widodo's mission.[13] A fair and inclusive transition is important but hard to model. At the heart of a fair and inclusive transition lies the fact that risks and returns are distributed fairly: that opportunities are created for the many, regardless of their background, and vulnerabilities are kept to a minimum. Many linkages between climate actions and development outcomes are positive, in which case objectives are mutually reinforcing. However, the two are not always neatly aligned and in certain instances they may involve difficult trade-offs or unrecoverable costs. Moreover, even in cases that the net impact of climate action is neutral or positive, this could very well hide trade-offs across aspects of development (i.e. SDGs), between groups of stakeholders, or across current and future generations. We take three approaches to incorporating inclusiveness in our analysis. First, by designing three contrasting scenarios with a focus on different stakeholders. Second, we disaggregate the modelling results, where possible, according to groups based on household size, age, etc. to identify where variation in impacts occurs. Third, we identify how barriers and enablers might have a different meaning and relevance for different stakeholder groups.

With these considerations in mind, we identify three scenarios until 2050 for our analysis as follows:

Baseline / Suralaya continued operation	In this scenario, we assume that each of the 7 units at Suralaya will continue operating until they reach an assumed total technical lifetime of 46 years. As the units retire according to age, they are replaced by commercial and residential rooftop installation and land- or water-based utility-scale solar parks (in equal shares) to make up for shortfalls in output so the total generation is around 21 TWh in all years. In this baseline scenario the capacity of 3.4 GW of coal-based power is gradually replaced with just over 12 GW of solar PV capacity by the early 2040s.
Affordable & reliable	In this scenario, we assume that over a 4-year period between 2022 and 2025 the 7 coal units are replaced, starting with the oldest. To make up for the shortfall in output, half of the generation gap is met by utility-scale, land-based installations and the other half by floating solar PV. In this scenario the output is 21 TWh in all years and solar PV capacity is around 11.8 GW by 2025 and for the years beyond. We label it 'affordable and reliable' because it is based on the technologies with the lowest costs and the largest potential for economies of scale and easy integration within the existing network.
Inclusive & empowering	Here too we assume that over a 4-year period between 2022 and 2025 all 7 coal units are replaced by solar PV, albeit this time by residential and commercial rooftop installations. In this scenario the output of 21 TWh in all years is met by solar PV capacity of around 13 GW by 2025 and for the years beyond. We label it 'inclusive and empowering' because it assumes a decentralised model where capacity is installed by many residential and SME-type consumers who directly benefit from the opportunities that renewable energy brings.

12 UN Energy (2021) Enabling SDGs through inclusive, just energy transitions

13 Joko Widodo (2019) Inauguration Speech October 20th 2019

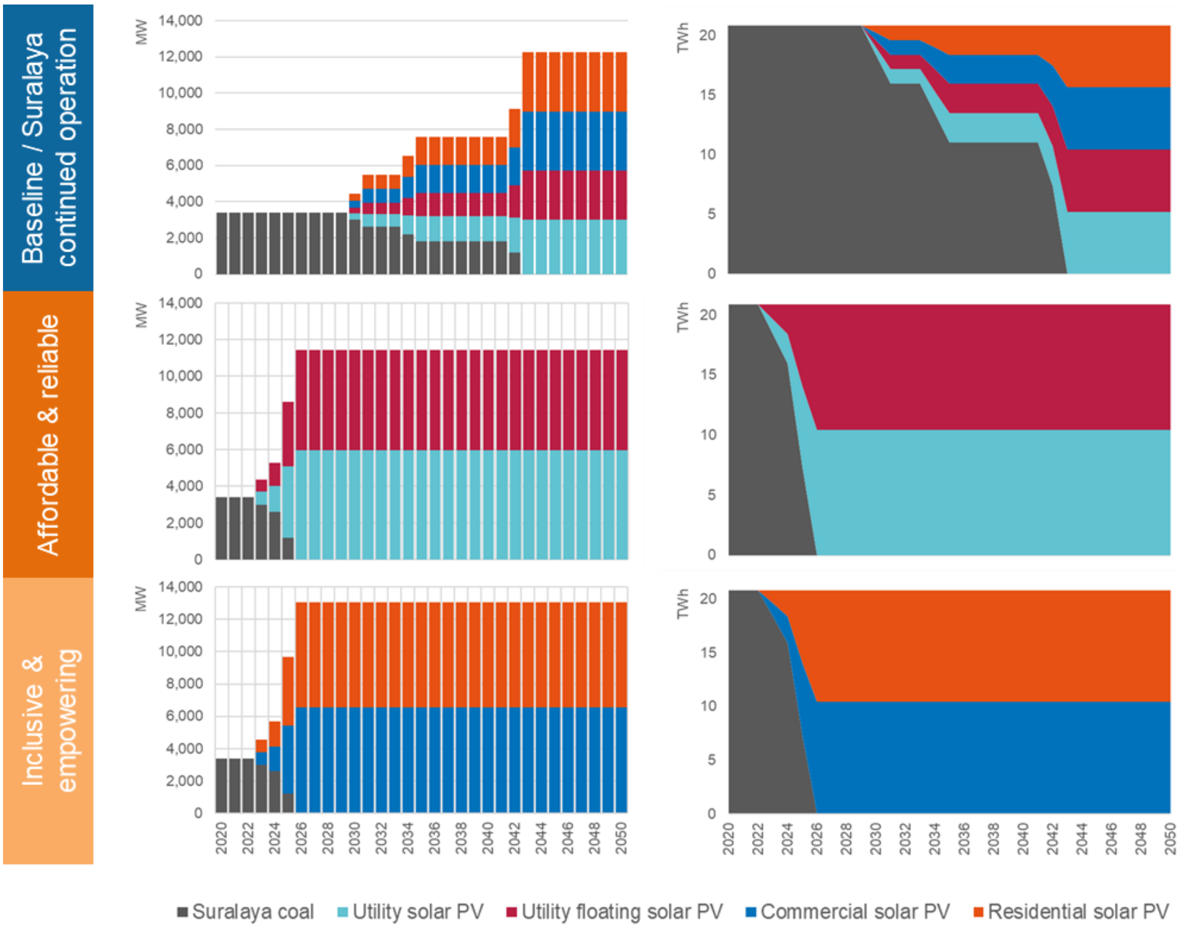

Figure 2: Three scenarios: capacity (MW) and output (TWh) per technology

2.4 METHOD AND LIMITATIONS OF THE ANALYSIS

The three scenarios analysed here are based on simple projections without sophisticated power system modelling to match demand and supply at a granular (e.g. hourly or daily) level, and we use simplifying assumptions on geographic and infrastructure aspects. We have not included the valuation of the coal assets that are taken offline before the end of their economic lifetime, nor did we include detailed costs associated with reorientation of business and employment opportunities associated with early phase-out. We use the latest publicly available international and Indonesian data on technology costs, where possible disaggregated into their component parts. Our input data and assumptions are based on publicly available data and interviews with experts, but the scope of the analysis did not allow us to go beyond relatively simple validation. Where possible we have used sensitivity analysis on key data inputs to offer information on the extent to which their level influences the final results.

The SCAN-tool is designed to provide an initial, high-level indication of which SDGs and targets may be impacted by specific mitigation actions. In reality, context-specific factors will greatly influence the magnitude and direction of any linkage. Moreover, the score attributed to a linkage is only indicative of whether it is likely to be positive or negative, with the estimation of magnitude requiring analysis with other tools.[14]

14 A2A (2018) SCAN Tool Methodology paper

AIRPOLIM-ES uses plant-specific emissions data, actual data on population living within certain distance bands from the power plant, and calibrated values on disease impacts. However, concentration change, and pollution intake fractions are based on generalised data and do not account for location-specific characteristics such as the exact height at which the emissions are released into the atmosphere, geographical location, or meteorological conditions.[15]

EIM-ES uses investment cost data that is disaggregated, where possible, into its component parts for new and existing electricity generation capacity. It then calculates the share of each investment that is spent domestically and the share of that domestic investment that is directed to the labour market. Cost estimates are scaled linearly and although learning curves are included, they do not directly account for potential economies of scale. The model draws on Input Output tables to provide important context on the economic structure and sector inter-relationships and allows an estimation of direct, indirect, and induced effects. This gives an approximation of – but will not necessarily truly reflect - the future structure of the economy over the modelling period. Employment is expressed in the number of full-time job years for a given scenario, broken down by technology and economic sector, but includes no assessment of the likely quality of these jobs.[16]

Despite these limitations, our analysis gives a sense of scale and direction of a first bold step in the energy transition in Indonesia and specifically in significantly scaling-up solar PV deployment. We strive for transparency in our analysis: The models we used are available for download, and the data and assumptions are well documented and available upon request.

