Danish Energy Agency

EMBASSY OF DENMARK
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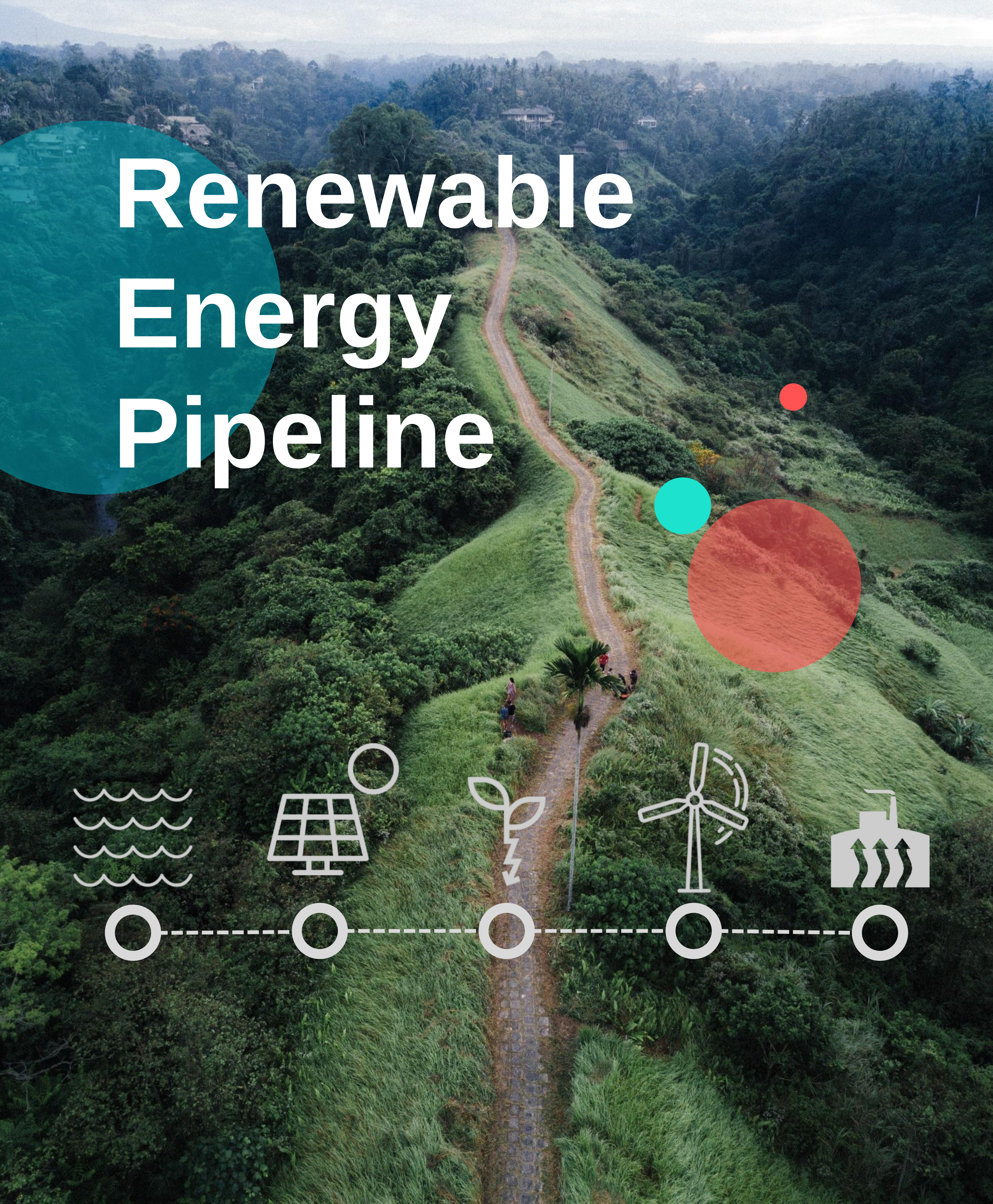
Ea Energy Analyses

Renewable Energy Pipeline



Foreword

This report has been jointly prepared by EBTKE and the Danish Energy Agency. The vision of the report is to create a pipeline in which the Indonesian electricity supply reaches a share of at least 23% renewable energy (RE) by 2025, as stated in the national energy policy, Kebijakan Energi Nasional (KEN). It collects data on power demand projections, renewable energy potentials, and aligns these with an RE pipeline. Indonesia is home to vast amounts of RE sources. Each region in Indonesia holds different potentials to develop expand the share of RE. In this report, the KEN target is reached by implementing five RE technologies across all regions, in Indonesia. However, actions must be accelerated and structured to ensure the required development of energy projects.

In essence, this report suggests a policy framework where regional quotas for RE capacity creates a pipeline of RE development towards 2025 and onwards. The RE pipeline can help kick start the RE project development and unlock the significant potentials, while setting a green trajectory in Indonesia. The development is feasible but can be improved and accelerated through an updated approach to energy planning where regionally set targets specifies capacities by regions to support the national energy planning. Furthermore, the proposed RE capacity additions are no threat to the security of supply. Many international examples have shown how conventional electricity grids can implement the first stages of variable RE without issues.

The recommendations in this report suggest changes that will communicate clear visions and development pathways to international investors and developers. From the perspective of foreign investors, Indonesia is a promising market but with an unclear route to reach the pledged energy and climate goals. This RE pipeline and its recommendations alleviates the uncertainty and risk-perception by investors. Hence, an RE pipeline will indirectly advance the environment for investments in RE and thereby help international finance in the Indonesian transition. Additionally, the recommendations aim to strengthen the vertical planning to help implementation of national targets. Provincial planning bodies can, in conjunction with national authorities, improve the planning for projects.

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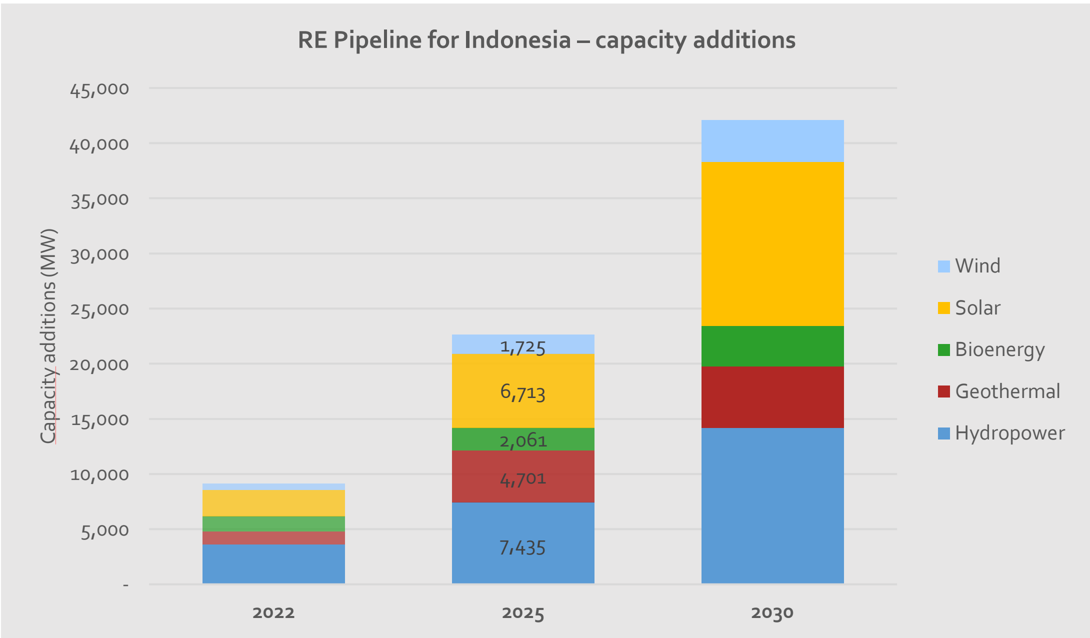
Executive summary

Along with some of the world's greatest geothermal and hydropower potential, Indonesia also possesses abundant resources of solar, wind and bioenergy. However, in the last 5 years the **renewable energy (RE) share in the power sector has been stagnating around 10-12%** with only 0.33% coming from solar, wind and biomass in 2019.

RE PIPELINE

The RE pipeline builds upon existing energy planning documents in Indonesia to provide a **clear pathway to reaching the 23% RE target in 2025** and input to set the RE quota in the various regional systems. Moreover, it extends the outlook to 2030 to provide more certainty in the longer-term commitment, attract developers and investors, and stimulate local industry.



Key findings:

- ✓ Towards 2025, **22.6 GW of RE capacity is needed, 8.4 GW of which is new solar and wind**.
- ✓ Geothermal and hydro remains the backbone of the RE contribution to the power mix, but it is important to complement them and **start tapping into the vast solar and wind potential** to minimize the cost to reach the target.
- ✓ Different regional systems contribute differently to the achievement of the 23% goal, depending on national and local plans, as well as the quality and potential of renewable resources. **Sumatra has the highest contribution to the target**, with 40% of their electricity coming from RE, especially hydro and geothermal.

- ✓ Indonesia is **abundant with RE potential** but will only just begin to tap into this. With the outlined capacity buildout from this pipeline the potentials remain largely unutilized for all technologies, with only 6-7% of solar and wind potential utilized country-wise.
- ✓ Maximum instantaneous penetration of variable renewable energy sources (VRES) is within a level that can **confidently be integrated in the four major regional systems**, namely estimated at 12-26% at the most extreme hour of the year (7-16% on average).
- ✓ The high reliance on geothermal in the short term constitutes a **risk to jeopardize the achievement of the 2025 RE targets** due to a longer planning horizon and uncertainties in drilling processes. To make up for a lag of geothermal development, 11GW of additional VRES would be needed.
- ✓ Given the current interest from developers and the recent drop in the cost of wind and solar in the latest Indonesian tenders, it is expected that the **solar PV and wind pipeline presented will likely be exceeded** in 2025 and 2030.

VRES INTEGRATION

In the current debate in Indonesia, the challenge of integrating variable renewable energy is often overstated. VRES integration challenges depend on the scale of renewable development. But as it can be seen from the analysis presented in this report, Indonesia is still at the beginning of the energy transition at which point renewable energy can generally be integrated through low-cost measures. Implementing the capacity targets set out in this pipeline would require increasing the VRES penetration at national level to only 3.1%. At these levels of wind and solar generation (Phase 1) found especially in major systems like Java-Bali and Sumatra, Indonesia would easily integrate their power into the system without major challenges. Some smaller systems with good wind and solar resources, like Nusa Tenggara, the penetration could reach 6-7% (Phase 2), potentially requiring some additional measures.

Experience from other countries show that it is feasible to integrate much higher levels of renewables penetration than previously expected, and Indonesia may benefit significantly from adopting and adapting best practices to the local context.

Based on the experience from Denmark and other countries with high shares of variable renewables, it is suggested to put a concrete set of actions in place to alleviate short-term integration challenges and pave the way for a more renewable intensive system in the longer term. Among these:

- **Changes to system operation practices** can allow access to significant existing flexibility, often at lower cost than options requiring new sources of physical flexibility. For example, updating grid codes and implementing **forecasting of wind and solar** in the control centers, to improve the dispatch of other generators and reduce need for keeping more reserves online;
- **Elicit flexibility of other power plants**, starting from hydro power, gas and coal. Experience from Denmark shows that coal power plant can be dispatched much more flexibility than currently done in Indonesia, with minor upgrades and interventions;
- Apply **market mechanisms even in a vertically integrated system**, for example by incentivizing cost-reflective dispatch, applying smart tariffs to consumers and by designing power purchase agreements with IPPs maximize their flexibility potentials;
- **Expand interconnectors and connect the different isolated systems**, while being quite capital-intensive, can help smoothen VRES generation and reduce the need for balancing and reserve resources on the supply side.

Power storage and more specifically electric batteries are currently at the center of the debate in Indonesia. While being an optimal solution for integrating large amount of VRES in the long term, it is not the most suited integration option at low penetration level such as the current and projected ones in Indonesia towards 2030. Coupling wind and solar development with battery storage installation could increase the capital spending and jeopardize the fulfillment of the target at an affordable cost. As a testimony of that, no large power system worldwide, even at 40% penetration level of VRES has yet deployed grid-level storage in large volumes.

Policy Recommendations

The primary recommendation in this report relates to the implementation of RE quotas. By distributing RE quotas, appropriately – according to local RE potentials available, this political framework will increase transparency of future energy planning by specifying regional targets, based on RUPTL and RUEN. The main recommendations of this report can be condensed to:

- Enable transparency through commitment to an RE development
- Secure compliance with national RE targets
- Provide a mechanism to support compliance through monitoring
- Communicate a signal to international investors and local governments about a mandatory development path
- Reduce risk for investors and lowering prices of RE

This development requires an acceleration in the current pace of RE expansion. A wider range of political actions can further support the sphere of implementation for an RE pipeline. In essence, these considerations alleviate existing barriers for RE projects to thrive in Indonesia. Increasing transparency and binding commitments to RE projects across Indonesia will attract investors. At the same time, securing level playing fields for RE and conventional power generation technologies ensures a better bankability for the RE development. The key recommendations of this report are presented below.

- As planned in the upcoming Presidential Regulation, **put in place mechanisms to support and de-risk RE investments**, given the need to accelerate the deployment and kick-start the industry. Make sure to include competition mechanisms such as auctions to stimulate competition, especially for larger projects into lower prices. The Indonesian RE market would benefit from a larger market volume of RE projects.
- Make sure **PPA contracts** follow international standards, distribute the risk optimally between the parties and that they make the investment in RE both bankable for developers and workable for PLN that need to integrate the power into the grid.
- **Improve access to capital by** engaging development banks and foreign aid funds. This could also lead to loan guarantees with low interest making RE even more compatible.
- **Introduce an institution as a one-stop-shop authority for RE projects.** Establish a single point of access for developers to streamline and simplify the processes surrounding permits for RE projects. In practice, this would mean that just one institution receiving bids, granting permits and reaching out to relevant authorities when a developer seeks to develop an RE project. This could be an upgrade of the existing Clean Energy Information Centre called “LINTAS” by EBTKE.
- **Easy access to information.** Make relevant regulation and other key information for investors and developers available and easy searchable online in both English and Bahasa Indonesia.
- **Secure a level playing field** where RE projects can compete more fairly with conventional power generation. Besides subsidizing low-carbon RE projects, calculating societal costs (externalities) from burning fossil fuels shows the benefits of RE technologies in comparison.

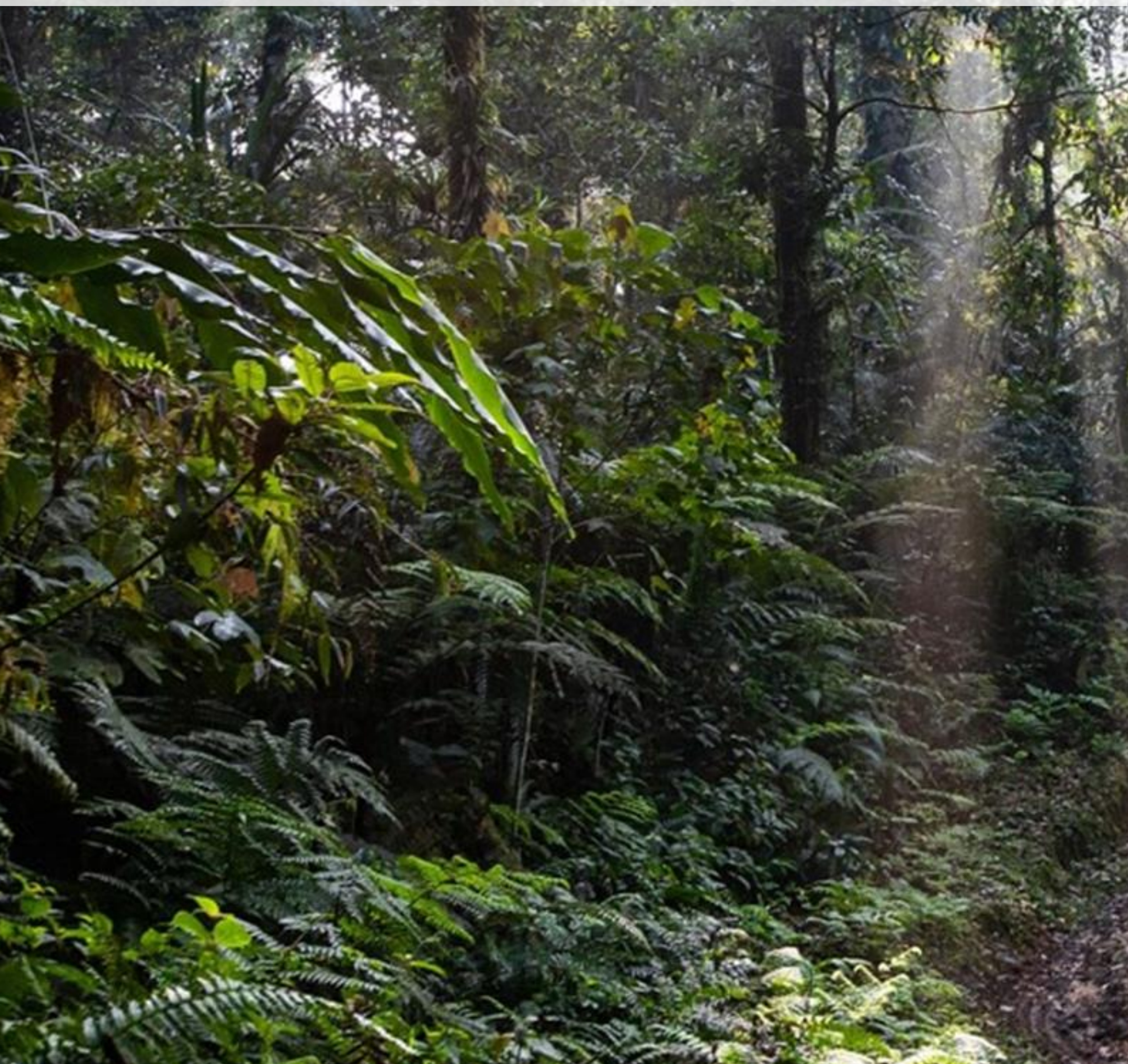
Implementing these actions will greatly push the commercial environment for increasing Indonesian RE capacity, while easing alignment and monitoring for local authorities within energy planning. As previously stated, a political push is required to kick-start the development and align the RE capacity with national targets in the near-term.

Nomenclature

Abbreviations

CO_2	*Carbon Dioxide*
DGE	*Directorate General of Electricity (MEMR)*
EE	*Energy Efficiency*
EV	*Electric Vehicle*
GDP	*Gross Domestic product*
GHG	*Greenhouse Gas*
KEN	*Kebijakan Energi Nasional (National Energy Policy)*
MEMR	*Ministry of Energy and Mineral Resources*
NEC	*National Energy Council*
PLN	*PT Perusahaan Listrik Negara*
PPA	*Power Purchase Agreement*
PV	*Photovoltaics*
RE	*Renewable Energy*
RUED	*Rencana Umum Energi Daerah*
RUEN	*Rencana Umum Energi Nasional*
VRES	*Variable Renewable Energy Sources*

CHAPTER 1.
BACKGROUND

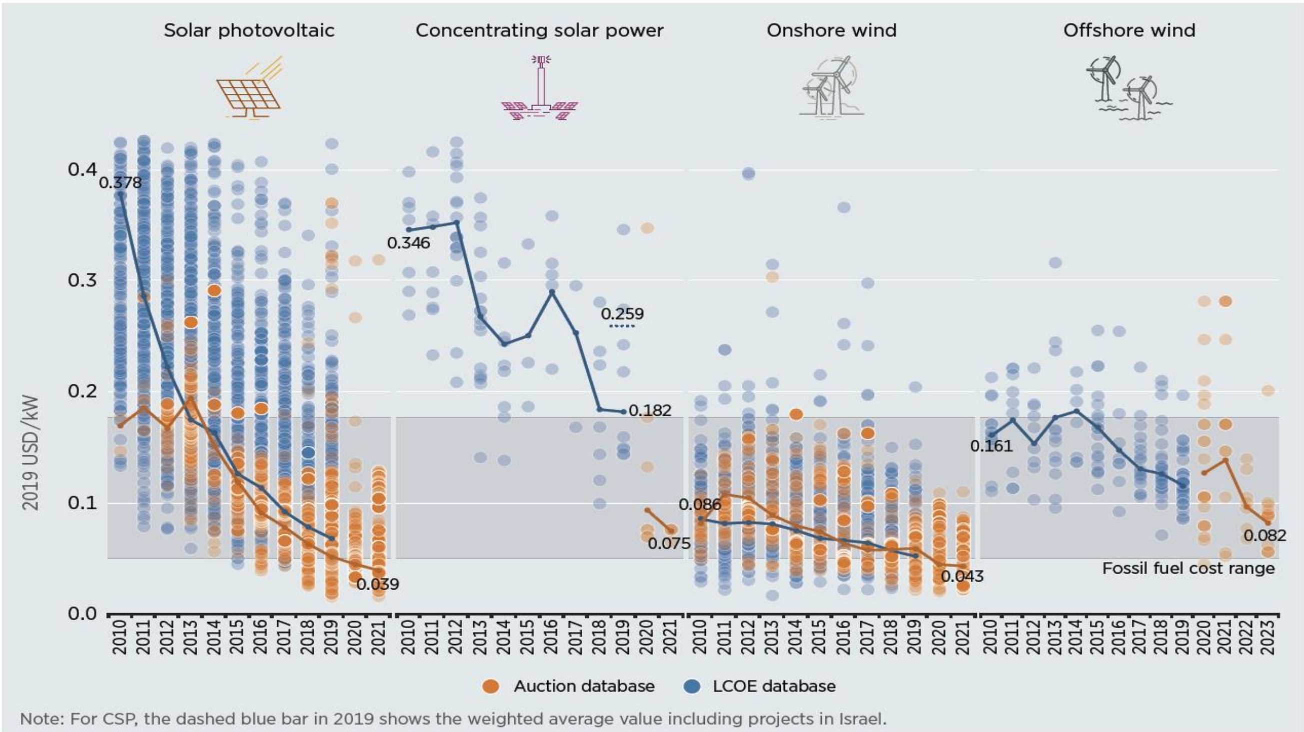


BACKGROUND

1.1. VRES COST DEVELOPMENT

Recent years have seen record breaking results for VRES tender prices. In 2020 and 2021, Saudi Arabia, UAE and Portugal saw auction bids as low as 150-194 Rp/kWh (~1.10-1.35 c$/kWh) for the procurement of solar PV plants [1][2]. Between 2010 and 2021 the levelized cost of solar has dropped almost 90% and is today around 3.9 c$/kWh worldwide [3]. With the vastly reduced prices VRES becomes much more cost competitive, often being the cheapest choice for new generation capacity, and in some cases outcompeting existing generation capacity.

