Ambition to Action

Three Indonesian solar-powered futures

Solar PV and ambitious climate policy

ECN.TNO Report Ambition to Action

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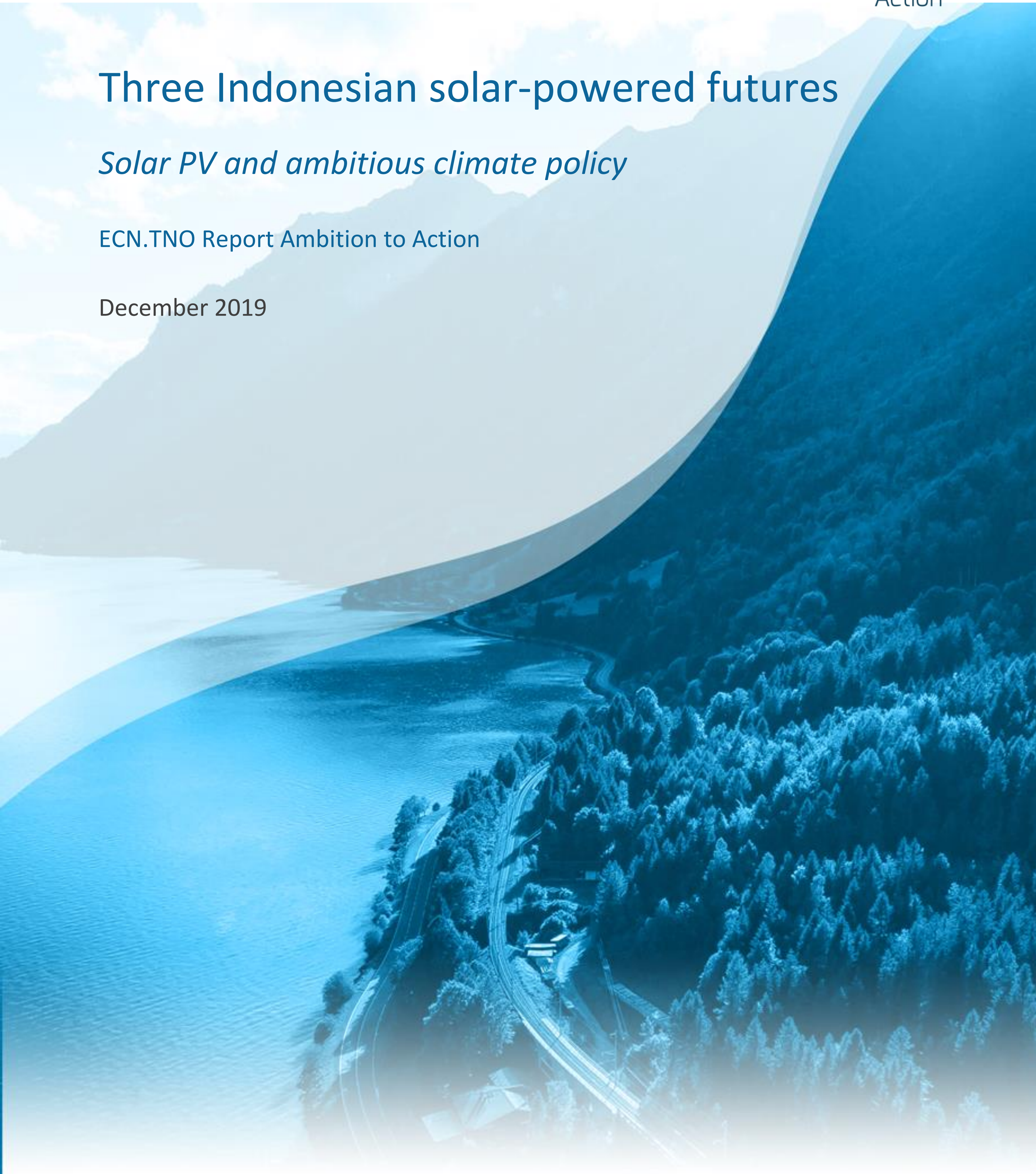

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Cover Summary

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Authors: Jasper Donker and Xander van Tilburg, with contributions from Himsar Ambarita and Sam Lamboo

Contact: jasperdonker@tno.nl

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Executive summary

The Intergovernmental Panel on Climate Change (IPCC) finds that in order to reach the goal of the Paris Agreement, all countries will need to phase out the use of oil, coal, and gas entirely in the next three decades (or face costly removals afterwards). This has major implications for the Indonesian energy sector: the current long-term energy policy focuses on diversifying the energy mix and keeping up with fast economic development while maximising domestic value added. But with two-thirds of the growth to be coal- and gas-powered, Indonesia's development pathway needs serious reconsideration. On the upside, clean technologies prove to have many development benefits and recently cost reductions have been spectacular (e.g. LED lights, solar power, and electric vehicles).

This report takes a closer look at solar photovoltaic (PV) as a clean alternative to coal-powered grid-connected electricity supply for Indonesia. We establish a sense of direction and scale of the impacts of solar deployment on energy security, emissions, employment, air pollution, and SDGs. Despite the good solar potential and plummeting equipment prices, we observe a remarkably slow uptake of solar PV in Indonesia to date (19 MWp in 2019).

To facilitate the imagination, we propose three scenarios for the uptake until 2030, the end of the current Paris Agreement NDC timeframe: 'rooftop pioneers (1 GW)', 'bright but cautious (10 GW)', and 'solar PV as growth engine (100 GW)'. Each of these variants can be integrated in the major power grids in Java-Bali or Sumatra, the 1 GW and 10 GW without compromising energy security. While the impacts of the 1 GW and 10 GW scenarios are modest, the 100 GW solar future is a game changer, providing around 20% of electricity supply and almost covering the renewable energy target of Indonesia. In the 100 GW scenario solar PV generates enough power to cancel all new and additional coal plants to 2030 under certain scenarios, effectively stabilising coal demand from 2020. In the 100 GW scenario, solar PV takes 36% of the energy sector emissions reduction, described in Indonesia's first Nationally Determined Contribution (NDC). With 100 GW of solar power, up to 24 GW of coal power can be cancelled which is good for air quality and has many positive impacts across a range of development goals (SDGs) and priorities.

The employment impacts of switching from coal to solar can be impressive: in the ambitious 100 GW scenario the solar PV sector could result in an additional 2.7 mln direct job years over a 10-year period. Even on a smaller scale, in the 1 GW and the 10 GW scenarios, direct and indirect domestic jobs in project development, electrical equipment, and construction can be significant.

There are a few reasons for caution related to employment impacts though. First, the bulk of labour shifts from the operational phase (coal) to the construction phase (solar PV), which should be included in the comparison. Second, even with an ambitious volume of 100 GW in ten years, it may not be realistic to capture each step of the solar PV production value chain by domestic industries and business. Demanding a local content share for solar PV goods and services, without providing a broader conducive policy environment can be counter-productive and might lead to domestic price increases and slowing down market expansion. Third, in order to successfully replace coal with solar PV, and harness the benefits, preparation is required in terms of skills development, quality insurance, resource and energy system planning, and mobilising finance.

Short term interventions that could help the nascent solar PV market in Indonesia (i.e. the low-hanging fruit) include more attractive net-metering and feed-in tariff arrangements, enabling and encouraging PLN to connect (variable) renewables, and realistic alignment of local content ratio to wider support.

Now is a good time to think through and discuss what different decarbonisation pathways could look like, how technology decisions impact development outcomes, and what this means for ambitious climate and energy policy. The first round of NDC updates is due in 2020, and for many countries this will be a chance to think through possible sector transitions pathways. With analyses such as this one, we hope to inform and inspire support for energy and climate policy that truly reflects Indonesia's 'highest possible ambition' towards achieving prosperity and fighting climate change.

Tables and figures

1. Introduction

The Paris Agreement and the latest Intergovernmental Panel on Climate Change (IPCC) reports confirm that drastic decarbonization is needed, requiring global emissions to reach net-zero in 2050 or shortly thereafter to avoid costly negative emissions afterwards. The global energy sector is the largest source of greenhouse gases (GHGs), responsible for about 35% of total anthropogenic emissions (IPCC, 2014) and transition of energy sectors is a matter of urgency, especially since it is among the easiest to decarbonize (compared to, for example industry). In Indonesia, the energy sector currently comes second in terms of CO_2 emissions (23%), after land-use, land-use change, and forestry (LULUCF) (65%). This is expected to change in the coming decade, in which the demand for power and transport will increase rapidly, making the energy sector the dominating source of CO_2 emissions in Indonesia. Even under the ambitious mitigation scenario in Indonesia's first Nationally Determined Contribution (NDC) to the Paris Agreement, CO_2 emissions from the energy sector are projected to nearly triple compared to 2010 levels. Until today, economic growth and prosperity have been inevitably linked to energy demand, and in a fast-developing country like Indonesia this means that energy demand is expected to grow significantly. To what extent this energy expansion also leads to an increase in emissions depends on technology choices now and in the near future (i.e. will the growth be fossil powered or renewables powered). It has become very clear recently that unabated coal, oil, and gas-based energy systems are incompatible with the long-term goals of the Paris Agreement, and will need to be phased out. Grid-connected solar photovoltaics (solar PV) is one of the promising technologies Indonesia can use - already today- to mitigate emissions in the power sector without putting undue burden on consumers (i.e. cost need not increase).

Because of the continuous decrease in cost, especially in the past decade, solar PV as technology is becoming competitive in more and more situations (both off-grid standalone and grid-connected). The effects of global cost reductions and improved efficiency have reached South-East Asia as well. For example, in Thailand and more recently in Vietnam, new solar PV installed capacity exceeds multiple gigawatts. In contrast, deployment in Indonesia has been limited so far, despite the significant solar potential and a clear but challenging target of 23% renewable energy by 2025. As stated by the Ministry of National Development Planning (Bappenas) in the Low-Carbon Development Plan: "*On energy Indonesia's advantage in and incentive to embark upon a rapid, bold transition towards renewable energy are both enormous and, yet, under-appreciated. Meanwhile, Indonesia's continued reliance on coal is built upon a now outdated perception that the cost of coal is lower than alternative sources of energy, along with a set of political economy considerations*" (GoI, 2018).

In addition to reducing greenhouse gas emissions, solar PV potentially has various co-benefits such as positive impacts on energy security, employment, and air pollution; in addition, solar PV can provide business and industrial development opportunities. This report touches on some of these potential co-benefits by identifying what solar PV could bring in a set of stylised scenarios: it gives a sense of the various impacts and co-benefits impact solar PV deployment could have until 2030 at different scale-levels: 1, 10, and 100 GW.

The report starts with an overview of solar PV in Indonesia and the state of the art in various solar applications. Based on this, three solar futures of 1, 10, or 100 GW are presented in Chapter 2. Next, Chapter 3 discusses the impact of each scenario on the energy system. Starting from an emissions reduction perspective, we look at impacts of deploying solar PV to replace planned and new coal power and find that even 100 GW of solar PV does not require existing coal operations to scale down - it does however affect the amount of new coal-power plants. Chapter 4 looks at the CO_2 mitigation potential under the three future scenarios and their contribution to the Paris Agreement pledge and national energy targets of Indonesia.

Chapter 5 provides an overview of the potential linkages of solar PV and the sustainable development goals (SDGs) using the SCAN-tool. Energy sector technology choices in order to align with the Paris Agreement can be a major source of future job growth. Ramping up Solar PV deployment not only provides energy and climate opportunities, but it also brings new employment opportunities for Indonesia. Therefore, Chapter 6 presents the domestic employment impacts and potential of the three different solar futures, compared to coal as an alternative. Lastly, and this is highly policy-relevant, considerations about local content requirements for solar PV are discussed in Chapter 7, both affecting employment and industrial development opportunities. Finally, Chapter 8 provides an overview of the three solar futures and brings forward considerations beyond the net impacts of employment, industrial opportunities and choosing between the three solar future ambition levels.

2. Three Solar PV futures

This chapter discusses the current state of solar PV deployment in Indonesia, gives a general sense of the 'state of the art' in solar PV deployment technologies globally, and based on this introduces three solar PV futures.

2.1. Solar PV in Indonesia

Solar PV deployment in Indonesia is currently limited. Estimates for online grid-connected solar PV deployment range from 9,9 MWp to 90 MWp[1]. An inventory done by PT South Pole Indonesia, as part of this study, reveals about 19 MWp of registered solar PV capacity connected to the grid, and around 46 MWp of projects in the pipeline. Appendix E provides an overview of this inventory of on-grid solar PV projects locations, status, capacity and developers. Indonesia's solar PV ambition is included in the 5-year National Energy Master Plan (RUEN; ESDM, 2017). It sets a target of 6,5 GWp for 2025 (i.e. over 300 times the current capacity) and estimates the solar potential for the whole of Indonesia to be 207,9 GWp. The International Renewable Energy Agency (IRENA) reports an even larger solar PV-potential of 532 GWp (IRENA, 2018).

The most concrete view on the next ten years of power system planning and implementation is found in the RUPTL, the 10-year business plan of the state-owned utility PLN. The RUPTL is updated annually and contains detailed projections for the electricity sector (i.e. at the level of specific power plants and transmissions/distribution infrastructure). The most recent RUPTL, covering the period 2018-2027, projects just over 1 GW of solar PV deployment by 2027, for which it relies heavily on independent power producers.

Theme	Numbers	Source
Installed and online:	9,9 – 90 MW (various)	Own research, triangulated with RUPTL (2019), IEEFA (2019), IRENA (2019), and MOE (2018).
Solar PV target	6.500 MW in 2025 (RUEN, 2017)	RUEN (2017)
Planned deployment	1.060 MW in 2027 (RUPTL 2018-2027)	PLN (2018)
Solar radiation	Good[2]	ESMAP (2017)
Solar PV potential	208 / 523 GW	ESDM (2018) / IRENA (2016)

Table 1: Indonesian solar PV overview

2.1.1. Solar potential

Due to proximity to the equator, the solar irradiation in Indonesia is very constant over the year. The potential is good, similar to the central-to-southern Europe (see **Figure 2**). The average annual solar energy received on a horizontal surface (Global Horizontal Irradiance, GHI) in Indonesia varies between approx. 1400 kWh and 2200 kWh per m^2 (see **Figure 1**). While the potential is especially good in the south-eastern part of the country. However, it is overall affected by monsoon, haze, dust, pollution and overall complex microclimates conditions (ESMAP, 2017; MottMacDonald, 2019).

[1] *Respectively RUPLT (2019), IEEFA (2019), IRENA (2019) and Ministry of Energy and Mineral Resources (2018)*

[2] *Perhaps counterintuitively,useful irradiation at the equator is often less than some distance away; this is caused haze, dust, pollution and complex microclimates with big differences*

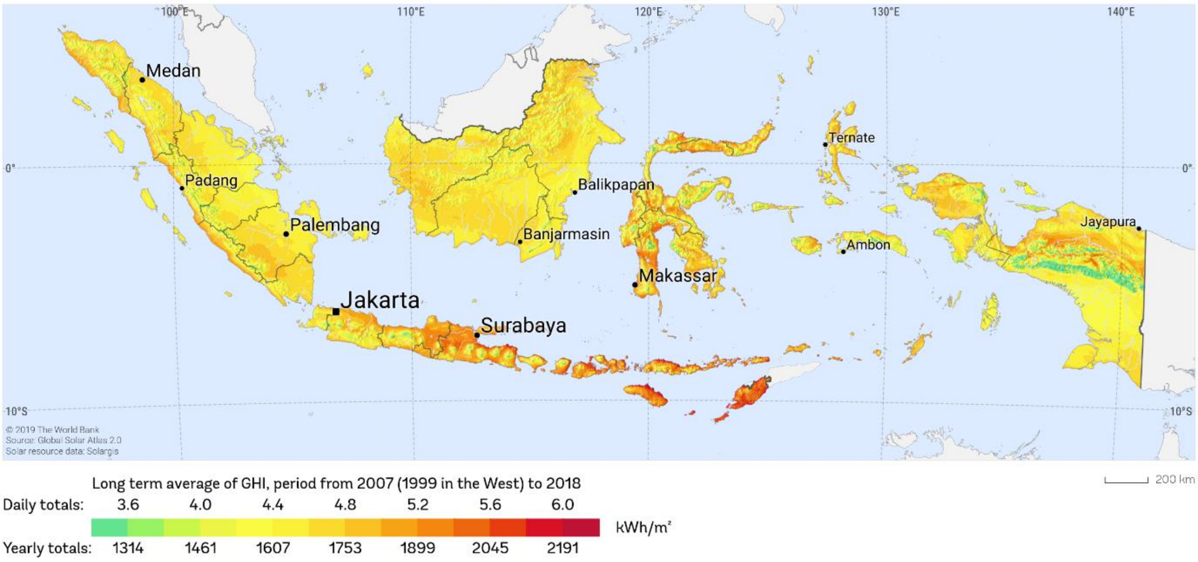

Figure 1: Global Horizontal Irradiation Indonesia (Global Solar Atlas 2019)

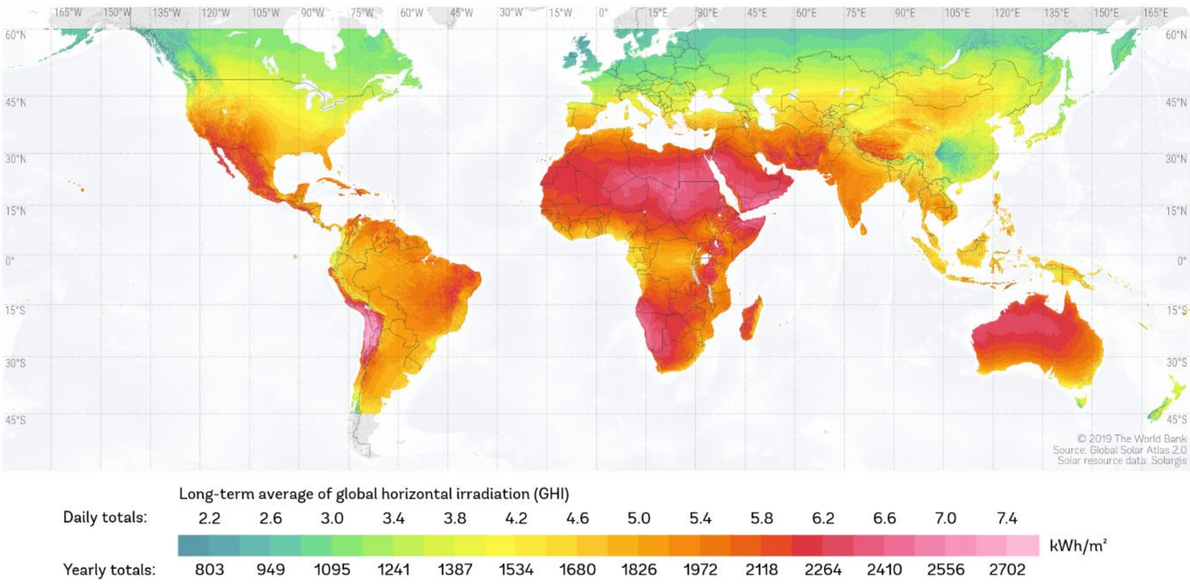

Figure 2: Global Horizontal Irradiation (Global Solar Atlas 2019)

2.1.2. Current capacity: Regional comparison

Comparing the installed capacity, ambitions and solar PV targets of Indonesia with other countries in the region shows that most neighbouring countries have more solar PV installed today than Indonesia does (**Table 2**). Almost all neighbours have more ambitious targets (esp. considering differences in size and growth expectations).