15 A2A (2019a) AIRPOLIM-ES short methodology note

16 A2A (2019b) EIM-ES methodology note

3 SUSTAINABLE DEVELOPMENT IMPACTS

Replacing the 3.4 GW Suralaya coal power plant with 10-15 GW of solar PV can deliver a range of substantial development benefits that positively contribute towards sustainable development goals within Indonesia. This can be a driver for greater prosperity and – if designed well – lay the foundation for an inclusive clean energy transition, but results are time-bound: the faster the replacement, and the earlier it starts, the larger the benefits. Figure 3 provides an overview of the key links to SDGs 13 (climate action); 8 (decent work and economic growth); 7 (affordable and clean energy); and 3 (health and well-being), and the potential benefits from rapid deployment of new solar PV capacity and the phase-out of coal units at Suralaya.

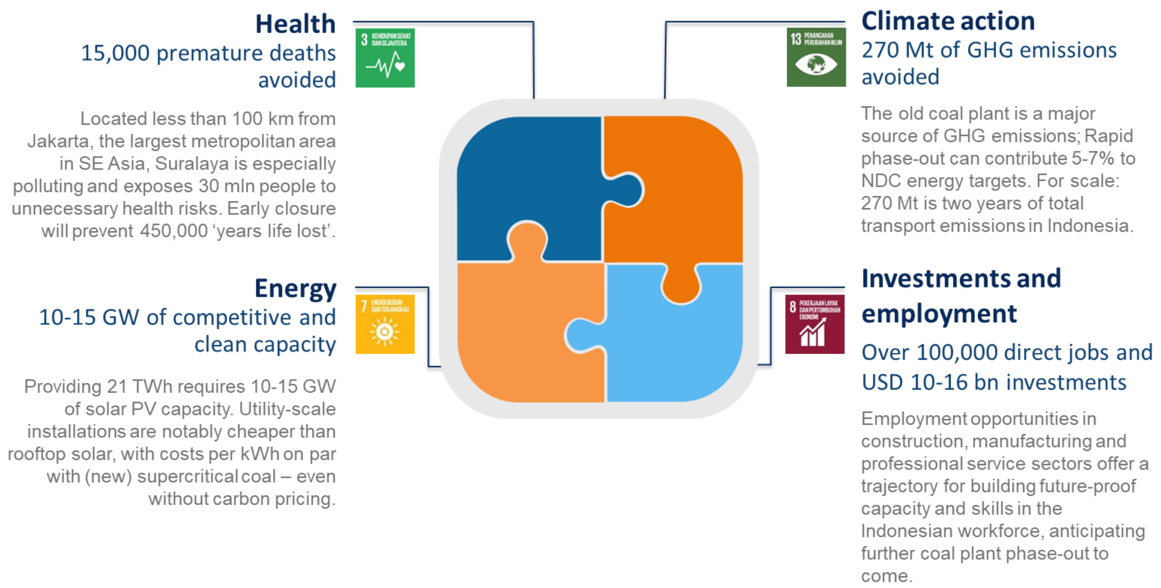

Figure 3: Overview of impacts

In the following sections we set out further details of our analysis of environmental and socioeconomic impacts across the three scenarios we considered. These cover both the positive opportunities, as well as potential trade-offs – e.g. use of land, or investment leakages – that need to be understood and ideally addressed in planning the transition to clean energy sources.

3.1 CLIMATE ACTION

Starting with perhaps the obvious impact, the old (and relatively inefficient) coal plant units at Suralaya are a major source of GHG emissions. Early and rapid phase-out of these units can help avoid the release of 270 million tonnes of carbon dioxide equivalent units into the atmosphere. This is equivalent to around two years of emissions from the entire transport system in Indonesia. The phase-out of Suralaya and its replacement with clean, zero emission technologies, such as solar PV, could alone contribute on the order of 5-7% of Indonesia's nationally determined contribution (NDC) towards the goals of the Paris Agreement.

Figure 4 shows the annual and total greenhouse gas emissions for the two phase-out scenarios (104 $MtCO_2e$ between 2020 and 2025) and the baseline scenario in which the coal plants continue to operate for their full economic lifetimes (373 $MtCO_2e$ between 2020 and 2042).

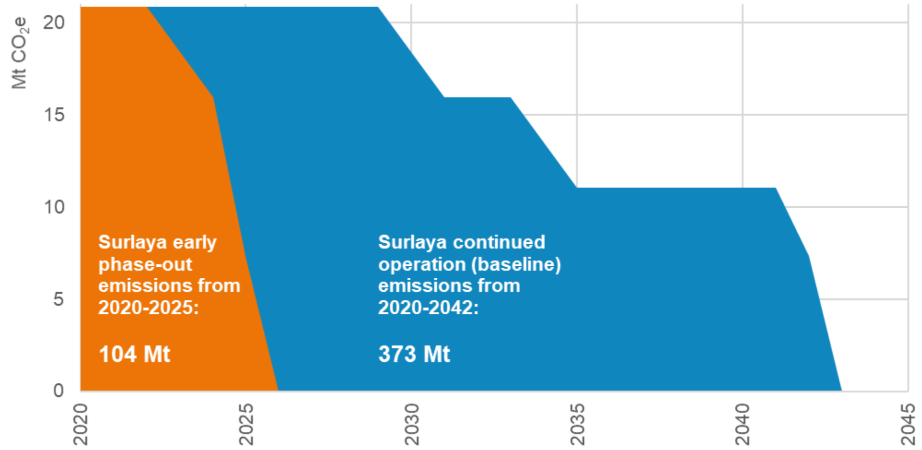

Figure 4: Total greenhouse gas emissions for the phase-out scenarios and the baseline ($MtCO_2$-eq.)

3.2 AIR POLLUTION AND HEALTH

The burning of coal to generate electricity at Suralaya releases harmful local air pollutants which negatively impact the health and well-being of the population exposed to these contaminants. Those living and working closer to Suralaya are likely to be the worst affected, although the pollution can affect air quality thousands of kilometres from the source, extending to neighbouring countries, such as Singapore and Malaysia. Located less than 100 km from Jakarta, the largest metropolitan area in South-East Asia, Suralaya is especially polluting and exposes in excess of 30 million people to unnecessary health risks. Our analysis, using the AIRPOLIM-ES tool, finds that early closure of the Suralaya units (over the next 4 years) will prevent 15,000 premature deaths, saving on the order of 450,000 years of life. Continued use of the coal plant up to the end of its economic lifetime would cause approximately 20,000 premature deaths over the period to 2042. The results of our analysis are summarised in the charts in Figure 5. In this instance we only include two scenarios (a baseline; and phase-out) because there is no difference in the health outcomes between the two scenarios we considered which analyse the phase-out of Suralaya and the phase-in of an equivalent generating volume of new solar PV; the construction and operation of new solar PV does not contribute to worsening air quality.