Recent tender results in Indonesia suggest low solar PV tariffs around 4 c$/kWh (~565 Rp/kWh) [4]. With the decreasing prices the potential for solar PV broadens in Indonesia. With very large development potentials and bettering economic perspectives the question becomes, how to best integrate higher levels of VRES in Indonesian power production to secure low generation prices and a stable power supply for years to come.



Source: IRENA Renewable Cost Database.

Note: Each circle represents an individual project LCOE (blue dots), or an auction result (orange dots), where there was a single clearing price at auction, for the actual or estimated year of commissioning respectively. The centre of the circle is the value for the cost of each project on the Y axis. The thick lines are the global weighted average LCOE, or auction values, by year. For the LCOE data, the real WACC is 7.5% for OECD countries and China, and 10% for the rest of the world. The band represents the fossil fuel-fired power generation cost range.

Figure 1-1: Global cost development for VRES. Source: [3]

At the same time coal financing is becoming more and more challenging in Indonesia, as well as worldwide. Over 100 financial institutions and 20 large insurers are divesting from coal projects globally and the trend only expected to increase over the coming years [5].

With coal prices increasing and solar PV and other VRES prices strongly decreasing, more and more existing units are rendered obsolete. According to IRENA: "By 2021, up to 1,200 gigawatts of existing coal-fired capacity would cost more to operate than new utility-scale solar PV would cost to install" [3].

NEW SOLAR CAN COMPETE WITH EXISTING COAL IN INDONESIA

Looking specifically at Indonesia, new solar PV in Indonesia can be cost competitive with existing coal plants, depending on coal capacity factor and expected prices. Figure 1-2, using technology data from the latest Indonesian technology catalogue of power generation technologies [6], shows the break points in 2023 for existing coal marginal costs compared to new solar PV costs, for capacity factors of respectively 80% (7000 FLH) or 57% (5000 FLH) and varying efficiencies expressed as heat rates.

At high coal prices (100 $/ton) a new solar PV is cheaper than even the more efficient existing plants already in 2023. For plants with lower capacity factors, solar PV is cost competitive even at lower coal prices and heat rates.

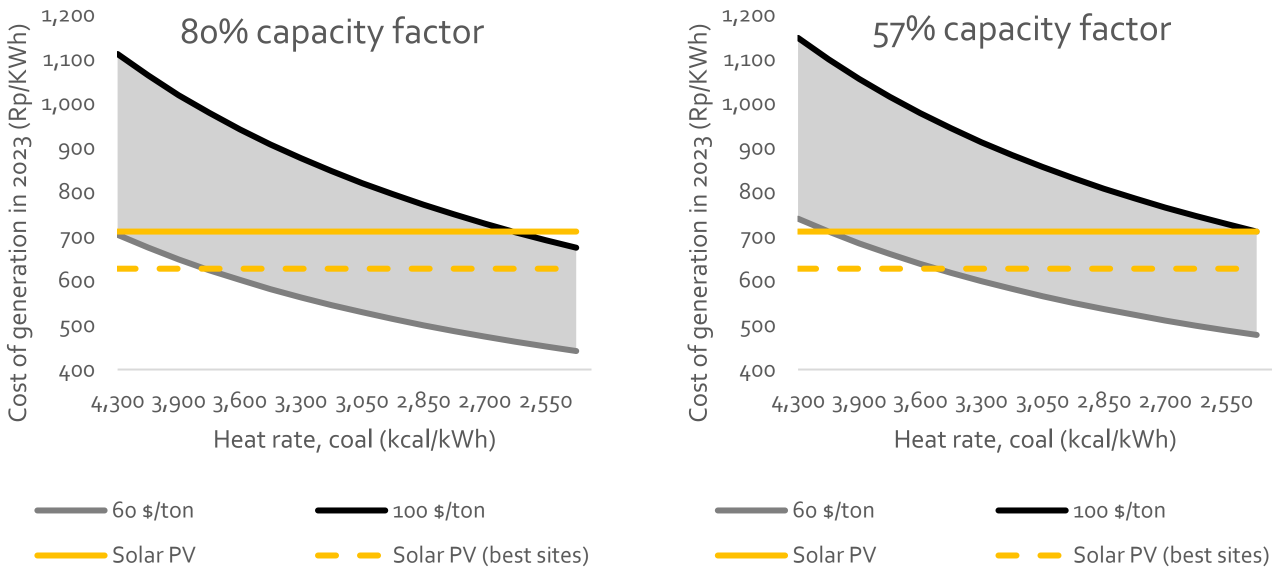


Figure 1-2: Cost comparison of new solar PV and marginal cost of existing coal plants at 80% and 57% capacity factors.

1.2. INDONESIAN ENERGY DEVELOPMENT

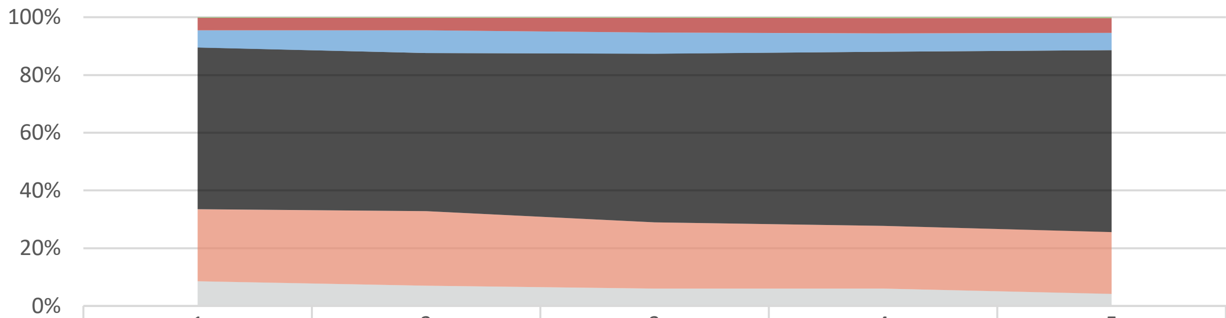
Along with some of the world's greatest geothermal and hydropower potential, Indonesia also possesses abundant resources of solar, wind and bioenergy. Although maintaining its reliance on domestic coal for power generation, in recent years Indonesia has started adding more renewable capacity to its energy mix. However, the contextual growth in power demand has led to a stagnating power generation share from renewables, which in the last five years has been stable around 10-12%. In 2019, the share of renewable energy in the power sector was 11.4%, of which the largest part is the combined contribution of hydro (6%) and geothermal (5.1%). The amount of other renewable energy like solar, wind, and biomass was only 0.33% (Figure 1-4) [7].

The Indonesian National Energy Policy (KEN), published as a government regulation in 2014 [8], established a framework for a national energy strategy and provides various targets on electrification ratio, energy intensity and elasticity, and primary energy use. Specifically, Article 9f sets a target for the Primary Energy Mix for 2025 and 2050, for the share of oil, gas, coal, and renewable energy. The most notable of the targets (summarized in Table 1) is the "New and Renewable energy" minimum target for 2025, equal to 23%.

Fuel	2025 share	2050 share
Oil	<25%	<20%
Gas	>22%	>24%
Coal	>30%	>25%
New and Renewable Energy	>23%	>31%

Figure 1-3: Fuel share for primary energy mix in 2025 and 2050 according to Article 9f of KEN.

Given the status of renewable energy use in the power sector and the 23% RE target for 2025, a clear gap is present, and the country might struggle to reach the goal in just 5 years. Currently, a new Presidential Regulation to accelerate the deployment of renewable energy is being discussed and is expected to be published in 2021. New Feed-in-Tariffs for all renewable energy sources are the main instrument considered to attract investors and accelerate the deployment of RE. As part of the presidential regulation, quotas for RE by regional system need to be set by MEMR.



	1	2	3	4	5
Series6	0.20%	0.25%	0.25%	0.31%	0.33%
Series5	4.34%	4.33%	5.03%	5.30%	5.11%
Series4	5.93%	7.88%	7.39%	6.37%	6.01%
Series3	56.06%	54.70%	58.41%	60.28%	62.98%
Series2	24.89%	25.88%	22.92%	21.70%	21.40%
Series1	8.58%	6.96%	6.00%	6.04%	4.18%

Figure 1-4: Energy sources in Indonesian power generation. Source: [7]

1.3. POWER SYSTEM REGULATORY LANDSCAPE

The current legal and regulatory landscape for electricity planning includes various numbers of stakeholders and planning documents, which are described in Figure 1-5 and Figure 1-6. The key document that sets the direction of the energy policy in the country is KEN (Kebijakan Energi Nasional), which is then detailed by a national plan presented in RUEN and a set of regional plans called RUED, developed in each of the Indonesian provinces. When looking more in depth into electricity, RUKN is the indicative national planning and RUKD the regional electricity plan. Both are prepared by MEMR and must comply with KEN. The last and more concrete and medium-term plan is the business plan for electricity provision (RUPTL) prepared and published annually by PLN. The last version, RUPTL 2019 [9], covers the years 2019-2028 and will be used as a basis for the RE pipeline calculations.

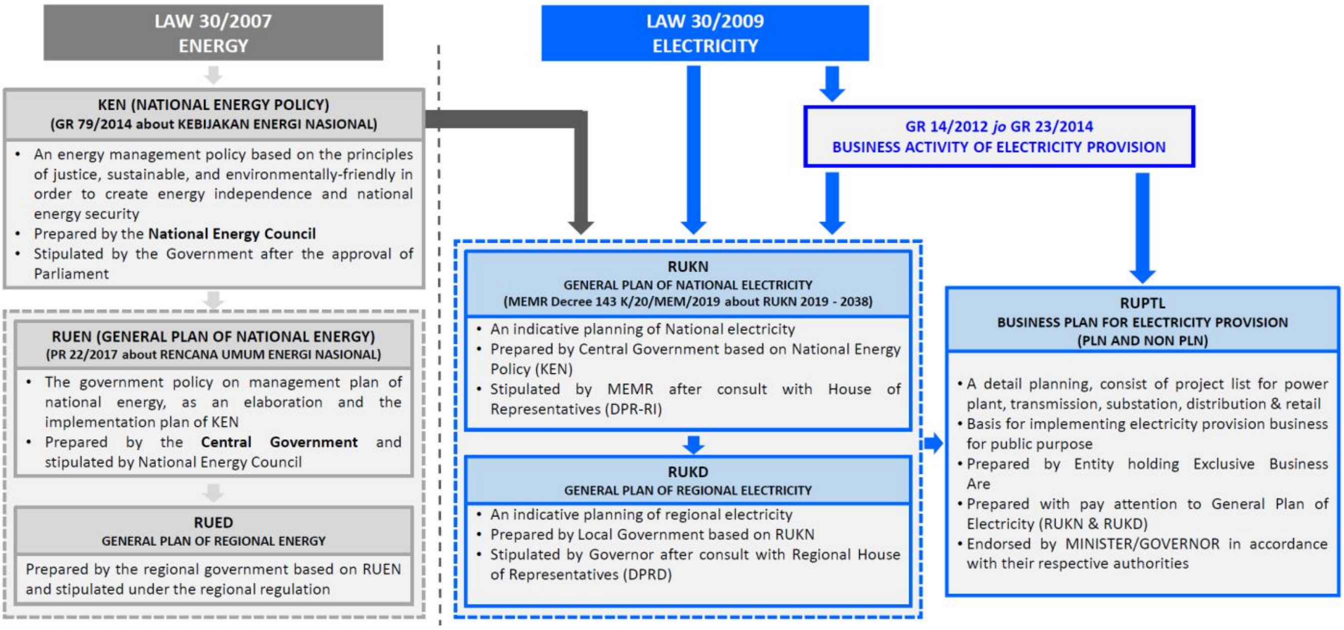


Figure 1-5: Regulatory landscape for planning documents.

Document	Responsibility	Timeframe
KEN	Central government and NEC	Until 2050
RUEN	Central government and NEC	Until 2050
RUED	Regional government and NEC	Until 2050
RUKN	Central government and MEMR	20 years (2019-2038)
RUKD	Local government and MEMR	20 years (2019-2038)
RUPTL	PLN	10 years (2019-2028)

Figure 1-6: Overview of planning documents.

Workshops and Cooperation

During 2020, through dedicated workshops, support has been provided to EBTKE on how to develop an RE pipeline and set regional quotas for renewable energy. At the workshops, various subjects were discussed to develop a process behind the creation of an RE pipeline, and experiences from Denmark in relation to medium- and long-term commitment to renewables were presented. Many Indonesian participants and stakeholders from various institutions took part in the workshops, including representatives of various PLN departments, EBTKE, NEC, DGE and others.

The three workshops, chaired by Pak Harris M. Yahya (EBTKE), focused on:

- **Workshop #1: How to choose a baseline.**
  Main outcomes: Existing energy plans such as RUKN and RUPTL have essential mandatory targets in the power system that should serve as a baseline for an RE Pipeline. The RE Pipeline plan should show more ambition in deploying renewables. Data collected from different plans/strategies developed by DGE, NEC and PLN.

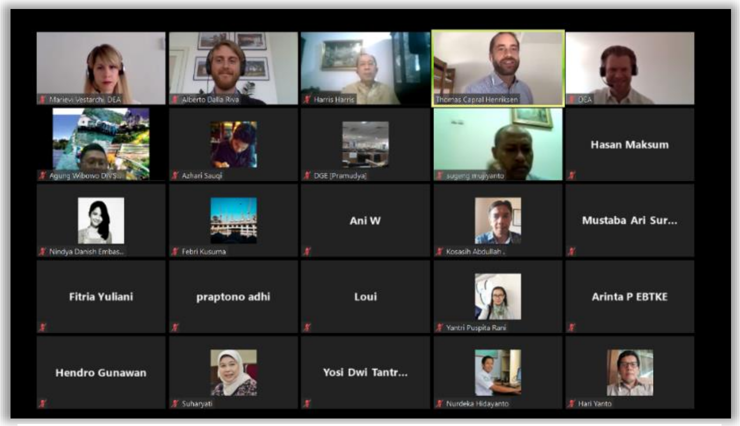


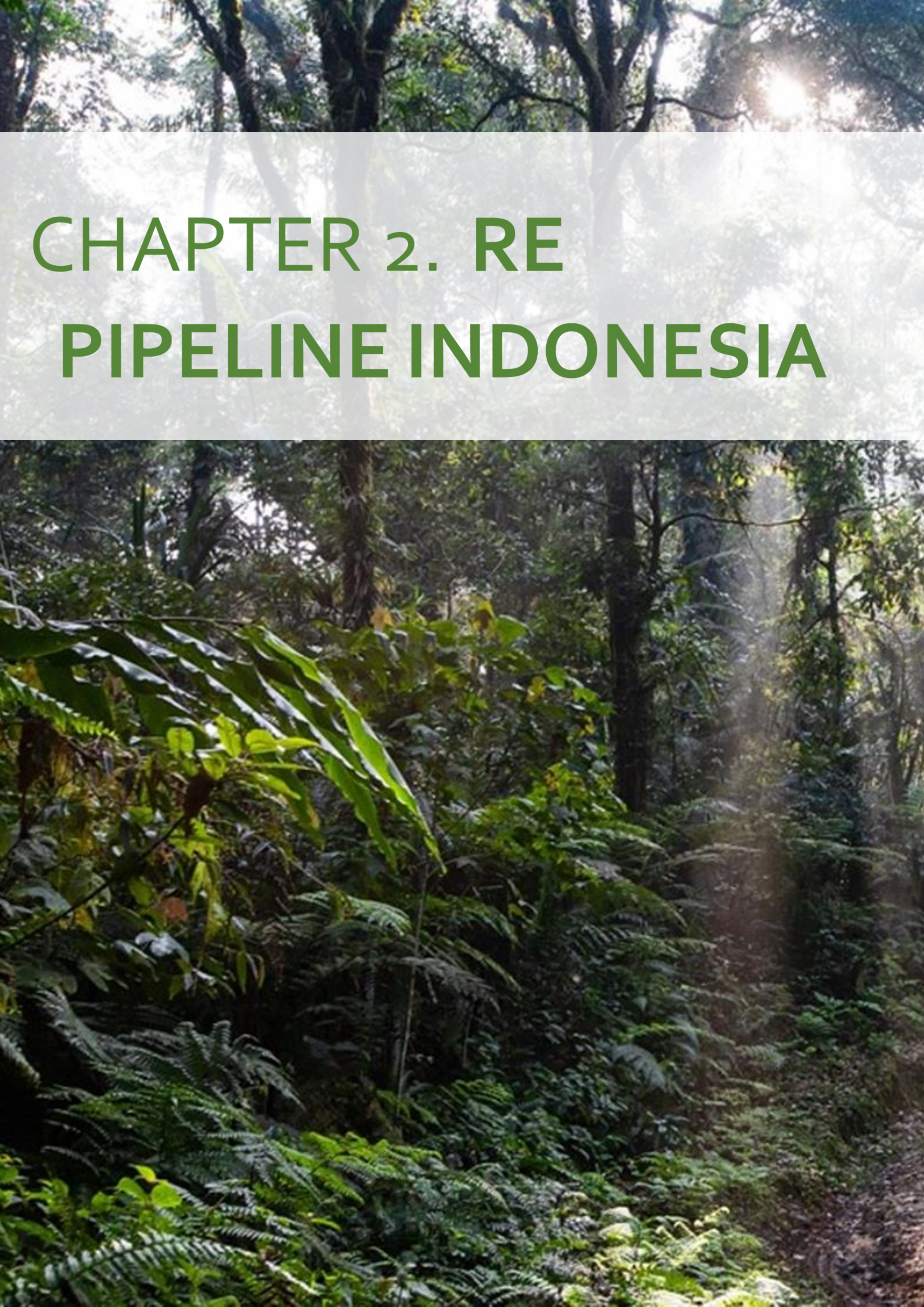
Figure 1-7: Screenshot from workshop on the RE pipeline.

- **Workshop #2: Work towards a methodology to set an RE pipeline.**
  Main outcomes: RUPTL is used as a baseline for the pipeline, but the demand considered should be from RUKN, since it includes non-PLN grids and plans for development of industry across Indonesia. The process and the responsibility of each stakeholder were discussed, as well as the national/provincial roles.

- **Workshop #3: Detailed recap of the steps and example of an RE pipeline for Sulawesi.**

In this document the process to create a pipeline is carried through as a demonstration of the methodology and to provide a starting point. The next step is to setup a solid process with clear responsibility across the stakeholders for regularly carrying out a revision of the pipeline and a monitoring of the progress towards the 2025 renewable energy target.

CHAPTER 2. RE PIPELINE INDONESIA



Introduction to the RE Pipeline

In the context of the new Presidential Regulation and the regional quotas, developing an RE pipeline that is binding in the short term and presents guiding targets for the medium-term commitment to the deployment of RE can create certainty and build trust in the development of RE in Indonesia. In this document, a potential RE pipeline to reach the target laid out in KEN for 2025 is explored, extending the focus period to 2030. The process and results presented can also lay the foundation for issuing regional RE quotas in the new regulation.

The renewable energy pipeline should present a clear path to fulfill the renewable energy policy goals and the Nationally Determined Contributions (NDCs) for Indonesia, build on existing knowledge and plans of various institutions, and be developed and reviewed in cooperation with relevant stakeholders, most importantly PLN and regional governmental offices, but also private investors, academia, and NGOs. The pipeline could be used for issuing binding RE-quotas per province for the next three years and indicative targets for five- and ten-years perspectives.

2.1. The Pipeline Process

The process conducted to create the current pipeline has been developed keeping in mind the starting point of renewables in Indonesia and the various plans developed both at national and regional level by the various stakeholders in the power and energy sector. The calculations for the presented pipeline are composed of 4 steps:

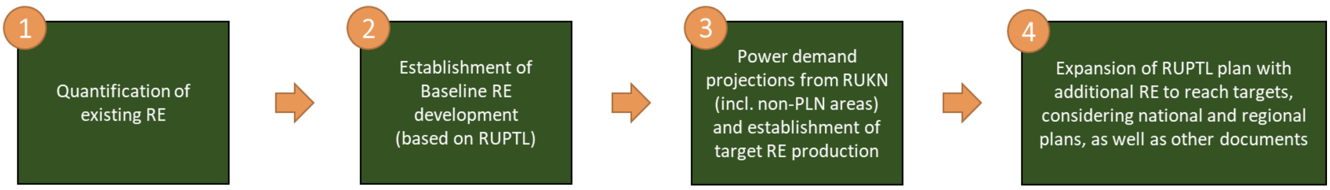


Figure 2-1: Current pipeline creation process.

National statistics are used to define the existing RE and to benchmark the average capacity factors of the various technologies. Secondly, the baseline development of the power system is laid out based on the proposed capacity addition in RUPTL 2019. As a third step, the power demand projection in RUKN from DG Electricity are considered, to create a pipeline for the whole of Indonesia including demand outside PLN grids. This demand is available at a provincial level but has been aggregated to the regional level. In 2025 RUKN demand is almost 40% higher than RUPTL demand at a national level, but the extra demand varies greatly between regions (e.g. +15% in Java-Bali, up to +780% in Maluku).