Country	Installed Solar PV (GWp)	Solar PV ambition (GWp)	Year
Vietnam	4,5	12	2030
Thailand	3+	15,5	2037
Philippines	0,89	3	2022
Malaysia	0,74	~1,6	2020
Philippines	0,89	3	2022
Indonesia	**0,014 – 0,090**	**6,40 / 1,06**	**RUEN 2025 / RUPTL 2027**
Myanmar	0,003	~1,5+	(-)

Table 2: Solar PV installed capacity and targets in the region

2.2. Applications and technologies

Solar PV comes in different shapes, sizes, and market-readiness: from the tried-and-tested silicon-based panels that can be mounted on roofs, to innovative solutions with thin films of organic materials that can be applied to existing surfaces. This section briefly presents five different categories of commercially available: residential rooftop solar PV, industrial and commercial scale solar PV, utility-scale solar PV, 'floating solar', and integration of solar technology into existing surfaces (e.g. roads or buildings). The three solar futures in this study include combinations of these applications, since they differ in aspects such as set-up requirements, feasible scale, cost profile, and stakeholders involved.

2.2.1. Residential rooftop solar PV

A *rooftop photovoltaic* (PV) power system is one of the possible applications of solar PV panels. Here, panels are mounted on the rooftop of a residential buildings. (**Figure 3** shows a typical solar rooftop PV setup; these systems are relatively small compared to ground-mounted solar PV systems, which suits the often-limited availability of suitable rooftop space. Typically, household rooftop PV systems are modular and consist of 200-350 Wp panels, adding up to maximum a few kilowatts peak (kWp). For reference: by today's standards, delivering 1 kWp requires between 6,25 and 10 m^2 including the various components (DEN, 2017; Fraunhofer, 2019). Rooftop panels and modules are typically made from connected assembly of crystalline silicon, thin film, monolithic, or perovskite solar cells together with a Balance of System (BOS) system. A Balance of System-system consist of a mounting system, inverter(s), cables, combiner boxes, optimizers, and control and monitoring equipment.

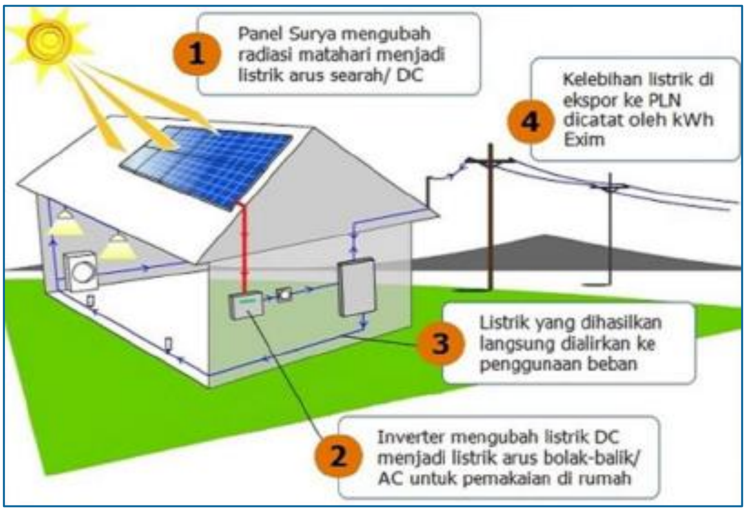

Figure 3: Typical solar rooftop PV setup[3]

In cities, solar PV has advantages over other types of renewable power sources such as biomass or wind because its modular nature fits well in the urban infrastructure (IEA, 2016): large amounts of empty rooftop spaces suitable for rooftop PV power systems, avoiding potential land use conflicts and providing power supply near areas of consumption.

Using rooftops leads to 'distributed generation' which reduces transport and infrastructure costs compared to centralized major power stations. In addition, it allows for a new business model for individuals and SMEs where they have the possibility to 'feed-in' electricity to the grid at moments when households do not use it themselves. This is a very common policy approach to integrating rooftop solar PV, as electricity usages of

[3] *Source: GIZ-INFIS & Kantar TNS - A study on market potential and financial scheme of rooftop solar PV in Jabodetabek Area*

typical household is low during the day but high in the morning and evening when there is no, or limited electricity produced by the rooftop solar PV system. Household can 'sell' their 'overproduced' electricity that is feed into the grid, to the servicing electricity utility. Net Metering or Feed-in tariff (FIT) mechanism are the most commons methods used for facilitating the 'sale' of the electricity. These power-producing-and-consuming households, are called 'prosumers'.

2.2.2. Industrial and commercial solar PV

A second, separate modality for solar PV is use by larger *industrial and commercial* consumers such as SMEs, industry, and public sector organisations (e.g. schools, railway stations, etc.). Industrial and commercial size solar PV systems are either installed on roofs or installed in ground-mounts on land. Commercial systems typically range from 50 to 500 kW in size (DEN, 2017). Most system are intended for levels of self-consumption, especially in businesses where the solar yield (i.e. during the day) coincides with the consumption pattern of these consumers.

2.2.3. Utility-scale solar PV

Utility scale PV power systems are typically ground-mounted and in the size range of 0,5 to 10 MW (DEN, 2017). However, there is no agreed definition or demarcation, and utility-scale can also be much larger: the current largest solar farm in the world has the size of 2.000 MW across 52,5 km^2, located in India (Summers, 2019). In contrast to household and commercial applications, utility-scale solar facilities are only focused on generating electricity to feed into the grid. In that sense, they are similar to other power plants like gas, coal or hydro plants.

Utility-scale systems, often referred to as 'solar farms', are mostly connected to the medium-voltage grid. Rooftop solar PV systems are connected to the low-voltage grid, while coal and gas-powered plants are usually connected to the high-voltage power grid. Apart from size, there are no major technical differences between household, commercial, and utility-scale solar PV systems. The same kind of modules, wiring, and components are used. In interesting advantage of ground-mounted systems is the ability to install a sun-tracking device, potentially increasing output by 22% by moving the panels to follow the sun (DEN, 2017).

Most of the recently installed solar farms across the world, are operated by independent power producers (IPPs) who sell their electricity to the electricity utility under a long-term fixed power purchase agreement (PPA). The location of choice for these solar farms is not only dependent on solar irradiation but also on land acquisition options, prices, and (future) grid connection conditions (by extension, the proximity advantage between supply and demand may not be all that relevant with large installations).

2.2.4. Floating solar panels

A recent development that speaks to the imagination of many, *floating photovoltaics* uses solar PV panels on a floating structure, placed in artificial basins, lakes, dams, estuaries, or even in open water in the oceans. The power generated by the floating panels is gathered by connector boxes and converted to alternating current (AC), after which the electricity is transported to the shore. Once onshore, the power can be used directly (i.e. onsite), stored in batteries, or it can be fed into the grid.

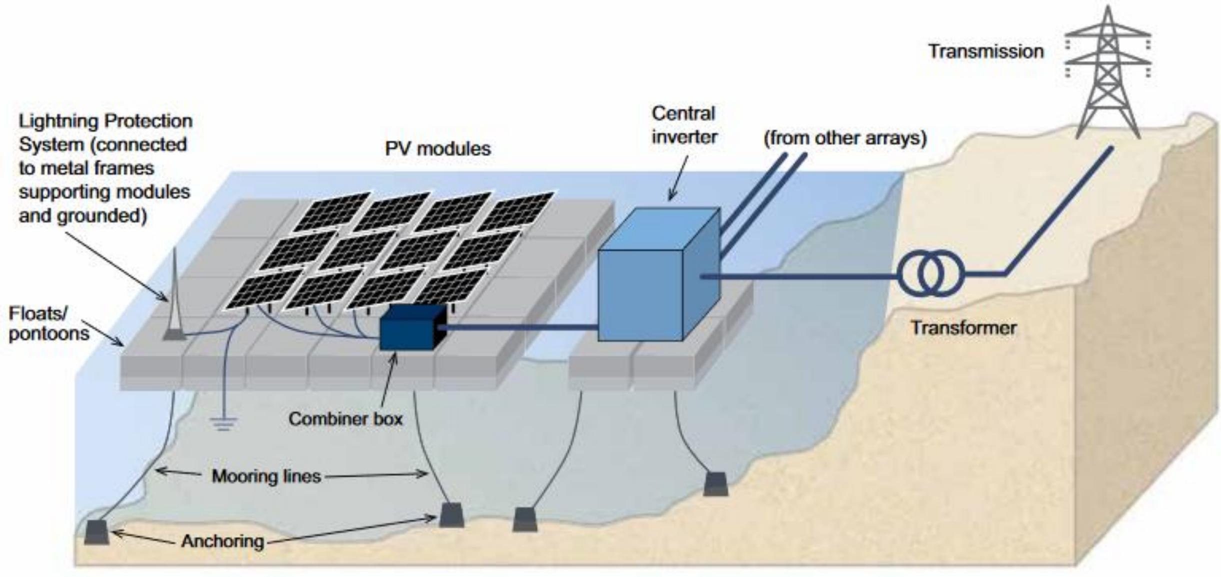

Figure 4: Floating solar PV installation[4]

The first floating solar PV installation was installed as recently as 2007, so there is less experiences with these systems compared to land-based deployment. In recent years the amount of floating solar PV installed has grown exponentially, with the cumulative installed capacity reaching 1.1 GWp as of mid-2018 (World Bank, ESMAP, SERIS 2018). Despite the slow uptake of solar in Indonesia (see section **Error! Reference source not found.**), entrepreneurs are seriously looking into construction of the world's largest floating solar plant in Indonesia (see Box 1).

Box 1: 200 MW Floating solar PV plant in West Java

The Indonesian power company PT Pembangkitan Jawa-Bali (PT PJB) signed a project development agreement (PDA) with PLN for the world's largest floating solar plant. With a capacity of 200 MW PV panels on 700.000 floats and an area of 225 hectares, it should be installed on the Cirata Reservoir in West Java. This 6.000-hectare reservoirs already powers a 1 GW hydroelectric power station. At first the deal was awarded to UAE developer Masdar but after the government was forced to hold a tender there is no clarity about the situation, at the moment.

Floating solar PV seems especially interesting in combination with hydropower plants, creating systems that are complementary in power output and the use of the water reservoir. One of the challenges faced by marine systems is the hostility of the offshore environment: harsher environmental conditions, salinity affecting the equipment, and the potential accumulation of organisms on the equipment (ESMAP, 2018). One of the main benefits of floating PV is that no (dry) land is required, which can be a benefit especially in countries where land acquisition can be challenging, where land and rooftop area are scarce, or where there are concerns about land competition with, for example, agriculture and forestry. An additional benefit can be increased efficiency, on average about 11%, compared to ground installed panels, due to cooling provided

[4] *Source: World Bank Group, Solar Energy Research Institute of Singapore*

by the water (Sahu *et al.*, 2016; Trapani and Redón Santafé, 2014; Choi, 2014; ESMAP, 2018). Furthermore, floating PV installations can create shade for the aquatic environment below, preventing water evaporation and increasing water quality by limiting algae growth (Sahu *et al*, 2016).

Installation costs today for floating PV systems are higher than for similar land-based systems; because of limited experience with floating PV technology and because additional investments in equipment are required (e.g. equipment such as floats, and more resilient electrical equipment able to deal with various environmental conditions). Although floating solar has not been widely applied and experience is still building, higher system costs could very well be offset by higher efficiency and output – making it comparable to ground-mounted systems even under conservative estimates for increased performance (ESMAP, 2018).

2.2.5. Integrated solar PV

With integrated solar PV, photovoltaic panels are used as part of a building or other construction, rather than as a separate module. The most common form of integrated solar is *building integrated photovoltaics* or BIPV. The advantage of BIPV is that it produces power while at the same time fulfilling other functions expected from conventional building materials, such as structural support, insulation, or provision of natural light. The most common use of BIPV nowadays, is integration into roofs, façades, and glass.

By fulfilling multiple functions, BIPV can sometimes be integrated without additional generation costs, or even be a cheaper alternative to a combination of conventional building materials and add-on PV or integrated even without additional cost. In addition, there are aesthetics integration opportunities and increased surface of buildings (façade and windows) that can be used to increase electricity generation of high buildings with limited rooftops.

As of 2015, the global BIPV installed capacity was 2.3 GW, only 1% of the global PV market (Osseweijer *et al.* 2018). However, its potential is expected to be much larger: in the EU alone it is estimated that BIPV can reach up to 1 TW (Defaix *et al.* 2012). Adoption and application of BIPV has until now been slow due to lack of awareness by architects and its affordability has not been sufficiently demonstrated (SEAC-SUPSI, 2015).

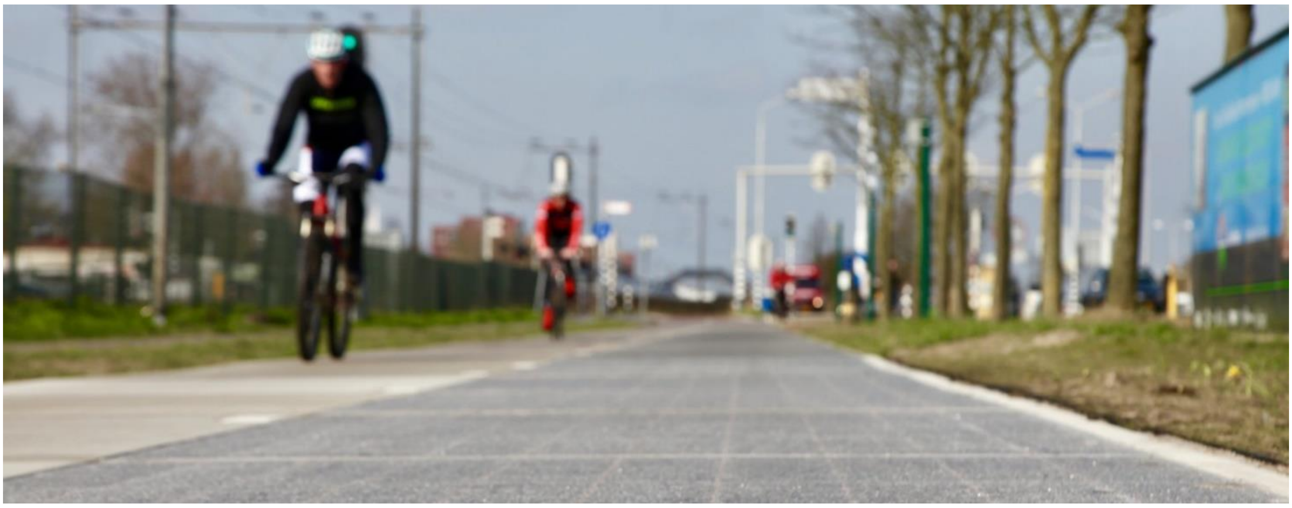

Figure 5: SolaRoad in the Netherlands

An obvious large-surface infrastructure exposed to sun is the road-network. Integration of thin-film PV is still being tested and further developed, but there have been early successes with the SolaRoad initiative in the Netherlands, introducing bike lanes and motorways with solar PV technology (TNO, 2019).

2.3. From rooftop pioneers to game changers

As mentioned before, this study aims to give a sense of the impact of solar PV on three different scale-levels. Therefore, three plausible futures for various uptakes of solar PV until 2030 of 1, 10 and 100 GW are presented, to get a sense of the various impacts and co-benefits of solar PV on three different scale-levels. We consider the three futures, with the timeframe of the National Determined Contribution (NDC) of Indonesia to the Paris Agreement by 2030. Within these futures we explore the following questions: What are the different possible solar applications? How much electricity can be produced? How does it affect energy security? What is the CO_2 mitigation potential and how does it relate to the Indonesian Paris Agreement pledge (Nationally Determined Contribution)? What are the benefits / impacts in terms of employment? What is the role of the Indonesian solar PV local content requirement policy, both affecting employment and industrial development opportunities? What role does quality control play? In the following paragraphs we introduce the three scale-levels and associated technology configuration. The impacts and co-benefits of these futures will be discussed in the subsequent chapters.

2.3.1. 1 GW: Rooftop pioneers

In the first scenario, 'rooftop pioneers', until 2030 solar power is embraced only by households, with around 500.000 households in Indonesia installing a total of 1 GW of solar PV panels on their roofs[5]. These panels are connected to the major power systems of Java-Bali and Sumatra dealing with most of the growth in power demand and emission in the upcoming decade. Their 4 million solar panels generate about 1.5 TWh of electricity annually in 2030. Part of the electricity will be used directly by the households, part of it will be feed back into the grid towards other electricity consumers. The 1 GW of residential rooftop solar PV covers about 10 km^2 of empty rooftop space. Deployment 1 GW of solar PV has about the same electricity output annually of 243 MW of coal power plants[6]. Thus, this solar PV future can e.g. result in not constructing 243 MW of new coal power plants that planned (more information in section 3.1.1 and specifically **Figure 9**).

2.3.2. 10 GW: Bright but cautious

In the 10 GW solar future, both households, businesses, independent power producers (IPP) and PLN start generating electricity via solar panels. In 2030 about 2 million Indonesian roofs are supplied with solar panels and connected to the power grid, resulting in 4 GW of installed capacity. Next to households, businesses and industries see the potential of generating electricity with solar panels, as well. They have installed 3 GW of solar panels in 2030. Their solar panel installations are mostly bigger than those of households. The panels are installed on roofs of their commercial buildings and production halls, integrated in the facades and skylights of their new buildings (building integrated PV) and installed on the grounds of land that they own. Finally, IPPs and PLN have deployed another 3 GW of solar panels on an even bigger scale by ground-mounted solar parks or floating solar parks. Altogether about 40 million solar panels are installed in Indonesia covering 100 km^2. Deployment 10 GW of solar PV has about the same electricity output annually of 2.43 GW of coal power plants.

2.3.3. 100 GW: Solar power as growth driver

In the 100 GW future, Indonesia embraces solar energy as the technology for clean and sustainable electricity generation in 2030. More than 12 million residential rooftops have a solar PV installation. On commercial and industrial properties another 25 GW is deployed. Finally, 50 GW of utility-scale solar is deployed in

[5] *Average of 8 solar PV panels of 250 watt each*

[6] *Capacity factor of solar is 17% until 2030, coal runs at 70% (DEN, 2017)*

ground-mounted and floating solar farms. The 400 million solar panels cover an area of about 1000 km^2, about 0,05% of the total land area of Indonesia. Deployment 100 GW of solar PV has about the same electricity output annually of 24.3 GW of coal power plants.

3. Energy system impacts

3.1.1. Capacity deployment in each of the solar PV futures

The main purpose of the three hypothetical scenarios in this study is to get a sense of scale and directions of the impacts of solar deployment. Although there is much to learn from the scenarios, it needs to be emphasised that the focus here is on the co-benefits of choosing solar PV over coal, providing insights into the impacts of deployment on different scale-levels could (i.e. the focus is *not* on specific support policies, cost developments, or actual grid integration). The growth path in each of the three futures is presumed to be similar, reaching their different targets in 2030 (see **Figure 6**). In constructing the pathways, we have considered overall growth of power demand in Indonesia, historical solar PV deployment in other countries, and potential (domestic) learning effects. Due to the current maturity of the technology, and short construction periods, high annual deployment rates should be feasible directly from 2020 onwards. Domestic learning effects, cost reduction and saturation effects, can affect deployment in later phases until 2030.

Even in the growth pathway of 100 GW until 2030, annual solar PV deployment remains well under the maximum growth steps seen until today in other countries. Comparison with the scenarios developed for the National Energy Outlook Indonesia 2016 (DEN, 2016) shows that only for 100 GW scenario the capacity addition is huge compared to the total installed power capacity in 2030: 161 GW in the business-as-usual scenario and 145 GW in the ALT1 scenario[7]. However, it is important to mention that an overarching energy system scenario including 100 GW of solar would result in a totally different overall generation mix.