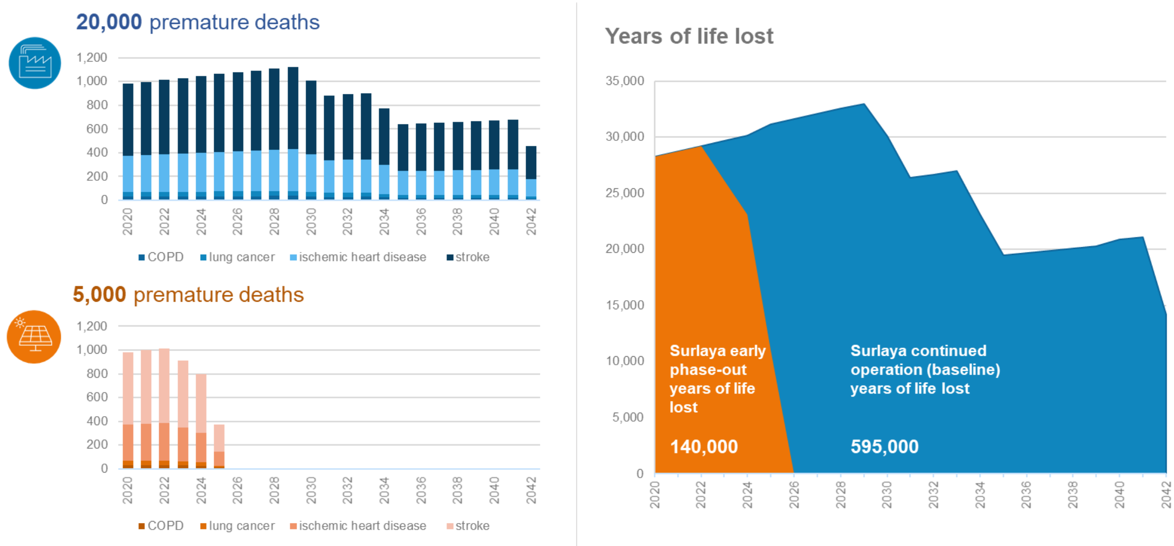

Figure 5: Health impacts in premature deaths, by disease type (left panel) and in years of life lost (right panel)

We also analysed the health impacts according to a range of age groups amongst the affected population in Indonesia. We find that older age groups are proportionately worse affected than younger age groups, with the highest share of deaths (in relation to their share of the overall population) occurring in age groups between 65 and 80. Air pollution therefore serves to disproportionately impact groups, such as the elderly, exacerbating existing vulnerabilities.

3.3 INVESTMENTS AND EMPLOYMENT

The scenarios we analysed can support between 0.6-1.0 million direct job years[17] and 1.3-1.8 million total job years when considering the wider economic impacts throughout the Indonesian economy. It is important to recognise that both the baseline scenario which reflects the continued operation of the Suralaya plant, as well as the scenarios in which it is replaced by solar PV over the coming few years, stimulate investment and support jobs in the Indonesian economy. The results of our analysis, shown in Figure 6, indicate that both solar PV phase-in scenarios would support at least as many domestic jobs as continuing to operate the Suralaya plant. The highest employment potential is in the 'inclusive and empowering' scenario, which is, in part, due to the higher investment cost requirements required to install rooftop solar PV on commercial and residential buildings.

Figure 6: Employment impacts (in job years) and investments (in bn. USD) for three scenarios

17 One 'job year' is equivalent to a full time employment position, lasting for a duration of one year. If 10 people are employed on a full time basis for 20 years, this would represent 200 job years (10x20=200). One person that is employed for half of their time for a duration of 2 years, would represent 1 job year (0.5 x 2=1).

Delivering 21 TWh of electricity supply over the period to 2050 may require on the order of 10-16 billion USD in direct investment, depending on the scenario. The 'affordable and reliable' scenario requires the lowest direct investments, with the continued operation of Suralaya requiring the highest investments across the three scenarios, primarily channelled towards the extraction and transportation of coal to fuel the plant. Approximately 6,000 jobs are currently supported in extraction and supply of fuel to Suralaya, with more than 2,000 further jobs supported in the operation of the units at the site and head office and in the general maintenance of the units.

Solar phase-in scenarios present significant domestic employment opportunities – mainly in construction, manufacturing and professional service sectors – reaching up to over 250,000 direct jobs a year (in the 'inclusive and empowering' scenario) and stimulating an additional equivalent order of magnitude of indirect and induced jobs in Indonesia. Ambitious roll-out of new solar installations can stimulate employment (and wider economic) impacts in the short term – given their relatively short planning and construction phases – which can offer important opportunities within the context of COVID19 recovery measures.

Whilst many of the jobs in the two solar PV phase-in scenarios are short-lived, e.g. they are required for the 1-2 years of constructing the new capacity, our analysis covers only a limited snapshot of the future development of solar PV in Indonesia. These jobs are likely to be sustained in future years as the workers involved in the installations included in our analysis then move on to other new projects. The solar PV phase-in scenarios therefore offer a trajectory for building the capacity and skills in the Indonesia workforce to deploy increasing volumes of new solar PV capacity. This new renewable capacity is needed to meet growing electricity demand and the shortfall from continued phase-out of coal units in line with pathways consistent with the country's pledge to the Paris Agreement.

Perhaps most critically, enhancing the conditions for developing labour force skills and wider economic activity derived from solar PV value chains can create sustainable, or 'future-proof', jobs. There is a continued need for building at least as much new solar capacity each year over the medium-to-long term. In contrast, jobs in the coal sector are likely to be increasingly insecure as pressure rises to reduce dependence on fossil fuels. Starting the energy transition in Indonesia as early as possible can limit exacerbating the social and economic issues that will inevitably arise amongst those businesses and workers that currently depend on the coal sector.

3.4 ENERGY SECURITY

The solar phase-in scenarios can positively contribute towards the goal of developing affordable and clean energy (SDG 7). The levelized cost of electricity generation (accounting for full lifetime costs, expressed in today's money) are currently similar for utility scale solar PV in Indonesia as they are for new 'supercritical' coal plants, with costs for solar PV expected to decrease much faster in the coming years, due to both global and local cost reductions. Introducing a material carbon price, which is not currently the case in Indonesia, would further emphasise the cost competitiveness of solar PV. Table 1 shows estimates[18] of the upfront investment requirements (expressed in USD/kW) and overall levelized cost of electricity (expressed in USD/kWh) for existing coal units, supercritical new coal plants as well as different types of solar PV. As the Suralaya plant is already built, it currently offers a cost advantage over new installations, particularly in the absence of a significant carbon price. Currently residential rooftop installations are the most expensive of the technologies considered, in particular because they are smaller in scale and typically involve more complexity (and cost) to install the panels, e.g. in erecting scaffolding to access the building roof.

18 Data are based on 2020 cost and lifetime estimates in DSK (2021), Technology data for the Indonesian Power Sector. LCOE's are estimated using a 10% discount rate for all technologies.

Table 1: Assumptions on investment costs (USD/kW) and levelized costs of electricity generation (USD/kWh) per technology.

Technology	Upfront Investment (USD/kW)	LCOE (USD/MWh)
Existing sub-critical coal	-	30.67
New supercritical coal	1,400	50.06
Utility scale solar PV	790	55.25
Floating solar PV	890	59.55
Commercial solar PV	1,190	91.21
Residential solar PV	1,320	94.83

The solar phase-in scenarios would develop on the order of 10-15 GW of solar PV capacity, providing 21 TWh of clean electricity supply per year. Our analysis of the Java-Bali-Madura power grid (see section 2.3 above) indicates that such volumes would not undermine the security of electricity supplies in any material way, given the abundance of coal- and natural gas-fired plants currently supplying the grid. Whilst some businesses and households may need time limited support to make choosing to install rooftop solar PV as attractive economically as purchasing electricity directly from the grid, costs are expected to fall over time. And, as we discuss later on, promoting rooftop solar PV can enhance participation in the energy transition from a different range of actors (households and small-to-medium sized businesses) to large-scale coal plants or solar parks.

3.5 LAND USE

Finally, our impact analysis looked at the land requirements under the different scenarios. This is particularly a challenge for solar PV as the panels require areas several orders of magnitude larger than coal plants to generate an equivalent volume of output.