Using the demand in RUKN and the target RE shares, the target RE production is calculated. In 2025, following the KEN target, 23% of electricity demand should be covered by RE. Using a conservative approach to 2022 and a linear regression between 2025 and 2050 with a 30% RE goal, the RE targets by year are shown in Figure 2-3.

Figure 2-2: Projected RE shares.

	2022	2025	2030
RE share assumed	16%	23%	24.6%

The target RE production, needed to reach the aforementioned RE shares, are then met in part by existing capacity, all of which is expected to remain operational until 2030, in part by expected capacity buildout under RUPTL 2019[1], and finally by the additional capacity proposed in this pipeline document.

An important assumption to point out is related to the expected capacity factors of power generation technologies. A different assumption on average capacity factors can lead to a dramatic under- or overestimation of the required renewable capacity to reach the target.

In this publication, capacity factors have been estimated for each technology and regional systems, correcting for the difference in irradiation, wind resource, precipitation, using a combination of historical data and resource maps such as the Global Solar Atlas [10] and wind mesoscale modelling of Indonesia [11]. The main assumptions for capacity factor by technologies are: 15-19% for solar PV, 23-37% for wind, 34-40% for hydropower, 57% for biomass and 76% for geothermal. A detailed overview of the capacity factor by technology and regional system is outlined in Appendix C.

In order to add the needed capacity on top of existing and planned under RUPTL to reach the needed amount of RE, documents such RUED, RUKN, RPJMN and Regional Energy Outlooks [12]–[14] are used as a basis for establishing possible capacity expansions for each region. A generation mix is then chosen based on the reported expected capacities in the various documents. With regards to VRES (wind and solar) a slightly higher ambition is considered, yet limiting instantaneous VRES penetration, as to not compromise grid stability.

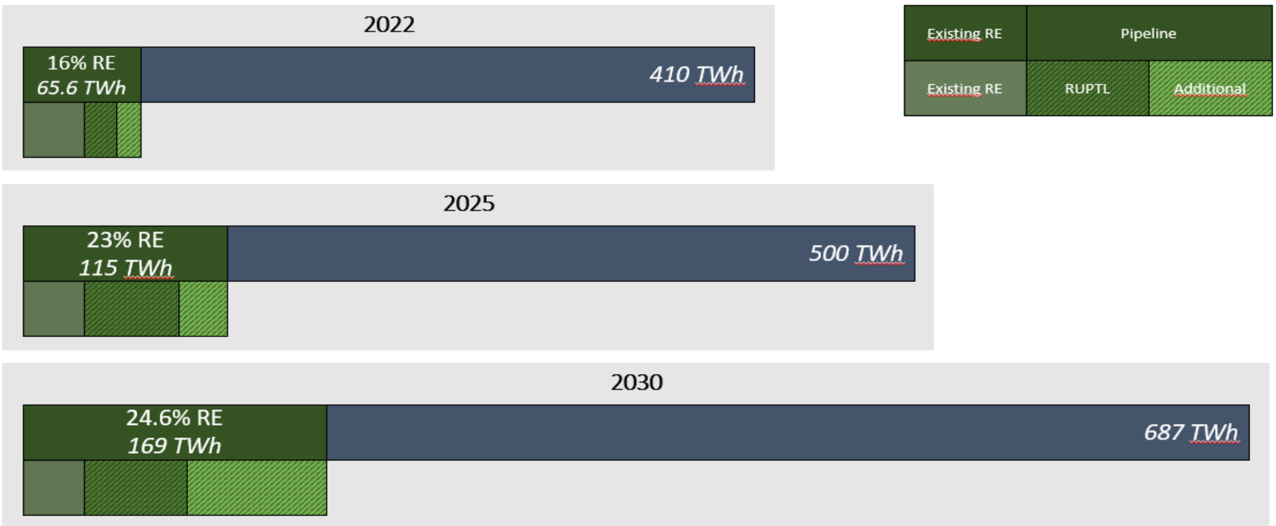


Figure 2-3: Projected electricity demand and corresponding RE generation with the proposed RE pipeline.

[1] Due to Covid-19, the 2020 version of RUPTL has not yet been published, therefore the 2019 version is used as baseline.

RE Pipeline

To meet the RE targets set forward as a basis for the pipeline, 22.6 GW of RE capacity additions are needed in 2025, increasing to 42.1 GW in 2030. Hydropower and geothermal provide the backbone of the pipeline with more than 12 GW capacity added towards 2025, generating an estimated 55.4 TWh of electricity. Wind and solar accounts for 8.4 GW new capacity in 2025, but in comparison just 15.1 TWh of electricity. Bioenergy provides 10.3 TWh of electricity through 2 GW of new capacity in 2025. For comparison, the expected capacity additions to 2025 are 11.8 GW in RUPTL (due to lower power demand), around 12 GW in RUKN (high reliance on hydro) and only 9 GW in RPJMN (by 2024, more focus on realistic buildout). RUED expectation for 2025 is to add 29.4 GW by 2025.

These capacities are based on demand projections from RUKN and are thus subject to uncertainties in demand, e.g. from impact of Covid-19. With RE targets in percentage of total demand, a significant change in demand prompts an adjustment of the RE pipeline. The potential impact on the required buildout depending on power demand development is analysed in Section 2.5.

Figure 2-5 details the capacities (right) and the generation (left) of the proposed RE pipeline.

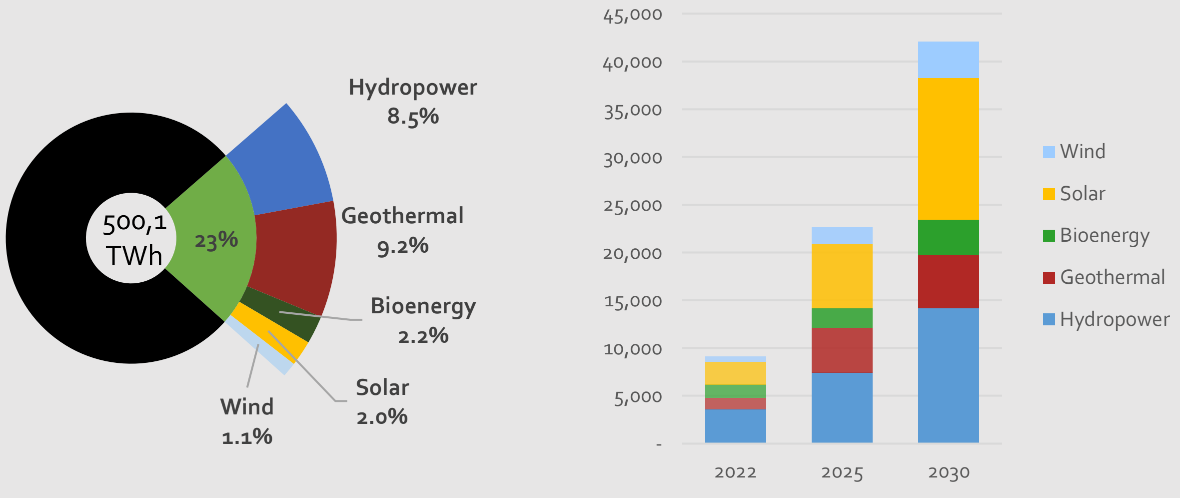


Figure 2-4: RE pipeline for Indonesia. Capacity additions in MW by year (right) and contribution to electricity generation in 2025 (left).

Perspectives on the RE Pipeline Feasibility

Given the recent developments in the cost of wind and solar, with the latest Indonesian tenders for PV expected to deliver electricity down to 3.7 cUSD/kWh (525 Rp./kWh) [4], it is expected that the VRES pipeline presented will likely be exceeded, especially for 2025 and 2030. With solar PV becoming competitive with even existing coal power plants, any of the current planning documents are likely to be much too conservative regarding RE buildout.

As a further argument, based on data from MEMR [7], the current number of projects already included in RUPTL or proposed by developers total 1.77 GW of wind by 2030 (1.12 by 2025) and 7.87 GW of solar PV by 2030 (2.82 GW by 2025). This means that already today, developers have expressed interest in developing projects covering more than half of the 2030 wind and solar capacity additions expected in the pipeline. With the commitment to an agreed RE pipeline, the interest from investors could likely increase, creating a stable environment for even more RE capacity buildout for low-cost electricity generation across Indonesia.

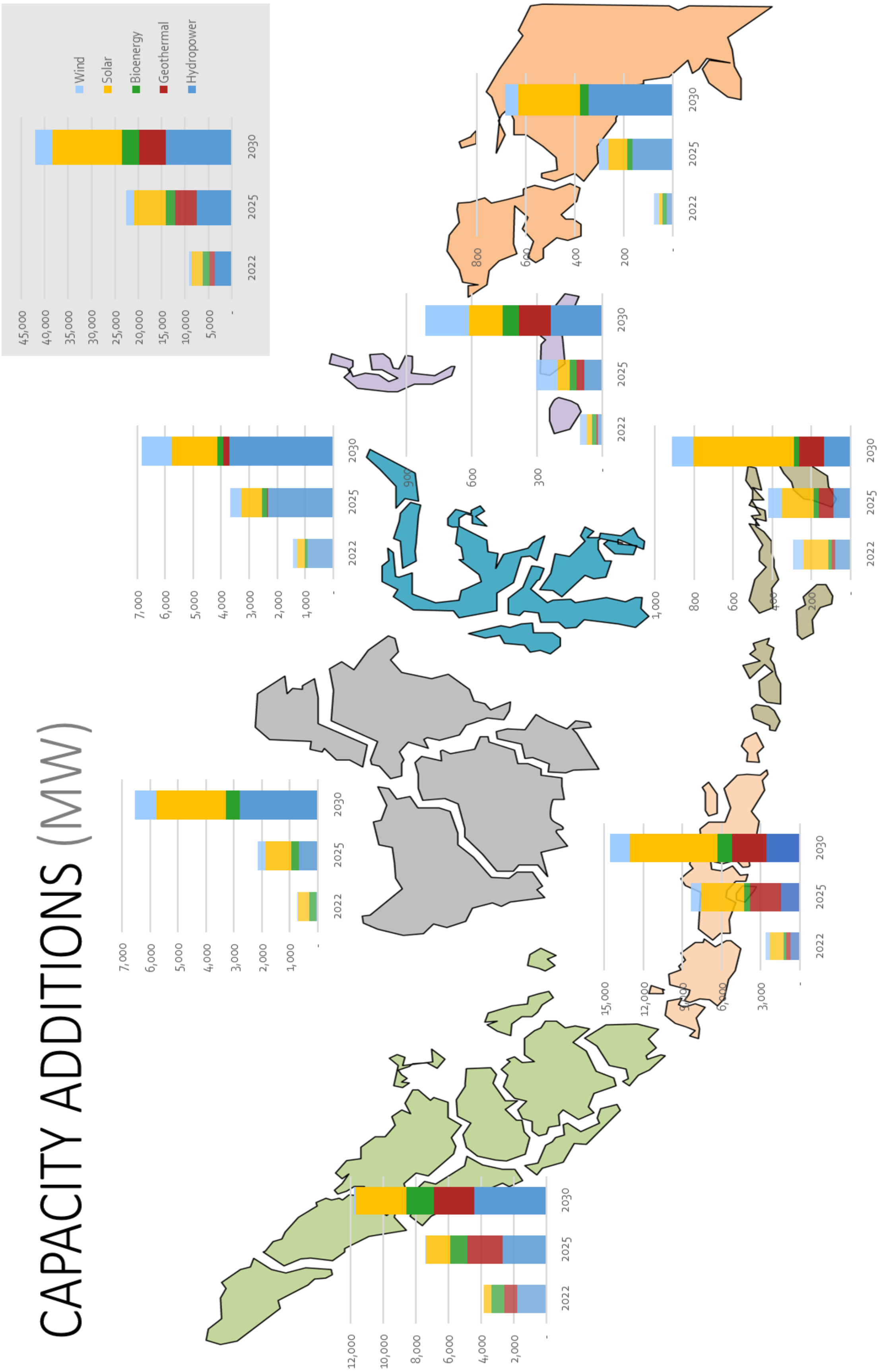


Figure 2-5: Regional RE pipeline capacity additions overview.

RE Pipeline Overview by Region

The following section presents selected overviews of the RE pipeline results. The full details are given for Indonesia as a whole and Java-Bali region. For other regions with lower electricity demands the 2025 generation distribution to reach the 23% targets are shown. Note that while at a national level the RE target for 2025 is reached, individual regional systems might not individually meet the 23% target due to variations of availability of RE sources in different regions.

Figure 2-6: Indonesia RE pipeline results.

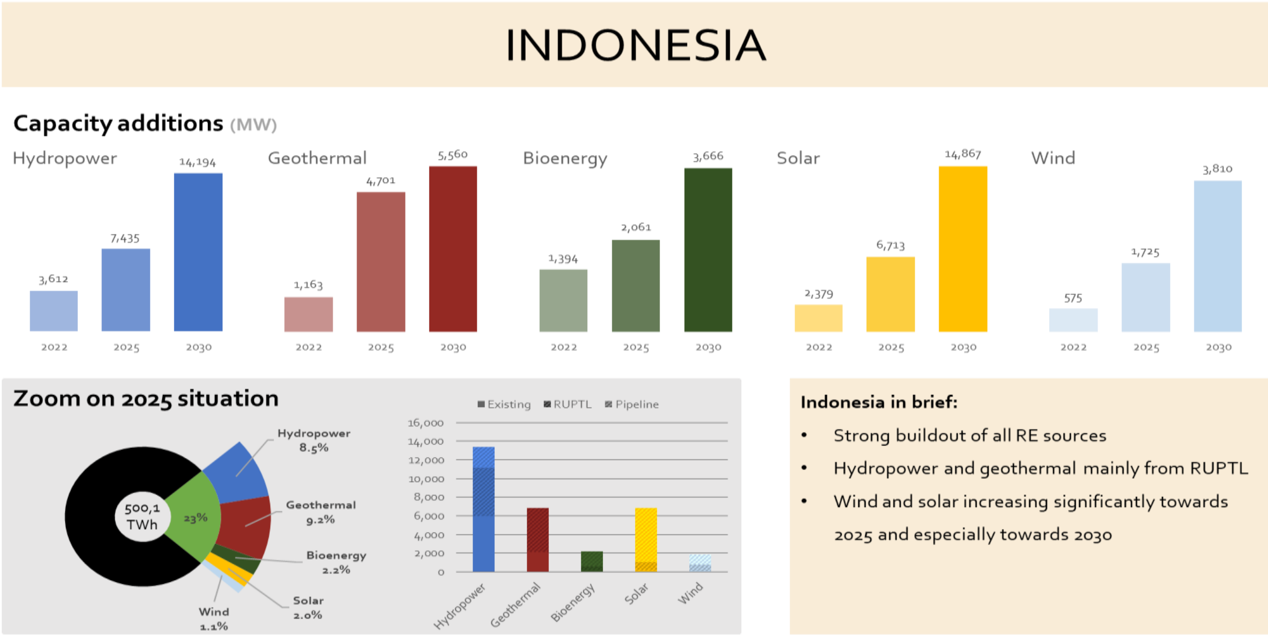
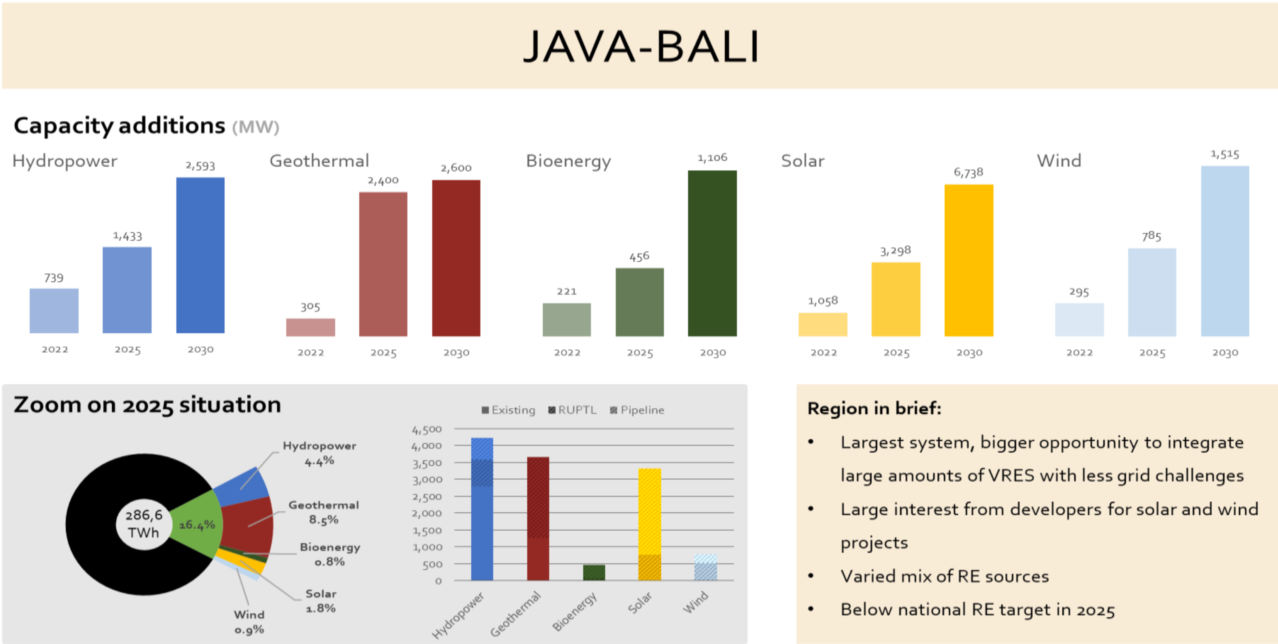


Figure 2-7: Java-Bali RE pipeline results.



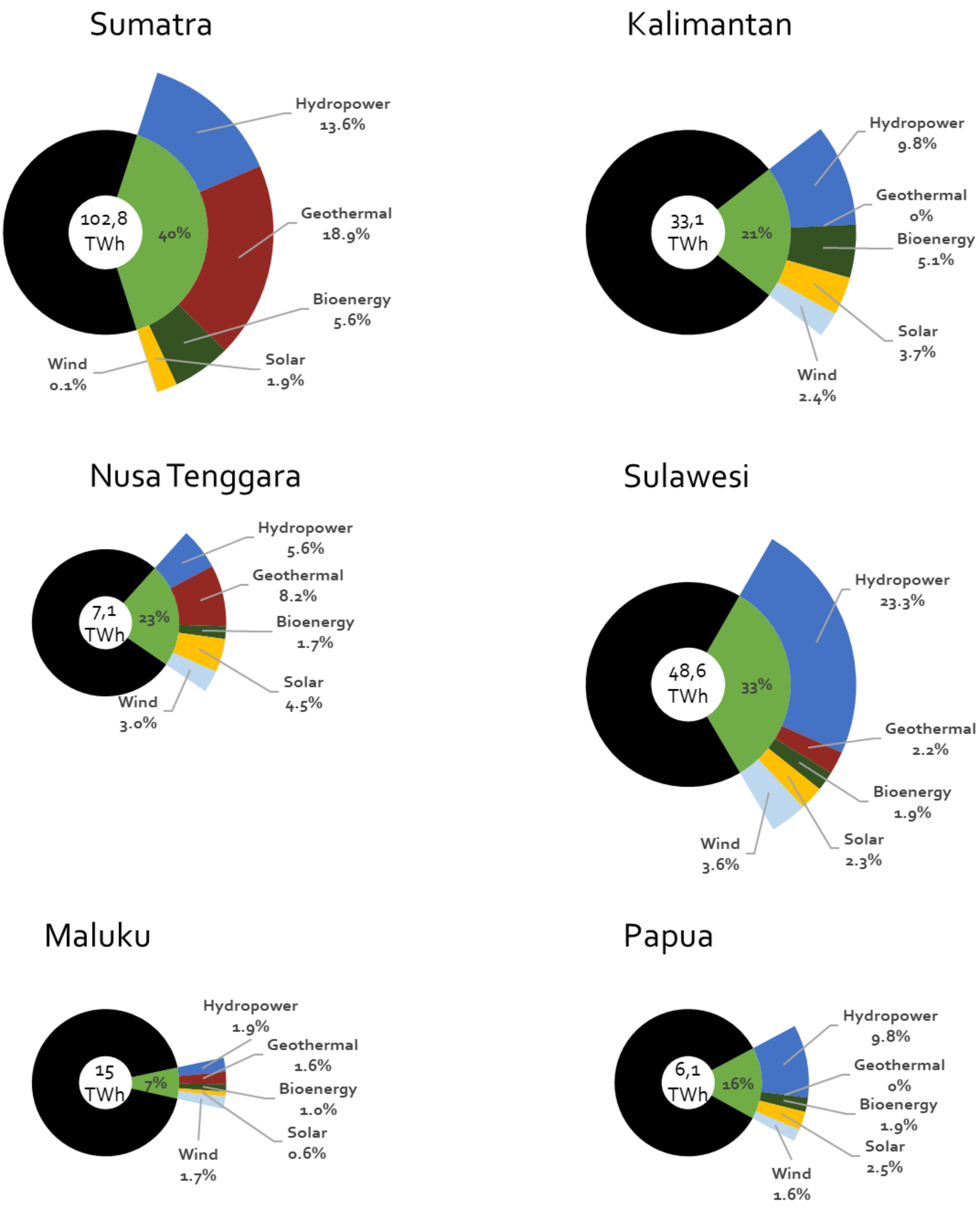


Figure 2-8: Electricity generation in 2025 including RE source distributions for other regions.