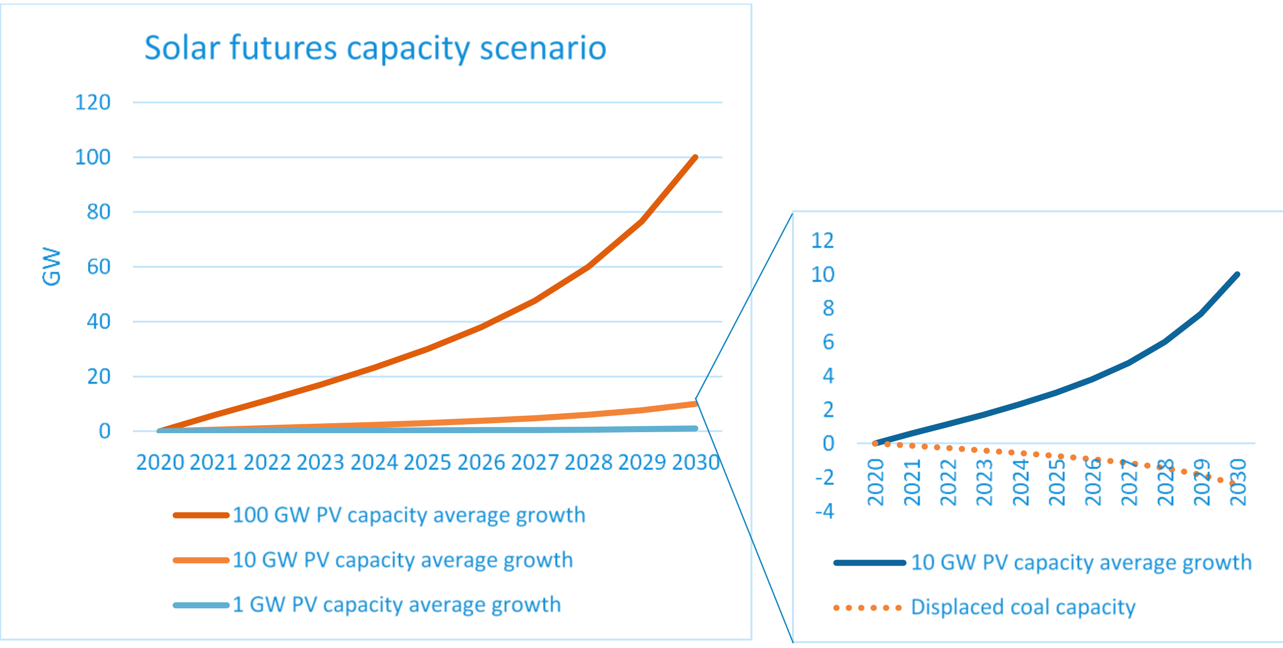

Figure 6: Three solar futures scenarios and 10 GW solar scenario close-up

Since the purpose of this study is to explore the role of solar PV in furthering the goal of the Paris Agreement, we look at strategies with maximum mitigation potential. Solar PV would have the greatest impact if it would replace existing 'dirty' power plants; the second most impactful approach would be to reconsider cancelling planned new coal power plants in favour of new solar PV capacity. Due to the difference in load factors (i.e. solar PV only provides electricity when the sun shines) displacing coal by solar PV does not reflect in a 1:1

[7] *The Indonesia Energy Outlook 2016 uses three scenarios: business as usual at moderate growth (5.6%), ALT1 with a high share of renewables and moderate growth (5.6%), and ALT2 with a high share of renewables and high economic growth (7.1%). In this study*

matter on installed capacity; 100 GW of solar deployment would displace about 24,3 GW of (new, future) Indonesian coal plant capacity. Similarly 10 GW can displace 2,43 GW and 1 GW can displace 243 MW of Indonesian coal power capacity in 2030[8].

Box 2: Scope and limitations

This study focuses on (extreme) solar futures and therefore has some limitations to the impact on the energy system as a whole and other power generation technologies. This study only compares the three solar futures to already existing and acknowledge Indonesian scenarios to get insights on the potential impacts. We focus on the potential net impacts for deployment at different orders of magnitude and the features and implications of this and do not present integrated power sector pathways and cost analysis[9]. Further research should focus on plausibility and the impact on the energy system as a whole and energy generation mix in more detail by development and modelling of new power sector scenarios, including high deployment of solar.

It is important to keep in mind that the power sector is expected to grow *so* fast in the coming decades, that large volumes of solar PV can be added without actually having to decommission existing (coal) capacity. This in contrast to for example European and US context where renewable energy displaces existing fossil generation, resulting in 'mothballing' or decommissioning of fossil power plants. The National Energy Outlook Indonesia (DEN 2016) shows strong growth of coal power generation between 2020 and 2030. The 100 GW solar future does not require existing coal operations to scale down but still require an addition growth of 15 GW of coal under the DEN BAU scenario between 2020-2030. Under the DEN 2016 ALT1 scenario, the 100 GW solar PV scenario generates enough power to cancel all new and additional coal plants to 2030, and a small decrease in absolute terms of 0,95 GW of existing coal capacity (2020 level) could be expected (see **Figure 7**). Alternatively, displacing 24 GW new coal in the 100 GW scenario is consistent with decommissioning all Indonesian coal plants built before 2015.

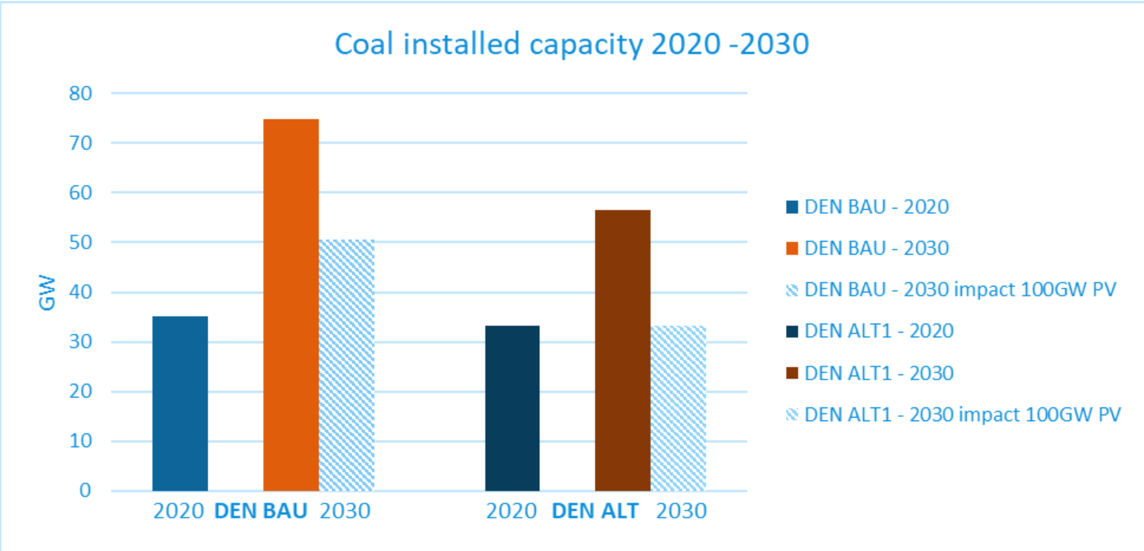

Figure 7: Displaced coal capacity

3.1.2. Electricity generation

Annual electricity output under the three solar futures is shown in **Figure 8**. Annual electricity generation in the 100 GW futures scenario increases to about 149 TWh annually from 2030. Comparison with the National

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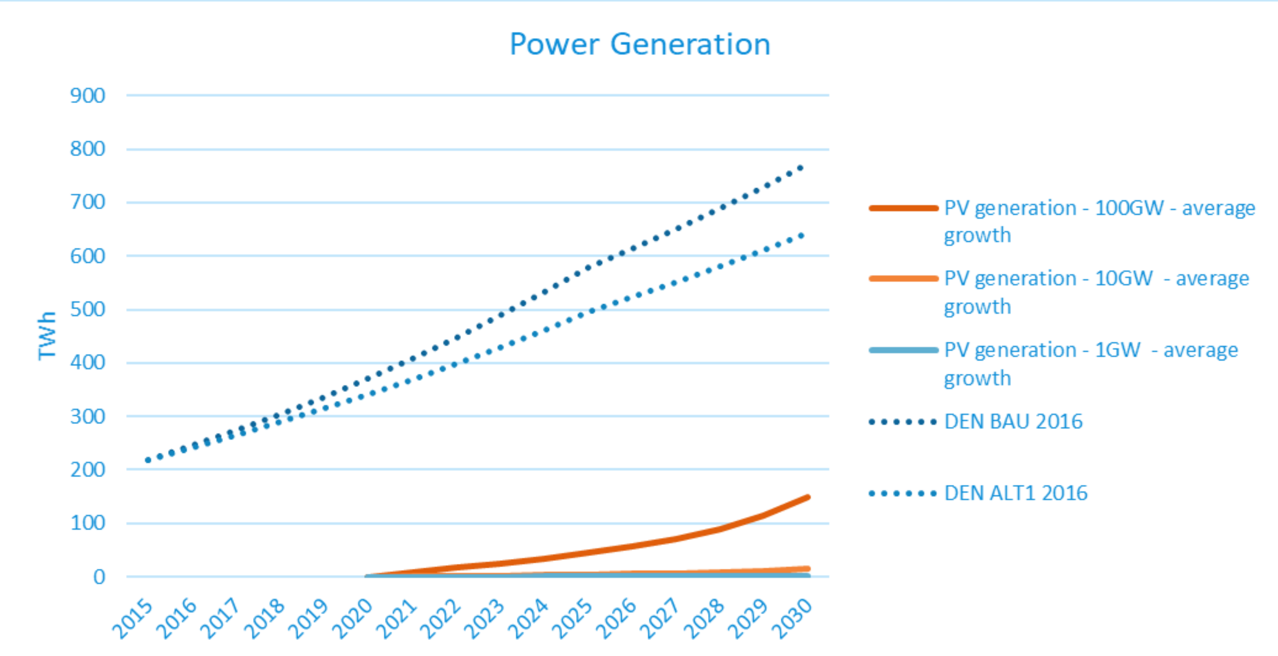
[8] *Indonesian coal plants run with capacity factor of 70% and 38% efficiency until 2030; Capacity factor of solar is 17% until 2030 (DEN, 2017)*

[9] *We did not look at policies needed to achieve or sustain solar cost reduction and deployment which is covered by other technical assistance projects (ICED, IESR, GIZ) (i.e. we assume solar cost are on par with for example coal and gas).*

Energy Outlook Indonesia (DEN, 2016) scenarios shows that the 100 GW of solar PV would contribute about 19% of the electricity production in 2030 under Business-as-Usual and 23% under ALT1 (excluding the 15GW solar capacity that is already part of that scenario). This is modest due to the low capacity factor of solar compared to other power generation technologies.



	1 GW Rooftop pioneers	10 GW	100 GW
Annual generation from 2030 TWh onwards	1,49	14,89	149
% DEN BAU generation in 2030	0,19%	1,92%	19,29%
% DEN ALT1 generation in 2030	0,23%	2,31%	23,1%

Figure 8: Three solar futures – compared to Indonesia Energy Outlook 2016

3.1.3. Energy security

As seen above, the 100 GW scenario can contribute to about 20% of the electricity generation in 2030 and hence becomes an important and substantial power supply source. From the perspective of power supply stability, there are several issues to take into consideration: 1) supply continuity, for example at night 2) variations in solar PV output, location of demand and supply, and 3) technical aspects of solar PV such as the inevitable non-synchronous nature of solar power. Although the integration of variable renewable energy (VRE) like wind and solar PV electricity is known to be challenging, a number of frequently mentioned claims turn out to be false when compared to practical evidence. Myths that turn out to be very well manageable with modern technologies, range from 'weather driven short-term variability is unmanageable', 'variable renewables require 1:1 back up', to 'storage is a must-have' (see for elaborate discussions: IEA 2017a & b, IEA 2018a & 2019).

Solar power production depends on weather conditions with actual electricity output changing in seconds (for example when clouds pass by) and on longer (even seasonal) timescales as a result of weather and climate fluctuations. Electricity generation from the installed solar capacity will in each of the solar futures be very constant over the year. This is due to Indonesia's geographical favourable location very close to the equator, where solar irradiation very consistent throughout the year, in contrast to many other countries. The 1 and 10 GW solar futures will not put the security of supply of the Indonesian energy system at risk. Various modelling exercises have shown that even higher deployment of variable renewable sources (e.g. ~27 GW in 2030 in the DEN 2016 and ~55 GW before 2027 (IESR, 2019) would not put energy security of supply in Indonesia at stake. The Lombok Energy Outlook 2030 (DEA 2019) study shows that even in the very small power system of Lombok, 40% of the total installed capacity could be solar capacity combined with almost no storage. No studies have investigated yet what the impact of installing 100 GW of solar PV would be on energy security. Further research should focus on this and on the consequences.

Adding more solar PV to the Indonesian generation mix would increase energy diversification. It can reduce the dependency on coal and offset the related projections in demand growth for domestic coal for the Indonesian power sector. Domestic coal demand for the power sector is expected to increase from around 90 Mton (2020) towards 200 Mton in 2030 for the DEN BAU and about 150 Mton for DEN ALT1 in 2030 (see **Figure 9**). Currently, government regulations force domestic coal miners to supply part of their coal production to the power sector for a capped price which is below the world market price, through a domestic market obligation (DMO). The 100 GW solar future could decrease the domestic coal demand projections with 33-44% in 2030, if solar capacity solely displaces coal capacity. In the DEN ALT scenario this would mean that in 2030 the demand for coal, as a fuel in power production, would be on the same level as in 2020.

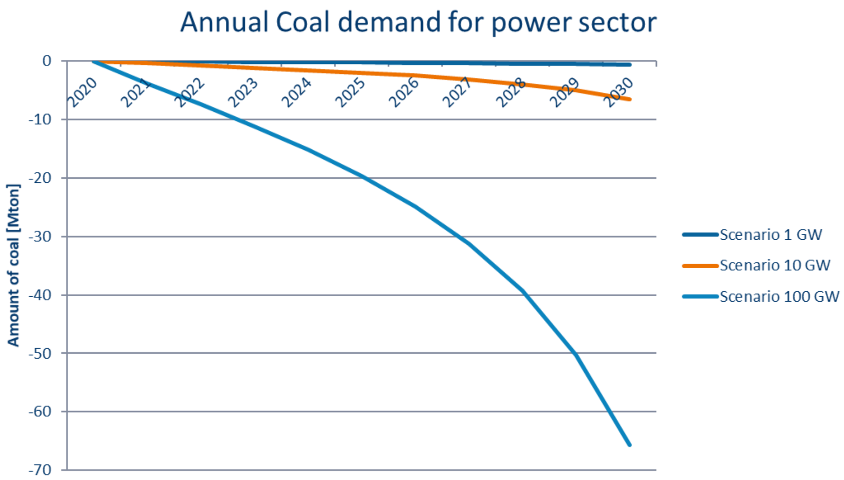


Figure 9: Three solar futures – displaced domestic coal demand

3.2. Grid integration and flexibility options

In the '1 GW: rooftop pioneers' and the '10 GW: bright but cautious' solar futures, the shares of solar power in the electricity mix of Java- Bali and Sumatra will remain low and grid integration should therefore not be a major obstacle, save perhaps from causing local level issues. IEA uses a framework with various phases of system integration of variable renewable energy (VRE) sources influencing power system operations. These phases range from no relevant impact (phase 1) until seasonal or inter-annual surplus or deficit at VRE supply (phase 6). (IEA, 2019). **Figure 10** shows that the 1 and 10 GW solar PV futures would remain in Phase 1 of the IEA framework – No relevant impact on the system. This is because their share, in the overall annual electricity generation of Indonesia in 2030, will remain very limited. The 1 GW rooftop pioneer future, only consisting of rooftop solar application, and the 4 GW of rooftop solar in the 10 GW solar PV future, will mainly impact the local distribution grids on neighbourhood level. It reduces transmission and distribution energy losses, since the electricity is produced close to where it is needed. On the contrary, significant localized growth of rooftop solar can raise concerns about grid congestion, voltage issues and reverser power flows on local level. Commercial solar applications are mostly connected to the distribution grid as well, or to mid-voltage level grids. Commercial or industry consumers achieve a particularly high rate of self-consumption, as long as their consumption profile doesn't collapse on the weekends (e.g. refrigerated warehouses, hotels and restaurants, hospitals, server centres, retail) (Fraunhofer, 2019). The impact of commercial solar PV application on the grid is therefore often limited. However, solar PV hotspots through significant growth of commercial solar PV can still result in similar concerns as mentioned by rooftop solar applications. Utility solar PV applications do impact the medium and higher voltage transmission & distribution grids. Depending on the size and location this can require analysis per project about the impact on the grid and required upgrades. More favourable: power system planning that integrates power grid development and reinforcement, and opportunities for variable renewable deployment including large scale solar PV deployment is developed. Hereby smoothing the integration of renewables and reducing system costs.

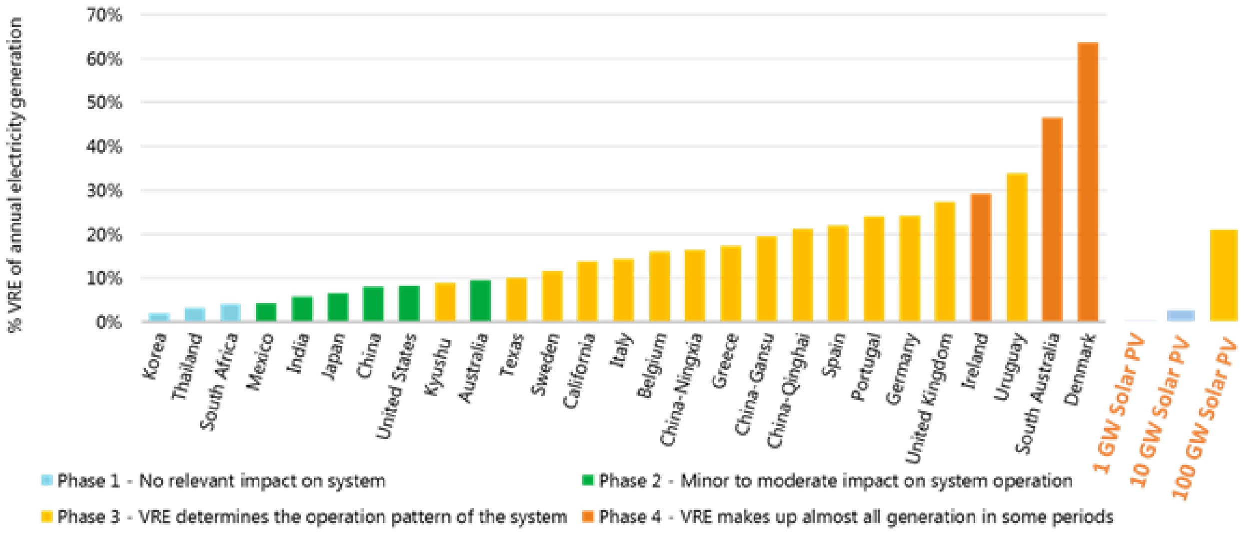


Figure 10: Variable renewable shares across countries (IEA, 2019)

Figure 10 shows that the '100 GW: solar power as a growth driver' future in 2030 would bring it to VRE integration Phase 3, in which variable renewable energy (VRE) determines the operation pattern of the system. Even nowadays this is not unfeasible, looking to other countries, but further research is needed that includes the specific Indonesian context and power systems. For integrating higher shares of VRE, like in the 100 GW solar future, best practices and strategies point to increased flexibility to keep power systems reliable, affordable and sustainable (Donker and Van Tilburg, 2018). Flexibility of power systems is the ability of the power system (actors, technologies, processes, measures and markets) to respond reliably and rapidly to large fluctuations in supply and demand balance (IEA, 2018b). Flexibility is essential to deal with, for example the famous solar PV duck-curve, where solar PV reduces demand of other generation sources during the day but requires them after sunset. Options to increase flexibility are available all over the power system, in operation, markets, supply, demand, grid, storage and conversion and system integration. There is not one single sort of flexibility: needs and supply options of flexibility do vary in time (seconds up to months), size and level of scale (household until international) (Donker and Van Tilburg, 2018). Although, the impact of the three solar futures on the energy system differ, all solar future scenarios require up-to-date grid management strategies by PLN, as they already present themselves as a barrier today (IEEFA, 2019)

Power systems across Indonesia, in eastern and western provinces, have in common that, in contrast to most European systems, they are expected to grow significantly in the coming decade. Most projections show that installed capacity triples or quadruples by 2030, compared to 2010 (Van Tilburg and Donker, 2018).