In the ‘affordable and reliable’ scenario, the installation of 6 GW of *ground mounted* utility scale solar PV by 2026 would require approximately 84 km^2 (around 16,000 full-size football pitches); and 5.4 GW of *floating* utility scale solar PV would require approximately 76 km^2 of water body area. Whilst technical studies indicate that there is an abundance of suitable land and water areas to build large-scale solar parks in Indonesia, identifying suitable areas and obtaining the necessary permits to develop them clearly poses a significant challenge.[19]

In the ‘inclusive and empowering’ scenario, the installation of 6.5 GW of solar PV on *commercial buildings* by 2026 would require approximately 65 km^2 of roof space; and a similar capacity added to *residential housing* would require approximately 46 km^2 of suitable roofing. Again, technical studies indicate the potential space is available in the Banten and Jakarta regions to accommodate this new capacity (and much more besides), yet deployment to date is extremely low and a concerted effort between government, city administrators, project developers and interested businesses and households (amongst other stakeholders) would be needed to ramp up deployment in the coming years.

19 Our analysis is based on space requirement estimates for different types of solar PV installation in Technology Data for the Indonesian Power Sector (DSK, 2021) p57-60 and we make extensive use of work by IESR (2020, 2021) on the prospects for rooftop solar PV in Indonesia (see also the discussion in section 4.3 below).

4 HOW FAST CAN THIS HAPPEN?

The impacts presented in Chapter 3 are based on two scenarios in which the Suralaya power plant is replaced in just four years' time. Compared to the existing state of the market in Indonesia this would be very fast, but it is not unreasonable compared to the challenge at hand (i.e. the required speed of the transition). Other countries have shown that with resolve and coordination it is possible to install large amounts of solar PV in a short time span and there is no obvious reason why Indonesia could not materially step up its efforts. This beckons the question 'how fast can the replacement happen' and involves investigating barriers that frustrate progress and enablers that accelerate it. Some barriers are relatively easy to address, while others are more difficult to overcome. Key improvements are needed in spatial planning and streamlining of permitting, a predictable medium-term pathway for clean energy to replace fossil, and establishing stable policies to incentivise large investments in capacity and manufacturing. Based on a series of interviews with both Indonesian and international experts we find that 4 years would be 'fast but feasible' but also that a lack of concerted effort and failure to address barriers could delay this by 7-10 years.

This section starts by discussing recent developments around the global coal phase-out (4.1) and calls for orienting COVID-19 recovery efforts towards 'building back better' infrastructure and institutions (4.2), followed by a presentation of four types of barriers and enablers that are important determinants of the speed and feasibility (0), and suggestions for stakeholder roles and actions needed to make fast replacement of coal generation a reality (0).

4.1 THE END OF THE FOSSIL FUEL AGE

The Paris Agreement in 2015 marked a turning point in the international efforts to address climate change. It introduced a bottom-up framework for national commitments and a (ratcheting) mechanism to make sure that over time the sum of pledges is sufficient to keep global warming well below 2 degrees centigrade. The IPCC 1.5-degree report in 2018 made clear what would be required to honour the Paris Agreement: global emissions need to be cut in half by 2030 and reduced to (net) zero in 2050, or shortly thereafter. The 26th COP in Glasgow, in November 2021, was an important milestone for the implementation of the Agreement because it marked the first update round of the NDC pledges. Analysis by the Climate Action Tracker showed that the collective updated commitments – if implemented in full – would still put the world on track for 2.4 degrees of warming above pre-industrial levels.[20]

There are three high-level positive outcomes from COP26 which make this analysis on phasing out coal more relevant than ever. These are not related to technical aspects and details, but rather to the way in which climate change is discussed and how coal is perceived. We can see that norms are shifting, at least among leaders of nation states. First, Parties are asked to phase down unabated coal power and inefficient subsidies for fossil fuels. Glasgow Climate Pact par 20: "Calls upon Parties to… accelerating efforts towards the phasedown of unabated coal power and phase-out of inefficient fossil fuel subsidies". (Decision -/CMA.3.26) Odd as it may sound, this is the first explicit reference to fossil fuels in a COP decision ever; these decisions require unanimity (i.e. all countries need to agree) and in the many editions before COP26, fossil fuel interests and lobbyists have been able to block any explicit reference. Second, we can cautiously say that the mechanism behind the Paris Agreement works and that limiting warming to 1.5 degrees may still be possible. Ratcheting remains important, because currently implemented policies are still way short of what is needed to avoid catastrophic damages from climate change. In recent years it has become clear that small increases over 1.5 degrees of warming can have serious effects. Third, and perhaps the most fundamental evolution in the years since the COP15 in

20 https://climateactiontracker.org/publications/glasgows-2030-credibility-gap-net-zeros-lip-service-to-climate-action/

Paris, is that fast and full decarbonisation has become the norm for strategizing climate action. There is now broad consensus across many countries and wider stakeholders around reaching net-zero emissions across all sectors of the economy around 2050 and mobilising resources to do so.

The speech by Joko Widodo[21] was a good case in point of the shifting narrative: "climate change is a major threat to global prosperity and development [and tackling it requires] solidarity, cooperation, and global collaboration… Indonesia itself will be able to contribute faster to the world's net-zero emissions goal [poses three pertinent questions]: how sizeable are developed countries' contributions for us, what kind of transfers of technology can be provided, [and] what programs can be supported to achieve the SDG targets that have been hampered by the pandemic?". In a similar vein, Indonesia signed up to consider accelerating coal phase out: "The Republic of Indonesia, Minister Arifin, endorsing clauses 1, 2 and 4. Indonesia signs up to the COP26 Coal to Clean Power Transition statement, excluding clause 3 but as part of its commitment to reach net zero by 2060, or sooner with international assistance, Indonesia will consider accelerating coal phase out into the 2040s, conditional on agreeing additional international financial and technical assistance."[22] It is now clear that the critical political discussions relate to *when* and *how* Indonesia will phase-out economic activities in its coal sector, rather than the questions of *if* and *why* it should transition its energy sector.

4.2 BUILDING BACK BETTER

Since the COVID-19 pandemic forced countries into various degrees of lockdown starting in spring of 2020, governments – including in Indonesia – have responded with policies to buffer the impacts and use short-term crisis responses to protect capital and labour

4.2.1 Offering post-pandemic resolutions

Over time, the focus is shifting from crisis relief and containment to recovery measures, to get economies back on track as quickly as possible and with minimal structural damage. Many countries recognized an overwhelmingly strong case for a green recovery, and in April 2020 G20 Finance Ministers committed[23] to "support an environmentally sustainable and inclusive recovery". This ambition is increasingly referred to as building back better and moves forward several urgent decisions with long-term effects.

There are two critical notes to place here. Despite attractive calls to 'build back better', many developing countries face fragile supply chains, and highly constrained fiscal space (through increased debt levels as well as limited ability to raise revenues) as a result of the pandemic[24], all of which leaves them more than ever dependent on international investments and support to come out of the crisis prosperously.[25] Second, actual progress on green recoveries is slow. There is quite some frustration around inaction and recovery spending that is not green and actually reinforces negative environmental trends.[26] These points of criticism are not to play down green recovery narratives but rather a call to step it up. The energy transition is not optional and it is a matter of when, not if. As we show in this note, a transition can come with significant benefits that can be enhanced through early action.

In the course of the exchanges several stakeholders suggested that the future of coal power can be prolonged by capturing the carbon emissions and storing them (i.e. Carbon Capture and Sequestration, or CCS). Combining coal power with CCS will lower its emissions in theory, but there are practical challenges. First, experience with long-term sequestration of CO_2 is still limited, especially at the scale

21 Government of Indonesia (2021) Statement by Joko Widodo at the world leaders' summit at COP26

22 COP26 UK Presidency (2021) Global coal to clean power transition statement

23 G20 (2020) Communiqué G20 Finance Ministers and Central Bank Governors Meeting 15 April 2020

24 Marquardt and Fearnehough (2021) Economic stimulus of climate action in developing countries: a framework for sustainable and pro-poor COVID-19 recovery

25 A2A (2020) An uncertain predicament: ambition and action in times of COVID-19

26 A2A (2021b) Beyond the smoke screen: co-benefits and trade-offs to support ambitious climate action

needed to keep a plant running, and improper storage can simply mean that the carbon dioxide is released into the atmosphere at a later date. Second, even if CCS shows its feasibility and becomes widely available, the costs of CCS are high. This will make the combination of CCS and coal more expensive than renewable power. It is therefore more likely that if CCS capacity becomes available it will be used for harder-to-abate emissions, for example in the production of steel or cement, and not for power generation for which readily available and affordable mitigation solutions already exist.