2.2. PLANNED AND NEW PROJECTS

Already planned projects make up a large share of the projected RE development in the RE Pipeline. In Table 1 a regional overview is given for capacities from projects planned in RUPTL and from "creating markets", which indicates projects that have been proposed by developers.

Table 1: Planned projects according to RUPTL and "creating markets".

Capacity (MW)	Year	Java-Bali	Kalimantan	Maluku	Nusa Tenggara	Papua	Sulawesi	Sumatra	Other National	Total
Geothermal	*Total*	*4.226*	*2.564*	*93*	*164*	*73*	*2.683*	*2.833*		*12.636*
	2020				1		90	34		*126*
	2021	156					22	115		*294*
	2022	20			2		237	697		*956*
	2023	38	3			3	82	272		*397*
	2024	1.347	37	19	26	19	274	230		*1.951*
	2025	1.077	797	20	25	2	621	574		*3.114*
	2026	238	740				190	349		*1.517*
	2027		745	54	93	10		407		*1.309*
	2028	1.000			17		200	35		*1.252*
	2029	350	243				335	103		*1.031*
	2030					40	632	17		*689*
Wind	*Total*	*1.258*	*70*	*45*	*118*		*198*	*81*		*1.770*
	2022				10					*10*
	2023	160		45	43		15	16		*279*
	2024	260	70		50		60	60		*500*
	2025	335								*335*
	2026	220					14			*234*
	2027	163								*163*
	2028						109	5		*114*
	2029	65			15					*80*
	2030	56								*56*
Solar	*Total*	*4.195*	*879*	*200*	*652*	*109*	*452*	*943*	*437*	*7.867*
	2020								135	*135*
	2021	205							106	*311*
	2022	130		4	8			102	96	*339*
	2023	589		1	5			48		*643*
	2024	442	4	0	142			56		*644*
	2025	400		195	155					*750*
	2026	542	180					312		*1.034*
	2027	551	50			109	199	2	100	*1.011*
	2028		445				253	302		*1.000*
	2029	961			39					*1.000*
	2030	375	200		304			121		*1.000*
All sources	*Total*	***9.679***	***3.513***	***338***	***934***	***182***	***3.333***	***3.857***	***437***	***22.272***

Many wind and solar projects are already proposed by developers, with 1.77 GW of wind by 2030 (1.12 by 2025) and 7.87 GW of solar PV by 2030 (2.82 GW by 2025). These planned projects cover a large part of the projected capacity buildout in the RE pipeline, as shown in Figure 2-10, showing that the ambition level of the solar and wind buildout is already largely backed by market interest.

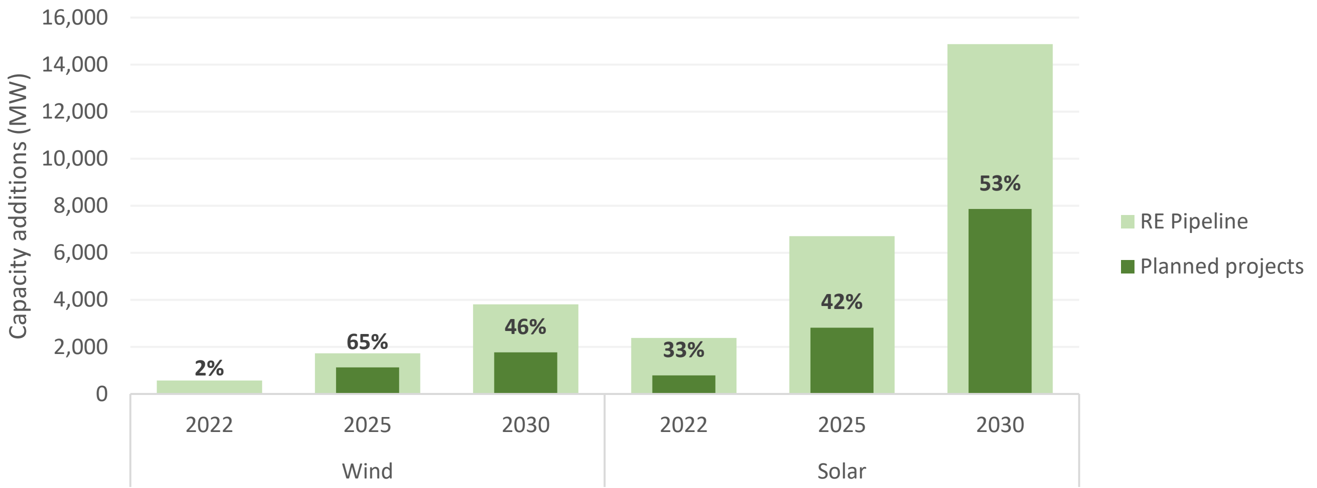


Figure 2-9: Share of RE pipeline capacity covered by currently planned projects for wind and solar.

In 2025 almost 65% of the proposed wind capacities are met by already planned projects, which drops to 46% in 2030. For solar PV 42% of the proposed new capacity is covered by already planned projects, but this rises to 53% in 2030. In Figure 2-11 the distribution of planned projects across RUPTL and creating markets is shown alongside the distribution across regions.

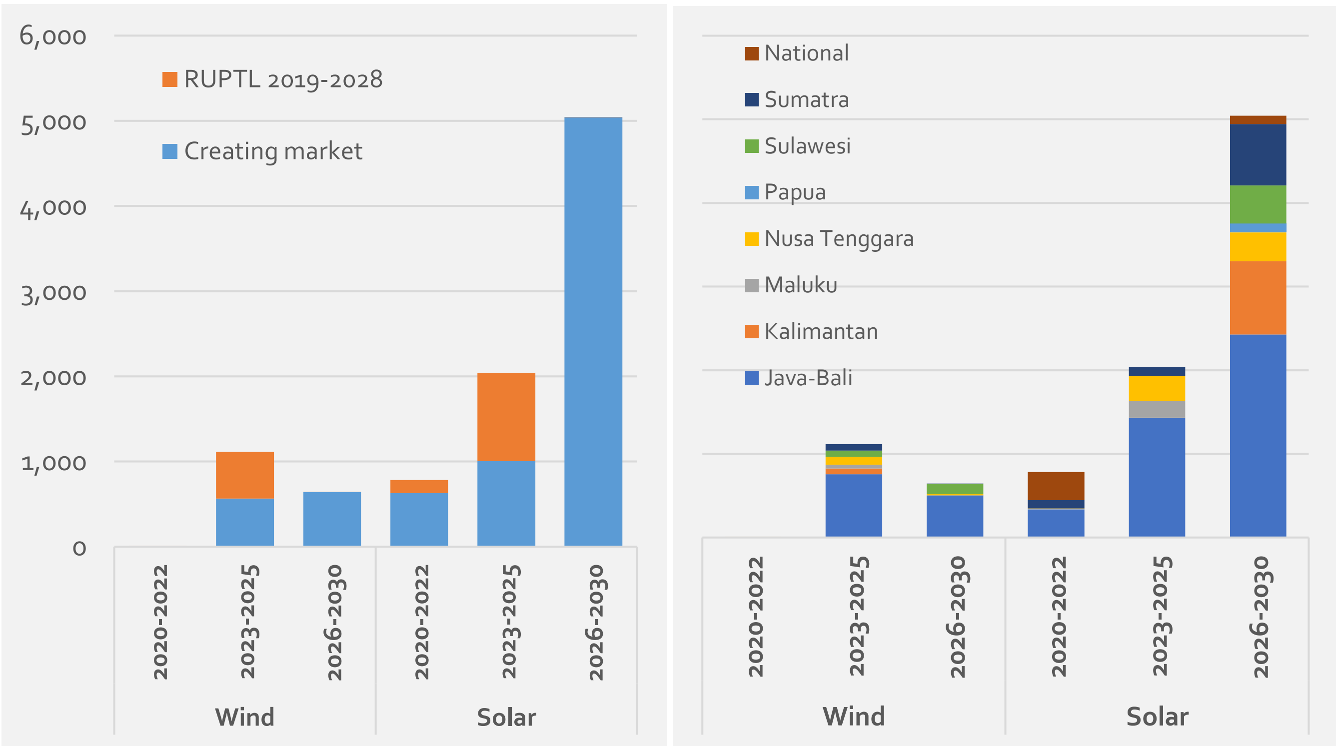


Figure 2-10: Projected wind and solar projects from RUPTL and "creating market" (project proposed by developers) by source (left) and by region (right).

2.3. RE POTENTIALS

Indonesia is abundant with RE potential but is only just beginning to tap into this. With the outlined capacity buildout from this pipeline, the potentials remain largely unutilized for all technologies. Based on reported potentials from RUEN, the utilization for each source nationally and for each region is calculated. In Figure 2-12 the national utilization degree is shown. Regional utilization is found in Appendix D.

Towards 2025 and 2030 the buildout of RE is increasing, and for the case of VRES especially towards 2030. There is a large unrealized potential for increasing levels of RE from all sources, especially for VRES sources with only 7% of solar and 6% of wind energy potential utilized in 2030.

Due to the focus of RUPTL on geothermal energy, this potential is utilized to a much larger degree, with 37% of geothermal potential realized already in 2025. In contrast, the second most utilized potential is hydropower at 12% in 2025. This strong focus on geothermal can pose risks, but with the large availability of other RE sources, this can be mitigated through introduction of additional capacity from other sources.

On a regional level the utilization varies significantly. Java-Bali shows large utilization of available hydropower and geothermal resources at roughly 50% in 2025. No region is using more than 11% of wind or solar in 2025, showing vast potential for further buildout with VRES if needed. Maluku is the only region to leverage a large share of the bioenergy potential with 31% utilization in 2025, rising to 79% in 2030, although the amounts are small due to Maluku's limited overall potentials outside of VRES.

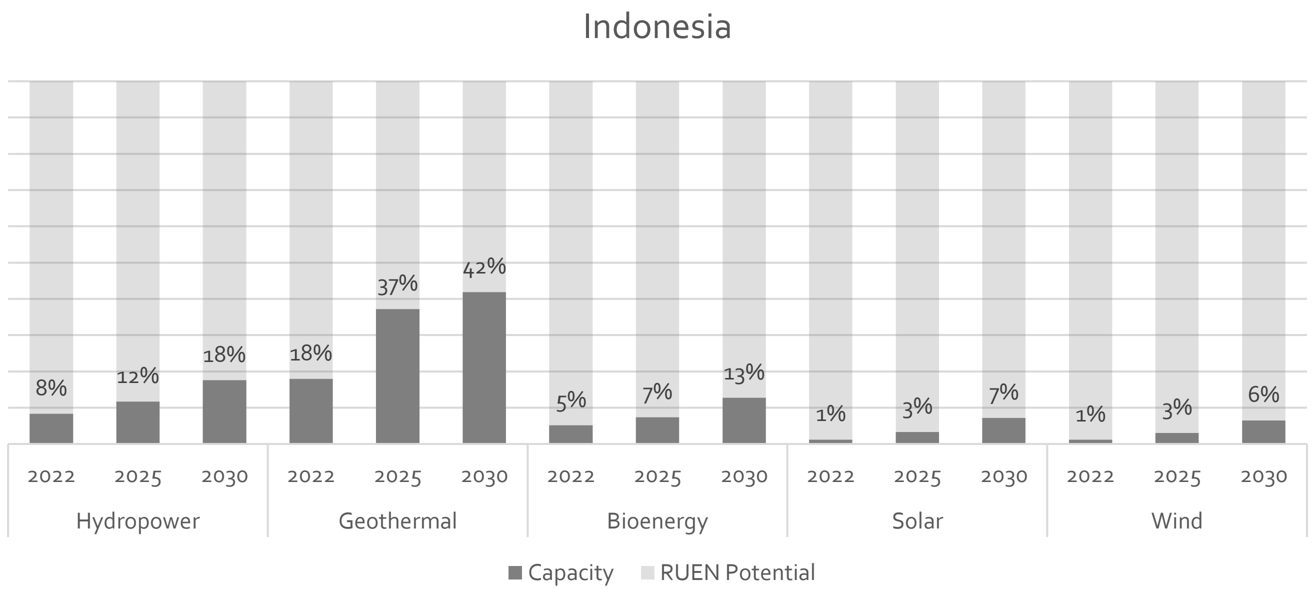


Figure 2-11: Utilization of RE potential in Indonesia, as defined in RUEN, based on proposed RE pipeline.

2.4. THE RISK OF HIGH RELIANCE ON GEOTHERMAL

On the shorter term, mainly towards 2022 and 2025, wind and solar are the most viable options for increasing planned RE capacity due to shorter construction times, 6-12 months according to the Indonesian technology catalogue (updated in 2020 [6]), compared to 2-6 years for hydro and 1.3-3 years for geothermal. Wind and solar are however only included in very limited amounts in RUPTL in 2022.

The very large geothermal focus in RUPTL gives rise to possible delays and risks of not meeting set targets. There is an indication that investment cost of geothermal is often underestimated due to the uncertainty in the drilling process and the resource assessment. New large hydropower projects, similarly, are affected by the multi-dimensional nature of the projects, as these often relate to access to drinking water, water needs for irrigation, etc. Moreover, both hydropower and geothermal sites are often located close to protected areas adding further uncertainties and risks in the planning process.

Compared to other official documents, RUPTL has a very ambitious plan for geothermal, especially in the short term. Both RPJMN and EBTKE's Geothermal Roadmap [7] feature much less geothermal capacity by 2025 ranging from 3.2 GW to 3.6 GW. In case the ambitious plan in RUPTL cannot be carried out, a capacity deficit of 3.2 GW of geothermal would appear, compared to the abovementioned plan, see Figure 2-13.

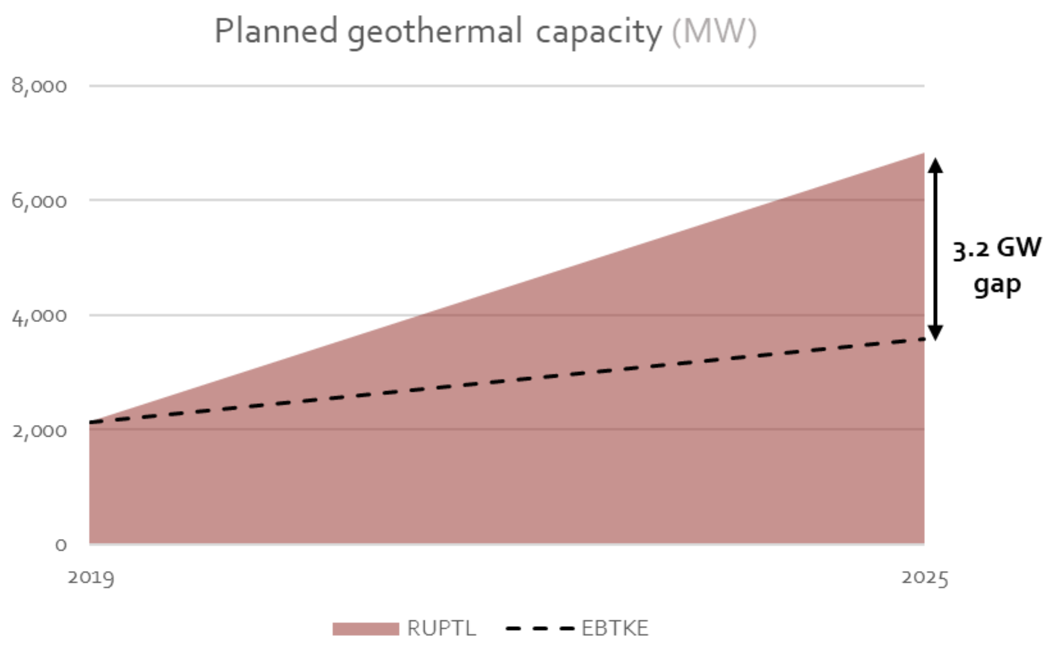


Figure 2-12: Geothermal capacity gap between EBTKE and RUPTL.

It is likely that this gap will give rise to the need for further buildout of VRES to meet the targets on the shorter time horizon. If this gap is to be covered by wind and solar, the RE sources with the shortest construction times, the requirements would be in the order of additional 7 GW of solar PV and 4 GW of wind in the pipeline, compared to what was presented in this document, yielding new capacities of wind at 5.7 GW and solar at 13.7 GW in 2025. These levels would require more ambitious and fast-paced buildout but is feasible given the right incentives.

2.5. POWER DEMAND UNCERTAINTY

The Covid-19 pandemic has had significant impact on power demand during periods of lockdowns and restrictions. Power demand reduced by 20-30% in some countries during initial lockdown, however there are clear signs of demand recovery, with India more than 10% above the demand level of 2019, according to IEA [15] - see Figure 2-14. The demand shrinkage is expected to be a temporary challenge without major long-term impact.

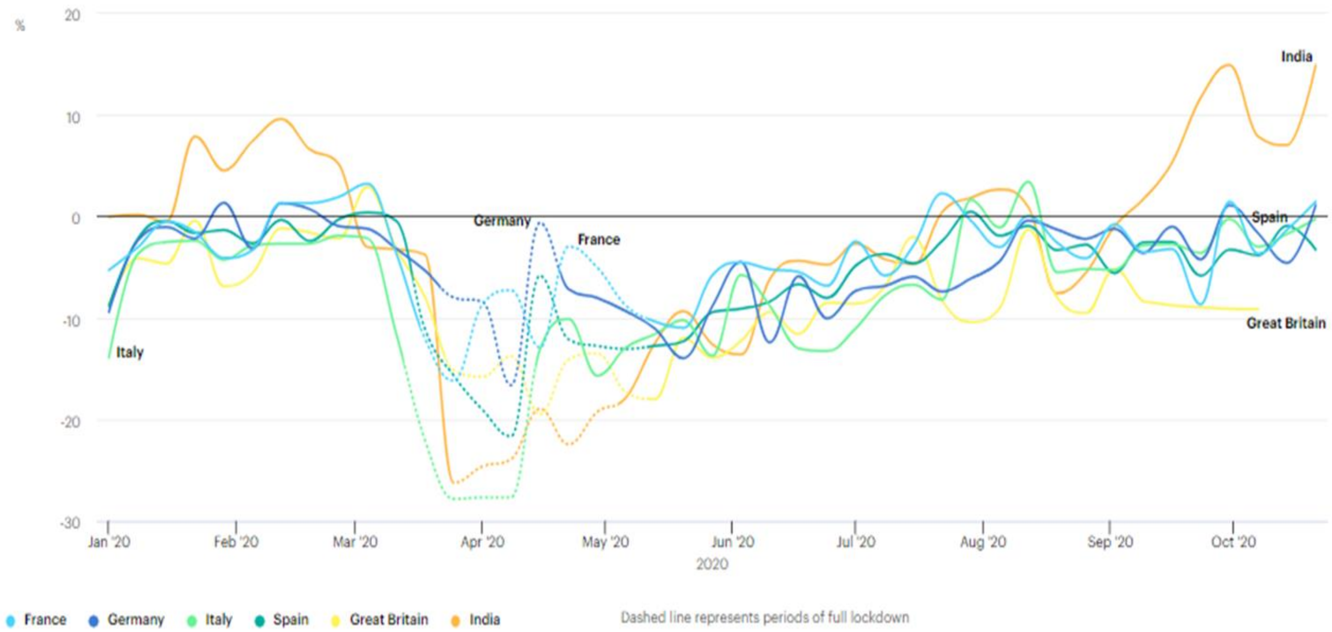


Figure 2-13. Year-on-year change in weekly electricity demand, weather corrected, in selected countries, January-October 2020

While the impact of Covid-19 will mostly affect demand short term, however demand growth in 2020 has been minor. In Figure 2-15 a sensitivity scenario is shown using a very conservative assumption of 15% reduced demand in 2025: combining one year with stagnant demand and reduced demand for the next 5 years. Production has been proportionally reduced by 15% for each RE technology based on total expected production in 2025.

In this worst-case scenario, the capacity additions of 22.6 GW in 2025 are reduced by just 4.6 GW to 18 GW to meet the 15% reduction in electricity demand. With the proportional reduction of all technologies, 7.1 GW of new wind and solar PV capacity remains in the pipeline.

Real impact of COVID on the power demand is expected to be smaller than analyzed here. The overall picture of the pipeline remains highly intact in all likely scenarios.

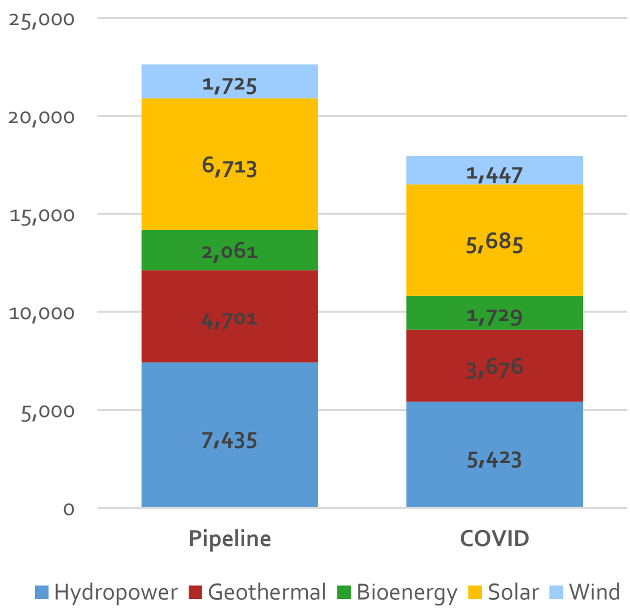


Figure 2-14: Impact of reduced demand on RE pipeline capacities.

SUMMARIZING THE RE PIPELINE

The RE pipeline builds upon existing energy planning documents in Indonesia to provide a clear pathway to reaching the 23% RE target in 2025 and to extend the outlook to 2030. Building upon the capacities set forward by PLN in RUPTL, and the total electricity demand projections from RUKN, the pipeline offers region-by-region RE capacity targets to support the development of RE quotas in Indonesia. Moving from 11.4 % RE in 2019, a significant capacity expansion must take place. An intermediate goal of 16% RE in 2022 and a target of 24.6% RE in 2030 are set based on linear development towards 2050.