Accommodating large amounts of new capacity requires major power grid reinforcements and extensions, independent of whether new capacity is based on variable renewables or not. Power grid extensions that support or prepare for variable sources are somewhat different, but not necessarily more expensive. With strategic planning and power system development, integrating higher amounts of variable renewable energy would therefore not necessarily lead to additional investment requirements beyond the cost of normal system development. International experiences so far on the integration of variable renewable energy are continuously exceeding experts' expectations with systems already today going beyond the 20% share (the share in the in the 100 GW solar future) like systems in China and countries like Spain, Portugal, Germany, UK Ireland and Uruguay. In Denmark a share of even more than 60% of variable renewable energy has been reached (IEA, 2019). Strategic planning and coordination are of the essence as solar farms can be operational within a year but building infrastructure can take up 5-10 years. The fact that Indonesia has a vertically integrated monopolistic managed power system by PLN, with expected massive expansions, offers a unique opportunity to increase flexibility and anticipate further integration of solar PV and wind.

3.2.1. Smart grids

The introduction of high amounts of solar PV deployment, especially in urban settings, together with evolution of end-use applications, provides interesting smart grid opportunities for Indonesia. There are multiple definitions for smart grids, most of which encompass the integration of power, communication and information technologies and the integration of behaviour and actions of all users connected to an electricity network (IEEE 2011; EC, 2010). The concept is linked to grid integration and flexibility options like demand-response and focusses on improving the economic, sustainability and security aspects of power system. Smart grids are not new to Indonesia; PLN and BPPT carried out a pilot smart microgrid on Sumba [GoI, 2010) and the prepayment model of PLN Listrik Pintar is a smart grid solution as well. However, with the introduction of new end-use evolutions like e-scooters, electric vehicles and smart home energy efficient appliances, new (business) opportunities can arise around smart charging, storage and energy efficiency concepts. Especially, when they are combined with the introduction of dynamic, or peak and off-peak pricing of electricity, that can act as a signal to consumers to respond on. Hereby grid integration issues through high levels of solar PV penetration, can be reduced on for example neighbourhood level. Secondly, increased intelligence and information gathering by for example smart metering, as part of solar PV deployment, can improve the operation of power systems on all levels.

4. Climate and environment impacts

4.1. Reducing CO_2 emissions

Solar power itself does not mitigate CO2 emissions. Solar power CO2 emission mitigation potential is dependent on the carbon intensity of the power generation it replaces. The most effective emission mitigation impact occurs if solar power replaces existing or planned coal power plants. Therefore, we assume all solar PV deployment displaces existing or future coal power plant capacity (see chapter 3).10 **Figure 11** shows the annual and total mitigation potential of the three solar futures, in the timeframe of 2020-2030. The 1 GW solar PV future has the potential to mitigate about 1,14 Mton of CO2 annually in 2030, the 10 GW solar PV future 11,4 Mton and the 100 GW solar future about 114 Mton of CO2. Cumulative emission potential between 2020-2030 is the abatement of 609 Mton (3359 Mton up to 2050) of CO2 emissions for the 100 GW solar future, and a factor 10 and 100 smaller for the 10 GW and 1 GW solar futures. As most solar PV systems are designed to have a lifespan of 20-25 years, the total mitigation potential over the lifetime of the installed solar capacity is a factor 5,5 larger[11].

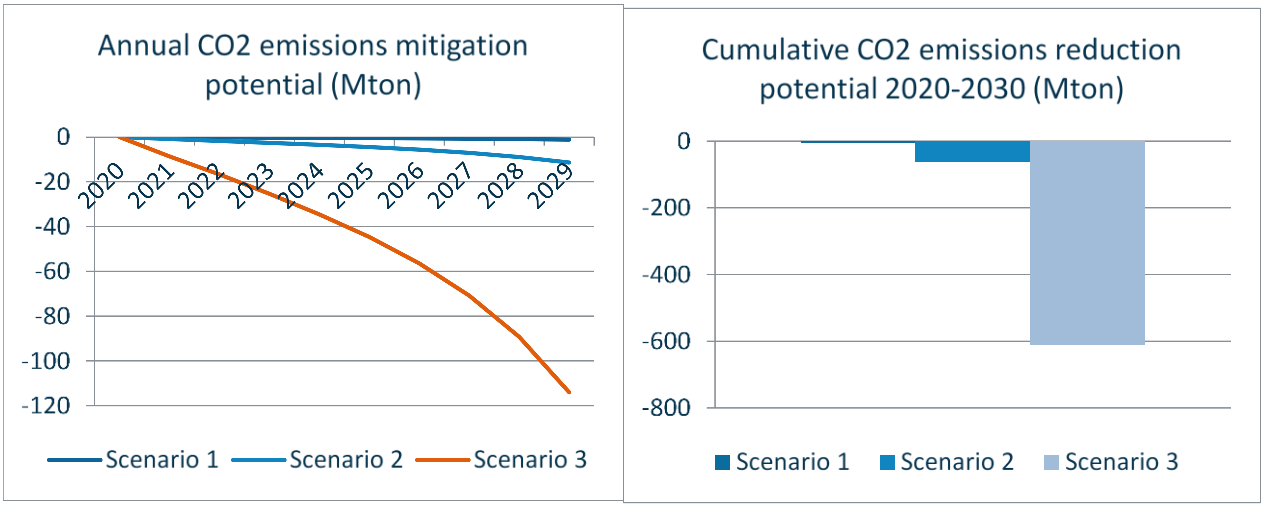


Figure 11: Three solar futures – CO2 mitigation potential 2020-2030

4.1.1. Paris Agreement and National Energy Policy (KEN) targets

At the COP21 climate conference in December 2015, all Parties to the UNFCCC reached an agreement to combat climate change: the Paris Agreement. This bottom-up framework starts from initial pledges and through a repeated five-year cycle of more ambitious pledges. The greenhouse gas (GHG) emissions are supposed to stay within the limits needed to keep global warming well below two degrees and preferably below 1.5 degrees. In September 2015, Indonesia presented its initial intended nationally determined contribution (INDC). Subsequently, Indonesia submitted its first nationally determined contribution (NDC) in November 2016, when signing the Paris Agreement. Indonesia's first pledge to the Paris Agreement is a 29% reduction by 2030 from business as usual, and up to 41% contingent on international support. It presents three projections for the period 2020-2030: a BAU scenario without mitigation policies, a mitigation scenario CM1 with sectoral development targets, and a more ambitious mitigation scenario CM2 conditional on

[10] *For the analysis we assume a coal plant load factor of 70% and the use of domestic coal with an emission factor of 1 kg CO_2/kWh.*

[11] *Based on timeframe 2020-2050*

international support (see **Table 3**). The NDC shows that 60% of the mitigation effort concerns LULUCF and 35% on the energy sector (and 5% from agriculture, waste, and IPPU).

No	Sector	GHG Emission Level 2010*	GHG Emission Level 2030 ($MTon CO_2e$)			GHG Emission Reduction ($MTon CO_2e$)		GHG Emission Reduction % of Total BaU		Annual Average Growth BAU (2010-2030)	Average Growth 2000-2012*
		$MTon CO_2e$	BaU	CM1	CM2	CM1	CM2	CM1	CM2		
1	Energy*	453.2	1,669	1,355	1,271	314	398	11%	14%	6.7%	4.50%
2	Waste	88	296	285	270	11	26	0.38%	1%	6.3%	4.00%
3	IPPU	36	69.6	66.85	66.35	2.75	3.25	0.10%	0.11%	3.4%	0.10%
4	Agriculture	110.5	119.66	110.39	115.86	9	4	0.32%	0.13%	0.4%	1.30%
5	Forestry**	647	714	217	64	497	650	17.2%	23%	0.5%	2.70%
	TOTAL	**1,334**	**2,869**	**2,034**	**1,787**	**834**	**1,081**	**29%**	**38%**	3.9%	3.20%

* Including fugitive **Including peat fire

Notes: **CM1** = Counter Measure (*unconditional mitigation scenario*)
CM2 = Counter Measure (*conditional mitigation scenario*)

Table 3: Indonesia first NDC: mitigation scenarios CM1 and CM2 (GoI, 2016)

The Indonesian energy sector is growing rapidly, and its emissions will keep growing; business as usual energy emissions are 1669 MtCO2-eq. in 2030. Even under the ambitious scenario CM2, emissions will nearly triple compared to 2010 levels. The GHG emission reduction, compared to business as usual, of the energy sector are 314 CO2-eq. in CM1 and 398 CO2-eq. in CM2 annually. The NDC does not provide clear numbers on emission reductions target for the power sector, of which the three solar future are part. However, the power sector will be an important factor for Indonesia's long-term commitments under the Paris Agreement (van Tilburg & Donker, 2018) and future NDCs will hopefully provide more insights and details. Table 4 shows the impact of the three solar futures on the CM1 and CM2 energy sector target. It shows that the impact of the 1 GW solar PV future on Indonesia Paris Agreement climate targets is limited. In contrast, the 10 GW and especially the 100 GW have significant impact, when they replace respectively 2.43 and 24.3 GW of existing or planned coal capacity.

	1 GW Rooftop pioneers	10 GW Bright but cautious	100 GW Solar PV Solar PV as growth driver
Emission reduction (Mt)	1.14	11.4	114
NDC Energy sector target CM1	0.36%	3.6%	36%
NDC Energy sector target CM2	0.29%	2.9%	29%

Table 4: Three solar futures – compared to NDC targets

In addition to the mitigation pledges, the Indonesia NDC and National Energy Policy (Government Regulation No. 79/2014) set out the ambition to transform the primary energy supply mix share as follows by 2025 and 2050:

- *New and renewable energy at least 23% in 2025 and at least 31% in 2050;*
- *Oil should be less than 25% in 2025 and less than 20% in 2050;*
- *Coal should be minimum 30% in 2025 and minimum 25% in 2050; and*
- *Gas should be minimum 22% in 2025 and minimum 24% in 2050.*

Figure 12 shows the contribution of the three solar futures towards national energy target on new and renewable energy in 2030[12]. Currently, about 37 TWh renewable energy is produced annually. To reach the new and renewable energy target, an additional 152.3 or 120 TWh (DEN 2016 BAU or ALT1) of renewable energy should be generated in 2030 (excluding the role of biofuels in the transport sector). The 100 GW solar

[12] We assume here a minimum of 24,6% of the power sector mix in 2030 (linear growth). Next to the power sector the energy sector also encompasses transportation and heat.

future could solely contribute enough to reach this 2030 target in the DEN ALT1 (see **Figure 8** as well) and almost generate enough under the DEN BAU scenario, as it would generate 149 TWh of renewable energy in 2030. As mentioned earlier in this report; this comparison is somewhat flawed because a high deployment of solar PV, like 100 GW, cannot be seen in isolation of the power sector as a whole and would probably result in a different generation mix.

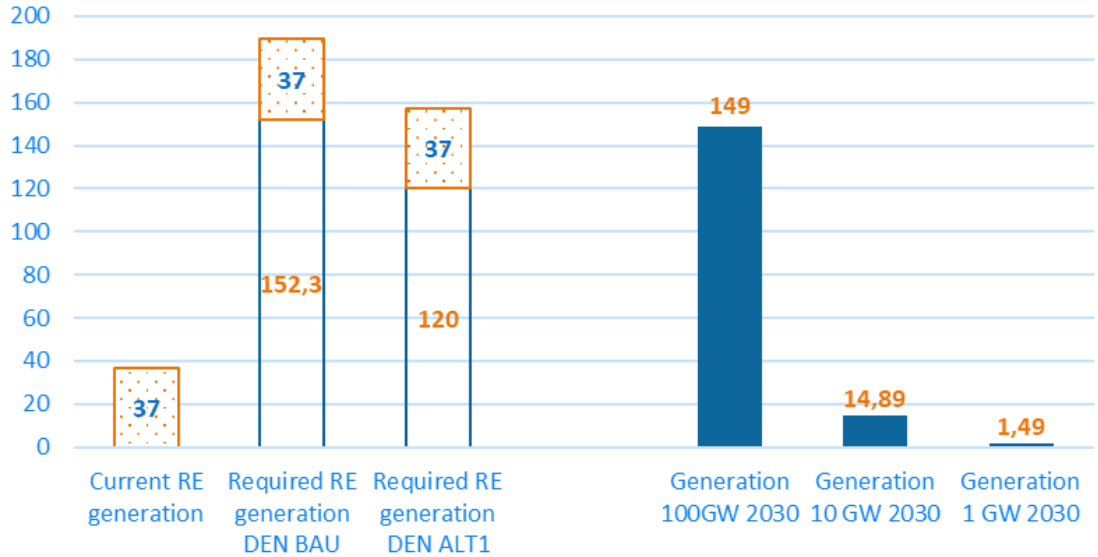


Figure 12: Three solar futures – compared to KEN energy demand targets

4.2. Reducing air pollution

Due to mobility and coal-fired steam power plants (PLTU) Jakarta was ranked as city with the worst air quality in Southeast Asia in 2018, with a daily average air quality 4,5 times worse that the limit set by the World Health Organization (IQAir, 2019). Coal-fired power plants emit next to CO_2, other pollutants like NOx and SO2. These gases are the major ingredients in the formation of acid rain and a major ingredient of fine particles (PM2.5 pollutions). They have been correlated with many health problems and directly and indirectly like skin, cardiovascular, brain, blood and lung diseases, and different cancers (Munawer, 2018). **Figure 13** visualizes the impact chain of air pollution by among others coal fired power plants.

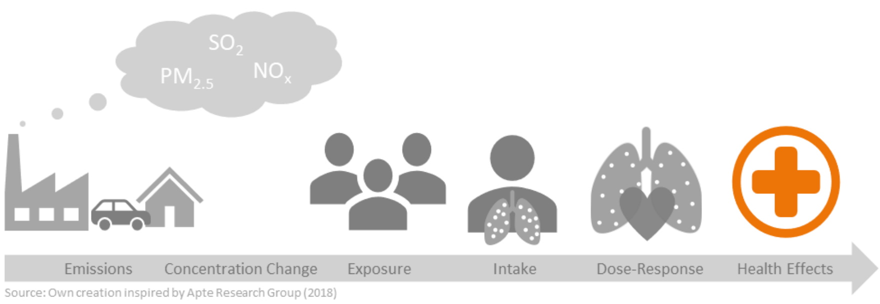


Figure 13: Air pollution - visualization of the impact chain

If solar deployment replaces new or existing coal-fired electricity generation, especially in dense urban areas of Indonesia, air pollution related health problems and deaths can be reduced. As a case example we look at a case study performed by New Climate Institute about the potential impact of the Central Java Power project. The Central Java Power project is also known as the Batang Power project: a proposed 1,900 MW coal fired power plant at the middle of the world most populated island of Java. The plant is expected to be commissioned in 2020 and has an assumed lifetime of at least 40 years. **Figure 14** shows the area in which the Indonesian population will be affected by various pollutions that the coal-fired power plant will emit. This covers potentially even more than only the 130 million inhabitants of the Java island itself, although by different levels.

Figure 14: Visualization of the affected area by the Central Java Power powerplant

An air pollution tool – AIRPOLIM-ES- the contours of which have been developed within the Ambition to Action project. The AIRPOLIM-ES is a transparent, Excel-based tool to provide a first avenue into quantifying the health impacts of air pollution from different fossil fuel electricity generation (see appendix C and D for more information and results). It provides an indication on the impacts on mortality from four adulthood diseases: lung cancer, chronic obstructive pulmonary disease (COPD), ischemic heart disease, and strokes, the prevalence of which is increased through exposure to air pollution. It is assumed that some emission control technologies will be installed in the Central Java Power project and the impacts are based on the average emissions factors for Indonesia from the renowned GAINS model on air quality.

	Premature deaths	Years of life lost
Average annual number	696	21,373
Until 2030	6,359	178,751
Until 2050	20,212	606,266
Total Lifetime (Until 2060)	27,860	854,946

Table 5: AIRPOLUM-ES results overview for Batang Power project

Table 5 shows that the Central Java Power project is expected to result, on average, in the premature death of 696 Indonesian every year, resulting in more than six thousand premature deaths until 2030. These results are in line with earlier research done by Greenpeace Indonesia on this specific power plant (Greenpeace, 2015). The ‘10 GW: bright but cautious’ solar PV future, could prevent the construction of about 2,400 MW of new coal-fired plants and thereby the premature death of hundreds of Indonesians every year through air pollution, based on the New Climate Institute case study.

5. Sustainable development impacts

This chapter provides an analysis on the potential linkages of solar deployment in each of the solar futures to the Sustainable Development Goals. The SCAN-tool used for this analysis, provides a first avenue into exploring the development impacts of Paris-compatible solar PV deployment. It points to situations where evidence-based analysis and dialogue can accelerate (co-benefits) the transition or hamper.

5.1.1. Nationally Determined Contribution & Sustainable Development Goals

In 2015, the Agenda 2030 on the Sustainable Development Goals and the Paris Agreement were agreed. Both frameworks are highly interlinked in their objectives: the Paris Agreement, focused on limiting climate warming to well below 2°C, emphasizes the need for sustainable development considerations in low-carbon transitions. At the same time avoiding dangerous climate change is one of the 17 Sustainable Development Goals (SDGs). This interdependency can be seen as an opportunity to pursue their implementation in a way to maximise mutual benefits. Mitigation actions part of the Nationally Determined Contributions of countries, are more likely to be implemented when they are embedded in and benefiting national development plans as well. In some cases, interactions between mitigation actions and SDGs actions may be mutually reinforcing, while in other cases action in one may undermine the achievement of the targets in the other. This holds true for solar PV deployment as well. Policy makers may be faced with strategic choices where insights into climate-development interactions are key for successful development and implementation of policies and targets, that serve both agendas. Such understanding can enable coherent policy planning and increase implementation efficiency, in particular when considering limited institutional capacities (Gonzales-Zuñiga *et al.*,2018).

5.1.2. SDG Climate Action Nexus Tool (SCAN tool)

The Ambition to Action project developed the SDG Climate Action Nexus tool (SCAN-tool) to create insights in the linkages between sector's mitigation actions and the seventeen Sustainable Development Goals (SDGs). The tool considers the potential synergies and trade-offs between SDGs and mitigation actions of sectors. The tool draws on existing scientific literature that maps the climate-development links and collects data from several studies on the nexus between climate action and specific development areas. It looks at different mitigation actions and their impact on achieving SDGs. Analysis of linkages to SDG 13 (climate action) and SDG 17 (Partnerships for the SDGs) are not included in the tool. Potential linkages to SDG 13 are not listed as the SCAN-tool is designed to help identify linkages between climate actions and other development areas, thus these links are implicitly represented in the assessed sectoral mitigation actions. SDG 17 is not included in the analysis because it is about mobilization of international resources to achieve the SDGs and is not a development area comparable to the other SDGs.