4.2.2 Addressing pre-existing conditions[27]

Like in many other places, the COVID-19 crisis exaggerated and magnified existing flaws, injustices, and vulnerabilities in the energy system of Indonesia. In order to effectively use a green recovery strategy to build back better, a number of weaknesses and vulnerabilities need to be addressed without delay. Each of these themes have been the topic of political discussion in the past years (i.e. they are 'pre-existing conditions', to use a healthcare metaphor) and can no longer be postponed. Even though these weaknesses are often well known, the prospect of accelerating the energy transition in Indonesia makes discussions around "pre-existing conditions" more urgent than before:

- The Electricity Bill Relief Mechanism for small connections was quick, but costly. Over time it needs to merge into a new comprehensive energy safety net for vulnerable households, as part of an accelerated phase-out of subsidising energy consumption.
- Current bailout support for PLN needs to be a stepping stone to a comprehensive revision of energy pricing and a structural reform of the company to ensure financially health and sustainability.
- After short-term protection for employees, the energy sector needs long-term clarity to reorient business models towards clean energy services, and away from fossil-based generation: This requires, among others, an update of long-term energy plans and acceptance of full carbon neutrality in 2050 as a goal, alongside clear and aligned interim targets.

27 A2A (2021a) The energy transition after COVID-19: perspectives on green recovery and NDC Ambition raising

4.3 BARRIERS AND ENABLERS

Although the fast growth of the solar PV market in our scenarios is technically possible, there are other factors that make this more, or less, feasible in the short term. Based on our initial results, we asked expert stakeholders what they would consider to be the most important barriers and enablers to fast roll-out of grid-connected solar PV capacity in Indonesia. The focus here is on the phase-in of solar PV and not on the phase-out of coal – a process that requires thorough attention and has a more localised character. We categorise the results of the interviews and focus group discussions under four themes and reflect concerns and opportunities specific to the current Indonesian context.

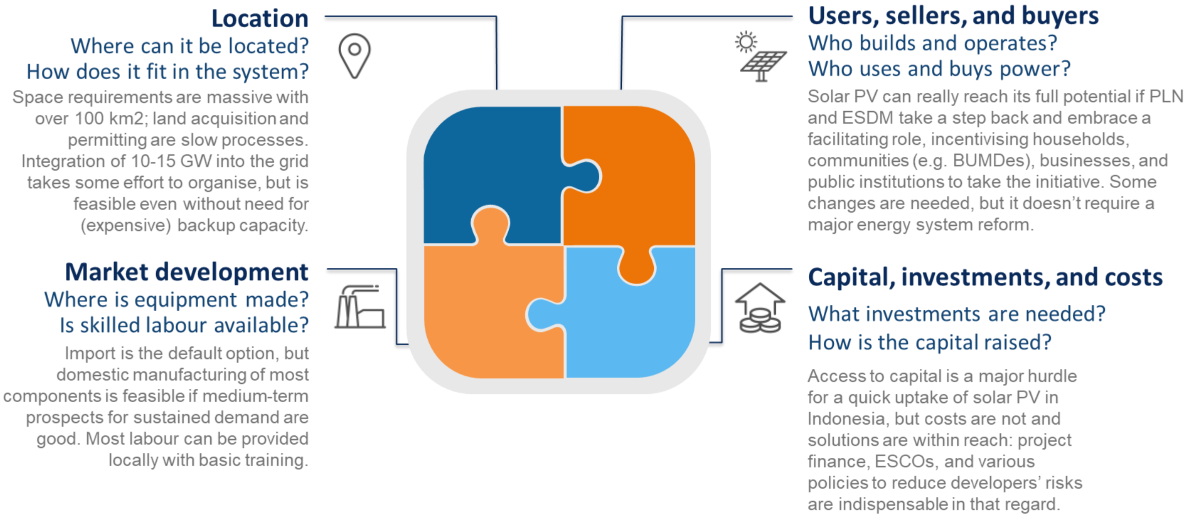

Figure 7: Overview of barriers and enablers

4.3.1 Location

Where can solar PV capacity be located? How does it fit in the system?

Solar PV needs a lot of space.[28] especially compared to other forms of power generation: installing a megawatt of capacity requires upwards of one hectare of surface area. In other words, every gigawatt of solar PV requires 10 km^2, or more depending on the technology.

In the *affordable and reliable* scenario, this corresponds to approximately 84 km^2 to install 6 GW of ground mounted utility scale solar and approximately 76 km^2 of water body area for floating utility scale solar. Technical potential studies show that there are large areas of suitable land available (83-484 km^2 depending on exclusion criteria) but in the most attractive areas there is competition with other productive uses of land (e.g. agriculture, housing, infrastructure). In the *inclusive and empowering* scenario, 6.5 GW of commercial scale rooftop solar is expected to need approximately 65 km^2 of rooftop/building space and similarly the 6.5 GW of residential rooftop solar requires around 46 km^2. The possible advantage of solar PV installations integrated with the built environment, e.g. on residential or commercial rooftops, is that these require no additional ground and do not displace other potential uses for land.

Experts are worried that space availability can present a serious bottleneck for fast rollout of solar PV capacity. Floating solar PV installations, such as the 145 MW plant under construction at Cirata, can limit conflicting demands on land resources and improve efficiency of electricity generation (due to the cooling effect of the water), but these plants come with their own limitations in terms of current use (e.g. fisheries activities) and potential negative environmental impacts that need to be considered carefully. At present

28 Our analysis is based on space requirement estimates for different types of solar PV installation in DSK (2021; p57-60) and we make extensive use of work by IESR (2020, 2021) on the prospects for rooftop solar PV in Indonesia.

only man-made water reservoirs are under consideration[29] for floating solar PV, which avoids conflicts with the social and cultural significance that many natural water bodies hold for local communities. The technical potential for rooftop solar in Jakarta and Bali combined is estimated in the range of 8-28 GW and potentially much more depending on the exclusion criteria, but clearly not everyone with a rooftop is willing or able to invest in a solar installation. A decent share of government buildings, luxury houses, and apartment complexes can serve as a starting point, but this will not be sufficient.

Related to physical availability of space, are the topics of acquiring the land and obtaining appropriate environmental and building permits. The prices for land in Java and Bali are high and rising, and land acquisition is a difficult and often untransparent process. Permitting is complicated: it involves multiple institutions and can take up to 18 months. Moreover, favourable locations are often already in use, the designated purpose does not allow for solar PV, or ownership is unclear. Additional challenges include complicated rules around the proximity to forest areas and the fact that PLN expects full legal access, including to a transmission corridor.

Grid integration of 10-15 GW does not pose an insurmountable problem. PLN is hesitant to integrate solar PV because it fears that intermittent power will increase their losses and compromise the stability of the electricity network. However, it is certainly possible to integrate large amounts of electricity with relatively simple supply forecasting and demand planning, and without the need for expensive backup capacity.[30]

In order to address these concerns, experts suggest that it might be necessary for the national government to involve local governments in the process of land acquisition and assignment, for example by setting targets and incentives for hosting solar PV installations. Permitting could be improved by offering a one-stop-shop procedure and a national spatial plan for solar PV, as well as (and in coordination with) strengthening of the distribution grid. Moreover, it might be necessary for PLN to forego the lead in determining where solar PV is located, but instead it could be forced/mandated to connect projects whenever there is an application that is consistent with the national solar PV spatial plan. Experts suggested that state-owned enterprises might be tasked with allocating areas, for example around timber production and plantation sites, as well as post-mining reclamation areas (notably in the southern and central parts of Java).

Future developments that could further increase the ability to balance the grid and respond to increased intermittent capacity include the advents of vehicle-to-grid infrastructure and balancing services based on prosumer backup capacity[31], as well as interconnections with Sumatra and the West and East Nusa Tengara provinces.