Towards 2025, 22.6 GW of new RE capacity is needed, 8.4 GW of which is solar and wind. Hydropower and geothermal supplies the majority of electricity in both 2025 and 2030 but increasing levels of VRES allow for cost effective paths to RE targets. RE potentials according to RUEN show massive unused potentials for all regions, also far beyond the capacities presented in the RE pipeline.

RUPTL has a large focus on geothermal capacity with an ambitious buildout plan in the short term, which poses a risk to jeopardize the achievement of the 2025 RE targets due to a longer planning horizon and uncertainties in drilling processes. The capacity gap between RUPTL and EBTKE’s geothermal roadmap is 3.2 GW, which would require an additional 7 GW of solar PV and 4 GW of wind if this is to be covered by VRES sources with shorter construction times. On the other hand, given both the interest expressed from developers and the recent development in the cost of wind and solar with the latest Indonesian tenders for PV expected to deliver electricity down to 3.7 cUSD/kWh (525 Rp./kWh), it is expected that the VRES levels of the RE pipeline presented will likely be exceeded, especially for 2025 and 2030.

The pipeline contains suggested capacity deployment both at the national and regional levels to support both national policies and local implementation.

CHAPTER 3. **VRES INTEGRATION**

3.1. INTEGRATION OF WIND AND SOLAR IN THE RE PIPELINE

In the RE Pipeline just presented, wind and solar accounts for 37% of the capacity additions in Indonesia towards 2025, but just 14% of additional RE generation, due to lower capacity factors compared to other technologies (see Appendix C). The presented wind and solar buildout provides 3.2% of total electricity demand in 2025, which increases to 5% in 2030.

The highest instantaneous VRES penetration at the hourly level is 12-26% in major regional systems. This is considering the most extreme hour of the year. The average daily maximum instantaneous VRES penetration is 7-16% in the four major systems, and happens around the central part of the day, when the solar radiation is at its peak. These levels of instantaneous VRES penetration are currently handled smoothly in multiple grids and countries with no risk for the security of supply.

The 24-hour period with largest single-hour projected wind and solar penetration in 2025 is shown in for the four largest regional systems. The VRES penetration is calculated based on RUKN demand for the region. Specific grids can have larger or smaller levels of VRES penetration.

Nusa Tenggara has the largest regional VRES penetration at 37% in the hour with maximum penetration. However, despite the large value in specific hours, there are only around 72 hours per year with more than 30% VRES in the electricity generation mix. The average daily maximum instantaneous VRES penetration throughout the year is only 20%.

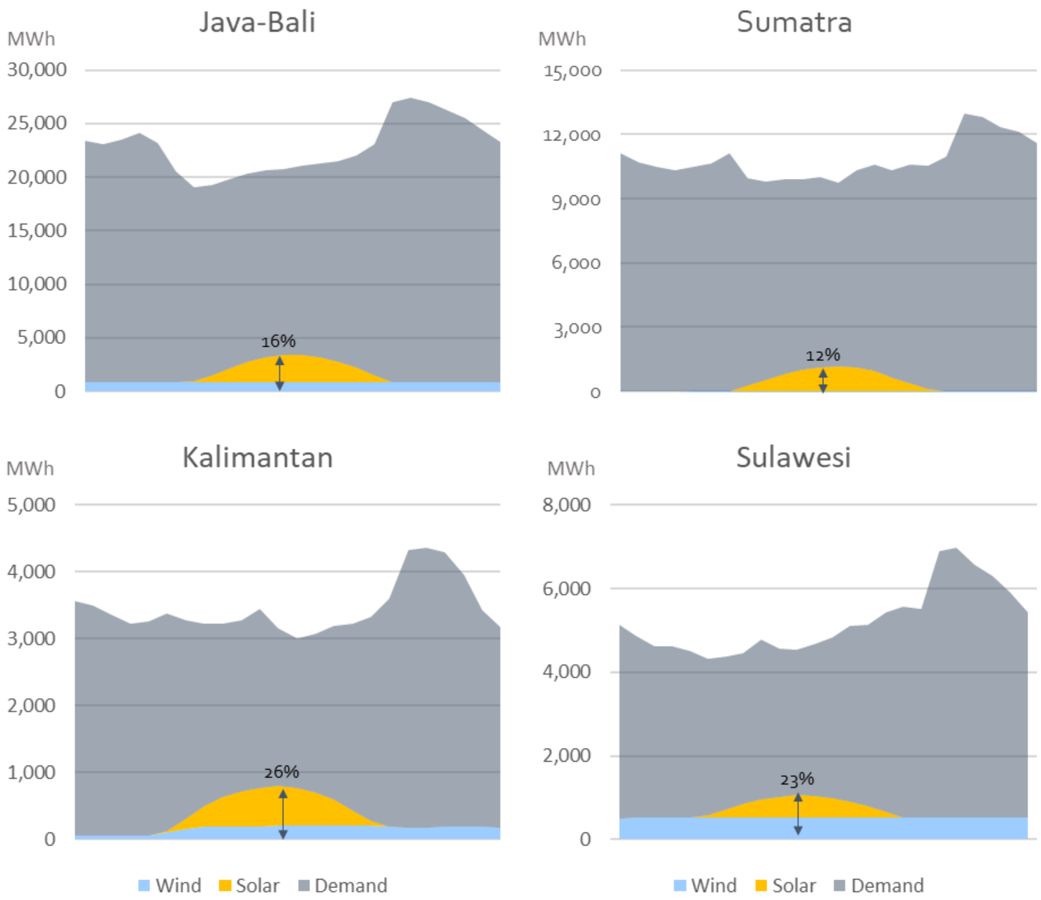


Figure 3-1 Highest instantaneous penetration of VRES in the four major regional systems.

3.2. VRES STATUS AND CHALLENGES IN INDONESIA

As shown in this analysis, Indonesia is home to vast amounts of renewable energy sources. Historically, hydro, and geothermal energy has been the predominant sources of renewable energy in Indonesia. Tapping into the possibilities of a future energy supply more reliant on cheap solar energy, changes will occur in the next few years. Only a small fraction of the solar and wind energy available is currently utilized. As solar and wind energy are cheap alternatives to expand the RE-share, they are expected to grow manifold towards 2025 and 2030.

The Indonesian RE-potentials derives from various sources behaving differently and offering shifting capacities over the course of a day, week, year and even from one year to another. For this same reason, the *integration* of renewable energy plays a large role in any energy system changing its course from fossil energy supply to a sustainable energy supply.

A proper integration of a diverse renewable energy supply mix can harvest the benefits while mitigating the challenges of variable renewable energy like wind and solar. However, specific knowledge and planning to alleviate these inherent challenges are required. Additionally, energy planners must be aware of what measures are needed for different shares of VRES. High VRE-shares require different tools and investments, while lower shares can enable cheap and easily available electricity without the need for large flexibility enhancements or storage deployment.

Different renewable energy sources and technologies have different characteristics and are characterized by specific opportunities and challenges. It is necessary to be aware of similarities and differences when understanding how to best integrate the available energy sources. This report includes five RE-sources: (1) Hydropower, (2) geothermal, (3) bioenergy, (4) solar and (5) wind. This chapter dives into their construction, behaviors, and performance in the interest of showcasing how they can be integrated in Indonesia and support the renewable energy target of 23% in 2025.

FIVE TECHNOLOGIES: COMMON BENEFICIAL TRAITS

The common traits for renewable energy technologies entails their capacity to produce energy at very low carbon emissions. This allows the technologies to be part of the effort to mitigate climate change. As indicated in the term 'renewable energy' indicates that these energy sources are potentially inexhaustible in their use. The technologies in this report, apart from geothermal, relies on energy from the sun, either directly or indirectly, allowing them to harvest constantly renewed energy. Geothermal power plants harvest naturally occurring heat from the underground. As such, they can ensure a high energy security if managed correctly. In an Indonesian context this could induce a lower reliance on energy from imported fuels while reducing the negative climate effects from energy consumption. Renewable energy sources rely on utilizing the natural energy flows from nature. In effect, this means there are no added fuel costs related to the operation of the suggested technologies in this catalogue (excluding bioenergy).

FIVE TECHNOLOGIES: DIFFERENT INTEGRATION CHALLENGES

Discussing the different challenges of the technologies is subject to the core of the issue behind integration of renewables.

Solar PV plants and wind turbines are both technologies that rely on multiple factors determining their power output. For example, solar PVs have their peak generation in the middle of the day when the sun's irradiance is the highest and the solar arrays can absorb the most energy. Solar PVs and wind turbines technologies are non-dispatchable and often defined as variable renewable energy sources.

Of the five technologies only hydropower and bioenergy are dispatchable, offering flexibility to meet the power demand - they are flexible. This trait makes them easier to integrate as they can fit the demand of the electricity consumption. Crucially, this feature is also what makes for a good tool to integrate the variable renewable energy sources. They can be said to go well with renewable energy sources such as solar or wind energy. Planning a cost-efficient, secure, and climate-friendly energy system requires finding the right balance between cheap variable renewable energy and dispatchable renewable energy.

CURRENT RENEWABLE ENERGY PENETRATION

IEA [16] created a framework to indicate six different levels of impacts from VRES in the power system grid (Figure 3-2). Stretching from Phase 1 to Phase 6, this model conveys the gradual steps required in terms of adapting the power and energy system to integrate the increasing shares of wind and solar. Due to the heterogeneity among power systems, this framework does not specifically define metrics, e.g. VRES penetration levels, at which the different challenges start to occur. At phases with high penetration, cost-effective integration of VRES calls for a system-wide transformation.

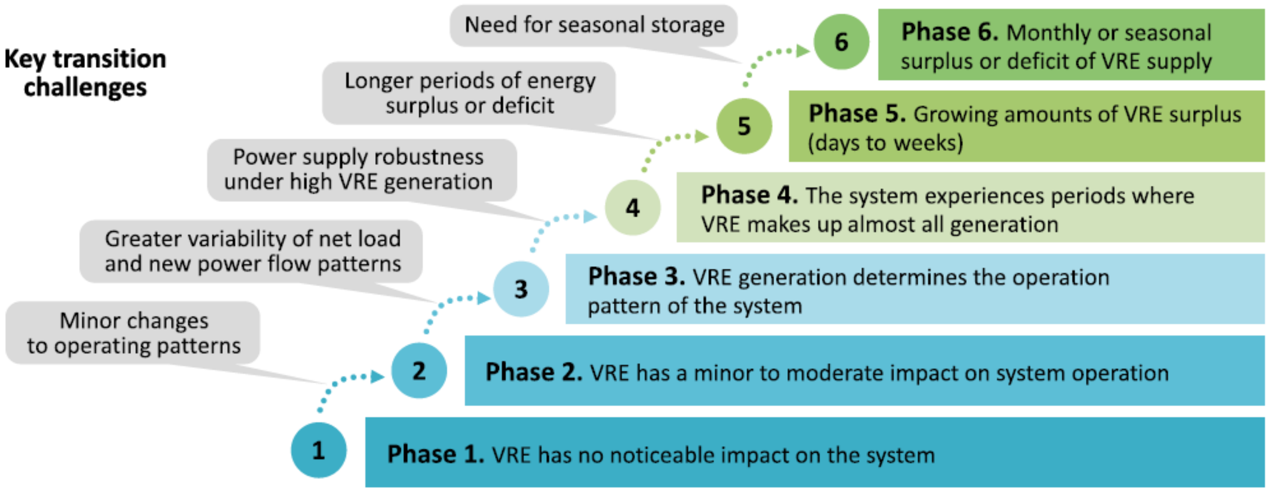


Figure 3-2. Key challenges by phase in moving to higher levels of integrating variable renewables in power systems. Source: [16]

The model is useful to express how different measures are required for progressing phases of VRES in a system. The first phase represents a level of VRES low enough to have no noticeable impact on the power system. Hence, there are no extensive measures required to integrate this amount of VRES. Progressing through the steps on the figure more and more considerations need to be taken to ensure the robustness of the system and security of the energy supply. Year after year, worldwide countries and power systems have been increasing VRES penetration and moving to successive phases. To date, no country is recorded having reached past phase 4.

Figure 3-3 shows examples of how selected power systems classify according to the different phases of challenges. Note for example, that Denmark (DK) on this figure, is ranking highest among countries in terms of VRES penetration level (above 60%) yet is still in phase 4 together with Ireland (penetration level of less than 30%). This is mainly explained by the fact that the Danish power system, contrary to the Irish, is highly interconnected with the electricity grids of neighboring countries, thereby significantly reducing the integration challenge.

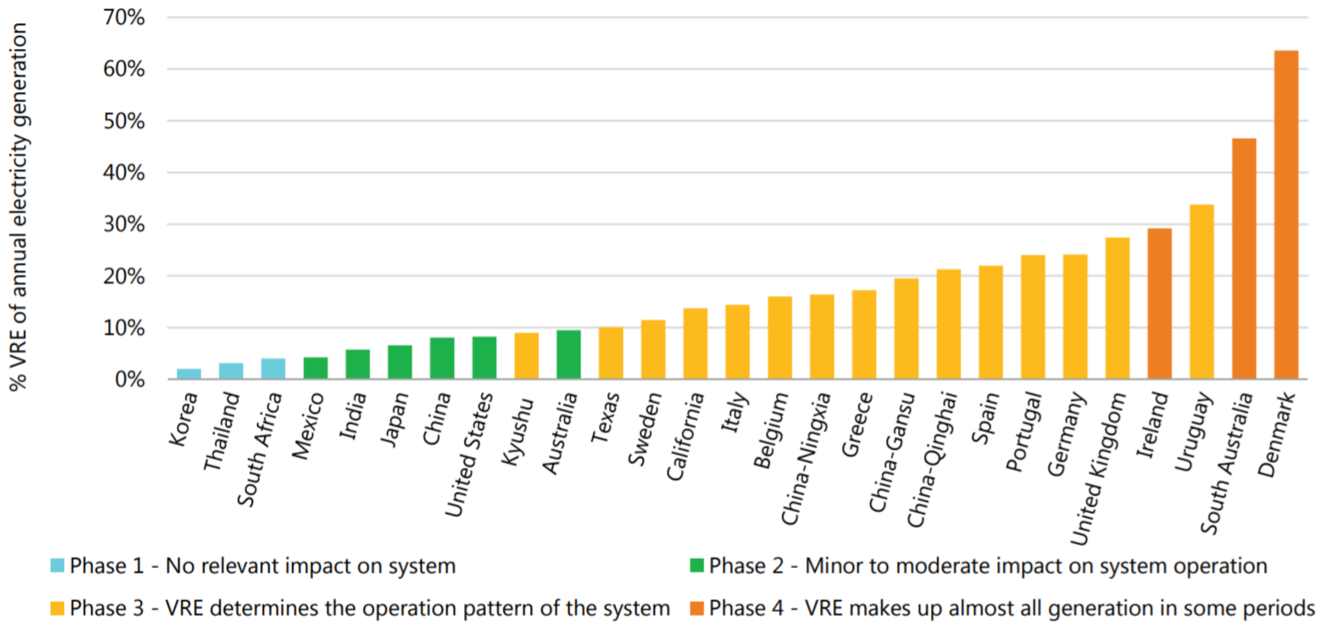


Figure 3-3 Categorization of several power grids by Phases of VRES integration challenges and their respective penetration levels in 2018. Source: [16]

In the current debate in Indonesia, the challenge of integrating variable renewable energy is often overstated. VRES integration challenges depend on the scale of renewable development and Indonesia is still at the beginning of the power system transition (phase I), at which point renewable energy can generally be integrated through low-cost measures. However, certain smaller power systems and remote areas may quickly achieve a higher penetration of VRES, meaning that they are at a higher phase and require more attention to the VRES share. In a fragmented power system such as the Indonesian one, it is important to recognize that starting to integrate wind and solar is easier and less expensive in larger and more interconnected grids, rather than smaller and isolated ones.

With these considerations in mind, it becomes apparent that Indonesia, especially in its larger regional system, is in a good place to significantly increase the VRES-share towards 2025, without compromising the reliability of the power supply and integrating VRES generation within the existing grid infrastructure and power mix.

Reduced need for storage at this level of integration

Energy storage is a heavily discussed topic in tandem with increasing variable renewable penetration. Storage technologies include different types of electrochemical storage, pumped hydro storage and mechanical storage systems. Under electrochemical storage lithium-ion batteries are touted to make up the major market share in the energy storage sector going forward. While lithium-ion batteries in electric vehicles and in combination with small solar and wind are seen commercially, grid scale batteries is yet to become mainstream.

A key reason for developing energy storage within the power sector is the improved flexibility, the possibility to shift renewable generation to hours of high power demand (making variable renewable energy partly dispatchable) and the possibility for batteries to provide additional system services. With increasing variable renewable penetration, like solar and wind, energy storage can store excess production, and discharge this stored energy when there is a supply deficit. Moreover, the cost of energy storage has been and continues to reduce significantly with time. There is no doubt that energy storage, in particular batteries, can help sources like wind and solar to overcome some of the integration challenges.

However, when taken in context of the framework presented in the previous section, it is expected that energy storage would be an important integration measure at higher phase of the power system transformation, where significantly longer periods of surplus and deficit become more and more frequent. This is testified by the fact that many of the power systems at higher phases, for example Denmark, have still to experience large battery storage deployment. Except for specific selected projects or application, no extensive use of grid-level energy storage has been yet seen at a global scale.

Therefore, in the Indonesian perspective, where the power sector is still in phase 1 in terms of RE penetration, the requirement for energy storage is not critical. The power grid is capable of handling most of the variation at this low level of penetration without support from energy storage. However, keeping in mind the immediate future and long-term perspective, investments in other integration measures like VRE forecasting, flexibility of power plants and increased interconnection, will be more beneficial. This will not only help with optimized grid operation, and security of supply, but also provide a better foundation along with paving the way for increased shares of renewable energy in the long-term. These measures will be discussed in more detail in the proceeding sections.

As can be seen in Figure 3-4, grid level storage is a cost-effective option at higher Phases of RE deployment and many measures are more proper to be implemented at lower penetration levels.

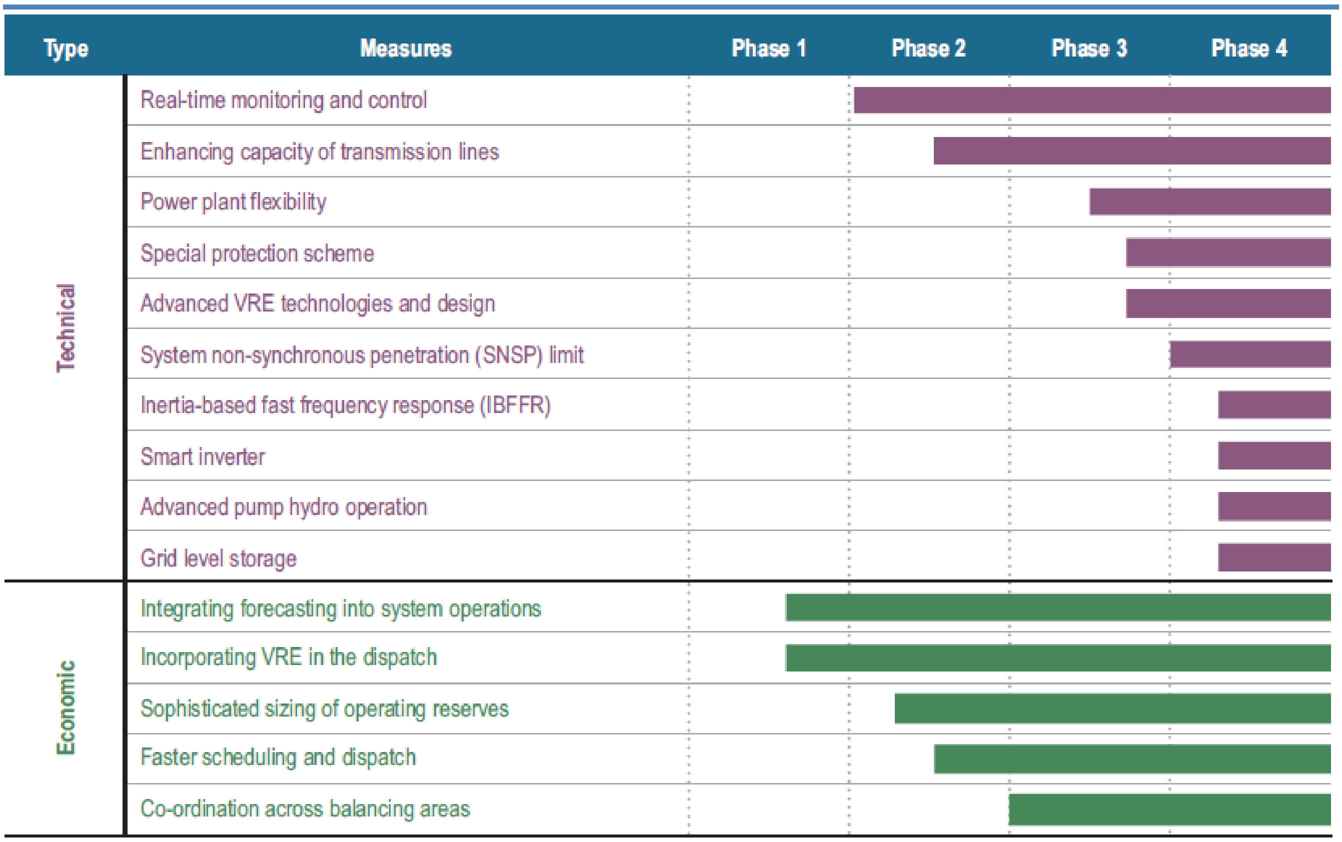


Figure 3-4 Measures to implement in different phases. Source: [17]

3.3. PREPARING FOR AN INCREASED VRES SHARE

INTEGRATION MEASURES

It is key to choose solutions that are proportionate to the phase of challenges and VRE integration. One solution might be appropriate for one phase, but too expensive or insufficient for another. Some solutions involve investments in expensive hardware, whereas others involve changing practices of system operation and soft costs related to improved system monitoring and changes to market design. In the first phases of RE integration, the soft measures are usually adequate.