5.1.3. Solar PV deployment and SDGs in Indonesia

The SCAN-tool shows that there are potential linkages between solar PV deployment with 11 SDG and 24 SDG targets. In total there are 27 linkages of which 22 are positive (synergies) and 5 negative linkages (trade-offs). **Figure 15** shows that most potential linkages are identified with SDG 8 Decent work and economic growth, SDG 9 Industry, innovation and infrastructure and SDG 15 Life on land. Potential linkages with two out of three SDG 7 – Affordable and clean energy targets are identified.

	SDG	Positive	Negative
-1	**1: No poverty**		Land access (1.4)
-1	**2: Zero hunger**		Land access (2.3)
2	**3: Good health and well being**	Reduced health impacts from FF pollution (3.4; 3.9)	
-	4: Quality education		
-	5: Gender equality		
2	**6: Clean water and sanitation**	Reduced water consumption and water pollution in power sector (6.3; 6.4)	
2	**7: Affordable and clean energy**	Reliability of energy (reduced energy imports, increased diversification) (7.1; 7.2)	
5 / -1	**8: Decent work and economic growth**	Growth; diversification; resource efficiency; decent job creation (8.1; 8.2; 8.3; 8.4; 8.5)	Job losses from displaced FF activities (8.5)
4	**9: Industry, innovation and infrastructure**	Sustainable infrastructure; adopt clean technologies; R&D (9.1; 9.2; 9.4; 9.5)	
-	10: Reduced inequalities		
3	**11: Sustainable cities and communities**	Sustainable (electric) transport and urbanization; reduced environmental impact (11.2; 11.3; 11.6)	
1	**12: Responsible consumption and production**	Sustainable management and efficient use of natural resources (12.2)	
-	13: Climate action		
1	**14: Life below water**	Reduced water pollution and marine ecosystem impacts from FF activities (14.1;)	
2 / -2	**15: Life on land**	Reduced ecosystem impacts (15.1; 15.5)	Supply chain ecosystem impacts; land use (15.1; 15.5)
-	16: Peace, justice and strong institutions		

Figure 15: Solar PV as mitigation option – synergies and trade-offs with SDGs

Positive potential linkages show co-benefits potentials of which some are analysed in this study in more detail; like SDG 8 on job creation and SDG 9 on the development of sustainable industries related to renewable energy project construction and operation. Nonetheless, negative linkages can be even of more importance as the can hinder the transition. The topic of land use, for example, is of importance in the Indonesian context. Not only can large scale solar PV deployment reduce and/or compete for land and resource access for dependent communities but may as well impact natural habitats. Solar PV deployment on existing infrastructure, should therefore be the first option to go for.

6. Employment impacts

This chapter dives deeper into the frequently mentioned potential co-benefit of employment of solar PV. As part of this project we have explored the differences in employment effects between the deployment of coal power plants and the three solar PV futures in Indonesia. In the following sections the methodology and results of the analysis are elaborated.

Taking action in the energy sector to align with the Paris Agreement can be a major source of job growth in the future of work. The International Labour Organization (ILO) state around 24 million jobs can be created by the end of century by adopting sustainable practise in the energy sector, largely offsetting any job losses (ILO, 2019). Solar PV application in Indonesia might thus not only provide energy and climate opportunities but also employment opportunities. However, the introduction of renewable energy sources might replace fossil energy related jobs within a country as well. In developed countries with somewhat saturated energy sectors this replacement might result in net fossil fuel related job losses.

6.1. Direct and indirect jobs

An employment tool - Economic Impact Model for Electricity Sector (EIM-ES) - has been developed within the Ambition to Action project. The EIM-ES is a transparent, Excel-based tool that estimates the domestic employment impacts of investments in the electricity supply sector within a country to aid policy decision makers. The model covers all relevant electricity generation technologies – both low carbon and fossil fuel-based plants – in order to provide an assessment of employment creation under different future pathways for the development of the electricity sector. In addition, it differentiates between capital and operational expenses to provide insights in longevity. The basic methodology is a “follow-the-money” approach based on investment data per technology, split into component level (like module, inverter etc), domestic and labour share and average salary (see **Figure 16**).

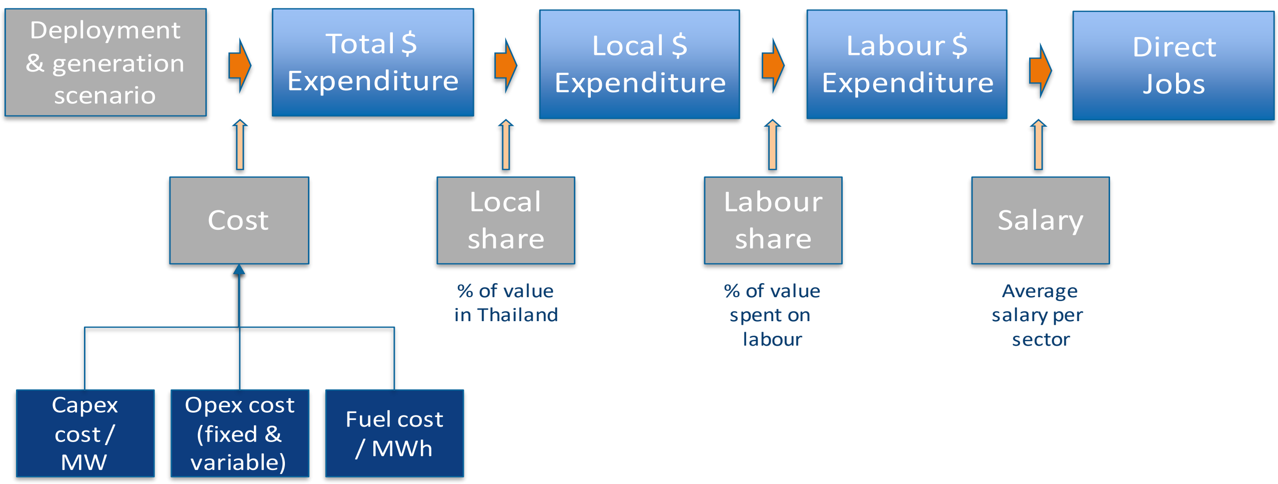


Figure 16: Schematic overview of the EIM-ES employment tool

The tool considers three different categories of employment, that extend beyond the electricity generation sector to all areas of the economy

- **Direct:** jobs created in the electricity generation sector (e.g. manufacturing equipment, construction of plants, professional services and project management, etc.)
- **Indirect:** jobs created in secondary sectors upstream in the supply chain (e.g. the metallurgical or mining industries)
- **Induced:** jobs created across all sectors of the economy as a result of an investment stimulus. The salaries of those that directly and indirectly benefit from the investment are spent on other, unrelated activities, such as rent, restaurants, healthcare, groceries…etc.)

Appendix A provides more information and an overview of the actual model inputs for the setup of Indonesia.

6.1.1. Employment impacts (1GW) Rooftop pioneers

The '1 GW: rooftop pioneers' futures consist of 1 GW of residential rooftop solar-PV deployment instead of 243 MW coal plant capacity (see previous chapters) and results in net positive employment impacts until 2030. Solar PV provides 47.500 directs job years compared to coal providing 16.300 direct job years in the period 2020-2030. This results in a net benefit (co-benefit) of 31.200 direct jobs years over a 10 years period.

The total net benefit of solar PV compared to coal, including induced and indirect jobs, is 55.500 job years of which the majority are direct job years (56%). Residential rooftop solar can provide about 98.000 job years until 2030, of which 47.500 direct (see **Figure 17**) These are only coming from capital expenditure (CapEx) of solar PV deployment. Operation and maintenance expenditures (OpEx) of residential rooftop solar are assumed to be negligible and/or performed by households themselves, like the occasional cleaning of the panels.

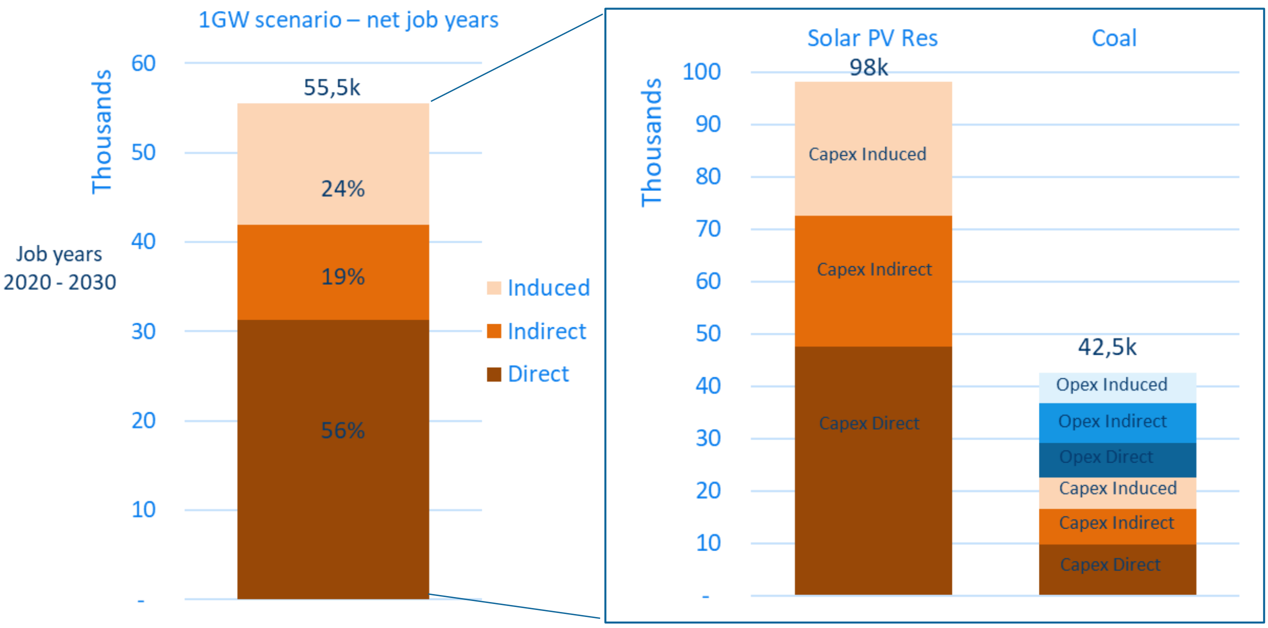


Figure 17: Employment impact of 'Rooftop pioneers' (1 GW scenario)

Generating the same amount of electricity with coal power plants could generate about 42.500 job years until 2030. The jobs years are more scattered among direct, indirect and induced jobs. Within the NDC timeframe until 2030, outcomes indicate that residential solar PV could overall provide more (direct) job years than the alternative of coal power plants, generating the same amount of electricity on a yearly basis.

Source: Sustainable Energy for All

6.1.2. Employment impacts (10 GW) Bright but cautious

The 10 GW solar future consist of 4 GW residential rooftop solar PV, 3 GW commercial and industrial solar application and 3 GW utility scale solar, as described in chapter 2. It could displace 2,43 GW of coal power plants. Choosing solar over coal generated electricity in this scenario until 2030, could result in an additional 286.000 job year until 2030. The various solar PV applications can provide 449.000 direct jobs years compared to coal providing 163.000 direct job years.

The total net benefit of solar PV compared to coal, including induced and indirect jobs, is 503.000 job years (see **Figure 18**). Dominant are again direct jobs (net 286.000 job years), coming from capital expenditures of solar deployment. Operation & maintenance expenditure and resulting job years of utility and industrial solar-PV are very limited. The alternative of coal power plants would result in more net operational & maintenance job years, compared to solar PV operational and maintenance jobs years until 2030, but do not outcompete the capex job years, resulting in the overall net positive employment impact of solar PV.

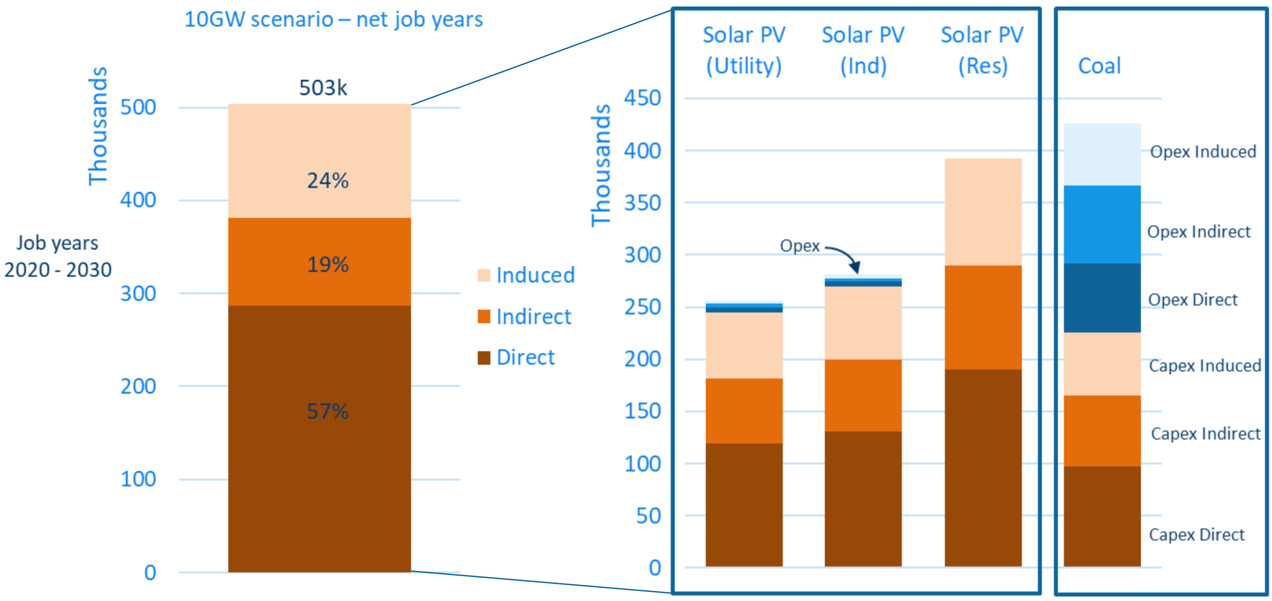


Figure 18: Employment impact of 'Bright but cautious' (10 GW scenario)

When looking deeper into the outcomes, it shows that solar PV module and inverter manufacturing (electrical equipment sector), solar-PV installation (construction sector) and project developing (other business services) could deliver most direct jobs along the value chain of the various solar PV applications, like the example of industrial and commercial application shown below.

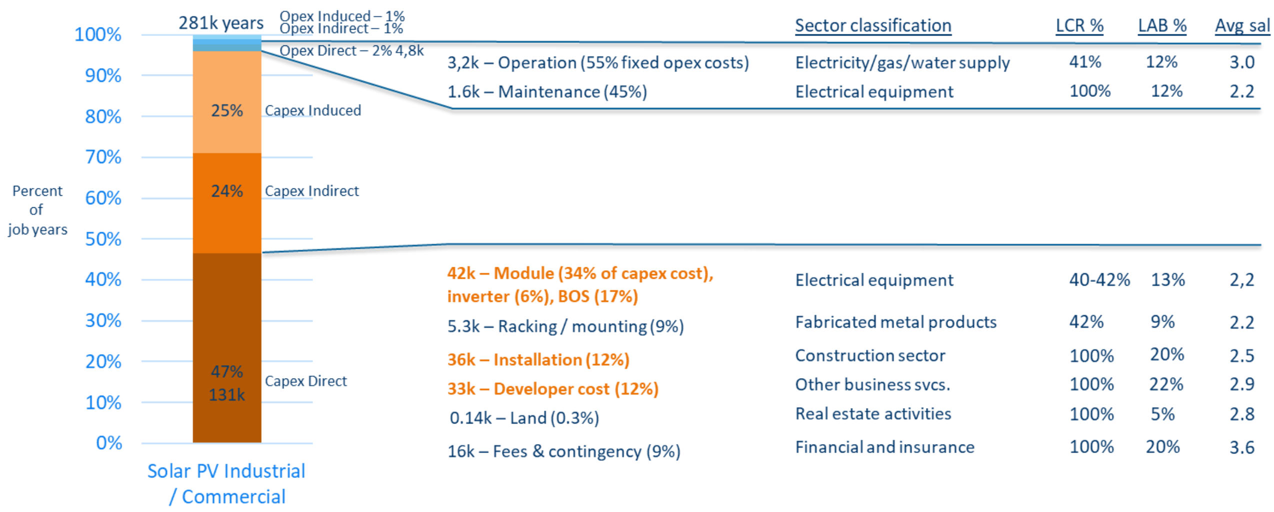


Figure 19: Direct Solar PV jobs: commercial and industrial

Comparing this with coal power plants jobs, expenditure on fuel cost (mining and extraction sector) and operation (electricity/gas/water supply services sector) delivers most direct jobs. It is worth mentioning that due to the intensive coal industry in Indonesia, the domestic share on fuel cost is assumed to be very high in contrast to coal importing countries, expecting positive employment impacts (other Indonesian domestic shares / local content ratio, including the 100% in **Figure 20** are based on Indonesian local content requirement regulation) However, the domestic price cap on coal, relative low labour shares in the mining and extraction sector compared to other sectors like construction and electrical equipment and high average salaries are offsetting factors.

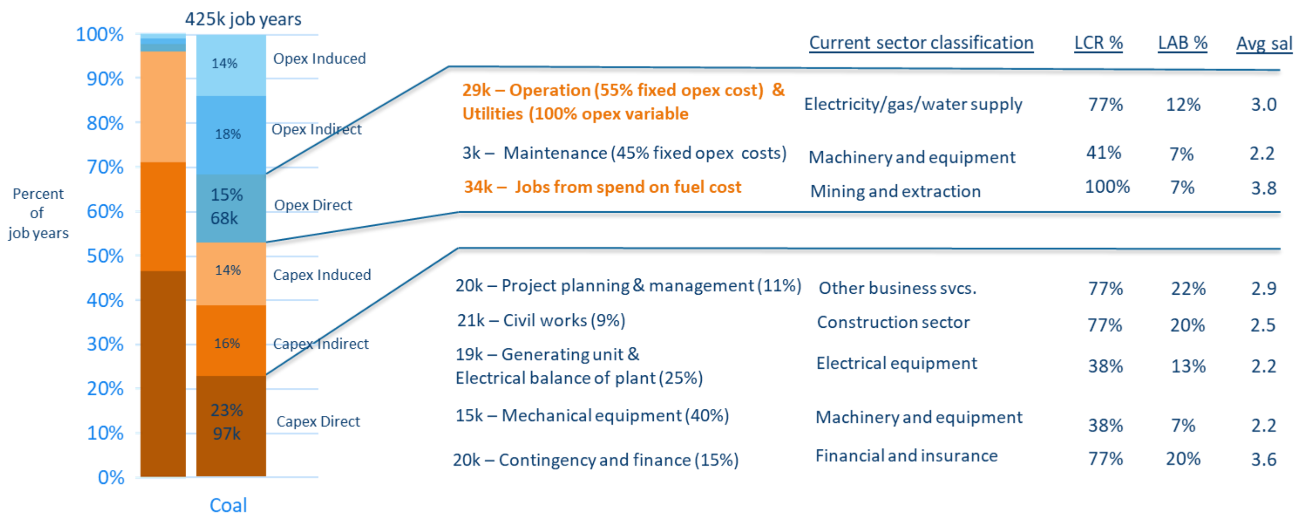


Figure 20: Direct Solar PV jobs: compared to coal

6.1.3. Employment impacts (100 GW) Solar power as growth driver

The 100 GW solar future consist of 25 GW residential rooftop solar PV, 25 GW commercial and industrial solar application and 50 GW utility scale solar, as described in chapter 2. It could compensate 24,3 GW of coal power plants deployment. The different solar PV application can provide about 4,4 million direct job years compared to coal providing 1,6 million direct job years. Choosing solar over coal generated electricity in this scenario until 2030, could result in an additional 2,7 million direct job years over a 10-year period.