4.3.2 Market development

Where is equipment made? Is skilled labour available?

Currently most solar PV equipment used in Indonesia is imported from China and a few other countries. As one expert put it “all hardware is imported, and the only local content is the labour involved in installation, operation, and maintenance”. There is limited domestic manufacturing capacity in Indonesia: around 10 conventional PV module manufacturers have an average capacity of 30-50 MWp each and can ramp this up to a maximum combined output of 600-700 MWp per year. In addition, there are early-stage plans for the development of a 300 MWp thin film manufacturing facility.

Despite the current limited manufacturing base, interview respondents invariably note that all parts of solar installations, except perhaps panels, can *in principle* be manufactured in Indonesia if there is sufficient outlook on demand, the price is right, and the risk is manageable. The practice of offering

29 Restricted to 5% of the total area by Ministry of Public Works and Public Housing (MPWH) Regulation No. 6 of 2020

30 A2A (2018b) Grid integration of variable renewables in Indonesia

31 Kloppenburg et al, (2019) Technologies of engagement

Engineering, Procurement, and Construction (EPC) services as a package could speed up market development and is relatively easy to scale up – again, this can *in principle* become more common when the conditions are right. Some of the respondents describe the current small market and manufacturing base as the result of a chicken-and-egg dilemma: since there is no demand for new renewable capacity, there is not enough demand for equipment to expand the domestic manufacturing beyond a few existing companies. A similar situation occurs in the availability of solar PV projects that are ready to be financed: as long as attracting capital is considered difficult and expensive, there may not be a large pipeline of projects ready to absorb capital if and when it becomes available.

The Indonesian government has tried to 'force' domestic manufacturing and project development by imposing local content requirements and limitations on foreign ownership of infrastructure. The aim of these restrictions is to stimulate a domestic market and ensure that most of the value added is captured by Indonesian businesses. However, the restrictions are considered unrealistic in the small and nascent market and only drive up costs and stagnate the uptake of renewable capacity. Developers indicate that it is not always clear where to get locally made equipment, equipment may be imported and relabelled, and quality is an issue.

Most jobs related to solar PV involve relatively simple engineering and construction tasks for installers, skills that can be developed 'on the job' or in established vocational training centres. An internal study conducted by Bappenas reveals that training infrastructure for solar PV rooftop installation workers is ready to scale up when demand increases. The state-owned vocational training centres can bring their educational materials in order in a short time span and are ready to train more instructors. For electrical engineers, work competency standards have been updated to include solar PV installation and although the number of assessors is limited, this is not a barrier to fast domestic employment growth.

Some areas of expertise are currently less well covered and could benefit from additional capacity building and technology transfer. Two areas that were specifically mentioned in the interviews are: (re)training project developers that want to move into the field of renewable energy, and training of industrial small and medium enterprises (SMEs) who want to convert existing manufacturing processes and workers' competencies towards manufacturing solar PV parts and components (electric and non-electric).

To address these concerns, experts suggest enablers across three themes. First, a national energy strategy overhaul consistent with a net-zero Indonesian economy around 2050, and consistent and credible messaging about fossil phase-out. This could include a clear industry strategy and policy framework, with associated medium-term targets and budgets, realistic local content requirements, and low interest loans for clean energy infrastructure and capacity. Second, stimulating technology transfer from abroad to build infrastructure and help domestic industry evolve. This could be enabled, for example, through foreign support with the roll-out of assistance programmes and active learning from, and dialogue with, third countries. Third on the demand side, there is room for improving public information about the opportunities of investing in solar PV and awareness campaigns, which could include practical steps to identify local installers.

4.3.3 Capital, investments, and costs

What investments are needed? How is the capital raised?

Solar PV requires a large upfront investment into equipment, while the costs for operation and maintenance are low. This is different from conventional fossil-based technologies that require lower upfront investments, but do need a steady stream of costly fuel feedstock. In our scenarios for phasing-in new solar PV capacity we estimate a need to mobilise on the order of 10-14 billion USD in direct investments over a period of 4 years.

Banks are generally not willing to provide 'project finance' for (small-scale) renewable energy projects and only developers with external collateral are able to secure the capital needed to invest. The main reasons for limited access to finance given to interview respondents by (private and state-owned) commercial banks include policy risk, offtake risk, and lack of familiarity with (and track record of) solar PV projects and solar PV-specific risk assessments.

Policy risk is directly related to hesitant and inadequate support for renewable energy over the past years, the lack of a firm strategic policy outlook on the energy transition, but also to the difficulties in acquiring land and permits, as described above. Offtake risk is almost exclusively related to dealings with PLN in their role as sole purchaser of electricity fed into the grid and under circumstances that do not give renewables preferential access. As a result of historically evolved (vested) interests and the current incentives and mandates from the Ministries of ESDM, Finance, and State-owned Enterprises, PLN offers preferential treatment to coal power over renewable generation. This has thus far lead to unfavourable power purchase agreements (PPAs) for renewables, delays in tendering procedures and grid connections, and a generally inflexible attitude towards independent power producers (IPPs) and customers who want to pursue captive power partly for their own consumption, and possibly for offering to PLN.

Experts have made various suggestions to facilitate an uptake of investments in renewable energy in general, and solar PV specifically. To address policy risk, the government will need to update its long-term energy strategy and fully integrate this across energy and development strategies and actions plans. Ideally such strategies and plans are aligned with international commitments to decarbonise the economy, include a spatial plan, and set clear interim targets for renewable energy technologies, as well as an exit-strategy for coal. The government could consider providing low-interest loans, either from domestic public sources or attracted from the international capital market, as well as more specific policies that reduce renewable energy project risk. Lastly, and this can be established independently of government actions, the financial sector could seek to educate itself and seek dialogue with international peers to improve awareness and increase skills and information to allow them to invest in solar PV projects with greater confidence.

4.3.4 Users, sellers, and buyers

Who builds and operates? Who uses and buys power?

In Indonesia, state-owned electricity company PLN owns most of the generating capacity and has a monopoly in electricity distribution. Electricity pricing is determined by the ministry of energy and mineral mining (ESDM). The existing scheme has three main issues that make it difficult for PLN to pursue an inclusive and aggressive green transition. First, generation costs are not covered by retail prices, but PLN is encouraged to minimise losses, so there is a bias towards the cheapest generating technologies. In Indonesia, with local availability of low-grade coal and lenient environmental standards, the cheapest power source is often coal. Second, contracts with suppliers are regulated and typically involve fixed term power purchase agreements with limited or no variation in offtake prices due to fluctuations in demand. And third, health and climate external costs associated with greenhouse gas emissions are not factored into prices, which presents a bias against clean energy. These fundamental issues preclude PLN from pursuing the greenest and most inclusive policies first. Moreover, PLN is financially vulnerable, and this limits its ability to borrow to invest in new capacity and grid expansion.[32]

Discussions with experts reveal that for solar PV to reach its full potential and for the market to grow to multiple gigawatts per year in a short period of time, it would be beneficial to broaden the pool of investors and to reduce dependency on PLN's organisational and financial abilities. With an overcapacity of 40-60% in the Java-Bali grid and the poor financial state of the company, PLN is unlikely to be the sole candidate to drive investments needed for scaling up renewables. It is more realistic to form a strategy in which new capacity is supplied by a combination of PLN (possibly backed by dedicated domestic or international public guarantees), independent power producers (IPPs) with their own capital, and through project finance, and businesses and households, possibly with the support of Energy Service Companies (ESCOs).

Investment in solar PV becomes more attractive if the investor (or owner) can use (part of) the power for their own consumption, so-called prosumers, and when they have full access to the multiple benefits that solar PV offers: predictable low costs, increased resilience and lower risk of power outages, guaranteed sustainable energy for consumers who want sustainable goods and services, and the opportunity to sell excess power back to the grid operator (PLN). Potential prosumer categories who can participate as early adopters of solar PV include: hotels, shopping malls, factories, and workshops; public facilities such as schools, ministries, agencies, and hospitals; luxury houses and apartment buildings; and communities. Some respondents alluded to the fact that there are tens of thousands of district and village community leaders (including village-owned enterprises; BUMDes) for whom solar PV can offer benefits.