Figure 3-5 provides a conceptual overview of various integration measures, including institutional, economic, and technical solutions along with an indication of their relative cost (actual costs are system-dependent) [18]. Interventions come with associated cost and administrative effort required in implementing them.

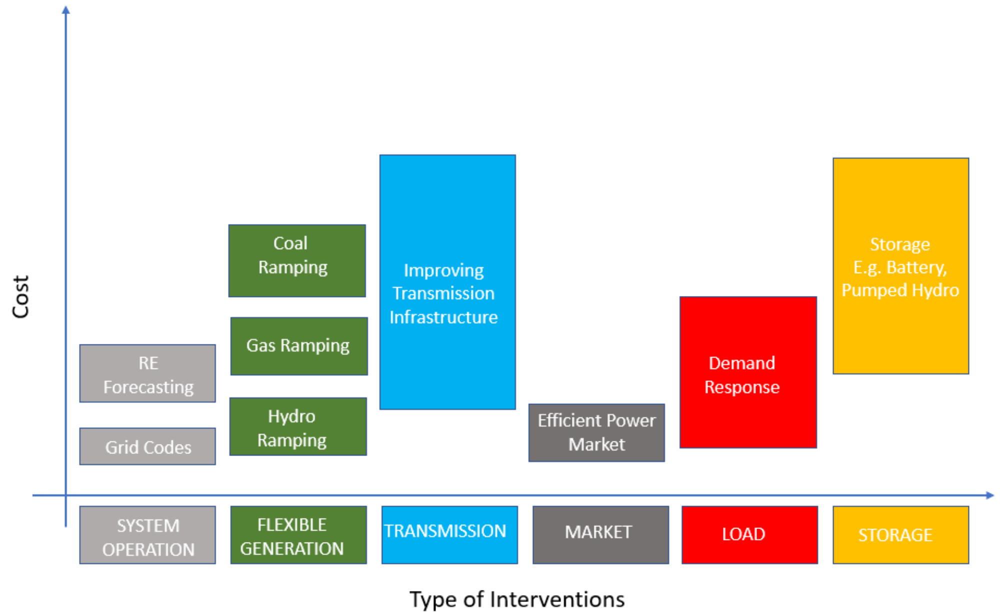


Figure 3-5 Options for improving power systems flexibility showing types of interventions and costs, inspired by [18].

Changes to system operation practices and markets can allow access to significant existing flexibility, often at lower costs than options requiring new sources of physical flexibility. Improving renewable energy supply forecasting can improve the dispatch of other generators to reduce need for keeping more reserves online, reduce the fuel consumption, and reduce the operating and maintenance costs. This type of intervention includes some of the cheapest solutions and is relevant across the Indonesian power system.

Being able to ramp production up and down according to the demand of the power system is an essential feature of any power system, but with increasing share of VRE flexible power plants becomes increasingly important. Practical experience from Denmark and other countries show that it is possible to operate existing coal fired power plants with very load minimum levels and steep ramping. Exploiting the potentials for flexible generation is particularly relevant to the archipelago but could quickly become important across the entire power system.

Creating enabling market frameworks has proved a very efficient means for VRE integration in Europe and many jurisdictions in the US and elsewhere. The price signals in the day-ahead market, intra-day market and ancillary service markets provide generators incentive to operate in a flexible way, to provide system services for the grid, to continuously enhance the flexibility of their assets and to adapt investments in new generation capacity to match the requirement of the power system. In Indonesia, PLN is responsible for the bulk of Indonesia's power generation, and has exclusive powers over the transmission, distribution, and supply of electricity. Still, there are plenty of possibilities to apply price signals to improve system flexibility under the current monopoly, for example by incentivizing cost-reflective dispatch, applying smart tariffs to consumers and by designing power purchase agreements with IPPs maximize their flexibility potentials.

Increasing the responsiveness of electricity demand improves flexibility by enabling or encouraging consumers to adjust their demand in response to system events or prices. Demand response is relevant also in the case of system with low VRE share but becomes more relevant in high VRES systems. The most cost-efficient potential for developing demand response is typically located at large industries or service companies rather than residential consumers. Developing demand response could particularly become relevant for the archipelago of isolated systems, as they prepare for the later phases and challenges.

Transmission capacity is often considered an integral part of system flexibility as it offers an alternative to using variable RE generation locally. With strong and sufficient interconnectors connecting the different isolated systems the balancing area could be expanded aiding VRE integration as variations of different RE generation sources are evened out and balancing resources on the supply side, such as thermal generator capacity and hydropower plants, could be shared. Expanding the transmission grid is highly capital intense, but the benefits can be significant, extending beyond VRE integration.

Storage technologies – such as pumped hydro and batteries – are the easy choice for integrating solar and wind and the cost of battery electric storage has decreased considerably in recent years. Still, storage technologies have a high capital cost relative to most other options for flexibility currently available. Storage may prove relevant for specific location in the archipelago but ought not be among the first solutions to be considered.

Three of the most relevant options for Indonesia to start preparing for increased RE penetration following the presented pipeline, namely VRES forecasting, power plant flexibility and increased interconnection are presented in the following sections.

VRES Forecasting

Accurate VRES forecasting helps to reduce the need for acquiring more reserves, reduces the starting up of costly reserves and reduces the imbalance at the time of dispatch. In countries with high RE share like Denmark, forecasting is based on a combination of so-called offline and online wind power. Offline forecasting uses inputs from Numerical Weather Prediction (NWP) models and online forecast uses both information from offline forecast and real time wind power and speed data. A typical mean absolute error in Denmark is around 4.5% of the installed capacity at a time horizon of 35 hours from actual hour of production and by improving the forecast through online data the mean absolute error is reduced to just 1.5% one hour in advance of production.

These levels of forecasting error closer to the delivery time are in line with the errors in the power demand, making the uncertainty on wind power less impactful on the need for reserve.

Solar forecasting is based on comparable methods. NWP models are applied to predict the specific weather conditions in the longer term, whereas digital cameras, producing high quality sky images, and satellite imaging data are used to predict the cloud formation, and thus irradiance and power production, at shorter time scales. On the short-term horizon, below 1-2 hours in advance, online measurements of PV generation solar forecasting are based on comparable methods. NWP models are applied to predict the specific weather conditions in the longer, whereas digital cameras, producing high quality sky images, and satellite imaging data are used to predict the cloud formation, and thus irradiance and power production, at shorter time scales. On the really short time horizon, below 1-2 hours, online measurements of PV generation can further improve the precision of the forecasting. Examples from Germany show that for a single site, the precision of forecasts can be reduced to less than 10 % one hour in advance of production and on the country level to just 1.5% [19].

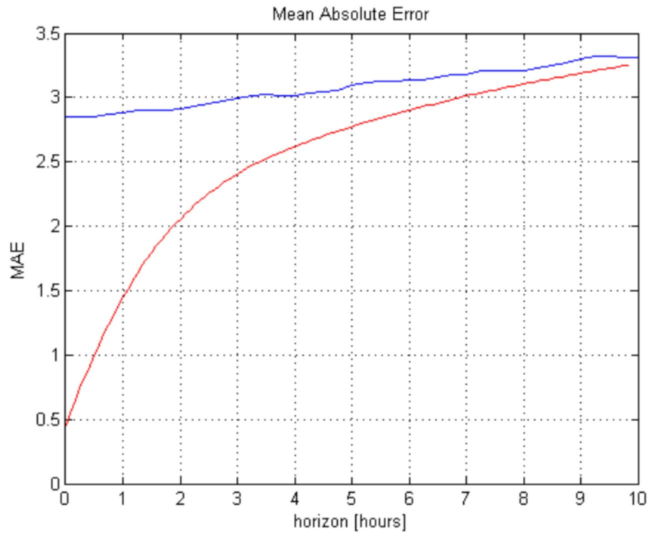


Figure 3-6 Mean absolute error (MAE) of wind forecast in Denmark in percent of installed capacity. The red line shows the performance improvements by smart use of online data. Source: [20]

To minimize the need for procurement of reserves it is pivotal that long- and particular short-term forecasting becomes integrated in system operation. It is a common misunderstanding that VRES like wind power and solar PV need to be fully backed up by a proportionate amount of reverse capacity or supplemented by electrical batteries. In contrast, experience show that in most jurisdiction, additional reserve requirements due to VRES are negligible or missing.

In Denmark for example, the requirements the electricity system is designed to comply with the so-called "N-1" contingency criterion, i.e., the system should be able to cope with the loss of one major component. The dimensioning fault is the tripping of power plants or the outage of interconnector with a capacity of 700 MW. Thus, a manual reserve with a capacity of approx. 700 MW is always enough to meet the criterion in the Danish electricity system. However, as seen from the previous section on forecasting, it is possible to reduce the mean absolute error (MAE) to 1-2% of installed wind power capacity an hour before operation, when the system operator takes over the physical balancing. With an installed wind power capacity of just above 5 GW the error on forecast amounts to less than 100 MW, which is well within the existing reserves.

In South Africa, the Ancillary Services Technical Requirements, require regulating reserves to be enough to cover the variations in net load (demand minus wind and solar) within the hour. However, a study of wind speeds and demand data, shows that variations in load by far exceed the variations of wind power. Thus, adding 3.8 GW of wind to the South African power system would only increase the reserve requirements by 9 MW from 550 MW to 559 MW [21].

The basic idea behind proper VRES forecasting is to plan ahead and to base the planning on the best available data at any time. With good forecasting, the need for buying expensive reserves is reduced as remaining anticipated imbalances could be balanced by using cheaper balancing sources.

Flexibility of Power Plants

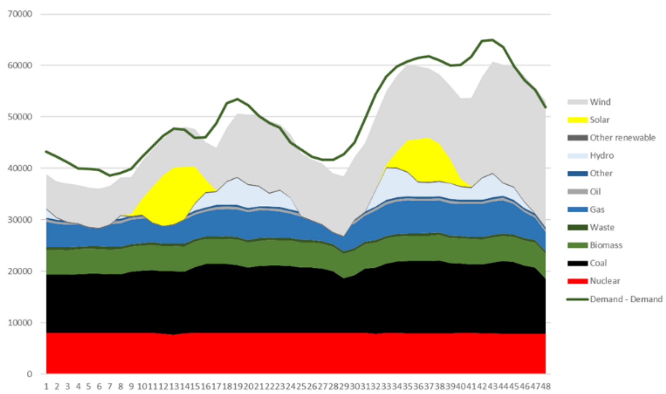
With appropriate VRES and demand forecasting schemes, the system operator can predict the required ramping (up and down) from other generators. Thus, the next important requirement is to have power plants that are flexible enough to adjust their generation as per the requirement. In Indonesia, coal fired generation makes up a large proportion of power generation and this is likely to remain the situation in the foreseeable power.

Table 2 Flexible Coal Power Plant, according to IEA [22]

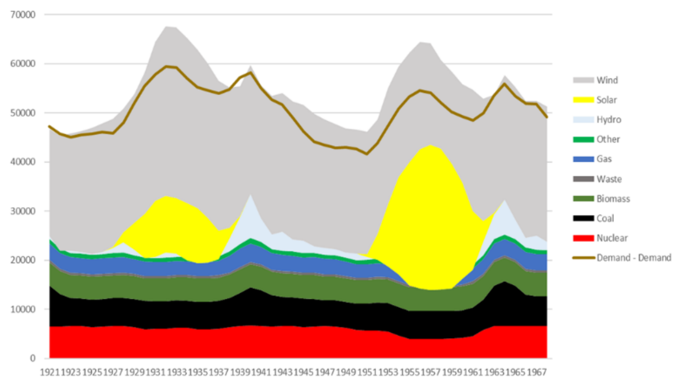
	Flexible Plant
Ramp Rate	3-8% per min.
Start-up	2-5 hours
Min. Load	20% of full load

According to the IEA [16], a flexible coal power plant (commercially available) can run at a minimum load of 20% and ramp power production up and down at a rate of 3-8% of maximum load per minute. This effectively implies that the plant can step from 20% load to 100% load in somewhere between 10 and 25 minutes. Also, a flexible plant should be able to start up in 2-5 hours after shutdown. Being able to operate at very low minimum loads is a key feature in high share VRE system as it allows the thermal generator to minimize costly startups.

Countries like Denmark, Germany and China are all working actively to prove the flexibility of thermal generators. In Denmark, ramp rates of 4% per cent per minute is already considered standard for coal power plants and 9 % per min for gas turbines, the minimum load of Danish power plants is typically 10-20% and plants can start up in 1 hour. German power plants are generally less flexible compared to Danish power plants. Still, Germany has been able to integrate 45 GW of solar and 59 GW of wind power in a system with approx. 45 GW of coal and 30 GW of gas power. In China, the plan is to make 220 GW of its coal fleet flexible by 2020. As a first step, 22 demonstration projects, totaling 17 GW of power generation capacity, are being retrofitted to improve plant flexibility [22]. Figure 3-7 shows some sample weeks from Germany with varying levels of renewable energy penetration, and the corresponding flexibility required from existing coal plants. In graph (a) there is low solar and wind generation, there for limited flexibility needed from coal. Whereas in graph (c), there is significant requirement for flexibility. This displays how plants that refurbished and retrofitted to improve flexibility play an important role in supporting generation from renewables.



(a)



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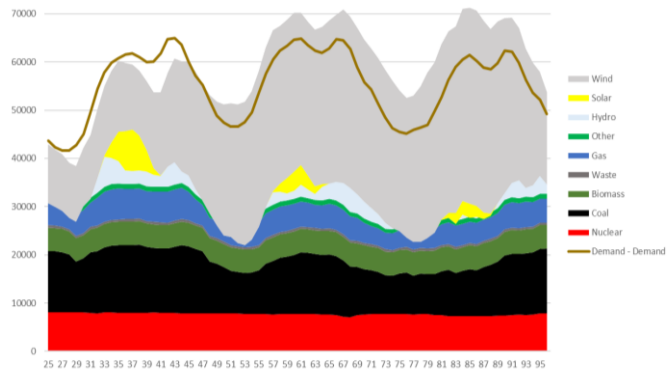

(c)

Figure 3-7 Examples of weeks in Germany with high VRE. Data from [23]

Furthermore, power plant operators are often reluctant to operate the plant below certain load even though technical characteristics allow them. For example, in India the technical minimum load for large power plant is set at 40% of rated capacity by authorities, but generators are reluctant to reduce the generation below 70% [24]. This reluctancy is coming from the fact that most of power plants have PPAs which give them payments for the power generated, if they are obliged to run at lower load, they are effectively reducing their income. Also, there is increased fuel consumption and increased operation and maintenance cost due to flexible operations. Thus, it is important to provide enough incentives for coal power plant operators to be operating under flexible conditions. This could be achieved through adding separate provisions for flexible operations in grid codes, by providing incentives in the PPA contract or in the longer-term through price signals in power markets.

Interconnections as an Integration Option

Transmission network expansion is another key tool in integrating large share of RE into the power system. Connecting different power systems, increasing the transmission capacity within the system and improved grid management techniques will enable more VRE integration. Expanding the transmission network by connecting isolated power systems will reduce the RE curtailment and decrease the flexibility requirements. With a strongly interconnected grid, total output of all renewables over the entire grid is less variable than an isolated system since the there is a geographical diversity associated with availability of RE resources like wind speeds and cloud cover. Moreover, new transmission infrastructure may connect regions with high power demand and regions with strong renewable resources, while reducing the difference between high tariff and low tariff regions. This is particularly relevant in the case of Indonesia, where demand and large conventional power plants are concentrated in the Java-Bali system and whereas areas that are rich in wind and hydro resources are typically located in islands with isolated system. In case of isolated systems very far away from main grid, it may not be economical and technically feasible to transmit electricity over large distances.

Indonesia will benefit from preparing a long-term strategy for closer interconnecting the individual grid systems of the Indonesian archipelago. Historically, economy of scale benefits of conventional power plants was a major driver for grid integration, but increased deployment of RES adds weighty arguments for further strengthening the grid and thus a long-term grid strategy would be key to analyzing and capturing potential gains.

CHAPTER 4. POLICY RECOMMENDATIONS

POLICY RECOMMENDATIONS

4.1. COMMITTING TO AN RE PIPELINE

WHY COMMIT TO AN RE PIPELINE?

Establishing a pipeline can enable transparent communication elaborating the amount of RE capacities that are required to reach the KEN target. As such, this pipeline is a tool meant to specify actual RE capacities per region. Currently, there are multiple documents for national and local energy planning working towards expanding the electricity grid. Finding an overview and a consolidated working plan for future RE projects is not available. The several energy planning documents at national and regional level, across many institutions, makes it difficult to assess the plan for acceleration of installations, which is detrimental to attract foreign investments and expertise. The challenge for realization of the capacity targets is to attract investors and convince them that their investments are safe and that Indonesia is an attractive market. The current lacking transparency prevents local industry from forming a supply chain, as the uncertainties of the future increases the risk-perception.

This study establishes a pipeline to reach national energy targets by combining inputs from national and local planning documents, resulting in a specific pipeline and distribution of RE generation capacities. The exercise for the near-term energy planning will be meeting future power demand by expanding RE[2]. How the future development eventually unfold will depend on the future policies, economic incentives and technological development. Nevertheless, working with a focus on policies can help shape the development, encouraging RE development in line with the RE target.

In brief, the RE pipeline presented is relevant at this stage of development in the Indonesian power system for the following reasons:

- Enable **transparency** through commitment to an RE development
- Secure **compliance** with national RE targets
- **Communicate** a signal to international investors and local governments about a mandatory development path
- **Reduce risk** for investors and lowering prices of RE
- Provide a mechanism to support compliance through **monitoring**

RECOMMENDED ACTIONS

Develop a system for RE quota distribution taking a role in the national energy planning process. The pipeline consists of politically binding RE quotas to develop RE projects. Every region in Indonesia will receive a capacity target to be reached annually. The accumulated regional targets are set in correlation with national energy targets. The quotas are based on capacity (MW) for RE towards 2025 and set after the expected power demand from RUKN. The RUPTL can help establish where the different RE technologies should be prioritized.

As explained in chapter 3, experience from other countries shows that it is feasible to integrate much higher shares

[2] RUKN estimates the projected power demand. This is also the baseline for the power demand in this report.

of renewables than what is currently present in the Indonesian grid. Realizing 23% RE should not induce a need for large-scale storage solutions or demand response. Therefore, the primary focus to implement the RE pipeline is non-technical but rather related to policies, energy planning and commitment to a standardized pathway.

Institutional efforts can help build the needed momentum for an RE pipeline. The following recommended institutional actions aims to improve the conditions for RE development in an Indonesian context. These are not meant to be exact guides for implementation, but rather indications for directions that would benefit conditions for RE projects in Indonesia. In relation to enforcing the pipeline and its key features the following central actions are important.

- **Commit to a pipeline** defining renewable energy capacity from 2021-2030. Communicate this pipeline clearly to convey a consistent and transparent work plan for reaching RE targets.
- **Issue provincial target quotas for additional RE capacity per year.** Make quotas mandatory towards 2025 and make indications for 2026-2030 quotas. The quotas should be decided in coordination between the ministry and PLN, to both ensure that eventual support (e.g. FIT proposed in the new Presidential Regulation) stays within the allocated state budget, and that the grid is ready to accept the RE capacity.
- Let an institution **monitor the fulfillment of quotas** in the regions. This will enforce keeping track of the development in a crucial timeframe for the RE projects. Communication of the progress and impact of planned RE projects will be a crucial aspect of the transparency of the pipeline.

The RE pipeline is only efficient if implemented and monitored. For the same reason, the commitment to a pipeline is essential to attract investors. Setting RE quotas on an annual basis will let provinces and developers know the specific local RE targets, which allows for specific tenders and RE projects. Besides these central steps to establish the pipeline, there are a number of actions can facilitate the RE deployment suggested in the study and help attract the needed investments:

- As planned in the upcoming Presidential Regulation, **put in place mechanisms to support and de-risk RE investments**, given the need to accelerate the deployment and kick-start the industry. Make sure to include competition mechanisms such as auctions to stimulate competition, especially for larger projects into lower prices. The Indonesian RE market would benefit from a larger market volume of RE projects.
- Make sure **PPA contracts** follow international standards, distribute the risk optimally between the parties and that they make the investment in RE both bankable for developers and workable for PLN that need to integrate the power into the grid.
- **Improve access to capital by** engaging development banks and foreign aid funds. This could also lead to loan guarantees with low interest making RE even more compatible.
- **Introduce an institution as a one-stop-shop authority for RE projects.** Establish a single point of access for developers to streamline and simplify the processes surrounding permits for RE projects. In practice, this would mean that just one institution receiving bids, granting permits and reaching out to relevant authorities when a developer seeks to develop an RE project. This could be an upgrade of the existing Clean Energy Information Centre called “LINTAS” by EBTKE.
- **Easy access to information.** Make relevant regulation and other key information for investors and developers available and easy searchable online in both English and Bahasa Indonesia.
- **Secure a level playing field** where RE projects can compete more fairly with conventional power generation. Besides subsidizing low-carbon RE projects, calculating societal costs (externalities) from burning fossil fuels shows the benefits of RE technologies in comparison.

While these recommendations will not alone transform the regulatory and financial aspects for the better, in relation to RE – they will advance key features of a low-risk market: transparency, consistency and compliance with set targets.

International RE developers, manufacturers and financing institutions have vast expertise and capital to invest in RE projects worldwide. However, when deciding where to focus their attention, they will carefully assess the risks and potential rewards for their investments, not just on the specific projects, but also in the supply-chain and broader industry. This means that Indonesia competes with other countries to attract capital from foreign investors.