The total benefit including indirect and induced jobs can be as much as 4,8 million job years until 2030. Dominant are again 2.7 million net direct jobs, coming from capital expenditures of solar deployment (see **Figure 21**). Similar to the previous scenarios, operation and maintenance expenditure and resulting job years of utility and industrial solar-PV are very limited. The alternative of coal power plants would result in more net operation and maintenance job years until 2030, but in the end do not outcompete the CapEx job years, resulting in the overall net positive employment impact of solar PV (see **Figure 21**).

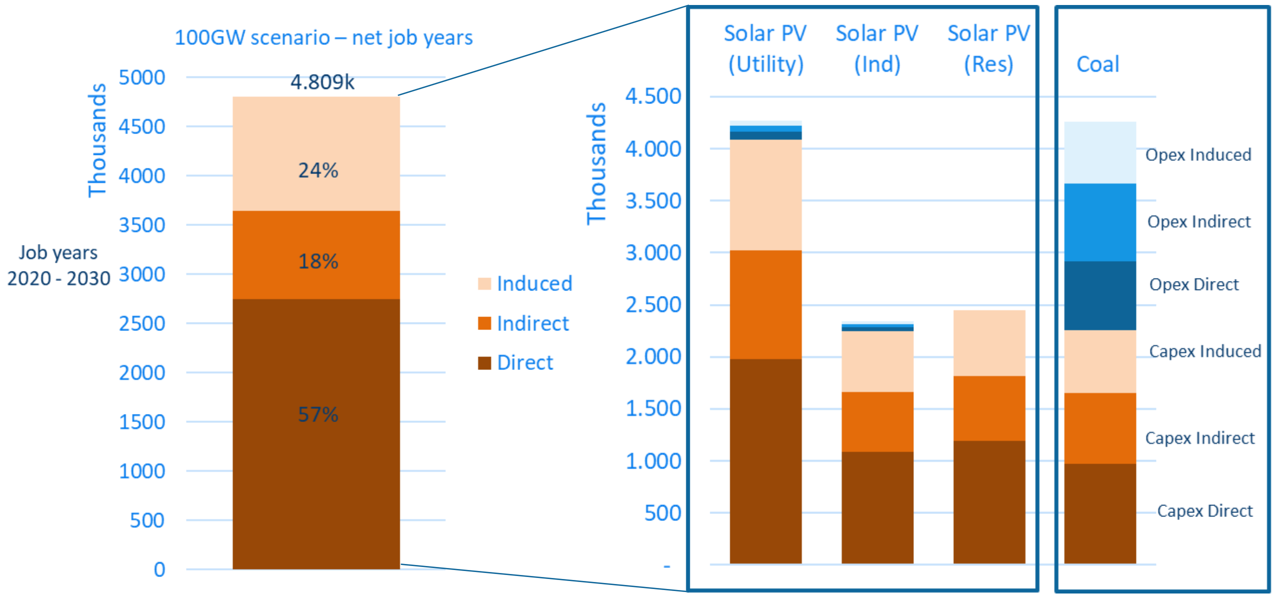


Figure 21: Employment impact of 'Solar PV as growth driver' (100 GW scenario)

7. Industry opportunities: local content and quality

Local content requirement policies can provide opportunities to harness additional shares of the value chain of solar PV, that otherwise would maybe not have been harnessed domestically, and opportunities for domestic industries to develop and mature in these parts. Therefore, the local content or domestic share is not only an important parameter regarding employment impacts of the various solar futures but is directly linked to industrial opportunities as well. This chapters provides an analysis of the current local content requirement (LCR) policy of solar PV in Indonesia (with input from PT Southpole Indonesia, commissioned by ECN.TNO) in relation with solar PV deployment.

7.1. Local content requirement

Industrial development and (green) growth opportunities are often presented as a co-benefit of climate mitigation actions. The Government of Indonesia realize the opportunities that can be "*gained by transforming our development model……. to a more innovative approach that puts in place the sustainable development principles and balance economic, social and environmental aspects. There is no need to make a trade-off between economic growth and environmental protection* (The Low Carbon Development: A Paradigm Shift towards a Green Economy in Indonesia - Bappenas, 2019).

These opportunities hold true for the energy sector as well, by for example clean technologies that can reduce energy and emission intensity and increasing renewable energy shares. Many governments justify renewable energy support policies on the grounds that such policies can help to create domestic employment (especially in the manufacturing sector), private (industrial) sector development, value added and promote exports. Therefore, some countries have coupled these renewable energy support policies to local content requirement (LCR). Local content requirements regulation requires renewable energy developers to source a given minimum percentage of their project equipment, goods and services from domestic sources (Rivers and Wigle, 2011).

In the past, China, Spain, Italy, France, Greece, Brazil, India, and the Canadian provinces Ontario and Quebec are examples of countries that used local content recruitment policies for wind and/or solar projects. China and Spain both used local content requirements since at least 1995. Most of them have abolished or loosened these requirements for quite some time, driven among others by the WTO ruling and scrutinizing against the use of local content requirements (OECD, 2015)[13]. In 2010, various WTO members raised concerns over local content requirements used in the Canadian province of Ontario's feed-in tariff program for renewable energy, that was inconsistent with international trade rules. This challenge resulted to more attacks of such measures e.g. the US dragged India to the WTO multiple times for non-compliance of India's solar domestic requirement under the country's National Solar Mission and the EU (member states) and China were both complainants and respondents of disputes (Hestermeyer and Nielsen, 2014; PV Magazine India, 2019; OECD, 2015). This made local content requirements a controversial industrial policy tool. Today, developing countries like Argentina, Brazil, South Africa, Jamaica and Jordan still use local content requirements for solar PV. Except for Indonesia and Malaysia (although more shaped like a premium), other ASEAN member countries do not have LCR policies in place for solar PV.

[13] *Local content requirements typically require components to be manufactured 'locally'or 'domestically' which is typically defined as taking place place in specific country or region, regardless of the firm's nationality.*

7.1.1. LCR on solar PV and wind – arguments and impacts

Various studies and countries experiences indicate that the impact of LCRs on solar PV, in terms of increasing domestic manufacturing, value added and creating local jobs, have a mixed or negative effect (OECD, 2015). LCR can, among others, hamper international trade and investment (diverting to countries with no LCR), reduce competitiveness and raise the cost of inputs for domestic and downstream businesses along the PV value chain. These increased cost result in diminished or no profitability of downstream project developers and investors. This result in the blocking new solar PV project development, resulting in reduced deployment of solar PV and in the end reducing domestic solar PV manufacturing. Alternatively, increased wholesale prices of electricity are also possible, as costs are passed through to the market (OECD, 2015). This introduces a trilemma between the (1) domestic share (via LCR), (2) the cost and (3) deployment of a clean power technology. From a climate mitigation perspective deployment is essential and very depended upon the cost of the mitigation option. High cost will limit deployment and/or negatively impact energy affordability, if they are not compensated with subsidies. It can therefore be argued that local content requirements can act as a barrier for climate mitigation options. However, LCR have often been introduced in countries to provide political benefits as they can broaden the basis of support for renewable energy incentive programmes and increased ambition (OECD, 2015).

7.1.2. LCR solar PV policy in Indonesia

Indonesia has a long history of local content requirement policies in various sectors. The first local content requirement policy can be traced back to the early years of independence around 1950 to reduce the economic dominance of the Dutch and ethnic Chinese businesses (Negara, 2016). One of the most prominent sectors were local content requirements have been used from the 1960s onwards, is the car manufacturing industry. Over decades the LCR in this sector has been gradually increased as part of a broader national automotive strategy that included as well supporting policies on R&D, education, market development and quality.

Regulation	Content	Target stakeholder
MoI Regulation No. 54 of 2012 on Guidelines for the Use of Domestic Products for Electricity Infrastructure	Minimum LCR for electricity infrastructure for various energy sources, including solar PV	• Project owner/developer
MoI Regulation No. 5 of 2017 revising MoI Regulation No. 54 of 2012	Revises MoI Regulation No. 54 of 2012 specifically to increase LCR for solar PV system	• Project owner/developer
MoI Regulation No. 4 of 2017 on the Definition and Calculation Method of Local Content Ratio for Solar PV System	Methods for calculation of LCR in solar PV system using weighting factors for each component. LCR calculation for solar PV module is also introduced in this regulation	• Project owner/developer for calculating the local content of their solar PV system • Solar module manufacturers for calculating the local content of their products
MoI Regulation No. 16 of 2011 on the Definition and Calculation Method of Local Content Ratio	Method for calculation of LCR for solar PV goods and services in Indonesia (except modules).	• Manufacturer

Table 6: Local content requirement – relevant regulations[14]

[14] *Source: PT Southpole Indonesia*

Local content requirements policy for the electricity infrastructure for various energy sources including solar PV, was first introduced in 2012 by MoI Regulation No. 54/2012. It was later revised in 2017 (MoI Regulation No. 5/2017) specifically to increase the LCR for solar PV systems and complemented with additional regulation (MoI Regulation No. 4/2017) as a follow-up to the '35.000 MW electricity generation target by 2019' set by the GoI in 2015 (see **Table 6**). The regulations were made to ensure the participation of domestic industry in the power sector and to boost domestic industry. Next to the Ministry of Industry, cross-sectoral stakeholders were involved in the policy formulation and setting the minimum requirements, like the Directorate General New and Renewable Energy and Energy Conservation under the Ministry of Energy and Mineral Resources (EBTKE ESDM), the Association of Indonesia Solar Module Manufacturers (APAMSI) and downstream solar PV manufacturers. Renewable energy project developers were not involved in the discussion. As stipulated in MoI Regulation No.5/2017, project developers are required to use domestically produced materials (local content) in their on-grid solar PV system. The minimum ratio of local content is as follows:

- solar modules (40%)
- goods (34.09%), services (100%) and combined (goods and services) (40.68%)

Type of system	Component	Weighting factor for local content	Local content requirement			
			Good-specific	Goods	Service	Combined
Centralised on-grid solar PV system	Solar modules	40.50%	40.00%	34.09%	100.00%	40.68%
	Inverter	13.50%	Not specified			
	Mounting system	10.80%	42.40%			
	Distribution panel (electric panel)	6.30%	40.00%			
	Transformer	5.40%	40.00%			
	DC combiner box	5.40%	20.00%			
	Protection system	4.50%	20.00%			
	Cables (AC and DC)	3.60%	90.00%			

Table 7: Detailed local content requirements for solar PV installations (Regulation No. 5/2017)

Solar module components	Weight factor
Solar cell	
Silica sands procurement	2.5%
Silicon metallurgical grade manufacture	7.5%
Silicon solar grade manufacture	15.0%
Ingot manufacture	5.0%
Brick manufacture	2.5%
Wafer manufacture	2.5%
Blue cell manufacture	7.5%
Printing cell	7.5%
Tempered glass	12%
PV junction box	8%
Back sheet	4%
Frame	9%
Eva film	4%
PV ribbon	2%
Solar silicon	2%
Labour	5%
Production machinery	4%

Table 8: Detailed local content ratios for solar PV modules (Regulation No. 4/2017)

The LCR on solar PV modules is even further detailed in MoI regulation No. 4/2017 for solar PV manufacturers. This regulation stipulates methods to calculate the LCR of solar PV systems and includes specific ratios for solar PV module components (see **Table 8**).

LCR policy in the power sector applies to all electricity infrastructure built by state-owned enterprises (e.g. PT PLN), region-owned enterprises, the private sector and cooperatives using the central/regional government budget/grants/foreign loans. Types of projects under the scope of LCR policy include PLN projects, Ministry of Energy and Mineral Resources projects, as well as Independent Power Producers (IPPs) entering into a power purchase agreement (PPA) with PLN. Behind-the-meter application (e.g. residential/commercial users) are not in the scope of the policy. For industrial application, if excess electricity is sold to PLN or a neighbouring community under a PPA, the LCR policy still applies. Projects owner/developer, who must adhere to the LCR policy, may import materials in some cases, like if materials are not produced or available domestically or cannot match requirements set by developers. However, it turns out to be difficult for developers to be allowed exemption in those cases. Even when materials are not available domestically, developers often need to have lengthy negotiations with PLN and local content surveyors and provide strong evidence to avoid sanctions. Both administrative (up to the company is being blacklisted from participating in PLN tenders process for two years) and financial sanctions (up to 10% of the project value) can be imposed on project developers if the LCR is below the required percentage, falsified or cannot provide supporting documents). On manufacturers only financial sanctions can be imposed if manufacturers deliberately produce goods/services with actual LCR below the proposed LCR. The amount of financial sanction is calculated as the difference between proposed LCR and actual LCR multiplied by the proposed offered price.

7.1.3. Impact of increasing the LCR

The MoI Regulation No. 05 of 2017 includes a plan to increase the minimum LCR specifically of solar PV modules from 40% (2017) to 50% (2018) and to 60% (2019). Hereby trying to harness a larger share of the solar PV value chain, and specifically of the solar PV module that, in spite of extreme declines in the last decade, remains dominant in the value chain (see **Figure 22**). The plan to increase the LCR on solar PV modules were set together with local manufacturers, who were confident at the time that the targets could be easily achieved, assuming demand for solar power generation would increase over time. However, it has proven more difficult to achieve the LCR for solar modules by domestic manufacturers, until now. To increase the overall LCR of solar PV modules, more upstream steps of the solar module manufacturing value chain should be performed domestically, like solar cell production or even ingot and wafer production. Ingot, wafer and cell production manufacturing is very capital and energy intensive. Almost all of the world-wide wafer and cell manufacturing is conducted by only a small number of large companies. For modules assembling this situation is different. Assembling of solar modules with imported and/or purchased solar cells is done by a somewhat larger group of companies in various countries and is also done within Indonesia by domestic and foreign companies.

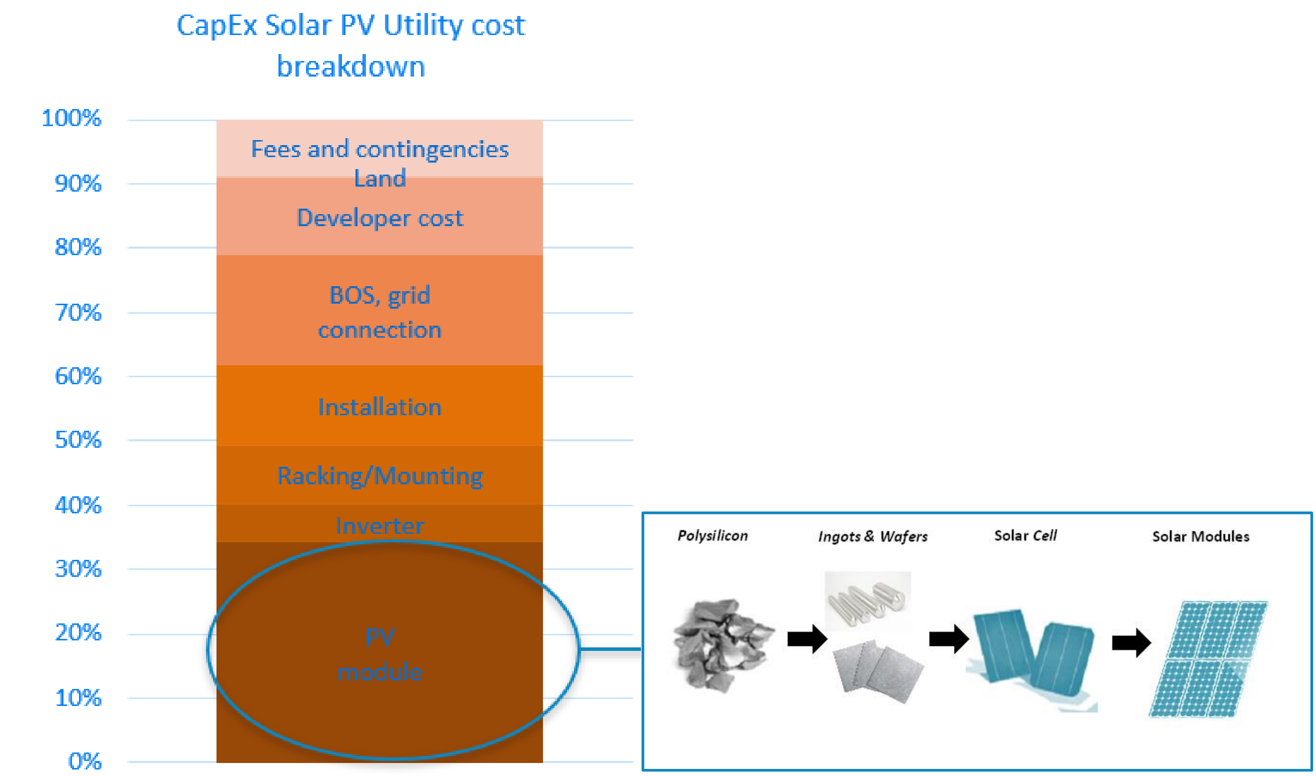


Figure 22: Solar PV capital cost breakdown[15]

7.2. Quality

The following section on quality aspects regarding solar PV in Indonesia is based on the Bappenas support study for the RPJMN 2020-2024 in the frame of the PTB project "Strengthening quality infrastructure with Special Regard to the Energy Sector – Priorities for quality infrastructure development for photovoltaics in Indonesia". PTB is the Physikalisch-Technische Bundesanstalt (PTB) is the National Metrology Institute of Germany and the highest authority for accurate and precise measurements in Germany. Quality aspects are crucial all along the value chain of solar PV, from manufacturing until operation and maintenance.

The different solar PV futures of 1, 10 and 100 GW do not influence the prioritization of quality infrastructure development and or requirements. In addition, quality requirements for different applications of PV systems are more or less the same. The same kind of PV modules are used in residential, commercial and utility scale systems. Likewise, the DC wiring and components used are the same. However, the size and numbers of PV systems does influence the demand for quality infrastructure services, and in return, the number of quality infrastructure service providers. Meeting a 6.5 GW target from 1 kW residential rooftop PV systems requires 6.500.000 systems. However, meeting the same target with 1 MW utility systems requires "only" 6.500 systems. In either case, the quality infrastructure requirements are large, but in the case of residential rooftop, more inspectors may be required. Secondly, distribution of services across Indonesia does influence the demand. The more demand across all regions of Indonesia, the more quality infrastructure services provides (e.g. testing, inspection, monitoring etc.) in different parts of the country will need to be developed.

[15] *based on a.o. IRENA 2019, NREL 2019*

Box 3: Quality standards for Solar PV

Solar PV is often perceived as a comparatively easy technology and therefore quality and safety issues might be given little consideration by policy makers, investors, end users and even industry actors. Nonetheless, industry experts note that quality and safety issues which lead to performance losses and safety risks remain frequent in the PV sector. This was confirmed in a study by TÜV Rheinland, which found that nearly one third of over 100 PV plants worldwide had serious defects (TÜV Rheinland 2015, p.6). It thus needs to be considered that quality gaps can occur along the PV value chain – from component production to operation of the system – and can have a substantial impact on the long-term performance of the PV plant.

Quality infrastructure development, including standardization, metrology, testing, inspection, certification and accreditation, as well as relevant regulations and other framework conditions for the PV sector need to be addressed with a holistic approach. The decision on which quality infrastructure services should be the priority, depends on the approach and focus chosen for PV development in Indonesia.