Many of the enablers mentioned above to address space constraints and capital availability will also be pertinent to builders, operators, and users of the new solar PV capacity. A larger share of solar PV in the grid does not itself require a major overhaul of the Indonesian energy system: it is, for example, very possible to integrate small and large scale, centralised and distributed capacity into the system *without* having to fully liberalise the energy market, or redesign consumer pricing policies. However, there are several adjustments that would greatly facilitate the uptake of solar (some of which are already emerging): cost-based pricing; phasing-out subsidies on energy consumption; providing preferential access for renewable energy; elaborating net metering schemes; offering opportunities to sell ancillary services (consistent with the vehicle-to-grid concept); and in general encouraging ESCOs, aggregators, and other facilitating businesses to participate in a new and promising solar PV market expansion. Through PLN, the government could offer guaranteed distribution grid connections, and be (more) forthcoming with exemptions on captive power and distribution.

32 A2A (2021a) The energy transition after COVID-19: perspectives on green recovery and NDC Ambition raising

4.4 HOW TO GET THERE

Addressing these barriers and putting in place the enablers to escape the ‘chicken and egg’ situations that hold back progress will require a strategic and collaborative approach, pragmatism and resolve, and a certain degree of entrepreneurial confidence and optimism.

It is outside the scope of our analysis to formulate a comprehensive view on ‘who should do what’ to give the solar PV market the push it needs, and the suggestions presented here are not the only way to go about this. Rather, they present a possible and highly simplify direction consistent with the challenge ahead.

Perhaps the most important ingredient for an accelerated transition is a change of mindset and narrative around clean energy. Support for phasing out coal in favour of renewable alternatives is only slowly gaining traction in Indonesia and if it hits the mainstream news this is only briefly. For example, in positive items on record breaking international cost reductions and domestic campaigns such as the “Million rooftop solar panel movement” (GNSSA), but also around more critical issues such as the decision of China and several other countries to stop financing coal-related investments abroad, or a court decision that the President needs to do more to curb air pollution in Jakarta. Climate change has thus far only played a minor role in public support for driving the energy transition in Indonesia. This is partly due to low awareness, but also the result of a (partly historical) sense of entitlement to use domestic coal to power Indonesia’s development path towards prosperity.

But this can change: the analysis presented here gives strong evidence to suggest that accelerating the clean energy transition can come with large positive development benefits, that it can make the energy system fairer and more inclusive, and that this presents an opportunity for growth and prosperity. A change in mindset is necessary, but not sufficient to make a real change. We believe that acceleration can only be the result of a combined supply push and demand pull: the government, PLN, and banks will have to move pro-actively, in coordination, and without delay, so that households and businesses can participate in the clean energy transition.

4.4.1 National and subnational government

The Indonesian government ratified the Paris Agreement in 2016 and acknowledged at COP26 in 2021 the need to fully decarbonise its economy in the next few decades, yet the national energy strategy (KEN, 2014/79) has not been updated since 2014 and still reflects a vision built around an energy mix dominated by fossil fuel. One of the most impactful signals the government can give now, in support of the clean energy transition, is a strong commitment to a zero-emissions energy system. An updated long-term energy strategy that is explicitly aligned with the Paris commitment of carbon neutrality around 2050 and phasing out fossil fuel accordingly, will send credible and ambitious (long term) signals that are critical for attracting foreign investments and boosting domestic industry. In practice, such commitment should then be propagated throughout energy and development planning updates, including the National Development Plan (RPJMN, every 5 years by Bappenas), the National General Energy Plan (RUEN, every 5 years by ESDM) and National Energy Supply Business Plans (annually by PLN).

To accomplish the growth of solar PV described in our analysis (and which would need to then continue into future years) the market would benefit from clear (sub)national solar PV strategies with a realistic spatial plan and a predictable pathway to phase out coal. This can then serve as guidance for streamlining permitting procedures and addressing legal issues regarding land acquisition. The government does not need to micromanage the massive roll-out of the market: as indicated in the previous section it is reasonable to expect that with clear and sufficient solar PV targets and incentives, other actors can take responsibility and opportunity: different ministries, permitting authorities, PLN, financial institutions, industry, schools and universities, and local leaders all play their part.

The government can lead by example, by giving PLN the right mandates, assigning public buildings, lands, and reservoirs for solar PV use, and tasking state-owned commercial banks to step up the provision of capital to investors (i.e. Mandiri, BNI, BRI, BTN).

As mentioned in section 4.2 it would be helpful if the government could address the 'pre-existing conditions' that plague the current energy system. Ending coal subsidies and putting a price on greenhouse gas emissions would be a welcome step in this regard. However, a note of caution is in order here, because if phase outs or redirection of subsidies are directly reflected in consumer energy prices this could trigger discontent and protests. The government is well aware that subsidy reform needs to be managed carefully as it has shown in 2015 with the successful phase out of gasoline and diesel subsidies.

4.4.2 State-owned utility PLN

In the past two decades PLN has been instrumental in the progress on improving household electricity access and affordability, as well as keeping up with the ever-increasing demand for electricity. However, at present it is not in the best position to face the clean energy transition because of its perilous financial position and the large overcapacity in the Java-Bali grid. Resolving the current challenges will take time and effort, but it is not impossible to take on and the calls for reform PLN faces are not unique (cf. ESKOM). PLN too should embrace decarbonisation and continue to work with national and international parties to establish a sustainable solution to its weak financial state.

The good news is that solar PV has much to offer in terms of a resilient and decentralised power system. PLN will have to play a key part in a successful transition and should prepare for a leadership role in a clean energy future. In order to take on this new role, PLN should demand the right mandates, targets, and incentives to flourish in a world without fossil fuels and facilitate Indonesians to participate in the energy transition – the earlier the better.

From a practical point of view, it is important that PLN makes technical and organisational preparations for the clean energy revolution by upgrading the distribution grid, improving supply planning, enabling demand response measures, and setting out a long-term infrastructure strategy, amongst other initiatives.

4.4.3 Financial institutions

The energy transition presents significant untapped opportunities to the financial sector. The switch from coal to solar PV analysed here (which represents only a starting point for the energy transition) could alone stimulate tens of billions of dollars of domestic investment and create a market for many energy service companies (ESCOs), aggregators, and EPC contractors. There is a strong argument for key actors in the Indonesian financial sector to make financing the clean energy transition its priority.

Because several of the current hesitancies and (perceived) risks revolve around the policy framework, financial sector stakeholders should strive to actively work with government and legislators to establish a stable and predictable policy framework that enables *them* to contribute to a phase out of fossil in favour of renewable energy (i.e. to reduce policy risk).

Gaps in knowledge and skills can be addressed relatively easily by seeking training to get sufficient understanding of solar PV technical aspects, the risk and return characteristics of projects, and the policies and strategies that the government put in place to create an enabling environment.

Internally, banks and funders could take steps to become more comfortable with providing capital to viable projects. For example, by developing and advertising standardised products such as take-or-pay PPAs, establishing guidelines for risk management, and piloting the use of business models and financing constructions that can be scaled up and replicated (e.g. project finance, ESCOs). Ideally, banks integrate the clean energy transition into their vision and strategy and set internal targets.

4.4.4 Households and businesses

A fair and inclusive transition allows for ‘everyone’ to participate and have access to the benefits and opportunities. Since solar PV has only recently become economically attractive and the domestic industry is still in its infancy, not many people will recognise solar PV from first-hand experience – simply because there are hardly any examples in peoples’ vicinity. By extension, households and businesses may not be aware that the feasibility of solar PV for their own consumption has increased, and if they do, they may not know which steps to take to install their own generating capacity.

Community leaders can act by creating and supporting awareness programmes, trainings, and demonstration projects; not only the more traditional leaders of provinces, districts, and villages, but also social media influencers and young professionals can play a role in spreading the word and as mentioned above, changing the mindset and narrative around energy.