TRANSPARENCY

As mentioned, pipeline itself will inherently increase transparency. But specific actions can add to the transparency and make it easier for developers to take part of the RE expansion towards 2025 and 2030. It is recommendable to **establish a one-stop-shop**, as seen in Denmark, where it has been a useful tool especially within offshore wind development, where many institutions are part of the licensing and permitting. This concept is also part of making important information easily available.

In the Danish example, the responsible institution is the Danish Energy Agency (DEA). In practice, the role of being a one-stop-shop means that DEA is the channel of communication for developers both in case of commissioning and decommissioning of, for example, onshore wind turbines. This concept helps simplifying the complex and administrative work related to energy projects. Depending on the nature of the RE project, there will be a wide range of responsible authorities to contact before a project can go ahead. Subjects such as environmental convers (both maritime and on land), resource extraction, defence issues, visual impact are all vital parts of the early stages of energy project development processes. In Denmark, DEA is the centre for communication between all involved parties related to both commissioning and decommissioning of energy projects:

Figure 4-1: The Danish Energy Agency as the center of communication between all involved parties of the permitting process in energy projects.

DEA facilitates and coordinates the routines related to preliminary investigations, permissions and licenses. Indonesia has previously had an initial concept for a one-stop concept, located in EBTKE and made in collaboration with DANIDA[3]. However, this service is no longer active meaning that Indonesia no longer has the concept inspired by the one-stop-shop. By establishing a one-stop-shop, it could spark similar benefits as seen in the Danish case and help developers manage the administrative routines related to RE projects. The one-stop-shop could be a strong feature in a country as big as Indonesia. With governmental bodies stretching throughout the central national organs all the way to provincial offices. The procedures and dialogues between this cast net of institutions are often complicated and not necessarily publicly available. Consequently, it is difficult for investors to determine the project opportunities and the process to find answers may take a long time. If an appointed Indonesian institution acts as a one-stop-shop, it would provide a simpler and more accessible process in connection to auctions and PPA agreements. Furthermore, the one-stop-shop would over time build the capacity in the responsible institution to efficiently facilitate dialogue between developers and central responsible actors.

Compliance & monitoring

One central aspect of the pipeline is that it should give certainty to the investor. Compliance and consistency are both key, and will let investors rest assured in the current progress because they know what the future plans are. The set capacities of renewable projects to be developed are based on the total expected power demand in 2025, including both PLN grids and other power demand sources. The pipeline should not be updated every time a new planning document is published or updated. However, the key document that has been used to set the demand expectations for 2025 at national level is RUKN. Therefore, it is important to have eventual changes in the expected power demand in 2025 reflected in the RE pipeline. As an example, if the expected power demand is lower due to the impact of Covid-19, this should be reflected in the establishment of the RE quotas. However, if a new RUPTL is published, including a certain amount of RE projects planned, this would potentially modify the baseline development but not the total amount of RE projects needed to fulfill the 2025 target.

Monitoring and reporting will also be a central part of a RE-pipeline setup. Successful compliance and monitoring will appeal to investors and RE developers, as they can rest assured that the RE expansion is consistently being developed according to plan. A central government institution should be the responsible party for monitoring. This institution will apply the quotas to the regions and have the regions report on targets, plans and accomplishments. A yearly status should be made and there should be aligned templates for the reporting.

An institution that could be in charge of monitoring the process could be NEC. This is because NEC is already a central institution responsible for some of the key planning documents in Indonesia. This situates a good position to progressively assess the compliance of the distributed RE quotas. The monitoring institution must have good contact to the responsible local authorities to be able to follow compliance.

Monitoring the development and providing a way of measuring the progress will be key to ensure the efficiency of RE quotas. When monitored, the compliance of the RE development can be communicated transparently. Signed PPAs, contracts and RE projects should be publically communicated, to allow developers to gain insight to the different projects under development, which lets them allocate more resources to their own project development.

[3] http://lintas.ebtke.esdm.go.id/

REDUCE RISK

Lower risk will lower the costs for projects. The suggested setup with monitoring and compliance will reduce the risk tied to developing RE projects, as it clearly states which targets are to be reached in different regions by a defined deadline. The mechanisms serve as guarantee for developers that their projects are in demand and that it is being tracked. This is an attractive feature for investing to achieve the quota targets.

The **upcoming Presidential Regulation on acceleration of renewable energy** will most likely introduce a remuneration scheme for RE projects. This is a good step in the direction of de-risking investments and kick-start the industry. Given the urgency of meeting the RE target and the early stage of RE market in Indonesia, a technology-based Fixed Feed in Tariff (FIT) with possible regional factors could kick-start the development. It is critical that the tariff will be a secured price, which the investor is guaranteed for the contract period. In the short-term, a transparent framework for revising tariffs should be prepared in case of excessive or non-adequate interest. For larger projects, this can transition towards a competitive process with auction system and price ceiling to ensure competitive procurement and lower costs. The right design of such auction scheme is very important, and Indonesia can learn from international best practices. A couple of further considerations that could be included in the revised regulations are:

- Relaxing the requirement for local content and work alongside to develop local supply chain, expertise and industry. Until then, a large local content requirement coupled with a non-existent industry and scarce qualification of labor can drive cost of projects up.
- Considering sharing the cost or including a tariff component to partially reimburse project developers of eventual construction works of infrastructure such as port expansion, road expansion, etc. if these are considered to be relevant for local context and community.

It is important that **PPAs for both VRES and dispatchable generators** follow international standards. For example, guidelines exist on how to distribute project risks between off-taker, developer and authorities, i.e. risk should be allocated to the entity with the best control over the possible mitigation measures, and the right balance of incentives for all parties should be found. With the right balance, all stakeholders have benefits to gain from developing RE projects: PLN is supported in the challenge of grid integration of VRES, the developer has access to financing and the projects are bankable, and the ministry have a reasonable impact on the state budget.

In the case of VRES, the most important aspect is to have bankable projects than can proceed and have access to capital from financing institutions. This means that the risk profile, for example stemming from land rights, currency, force majeure, curtailment, etc. should be manageable and do not jeopardize the project expected return.

In a collaboration between PLN the Danish Energy Agency, there are currently policy briefs looking into the specific challenges regarding PPAs. There are indications from developers that PPA conditions have been improving overtime with various regulations update and that minor barriers still exist. One important factor is that PPAs should consider the variable nature of power generation and the uncertainties related to wind and solar generation, for example allowing for interannual variations of generation output without punishing variations from the expected capacity factor.

To support the integration of VRE, new PPAs for other dispatchable power plants should consider incentivizing flexibility for these plants. For example, a technology like hydropower reservoir plants, with fast ramping times and a reservoir to control the flow of water, can and should be used to balance the variable nature of wind and solar. It Therefore, it should not be contracted through PPAs with typical characteristics of baseload service, but it should rather be allowed to offer the flexibility to the system without strict capacity factor requirements at sub-annual level.

COMMUNICATE CLEARLY

Communication is an important aspect of the implementation of the RE pipeline. And it is a wide range of information that needs to be announced. Compliance progress, regional quota distribution, current and projected projects are all important details to communicate.

Communication serves multiple purpose with transparency being at the hearth of this. Due to the short timeframe to expand the RE capacity, investors will look for signs that there is a commitment to realize the KEN target. The RE pipeline can increase the developers trust in the specified needs for RE expansion. MEMR must communicate clearly what the quotas are, how they can be fulfilled, and which regions must live up to the different targets. Furthermore, it will be paramount to have clear communication about the progressive achievement of annual quotas. MEMR should communicate the status of achieving quota targets, as different projects begins to fulfil the quotas distributed, This means publishing data on both current and upcoming projects to establish the future need for projects.

With a transparent and clear communication, developers and investors will be able to assess where projects are feasible while resting assured that the demand for RE is present. This can attract more companies and investors within relevant RE technologies. The pipeline will then serve as a good indicator of where demand is high for new RE projects and, on the other hand, where the quotas are being fulfilled.

DEVELOPER PERSPECTIVE

The actions recommended aims to increase the financial interest in the Indonesian RE expansion. Investors will put their investments where they assess a potentially profitable market and a relatively low risk. Currently, countries comparable to Indonesia have massively expanded their RE capacities in recent years. Fortunately, there are international examples proving that the development can be kick-started under the right circumstances. Vietnam was the first country in the ASEAN region to kick-start large-scale solar PV deployment. In June 2018, Vietnam had an accumulated solar PV capacity of less than 10 MW. One year later, in July 2019, the capacity had skyrocketed to 4,460 MW while growing to 6,314 MW in September 2020. This development follows a feed-in-tariff first announced in 2016 [25]. The example from Vietnam is a testimony of the significance and importance of the right political frameworks to attract developers but also how fast a transition can take place. This has been made possible by transparent frameworks and easier access to gain required permits. Furthermore, the consolidation and adaptation of international norms within PPAs has further eased the risk-taking and complexity of initiating RE-projects.

This means that Indonesia competes with other countries to attract capital from foreign investors. Currently, countries comparable to Indonesia have massively expanded their RE capacities in recent years. Vietnam was the first country in the ASEAN region to kick-start solar PV projects. In June 2018, Vietnam had an accumulated solar PV capacity of less than 10 MW. One year later, in July 2019, the capacity had skyrocketed to 4,460 MW while growing to 6,314 MW in September 2020. This development follows a feed-in-tariff announced first announced in 2016[4]. The example from Vietnam is a testimony of the significance and importance of the right political frameworks to attract developers.

This has been made possible by transparent frameworks and easier access to gain required permits. Furthermore, the consolidation and adaptation of international norms within PPAs has further eased the risk-taking and complexity of initiating RE-projects.

4.2. EXAMPLE OF REGULATORY SETUP FOR AN RE PIPELINE

In order to realize and benefit from RE quotas a regulatory setup is required. The 23% RE target sets an objective for 2025 and should be the benchmark for the quota system when designed. The best suited distribution should take the local resources into consideration. For the same reason, this report recommends a collaborative approach where national energy authorities draft a first draft of how a distribution of regional RE quotas could look. This draft is then shared with local authorities who can feed their input back allowing for an adjustment of the draft, for example based on plans under RUED and RPJMD. When a compromise has been found in the dialogue between national and local authorities the final quotas can be issued. The following figure serves as an example of a setup for the dialogue between NEC, MEMR, Dinas ESDM and PLN.

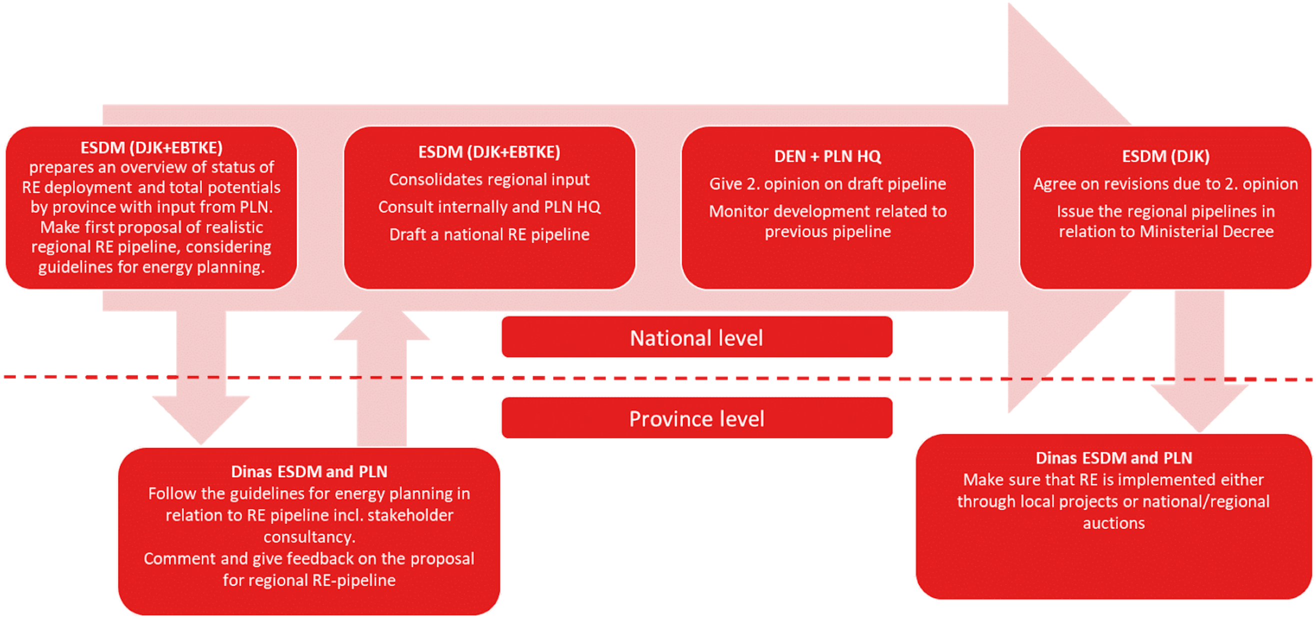

Figure 4-2: potential scheme of implementation for the RE pipeline.

The model indicates how the dialogue between national and provincial planning levels can reach a consolidated compromise reaching a fair distribution of RE quotas. The key aspects in the process are:

- Development of the first draft at national level, where data foundation is stronger and where a more detailed overview is possible. Key stakeholders are MEMR and PLN, while national plans such as RUPTL and RUKN provide the basis.
- Involvement of local stakeholders like local PLN offices and local offices of MEMR (Dinas ESDM), which provide input based on plans under RUED.
- A consolidation of regional inputs and revision of the pipeline is carried out at central level with involvement of all institutions (PLN, NEC, DG Electricity, EBTKE).
- The establishment of a monitoring process for the compliance to the pipeline is also a key aspect of the successful implementation of the plans.

The **involvement of local stakeholders** is key in the establishment of a proper RE pipeline. Both local authorities and local PLN offices should take part in the assessment by providing insights into potential development sites, choice of RE technology, size of projects and timeline. The experience of local stakeholders in the development of RUED, as well as local political ambition on realization of RE projects should feed into the national planning. From

PLN side, local offices are often those in charge of the integration of VRES in the system and the finalization of the impact studies, therefore their input is key to assess the capacity of the grid to accept more RE.

4.3. ENERGY PLANNING

With the suggested dialogue between planning offices, the local and national authorities will jointly agree on the terms for RE quotas per region. The immediate RE potential varies from region to region. International reports on energy and technology, data websites and specific energy tools can guide the choice of specific technologies and their feasibility in different areas. Ensuring the coordination between national and local authorities will strengthen implementation processes and invite the local authorities to participate in the energy planning.

The energy partnership between Denmark and Indonesia developed a selection of tools and reports, made for the Indonesian energy planners [26]. While there are a considerable number of reports and tools to be found online, the following content exemplifies how different reports and software play an active role in different levels of planning.

TOOLS AND REPORTS IN THE ENERGY PLANNING

At different levels of government, there are different relevant tools available for energy planners. Provinces play a vital role in the implementation of the RE expansion. It is in the provinces where land acquisition, zoning, local tariffs, permitting etc. get issued. As such, the provinces are a vital part of directing projects to a path maximizing value. The processes often require specific knowledge and routine. Therefore, it can alleviate the pressure for local planning authorities, to have a set of tools to help assess the complexities related to energy infrastructure and generation. The figure below entails a non-exhaustive list of reports and software beneficial in the approach of planning, where national energy targets are guiding the energy planning for local projects.

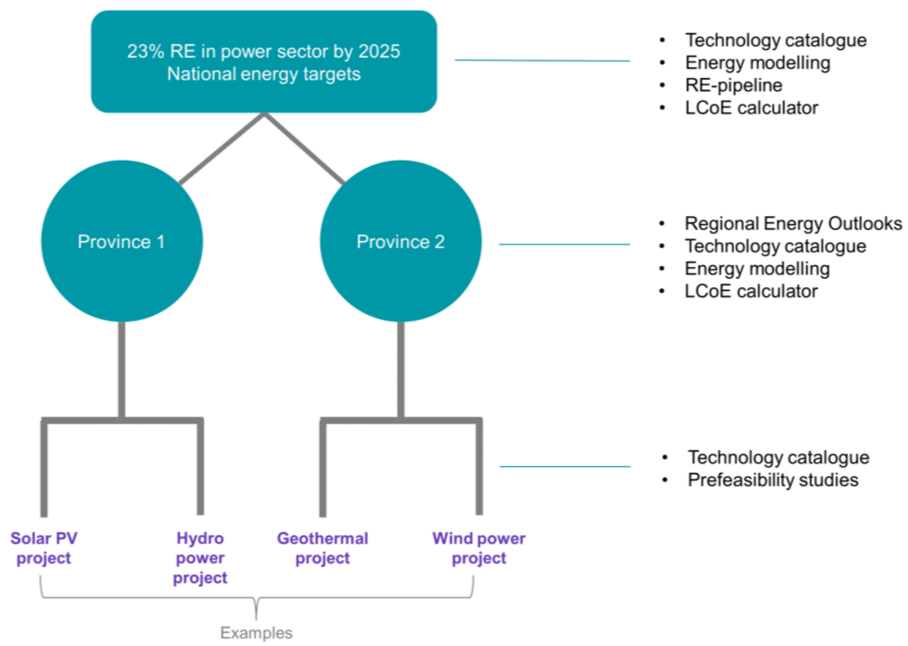

Figure 4 -2: Non-exhaustive list of reports and modelling software available throughout the different levels of government institutions.

The model shows how different tools and reports can play into different levels of energy planning. At the top on the figure, KEN and RUEN are the central planning documents providing the overall targets for the planning documents downstream having an impact on which projects goes into consideration in the provinces. The RE pipeline can, alongside the levelized cost of energy (LCoE) calculator[5], technology catalogue on power generation technologies[6] and energy modelling software, help determine macro-perspective planning. Looking at technical and economic performances of commercial renewable energy technologies can feed into energy modelling giving educated estimates. The outcome of combining and analysing these sources can be nationally stated requirements for the energy project development towards 2025 and onto 2030. Considering LCoE is a good tool in early stages of planning when estimating the cost and economic performance of a given technology and compare the cost of competing technologies. These tools are publicly available and can be supplemented with other international reports to enhance accuracy of the RE quota distribution.

On regional levels of energy planning the RE pipeline gives incentives to start preparing for new RE projects. The technology catalogue can be utilized for performance overviews in this step as well. Matching data from the technology catalogue with the Regional Energy Outlooks [12]–[14] that have been performed for some Indonesian regions can help analyse the technical and economic performance of various technologies.

Active sustenance of RE projects can be supported by making Dinas ESDM responsible for conducting prefeasibility studies on relevant RE technologies and let prefeasibility studies indicate sites for different RE technologies while being in line with the national targets (KEN). The suggested guideline for performing prefeasibility studies for the five technologies can guide the regional studies[7].