At the same time, locally manufactured PV components are not always able to satisfy international quality standards. This is a common issue in countries with a relatively new PV sector, as the industry is still lacking practical experience. This knowledge can only be developed over time. Strict requirements for module selection are important to reduce risks by obliging the supplier to provide evidence of long-term durability of products. Certification in accordance with international standards should be the minimum quality requirement for PV components.

Source: PTB (2018)

Another aspect that does influence quality aspects, is the type of scenarios for the solar PV (manufacturing) sector development occurring in Indonesia, as touched upon earlier. In theory, the more added value is created in Indonesia (manufacturing of new components, increase productivity and performance, innovations etc.) the more and new quality infrastructure services would be needed and developed in Indonesia. However, quality infrastructure focusing on the downstream components of the value chain should be developed first.

Finally, lacking a quality infrastructure would have enormous negative impacts on Indonesia. Not only, would it have direct financial and emissions impacts due to reduced electricity generation, but moreover it would make people believe that solar PV is an unreliable technology and this in turn, would negatively affect future investment and policy decisions.

8. Discussion

The Paris Agreement and latest IPCC reports confirm that drastic decarbonization is needed. The fast-developing power sector of Indonesia will become the largest CO_2 emitting sector and an important factor for Indonesia's long-term commitments under the Paris Agreement. The dramatic drop in the cost of solar PV globally has also resulted in plummeting cost of solar PV in Indonesia. Although there is good solar PV potential, the deployment in Indonesia is limited so far compared to other countries in the regions where deployment has increased significantly over the last few years. The three solar futures of 1, 10 and 100 GW give a sense of the features and implications of solar PV deployment on three different scales and ambitions over the period 2020-2030.

	1 GW Rooftop pioneers	10 GW Bright but cautious	100 GW Solar PV as growth driver
Capacity[16]	1 GW residential rooftops solar PV	4 GW residential rooftops solar PV	4 GW residential rooftops solar PV
		3 GW commercial solar PV (<1 MW and including BIPV)	3 GW commercial solar PV (<1 MW and including BIPV)
		3 GW utility scale solar PV (> 1 MW and including floating solar)	3 GW utility scale solar PV (> 1 MW and including floating solar)
Numbers	~ 500k residential rooftops (average size 2kWp)	~ 2 million rooftops (average size 2kWp) > 3.000 commercial solar PV rooftops / ground mounted installations / BIPV.	~ 12,5 million rooftops (average size 2kWp) > 25.000 commercial solar PV rooftops / ground mounted installations / BIPV.
	~ 4 million solar panels of 250W	~ 40 million solar panels of 250W	~ 400 million solar panels of 250W
	~ 10 km^2 solar PV installations	~ 100 km^2 solar PV installations	~ 1000 km^2 solar PV installations
Energy[17]	1,49 TWh annually (2030 onwards)	14,9 TWh annually (2030 onwards)	149 TWh annually (2030 onwards)
	Coal capacity equivalent: 243 MW	Coal capacity equivalent: 2,4 GW	Coal capacity equivalent: 24,3 GW
Emissions reduction[18]	1,14 Mton CO_2 (2030 onwards)	11,4 Mton CO_2 (2030 onwards)	114 Mton CO_2 (2030 onwards)
Employment	32.000 clean energy job years (until 2030) and up to 58.600 including indirect and induced jobs	Over 300.000 clean energy job years (until 2030) and up to well over half a million including indirect and induced jobs	Over 3 mln clean energy job years (until 2030) and up to well over 6 mln including indirect and induced jobs

Table 9: Overview of three solar PV futures in numbers

8.1. Look beyond net impacts

The outcomes presented above are based on the Indonesian NDC timeframe until 2030, to provide insights in the potential role of solar PV in future Indonesian NDCs. Solar PV deployment provide most opportunities

[17] *Solar runs at 17% capacity factor; 1kWp takes up 10m2.*

[18] *If solar PV replaces coal. Coal runs at 70% with an emission factor of 1;*

for jobs at the beginning of the lifetime of solar PV power plants (CapEx related jobs). Coal power plants, in contrast, spread out a significant part of the job opportunities over the whole lifetime of the coal power plant (OpEx related jobs). Thus, the timeframe itself chosen affects employment impacts across both technologies. An additional analysis was performed with a longer timeframe of 2020-2045 (with no capacity addition after 2030). Outcomes still showed more direct jobs (of CapEx & OpEx) for solar PV until 2045, compared to coal power plants, however with a much smaller margin. Hence, results seem to still be in line with outcomes of the analysis until 2030. In contrast, indirect and induced job years showed to be in favour of coal power plants. One explanation of this can be the role of coal, interwoven in the economic structure of Indonesia, reflected by the input-output table. Finally, the downside of these more longer-term analyses is among others, the higher uncertainty as even more changes on the input variables can be expected over time, like fuel costs.

Another important consideration is the local content requirements regulation that is used in this analysis versus actual domestic shares that are achieved. Enforcement and actual achievability of domestic shares are essential to actual harness the job potential.

Although automation within solar PV modules is already very advanced, it can be further affected by robotization and manufacturing to achieve productivity gains and cost reduction. The availability of well qualified personnel is essential to fulfil solar PV job opportunities. Human resource development, education, training and skill development are essential to provide enough and well qualified personnel for example solar PV plant design, installation and operation and maintenance services and key for the successful development of the sector.

While national level analysis may show that the employment impacts for solar PV deployment can be positive, this might hide important differences at the regional or sector level. Additional research should provide more insights in this, in combination with distribution among gender, religion, age and income classes. The distributed characteristic of solar PV deployments provides more opportunities of geographical spreading and reduced labour mobility effects compared to centralized, large-scale coal power plants that attracts many workers, impacting local communities. To ensure a 'just transition' it will be necessary to identify the potential losers as the energy and economic systems decarbonize and provide them with the necessary support. Failure to do so will quickly create strong opposition to mitigation policy.

8.2. Set realistic business expectations

Today Indonesian domestic assembled solar panels are already about 25-30% more expensive than imported solar PV panels, after tax (according to interviewed industry sources). Subsidies on solar PV module manufacturing, predominantly by China, contribute to this difference. Nonetheless, the role of the Indonesian LCR on solar PV cannot be ignored as a driver of this difference in price as well. Therefore, the gist of a further increase of the LCR on solar PV modules (as included in MoI Regulation No. 05/2017) is rather about the impact on the cost of solar PV in Indonesia, as it is about the technical feasibility. A further increase of the LCR on solar modules without focus on cost competitiveness improvements, would results in even higher prices of solar PV modules. As described earlier, a further increase of the cost of solar PV by domestic manufactures would result in even more reduced or no profitability of downstream investors and projects. If not compensated with subsidies, this would decrease deployment of solar PV and thereby reduce the demand and insufficient market for scale up for domestic manufacturing of solar PV modules. Hence, the employment benefits of solar PV, as shown before, could not be harnessed in such a situation. In addition, the global solar PV manufacturing sector has evolved to a scale that goes far beyond most domestic market's needs, with companies producing on GW scales annually. To remain competitive in this sector an internal market will not per se be enough and exporting opportunities have to be considered, at least within solar futures of 1 or 10 GW up to 2030 as presented in this study.

Deployment of solar PV without local content requirements policy, would still have a local content in straightforward domestic activities along the value chain, like civil works, installation and project developing. In the Netherlands, recent offshore wind tenders (without LCR requirements) won by foreign project developers do result in domestic settlement, setup of maintenance centres and involvement of domestic companies in the development and maintenance of these offshore wind parks. Local content requirement policies can indeed provide opportunities to harness additional shares of the value chain, that otherwise would maybe not have been harnessed domestically, and opportunities for domestic industries to develop and mature in these parts. The impact of LCR percentages on solar PV might be limited when they cover activities that are naturally performed domestically or can be easily met. The Indonesian solar PV LCR policy, especially the urge to increase the LCR on solar PV modules, are beyond this point and do have its impacts like increased cost of solar PV modules compared to global prices. Moreover, the introduction of the LCR has not resulted in a flourishing domestic sector so far. Integrated policy or policy alignment on affected sectors like industry, energy and education is essential to overcome this. For example, industry policies should stimulate local industry (capabilities) and effective LCR policy that is aligned with energy policies that should provide ambitious domestic market opportunities by solar PV deployment on a scale that goes far beyond the 1 GW and 10 GW solar PV futures. Finally, education, training and skill development are essential to build the skilled workforce that are necessary to harness the employment opportunities that can arise from an integrated solar PV strategy.

8.3. Choose the right ambition level

The 1 GW ‘Rooftop pioneers’ solar future focuses on residential rooftop solar provides advantages in urban settings. The 1 GW solar PV future is not ambitious for Indonesia and the impact on national energy and NDC climate mitigation targets is limited. Still, it can provide valuable experience and employment opportunities. The 10 GW ‘Bright but cautious’ solar PV future is more ambitions, although the impact on national renewable energy and NDC climate mitigation targets remains limited as well. It provides opportunities to harness additional direct, indirect and induced jobs, compared to coal power plant deployment, for an equivalent amount of electricity generation, and if local content requirements turnout to be feasible. The 10 GW solar PV future does present a market for domestic industrial opportunities along the value chain. Yet, it can be argued that the domestic 10 GW solar future itself is not ambitious enough to set up a sustainable, competitive domestic solar manufacturing sector (including solar cell production), with global players today already producing on GW scales annually. Exporting opportunities on regional and global scale can provide additional market opportunities but require even more competitiveness on cost, quality and innovation levels. In the solar futures of 1 and 10 GW, the shares of solar power in the electricity mix of main Indonesian grids (Java-Bali and Sumatra) will remain low and grid integration should therefore not be a major obstacle in these grids, excluding local level issues.

The 100 GW ‘Solar Power as growth driver’ future is a game changer. It could contribute to about 36% of the NDC energy sector mitigation target (if solar is deployed instead of new coal power plants), produce about 20% of the power sector demand in 2030 and could almost full achieve the national renewable energy target. It increases the diversification of the Indonesia electricity generation mix and can thereby strengthen energy security. Integration of high shares of variable renewable energy like in the 100 GW solar future do bring challenges regarding grid integration in Indonesia. More research is required on security of supply and grid integration of this solar PV future. However, accommodating large amounts of new capacity that are expected in Indonesia anyhow, already require major power grid reinforcements, extensions and up-to-date grid management, independent of whether new capacity is based on variable renewables or not. International experiences in various countries today, already show far beyond 20% share of variable renewable energy is feasible without compromising energy security. Best practices and strategies do not point solely to storage, but at various options available all over the system (operation, markets, supply, demand, grid, storage and conversion and system integration) that can increase flexibility to keep power systems reliable, affordable and sustainable. Even adding 100 GW of solar PV does require almost none existing coal operations to scale down. The 100 GW 'Solar power as growth driver' future can generate enough power to cancel all new and additional coal plants to 2030, considering the ALT1 power sector growth projection of the National Energy Outlook Indonesia (DEN). In addition, the 100 GW solar future could decrease the growth of domestic coal demand (taxed with a domestic price cap) with 33-44% in 2030.

The 100 GW solar future presents substantial employment co-benefit (more than 2,7 million direct job years additional over the period 2020-2030 compared to coal, based on our analysis and estimates. Harnessing this opportunity is inter alia highly dependent upon aligned or integrated policies. Industrial policies should stimulate domestic industry (capabilities) and effective LCR policy that is aligned with energy policies that should provide ambitious domestic market opportunities by solar PV deployment. LCR can only become effective if it is combined with stabile renewable energy (solar PV) support to harness industrial development and employment opportunities. Education, training and skill development are essential to build the skilled workforce that are necessary to harness the employment opportunities that can arise from an integrated solar PV strategy. Finally, an integrated and ambitious solar PV strategy can be used as message to the international community to attract foreign investment to accelerate a transition towards a low-carbon energy sector of Indonesia.

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Appendix A – Employment model inputs

Employment model[20] methodology and setup

The first step is to input the deployment and generation scenario, detailing annual capacity additions and retirements (in MW) and annual generation in (MWh) for each technology. The model allows multiple different scenarios to be compared.

Cost inputs are then used to estimate the total required expenditure for a specific deployment and generation scenario. Various costs are included: capital expenditure ('capex') investment costs per MW of new capacity; operations and maintenance costs ('opex'; including both fixed yearly costs per MW and variable costs per MWh), and fuel costs. The capex costs for each technology are entered at a component level (e.g. solar PV cost inputs are entered for the PV module, inverter, balance of system, as well as costs for construction, project development, financing, etc) and these costs are allocated to specific sectors of the economy (e.g. investment on PV modules and inverters is allocated to the electrical equipment manufacturing sector, and plant construction expenditure to the construction sector) so that the economic results can be shown at a sector level (as well as by technology).

The next step is to work out what proportion of the total required expenditure is retained in the country (rather than being spent on imports of equipment, fuel or services). The key input is estimates of the 'local share', which represent how much expenditure is spent domestically and what portion is spent on imports. By default, the EIM-ES determines local share values for each component of a technology based on a country-specific Input-Output (IO) table, for the sector the component is allocated to. While the IO tables provide estimates of the percentage of imports used at a sector level, these are unlikely to be accurate for specific power generation technologies and components. For example, while the IO table may show that the electrical equipment sector has a local share of 60%, specific components such as PV modules may be mainly imported, so a much lower local share would be more accurate. In the case of Indonesia detailed local content requirements are set by the Ministry of Industry on solar PV components and coal power plants projects. More information on the local content requirement policies and ratios is provided in Chapter 8.

The third calculation step in the EIM-ES is estimating how much of the domestic expenditure is spent on labour, based on economic statistics on the portion of expenditure spent on labour (and not on e.g. land, materials, etc.). As with local shares, by default sector average labour shares are estimated from the country-specific IO table but the user can specify other labour shares if better data is available.

[20] *More information on the tool (methodology, overview and user guide) and the tool itself can be found at: http://ambitiontoaction.net/*

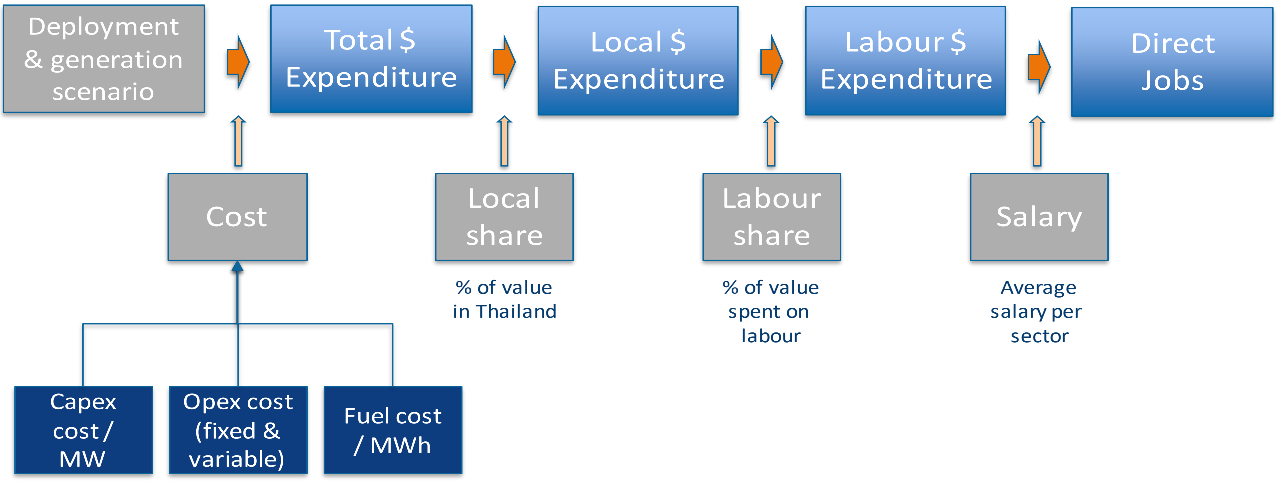


Figure 23: Schematic overview of key inputs (grey boxes) and calculation steps in the EIM-ES

Quantifying the indirect and induced employment impacts are drawn on macroeconomic statistics (input – output tables) of the country. **Figure 24** provides an overview of other necessary Indonesian model inputs to analyse the three solar futures.

New capacity	1, 10, and 100 GW solar futures and developed growth pathways
Generation	Calculated
Investment	PT SouthPole Indonesia & ECN research
Local share	Indonesia LCR policies: Ministry of Industry (MOI) Regulation No. 54/2012, MOI Regulation No. 5/2017 & No. 4/2017
Sector	ECN & NewClimate Institute analysis
Input Output	OECD tables
Salaries	Sakernas - National Labour Force Survey (NLFS) 2017-2018

Figure 24: Overview of inputs and input sources

Average annual salaries

The average annual salary should be a Full-time Equivalent (FTE). Investment estimates are divid

Sectors	Salary *US$k*
D01T03: Agriculture, forestry and fishing	1,56
D05T06: Mining and extraction of energy producing products	3,79
D07T08: Mining and quarrying of non-energy producing products	3,79
D09: Mining support service activities	3,79
D10T12: Food products, beverages and tobacco	2,23
D13T15: Textiles, wearing apparel, leather and related products	2,23
D16: Wood and products of wood and cork	2,23
D17T18: Paper products and printing	2,23
D19: Coke and refined petroleum products	2,23
D20T21: Chemicals and pharmaceutical products	2,23
D22: Rubber and plastic products	2,23
D23: Other non-metallic mineral products	2,23
D24: Basic metals	2,23
D25: Fabricated metal products	2,23
D26: Computer, electronic and optical products	2,23
D27: Electrical equipment	2,23
D28: Machinery and equipment, nec	2,23
D29: Motor vehicles, trailers and semi-trailers	2,23
D30: Other transport equipment	2,23
D31T33: Other manufacturing; repair and installation of machinery and	2,23
D35T39: Electricity, gas, water supply, sewerage, waste and remediati	2,98
D41T43: Construction	2,25
D45T47: Wholesale and retail trade; repair of motor vehicles	1,95
D49T53: Transportation and storage	2,77
D55T56: Accomodation and food services	1,87
D58T60: Publishing, audiovisual and broadcasting activities	3,63
D61: Telecommunications	3,63
D62T63: IT and other information services	3,63
D64T66: Financial and insurance activities	3,63
D68: Real estate activities	2,83
D69T82: Other business sector services	2,92
D84: Public admin. and defence; compulsory social security	3,37
D85: Education	2,43
D86T88: Human health and social work	2,72
D90T96: Arts, entertainment, recreation and other service activities	1,35
D97T98: Private households with employed persons	1,35

Year 2017-2018

Source: National Labour Force Survey (Sakernas) - Labour cost Indonesia

Table 10: EIM-ES Input data – average annual salaries in Indonesia

Solar PV (Utility)

Technology	Cost Item	Cost Category	Value Input	Share Input	Value	Unit	In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Total capex and opex input fields - leave blank if using detailed cost item inputs													
Tech3	Total	Capex	1.000			USDk/MW							
Tech3	Total	OpexFixed	14			USDk/MW/yr							
Tech3	Total	OpexVariable	-			USD/MWh							
Detailed cost item input fields - if using total capex and opex cost inputs, data in the value input column will not be used													
Tech3	PV module	Capex		34%	341	USDk/MW	40%	69%	136	D27: Electrical equipment	13%	na	18
Tech3	Inverter	Capex		6%	60	USDk/MW	40%	69%	24	D27: Electrical equipment	13%	na	3
Tech3	Racking/Mounting	Capex		9%	92	USDk/MW	42%	72%	39	D25: Fabricated metal products	9%	na	4
Tech3	Installation	Capex		12%	124	USDk/MW	100%	82%	124	D41T43: Construction	20%	na	25
Tech3	BOS, grid connection	Capex		17%	172	USDk/MW	30%	69%	52	D27: Electrical equipment	13%	na	7
Tech3	Developer cost	Capex		12%	121	USDk/MW	100%	89%	121	D69T82: Other business sector services	22%	na	27
Tech3	Land	Capex		0%	3	USDk/MW	100%	93%	3	D68: Real estate activities	5%	na	0
Tech3	Fees and contingencies	Capex		9%	88	USDk/MW	100%	93%	88	D64T66: Financial and insurance activities	20%	na	18
Tech3	Maintenance	OpexFixed		45%	6	USDk/MW/yr	41%	69%	3	D27: Electrical equipment	13%	na	0
Tech3	Operation	OpexFixed		55%	8	USDk/MW/yr	100%	90%	8	D35T39: Electricity, gas, water supply, sewerage,	12%	na	1
Tech3					-			0%	-			na	
Tech3					-			0%	-			na	
Tech3					-			0%	-			na	
Tech3					-			0%	-			na	
Tech3					-			0%	-			na	