Businesses can contribute to growing demand for solar PV by actively considering becoming a prosumer themselves, for example through technology cooperation, skills development, and preparing their industrial infrastructure to allow for captive power production and smart grid integration.

5 A BRIGHT FUTURE AHEAD

The age of fossil fuel is coming to an end: phasing out coal in the coming decades is inevitable and a matter of 'when' rather than 'if'. The switch to a clean energy system can deliver significant development benefits and the sooner bold government action is taken, the higher these domestic benefits can be, and the more choices are available. Our analysis shows, by way of illustration, how rapidly replacing a large coal-fired powerhouse by solar PV capacity in the Java-Bali grid can significantly contribute to achieving a range of critical sustainable development goals including climate action, while maintaining energy security and driving economic growth.

5.1 APPROPRIATELY AMBITIOUS

Indonesia has a large potential for solar PV, but it is unlikely that a single technology offers a silver bullet: limitations in terms of intermittency and space availability mean that the future energy system will need to rely on a combination of technologies, with especially large roles for increased energy efficiency, solar PV, hydropower, and geothermal. Nevertheless, the emerging market for solar PV could comfortably grow to 5-10 GW per year for the coming decade and beyond, especially in the face of growing electricity demand, driven by economic development and increased electrification of energy intensive activities.

The current energy system requires a structural overhaul, and this will inevitably lock-in a new set of infrastructure and technologies for the coming decades. It is therefore critical to take the opportunity to invest in a new system that delivers clean energy efficiently, development benefits for all, and which is sustainable to the needs of the economy and society over the coming 5, 10, and 20 years and beyond. Failing to take considerations of fairness and inclusivity seriously and failing to properly plan the renovation of the energy system, risks channelling scarce resources into assets that will require replacing (or simply cease to be productive) well before the end of their useful lifetimes.

5.2 DOMESTIC EFFORTS AND INTERNATIONAL SUPPORT

Based on our analysis we argue for a concerted effort in which stakeholders each play their part: government, PLN, financial sector, and consumers. We also emphasize that Indonesia does not need to do this alone: international support for climate action is an essential part of the Paris Agreement and has recently been re-emphasized in the Glasgow Climate Pact. But it needs to be a true and long-term collaboration, because it is unlikely that international support to scale will materialise independent of domestic efforts to accelerate the energy transition. For example, there will be little enthusiasm for 'buying out' an old coal plant if there is a risk that a new one is built in its place. Significant and long-lasting international support for the Indonesian energy transition is most likely to succeed if the following five themes are addressed simultaneously:

1. Create favourable policy conditions and establish clean energy targets.
2. Negotiate an exit strategy for coal, possibly with international support.
3. Address pre-existing conditions (see section 4.2), possibly with international support.
4. Strengthen international climate pledges to signal ambition and commitment.
5. Establish a framework for continued dialogue and discovery between Indonesian and international stakeholders, with attention to transparency and flexibility to respond to changing conditions.

There is a growing realisation among international donors that support for climate action in developing countries will need to go beyond accelerating renewable energy and energy efficiency; there is an emerging trend to include early and full retirement of fossil infrastructure as part of more comprehensive support packages. At COP26, for example, two multi-donor initiatives were announced that go in that direction. The Asian Development Bank (ADB) presented their Energy Transition Mechanism (ETM) which is setting up pilots in Indonesia, the Philippines, and Viet Nam with the aim to "significantly shorten the life of legacy coal-fired power plants and unlock new investments in sustainable and renewable energy". Second, the UK, US, along with France, Germany, and the EU announced their 'Just Energy Transition Partnership' with South Africa, which pledged an initial 8.5 billion USD with the aim to boost clean energy investments and enable state-owned utility Eskom to move away from coal fired power. Initiatives such as these, which put real finance on the table as part of a negotiated deal, could provide an attractive collaboration opportunity for Indonesia to realise its sustainable development objectives, including climate action, with the support of international finance.

5.3 JOKO WIDODO'S THREE QUESTIONS

As mentioned in section 4.1, the Indonesian president Joko Widodo made a strong statement at COP26 in Glasgow, acknowledging the threat global warming poses to prosperity and progress and signalling that Indonesia is ready to increase its ambition and accelerate its action in return for international support. In his opening speech he offered three valid and understandable questions that can be paraphrased as: How sizeable are developed countries' contributions for us? What kind of transfers of technology can be provided? And what programs can be supported to achieve the SDG targets that have been hampered by the pandemic? To help answer these questions, we offer the following considerations regarding replacing coal with solar PV, based on the findings of our research.

To get a sense of the **size of the contributions needed** it is important to make a distinction between 'compensation' to coal asset owners and workers, which is likely to be a cost (i.e. investments with no financial return), and access to capital required to build solar PV capacity, which generates revenues and will be paid back over time (i.e. investments with return, subject to risk and conditions). As discussed in section 2.4, our analysis only considers the capital required for building new capacity. Every GW of coal replaced by solar PV requires around 5 bn USD investment in generating capacity. This is without balancing infrastructure and without compensating the coal retirement. An ambitious 10-20 bn USD per year from 2022 until 2030 could therefore support 8x15=120 bn USD of investments to replace 24 GW of coal with 120 GW of solar PV. This can only realistically deliver the full potential of local benefits if investments of this scale can be absorbed domestically[33] and this does not include compensation for ending coal 'early' (which will need to be a matter of political negotiation).

In terms of **technology transfer** needs it is useful to realise that solar PV hardware is readily available and for the most part it is a matter of mobilising the necessary capital for the investments. In terms of know-how, we find that there is significant room for improvement on four topics. First, there is a need for financial skills development, specifically related to renewables investments. Second, there is value in transferring skills related to project development and setting up specific manufacturing facilities (for example for power inverters). Third, Indonesia can benefit from other countries who have a longer experience in reaching and educating people to create larger demand for solar PV, for example through innovative business models and organising public outreach. Lastly, there will be value in exchange of technical expertise around balancing the power system with high shares of variable renewables – both in the system as a whole and in local distribution grids.

Our analysis shows that investing in the clean energy transition can come with significant development benefits and as such can be a strong driver for achieving **SDG targets**. Chapter 3 presents the impacts and synergies related to SDGs 3 (Good Health and Well-being), 7 (Ensure access to affordable, reliable, sustainable, and modern energy for all), 8 (Decent work and economic growth), and 13 (Climate action). These are the most prominent linkages with sustainable development, but not the only ones. Solar PV is widely recognised as a suitable technology to provide access for those (remote) communities that are not grid-connected and hailed as an interesting replacement for areas that depend on expensive diesel

33 Subramanian (2022) Is Climate Finance the next bubble?

fuel. Our study emphasises that the benefits of clean energy are not just interesting for geographically remote communities, such as in the so-called ‘outer islands’, but that solar PV is ready to also support the transition in well-connected and densely populated centres of economic activity, such as in Java and Bali, as well as in Sumatera, Sulawesi, Kalimantan, etc.

5.4 STRENGTHENING CLIMATE PLEDGES (NDCS)

Our work shows how accelerating the clean energy transition can combine climate ambition and action with enabling prosperity and a fairer, more inclusive energy system. In addition, as mentioned above, international climate support will most likely be part of a collaboration; a package in which Indonesia is also expected to signal its ambition, action, and resolve to the global community as well as its domestic investors and workers. Parties to the UNFCCC, including Indonesia, have agreed that their NDC should reflect the highest possible ambition, and from now on will need to be updated annually. As part of our analysis[34], we present the following considerations for strengthening Indonesia’s NDC:

- Acknowledge that full and fast decarbonisation is needed, and that the energy transition will need to accelerate significantly. Commit to realigning national and sector targets and strategies accordingly and introduce clear targets and timelines for the phase-out of fossil fuels (especially coal) and the uptake of clean energy.
- Make green recovery a central tenet of the energy sector and integrate public support into NDC planning and implementation.
- Identify existing vulnerabilities and weaknesses in the energy system and commit to addressing these without delay to avoid transition roadblocks later on that cause or perpetuate social injustices.

34 A2A (2021a) The energy transition after COVID-19: perspectives on green recovery and NDC Ambition raising

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