Technology	Fuel	Cost Category	Average plant efficiency				In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Fuel cost inputs													
Tech3	Not applicable	Fuel	100%		-	USD/MWh		0%	-			na	

Table 11: EIM-ES Input data – utility-scale solar PV in Indonesia

Solar PV (Ind)

Technology	Cost Item	Cost Category	Value Input	Share Input	Value	Unit	In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Total capex and opex input fields - leave blank if using detailed cost item inputs													
Tech4	Total	Capex	1.100			USDk/MW							
Tech4	Total	OpexFixed	14			USDk/MW/yr							
Tech4	Total	OpexVariable	-			USD/MWh							
Detailed cost item input fields - if using total capex and opex cost inputs, data in the value input column will not be used													
Tech4	PV module	Capex		34%	375	USDk/MW	40%	69%	150	D27: Electrical equipment	13%	na	20
Tech4	Inverter	Capex		6%	66	USDk/MW	40%	69%	26	D27: Electrical equipment	13%	na	3
Tech4	Racking/Mounting	Capex		9%	102	USDk/MW	42%	72%	43	D25: Fabricated metal products	9%	na	4
Tech4	Installation	Capex		12%	136	USDk/MW	100%	82%	136	D41T43: Construction	20%	na	28
Tech4	BOS, grid connection	Capex		17%	189	USDk/MW	30%	69%	57	D27: Electrical equipment	13%	na	8
Tech4	Developer cost	Capex		12%	133	USDk/MW	100%	89%	133	D69T82: Other business sector services	22%	na	30
Tech4	Land	Capex		0%	3	USDk/MW	100%	93%	3	D68: Real estate activities	5%	na	0
Tech4	Fees and contingencies	Capex		9%	97	USDk/MW	100%	93%	97	D64T66: Financial and insurance activities	20%	na	19
Tech4	Maintenance	OpexFixed		45%	6	USDk/MW/yr	41%	69%	3	D27: Electrical equipment	13%	na	0
Tech4	Operation	OpexFixed		55%	8	USDk/MW/yr	100%	90%	8	D35T39: Electricity, gas, water supply, sewerage,	12%	na	1
Tech4					-			0%	-			na	
Tech4					-			0%	-			na	
Tech4					-			0%	-			na	
Tech4					-			0%	-			na	
Tech4					-			0%	-			na	

Technology	Fuel	Cost Category	Average plant efficiency				In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Fuel cost inputs													
Tech4	Not applicable	Fuel	100%		-	USD/MWh		0%	-			na	

Table 12: EIM-ES Input data – commercial and industrial-scale solar PV in Indonesia

Solar PV (Res)

Technology	Cost Item	Cost Category	Value Input	Share Input	Value	Unit	In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Total capex and opex input fields - leave blank if using detailed cost item inputs													
Tech5	Total	Capex	1.200			USDk/MW							
Tech5	Total	OpexFixed	-			USDk/MW/yr							
Tech5	Total	OpexVariable	-			USD/MWh							
Detailed cost item input fields - if using total capex and opex cost inputs, data in the value input column will not be used													
Tech5	PV module	Capex		34%	409	USDk/MW	40%	69%	164	D27: Electrical equipment	13%	na	22
Tech5	Inverter	Capex		6%	72	USDk/MW	40%	69%	29	D27: Electrical equipment	13%	na	4
Tech5	Racking/Mounting	Capex		9%	111	USDk/MW	42%	72%	47	D25: Fabricated metal products	9%	na	4
Tech5	Installation	Capex		12%	149	USDk/MW	100%	82%	149	D41T43: Construction	20%	na	30
Tech5	BOS, grid connection	Capex		17%	206	USDk/MW	30%	69%	62	D27: Electrical equipment	13%	na	8
Tech5	Developer cost	Capex		12%	145	USDk/MW	100%	89%	145	D69T82: Other business sector services	22%	na	32
Tech5	Land	Capex		0%	3	USDk/MW	100%	93%	3	D68: Real estate activities	5%	na	0
Tech5	Fees and contingencies	Capex		9%	106	USDk/MW	100%	93%	106	D64T66: Financial and insurance activities	20%	na	21
Tech5	Maintenance	OpexFixed		45%	-	USDk/MW/yr	100%	69%	-	D27: Electrical equipment	13%	na	-
Tech5	Operation	OpexFixed		55%	-	USDk/MW/yr	100%	90%	-	D35T39: Electricity, gas, water supply, sewerage,	12%	na	-
Tech5					-			0%	-			na	
Tech5					-			0%	-			na	
Tech5					-			0%	-			na	
Tech5					-			0%	-			na	
Tech5					-			0%	-			na	

Technology	Fuel	Cost Category	Average plant efficiency				In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Fuel cost inputs													
Tech5	Not applicable	Fuel	100%		-	USD/MWh		0%	-			na	

Table 13: EIM-ES Input data – residential solar PV in Indonesia

Coal

Technology	Cost Item	Cost Category	Value Input	Share Input	Value	Unit	In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Total capex and opex input fields - leave blank if using detailed cost item inputs													
Tech12	Total	Capex	1.500			USDk/MW							
Tech12	Total	OpexFixed	47			USDk/MW/yr							
Tech12	Total	OpexVariable	12			USD/MWh							
Detailed cost item input fields - if using total capex and opex cost inputs, data in the value input column will not be used													
Tech12	Project planning and management	Capex		11%	161	USDk/MW	77%	89%	124	D69T82: Other business sector services	22%	na	28
Tech12	Civil works	Capex		9%	141	USDk/MW	77%	82%	108	D41T43: Construction	20%	na	22
Tech12	Generating unit	Capex		14%	214	USDk/MW	38%	69%	81	D27: Electrical equipment	13%	na	11
Tech12	Mechanical equipment (ash handling, coal handling...)	Capex		40%	601	USDk/MW	38%	72%	228	D28: Machinery and equipment, nec	7%	na	16
Tech12	Electrical balance of plants	Capex		11%	162	USDk/MW	38%	69%	62	D27: Electrical equipment	13%	na	8
Tech12	Contingency and finance	Capex		15%	221	USDk/MW	77%	93%	170	D64T66: Financial and insurance activities	20%	na	34
Tech12	Operation	OpexFixed		50%	24	USDk/MW/yr	77%	90%	18	D35T39: Electricity, gas, water supply, sewerage,	12%	na	2
Tech12	Maintenance	OpexFixed		50%	24	USDk/MW/yr	41%	72%	10	D28: Machinery and equipment, nec	7%	na	1
Tech12	Utilities	OpexVariable		100%	12	USD/MWh	77%	90%	9	D35T39: Electricity, gas, water supply, sewerage,	12%	na	1
Tech12					-			0%	-			na	
Tech12					-			0%	-			na	
Tech12					-			0%	-			na	
Tech12					-			0%	-			na	
Tech12					-			0%	-			na	
Tech12					-			0%	-			na	

Technology	Fuel	Cost Category	Average plant efficiency				In-country Share Manual	Sector In-country Share	In-country Spend	Sector	Labour Share of Spend	Labour Share Override	In-country Labour Spend
Fuel cost inputs													
Tech12	Coal	Fuel	38%		31	USD/MWh	100%	88%	31	D05T06: Mining and extraction of energy producin	7%	na	2

Table 14: EIM-ES Input data – coal power in Indonesia

Appendix B – Arguments for and against local content requirement policies

Arguments *in favour of* local content requirements for solar and wind

- Fostering nascent industries by protecting them from foreign competition until they achieve their latent competitive advantage
- Providing medium-run economic spill overs by increasing the number of market players, which can lead to increased competition and innovation
- Learning spill overs (e.g. local training, technology transfer, knowledge and innovation), through learning by-doing and capacity building
- Economic diversification by creating business linkages locally
- Short-term benefits e.g. local job creation in manufacturing
- Improved public acceptance of policy support to renewable energy
- Increased manufactured exports
- Increased local ownership and control of manufacturing capacity
- Increased tax base for governments due to a larger manufacturing industry
- Greater deployment of solar and wind energy in support of climate change mitigation

Arguments *against* local content requirements for solar and wind

- Inefficient allocation of resources, trade diversion and distortion of competition. LCRs distort international trade because they encourage the substitution of imports by domestic goods, even when their quality may be inferior and their price higher than those of foreign imports.
- Reduced imports and competition (i.e. market power) in the short run between domestic manufacturers and foreign competitors.
- LCRs can delay economies of scale and prevent cost reductions for manufacturers by attracting high-cost firms and encouraging investment decisions based on public support, rather than on the cost-efficiency of specific locations
- Increased overall costs for downstream power producers in the short run as LCRs can force firms to purchase more expensive or less efficient solar panel or wind turbine equipment to benefit from public support
- Increased wholesale electricity prices in the short-term to offset increased costs
- Limited capacity to create additional local green jobs in the short-term
- Higher technology risk in the short-run for downstream firms forced to switch to less-known local technologies
- Increased cost of capital and restrained access to financing for project developers in the short run by lowering the bankability of projects forced to purchase less reliable domestic components
- Reduced innovation and technology transfer from trade for intermediate goods
- Higher revenue risk for downstream firms in the short run since the potential for governments to adopt LCRs makes the cost of components, and therefore profits, less predictable
- Reduced competitiveness and thus lower deployment of solar and wind energy vis-à-vis fossil fuels, detrimental to climate change mitigation
- Missed opportunities to support downstream services
- Increased policy uncertainty and investment risk

Appendix C – Air Pollution Impact Model for Electricity Supply (AIRPOLIM–ES)[21]

The AIRPOLIM-ES is a spreadsheet-based model that uses an accessible methodology for quantifying the health impacts of air pollution from different sources of electricity generation and other fuel combustion. The first version of this tool focuses on electricity generation from coal- and gas-fired power plants. It calculates the impacts on mortality from four adulthood diseases: lung cancer, chronic obstructive pulmonary disease (COPD), ischemic heart disease, and strokes, the prevalence of which is increased through exposure to air pollution. It has been developed by NewClimate Institute under the Ambition to Action Project.

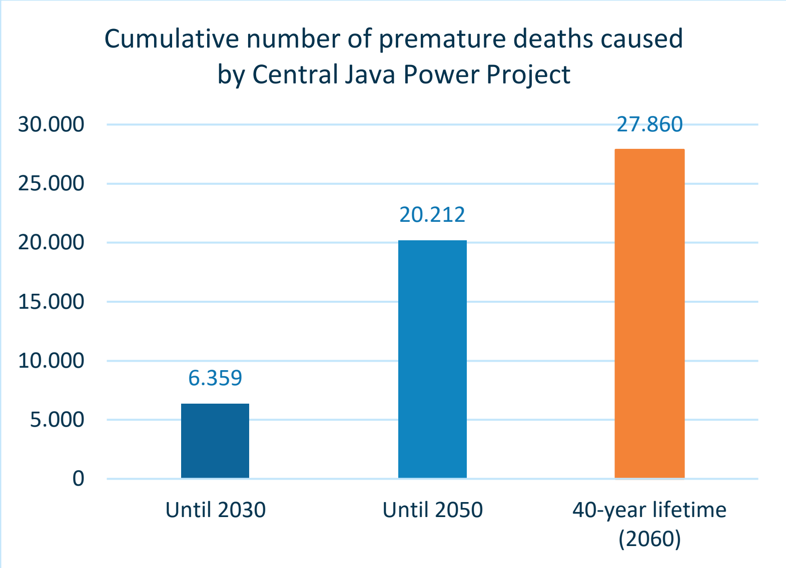
The health impact assessment is based on emissions of particulate matter (PM2.5), NOX, and SO2. The model estimates the annual and lifetime electricity generation (GWh) for each plant, as well as the corresponding emissions of air pollutants using plant-specific data and emission factors. Depending on the type of emissions control equipment installed, the model multiplies the estimated fuel consumption with the corresponding country-specific emission factor. Where more detailed information is available, plant-specific emission factors can be entered into the model to improve accuracy.

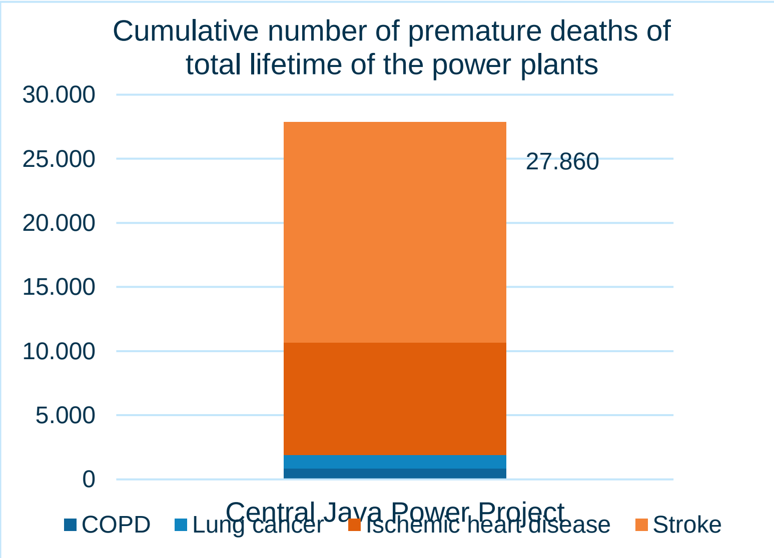
The exposed population living within four distance bands (0–100 km, 100–500 km, 500–1,000 km, and 1,000–3,300 km) from each power plant is estimated using open-source Geographic Information System (GIS) software, also considering population growth. The model uses the intake fraction concept to estimate the change in PM2.5 concentration in the ambient air based on the calculated pollutant emissions. Intake fractions indicate the grams of PM2.5 inhaled per ton of PM2.5, NOX, and SO2 emissions. These fractions - drawn from literature based on air dispersion modelling – enable estimation of the change in PM2.5 concentration. In order to estimate the intake fractions for the three pollutants, the model applies coefficients from a widely cited study from Zhou et al. (2006). One limitation of this approach is that the coefficients do not account for location-specific characteristics such as stack-height or meteorological conditions; nevertheless, Zhou et al. show that population exposure by distance is by far the most significant determinant of the level of intake of pollutants.

To calculate the increased mortality risk per additional ton of pollutant emissions, the estimated change in PM2.5 concentration is multiplied with the respective concentration-response function. Concentration-response functions are estimated based on long-term medical cohort studies and indicate the increase in cause-specific mortalities per 10 mg per cubic metre increase in PM2.5. The Global Burden of Disease project provides mortality rates by disease for different age groups at the country level. The model obtains age-weighted mortality rates by disease using the share of the country's population in each age class. The risk estimates, age-weighted mortality rates, and exposed population are combined to calculate the number of premature deaths per ton of pollutant for each cause of death. Finally, these numbers are multiplied with the estimated pollutant emissions to obtain the total premature deaths per pollutant and cause for each power plant. Premature death refers to deaths that are attributed to exposure to a risk factor, e.g. air pollution, and could be delayed if the risk factor was eliminated.

[21] *The AIRPOLIM-ES and associated materials can be found at www.ambitiontoaction.net*

Appendix D – Central Java Power air pollution graphs





PREMATURE DEATHS BY CAUSE/LIFETIME				
COPD	LUNG CANCER	ISCHEMIC HEART DISEASE	STROKE	**TOTAL**
869	1,036	8,733	17,221	**27,860**

Appendix E – Overview of on-grid solar PV projects in Indonesia (Nov 2019)

Location	Status	Capacity	IPP
Sumalata Timur, Gorontalo Province	Running	2	PT Brantas Energi -Adyawinsa KSO
Kupang, East Nusa Tenggara	Running	5	PT Len Industri
Atambua, East Nusa Tenggara	Construction	1	PT Global Karya Mandiri
North Lombok, East Nusa Tenggara	Running	2	PT Berkah Surya Madani
Maumere, East Nusa Tenggara	Running	2	PT Indo Solusi Utama
Kotabaru, South Kalimantan	PPA signed; never constructed	2	PT Global Karya Mandiri
East Sumba/East Nusa Tenggara	PPA signed; never constructed	1	PT Buana Multi Tehindo
Isimu, Gorontalo	PPA; under construction	10	Quantum Energi
Sengkol, Lombok	HoA signed, Under construction	5	PT Infrastruktur Terbarukan Cemerlang (Equis Energy Group)
Selong, Lombok	HoA signed, Under construction	5	PT Infrastruktur Terbarukan Buana (Equis Energy Group)
Priggabaya, Lombok	HoA signed, Under construction	5	PT Infrastruktur Terbarukan Adhiguna (Equis Energy Group)
Likupang, Minahasa, North Sulawesi	HoA signed, Under construction	15	PT Infrastruktur Terbarukan Lestari (Equis Energy Group)
Sambelia, Lombok (was Kuta Lombok)	HoA signed, Under construction	5	NV Vogt Pte. Ltd. - PT Delapan Menit Energi
Cirata, West Java (Floating Solar)	Masdar cooperation cancelled; open for retender	200	
Jembrana, Bali	Loi signed, but then revoked, and will be retendered	50	
Kubu, Bali	Loi signed, but then revoked, and will be retendere.	50	PT Akuo Energi Indonesia
Minahasa, North Sulawesi	Running	0,1	PT Infrastruktur Terbarukan Fortuna / PT Karangasem Sejahtera
Tahuna, North Sulawesi	Running	0,6	PLN
Manado, North Sulawesi	Running	0,3	PLN
Molawahu, Tibawa, Gorontalo Province	Planned; Under Local Gov. review		PLN
Purwakarta, West Java	Running	1,3	PT Quantum Energi
	Only connected recently	1	PLN
	Running	0,6	
	Running	0,6	PLN
	Running	0,2	PLN
	Running	0,1	PLN
	Running	0,9	PLN
Palembang, South Sumatera	Running	2	PLN

The Ambition to Action Project

This report is an output of the Ambition to Action (A2A) project, which supports NDC implementation through technical assistance and thought leadership. The project is implemented collaboratively by the Energy research Centre of the Netherlands (ECN part of TNO) and NewClimate Institute, over a three-year period until the end of 2019. Project funding is provided by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU). Ambition to Action's technical assistance aims to support the mainstreaming of climate and development goals at the sector level, through the development of evidence on social, economic and environmental benefits of mitigation actions and pathways. This benefits evidence, for example detailing employment, energy security, and air pollution impacts, will show how sector planning decisions can support NDC implementation as well as national development priorities and can help reduce policy costs, identify trade-offs, and build stakeholder support for ambitious mitigation approaches at the sector level. The project focusses on the energy sector and provides direct support to Argentina, Kenya, Indonesia, and Thailand. A benefits assessment methodology and guidance will be published for use in other sectors and countries. The Ambition to Action project is part of the NDC Cluster established by the BMU in 2015. The NDC Cluster currently exists out of seven projects, with a total funding volume of approximately EUR 56 million, ten climate and development implementing partners coordinating their activities to allocate resources effectively and efficiently in 27 selected partner countries.