[5] LCoE calculator for Indonesia (link)
[6] Technology Data for the Indonesian Power Sector (link)
[7] Pre-feasibility studies on RE projects – guidelines (link)

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Credits for the frontpage:

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- Bio Energy by Icon Island from the Noun Project
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Glossary

Levelized cost of electricity

This parameter expresses the cost of the MWh generated during the lifetime of the plant and it represent a life-cycle cost. It can be calculated as:

$$LCoE = \frac{I_0 + \sum_{t=1}^{N} \frac{V_t}{(1+i)^t}}{\sum_{t=1}^{N} \frac{E_t}{(1+i)^t}}$$

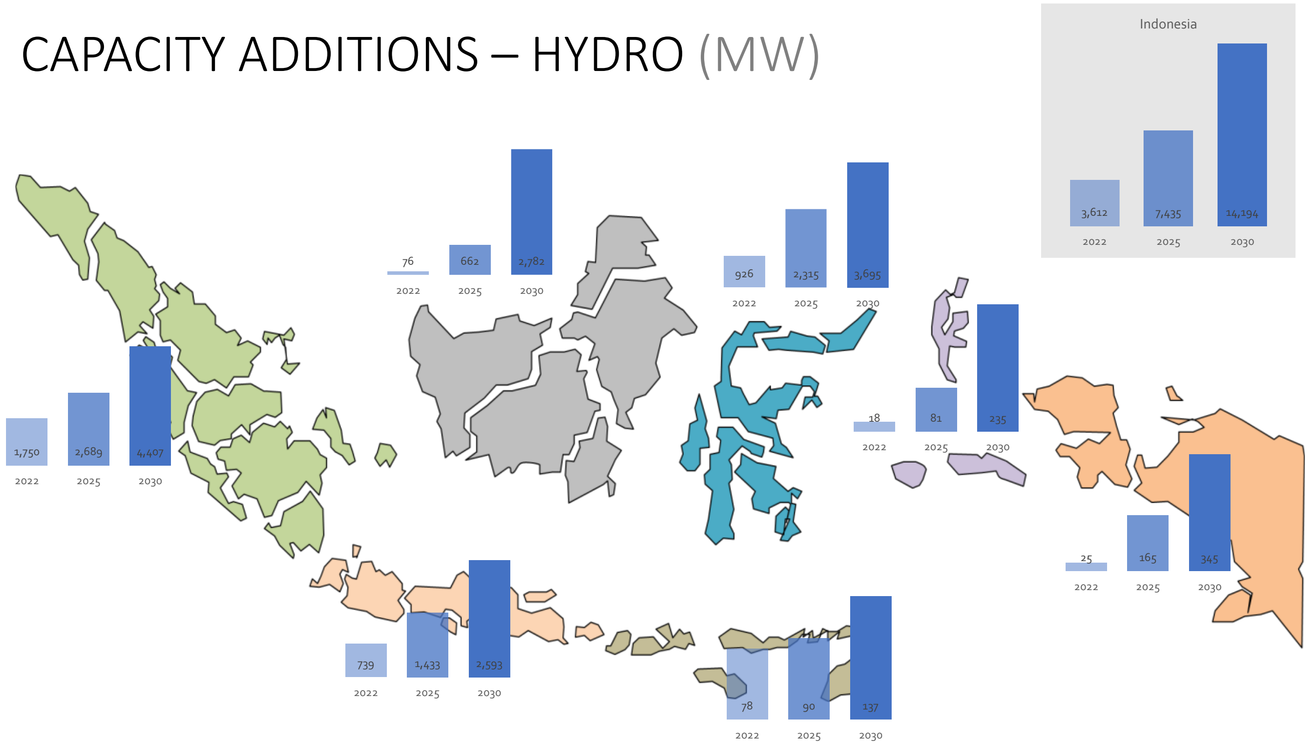
where:
I_0 *= Overnight cost or Investment cost [IDR]*
N = Technical lifetime of the plant [years]
V = Variable cost including O&M and fuel cost [IDR in year t]
E = Electricity produced in the year t [kWh in year t]
i = real discount rate [%]

Full Load Hours (FLH)

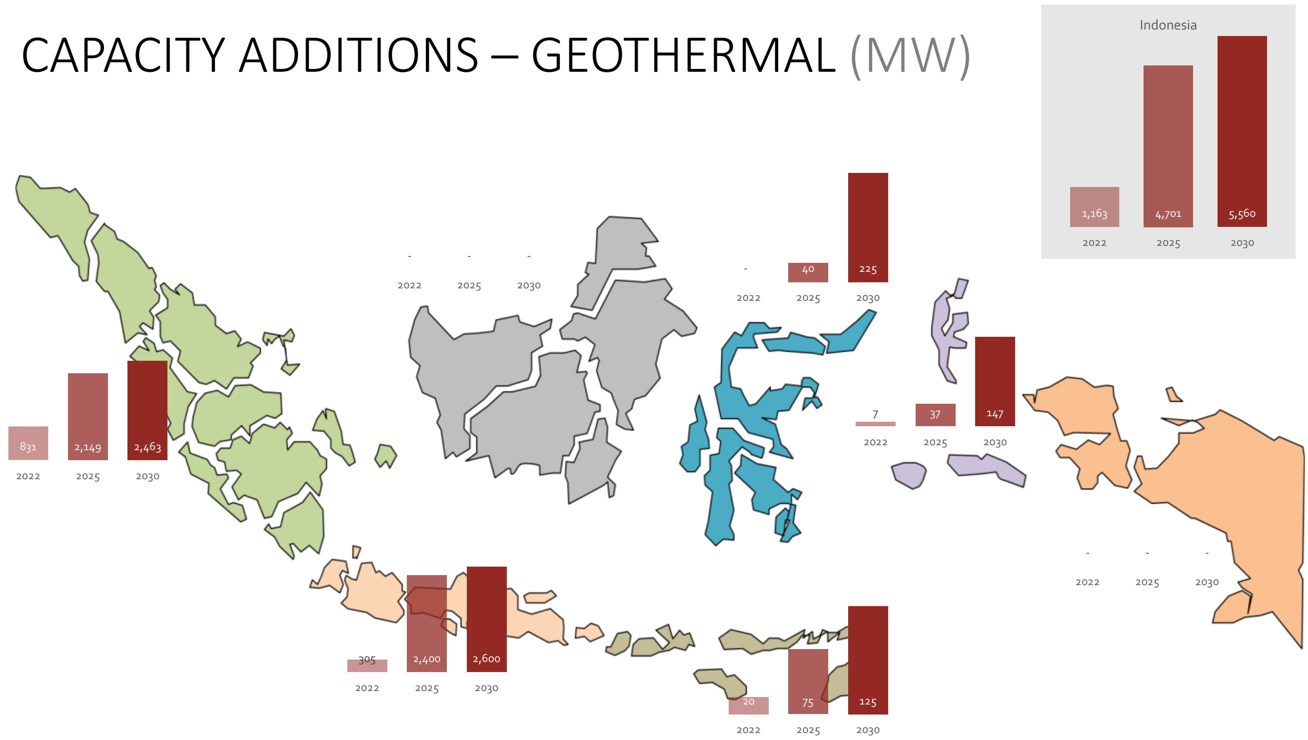
Full Load Hours (FLH) are another way of expressing the Capacity Factor of a power plant. While capacity factor is defined in %, Full Load Hours are expressed in hours in the year or kWh/kW. 100% capacity factor corresponds to 8760 hours.

Appendix A. OTHER CHARTS: PIPELINE BY RE SOURCE

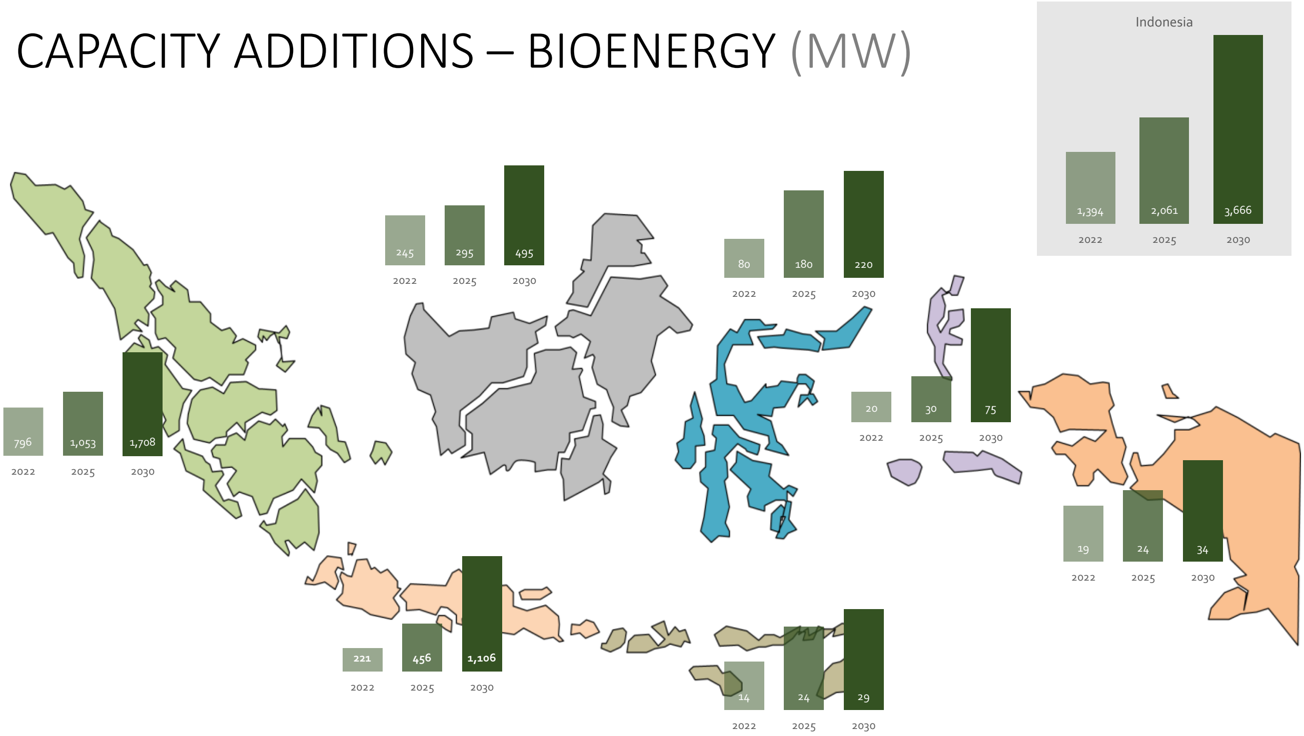
CAPACITY ADDITIONS – HYDRO (MW)



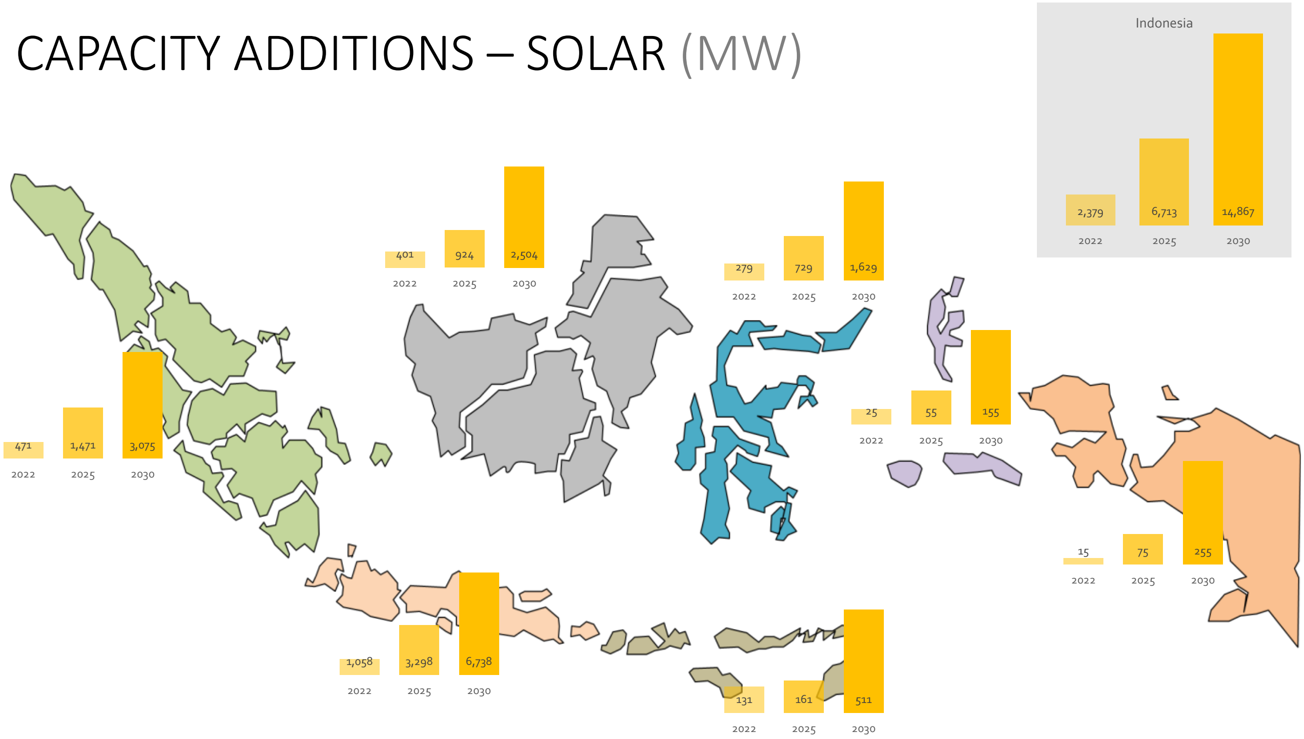
CAPACITY ADDITIONS – GEOTHERMAL (MW)



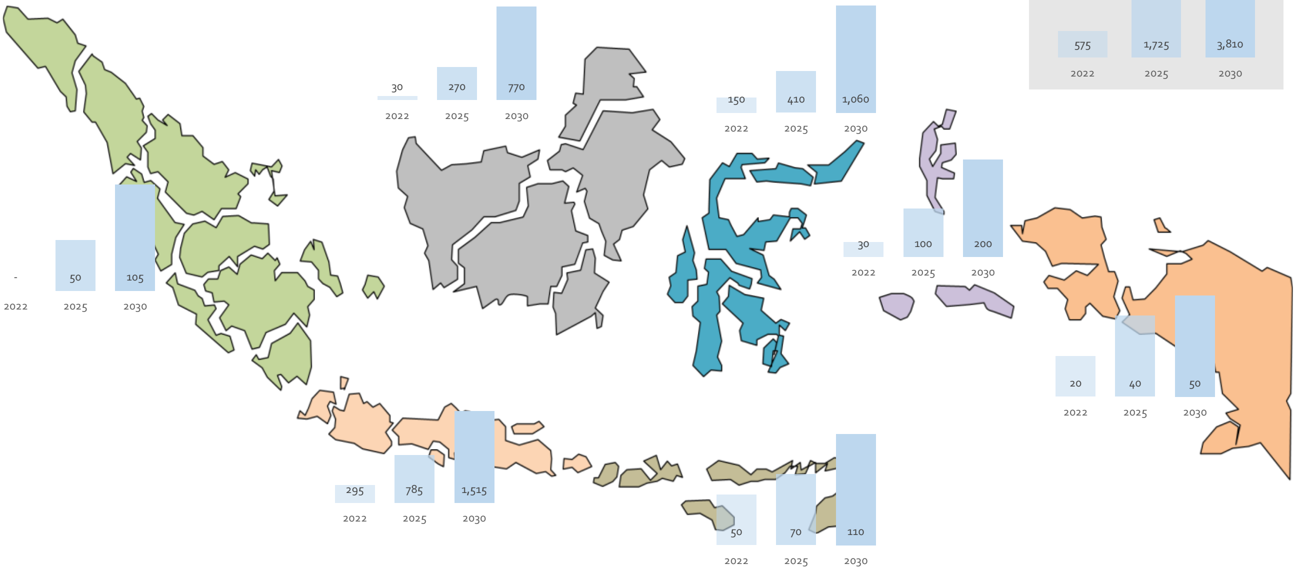
CAPACITY ADDITIONS – BIOENERGY (MW)



CAPACITY ADDITIONS – SOLAR (MW)



CAPACITY ADDITIONS – WIND (MW)



Appendix B. Power Demand – RUKN and RUPTL

Regional demands are shown below for RUPTL and RUKN, displaying the large additional demand covered by RUKN. While RUPTL considers only PLN grids, RUKN also includes other demand sources such as non-PLN grids and large industrial projects, e.g. smelters with very large local demands.

Overall demand in RUKN is 37-39% higher in 2022 and 2025 compared to the respective years in RUPTL, and 59% higher in 2030 compared to 2028 in RUPTL.

Demand (TWh)		*Total*	Java-Bali	Kalimantan	Sumatra	Sulawesi	Maluku	Nusa Tenggara	Papua	Other
RUPTL	**2022**	*300,2*	*215,0*	*14,1*	*48,8*	*14,3*	*1,4*	*3,9*	*2,0*	*0,7*
	2025	*357,6*	*249,8*	*17,8*	*61,4*	*18,6*	*1,7*	*5,0*	*2,5*	*0,8*
	2028	*433,6*	*301,1*	*21,6*	*75,1*	*23,3*	*2,1*	*6,3*	*3,1*	*1,0*
RUKN	**2022**	*409,7*	*249,5*	*19,0*	*77,6*	*38,9*	*13,6*	*6,8*	*3,6*	*0,7*
	2025	*500,1*	*286,6*	*33,1*	*102,8*	*48,6*	*15,0*	*7,1*	*6,1*	*0,8*
	2030	*687,4*	*387,7*	*51,7*	*151,5*	*61,2*	*16,6*	*8,2*	*9,5*	*1,0*

Appendix C. Capacity Factors and FLH

Full load hours (FLH) is a convenient notion expressing the equivalent number of hours of production at rated capacity that would give the same annual generation. Multiplying the FLH value by the installed capacity gives the production throughout one year. The concept is equivalent to that of capacity factor (%); to convert capacity factor to FLH simply multiply the capacity factor by the total number of hours in a year (8760).

Full load hours are a key concept in relation to the RE pipeline. In fact, once the power demand is estimated, as well as the total amount of RE needed in TWh based on the target (23% in 2025), capacity additions needed to reach the target depend on the assumption in relation to the FLHs of each technology.

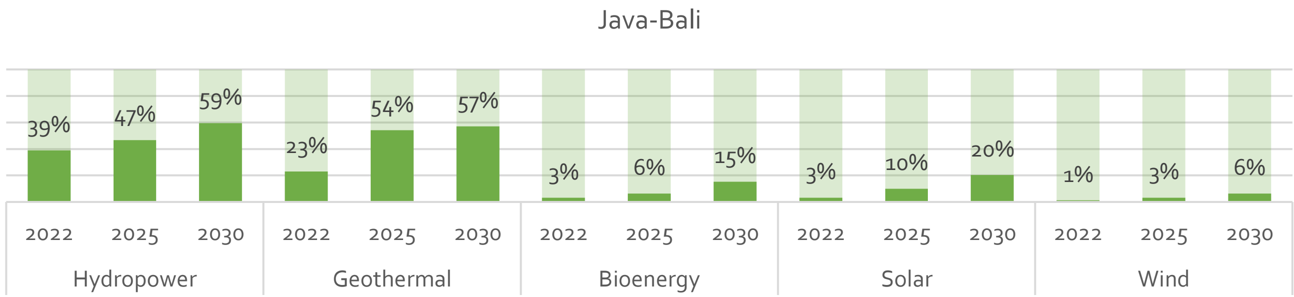
For this study, FLH of the various technologies are estimated per region and calibrated to known levels of RE production in 2019. To calibrate the full load hours the gross RUKN demand in 2019 was used.

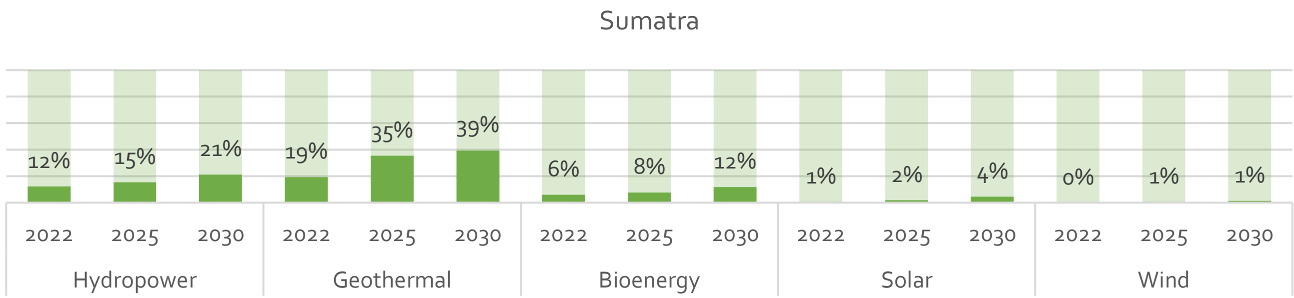
Full load hours (Capacity Factor)	Java-Bali	Kalimantan	Sumatra	Sulawesi	Maluku	Nusa Tenggara	Papua
Solar	**1550** (17.7%)	**1300** (14.8%)	**1350** (15.4%)	**1450** (16.6%)	**1650** (18.8%)	**1600** (18.3%)	**1650** (18.8%)
Wind	**3200** (37%)	**3000** (34%)	**2000** (23%)	**3200** (37%)	**2500** (29%)	**3000** (34%)	**2500** (29%)
Hydropower	**3000** (34%)	**3500** (40%)	**3000** (34%)	**3500** (40%)	**3500** (40%)	**3500** (40%)	**3000** (34%)
Bioenergy	**5000** (57%)	**5000** (57%)	**5000** (57%)	**5000** (57%)	**5000** (57%)	**5000** (57%)	**5000** (57%)
Geothermal	**6700** (76%)	**6700** (76%)	**6700** (76%)	**6700** (76%)	**6700** (76%)	**6700** (76%)	**6700** (76%)

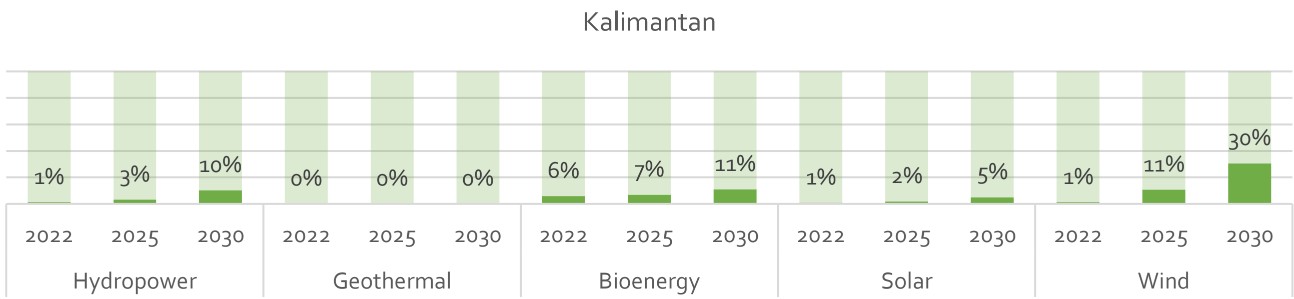
Appendix D. Regional Utilization of RE Potentials

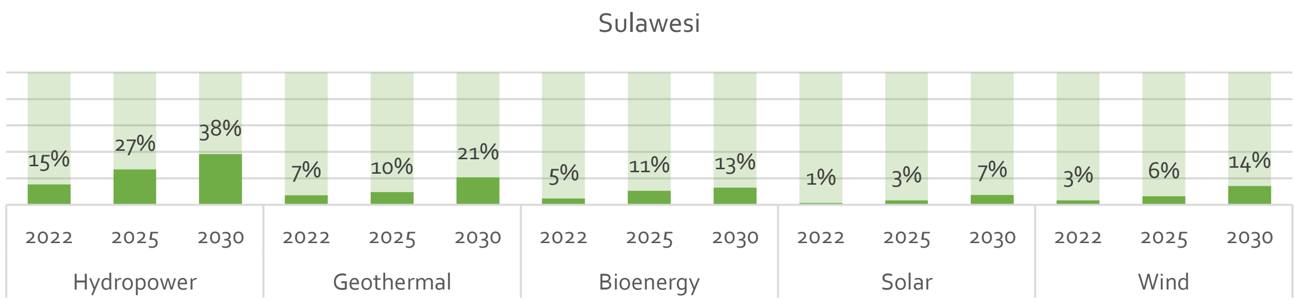
RUEN estimates RE potentials for each Indonesian region. Considering the proposed buildout of RE in the pipeline and the existing RE capacity, the utilization of potentials are shown in the graphs for each region.

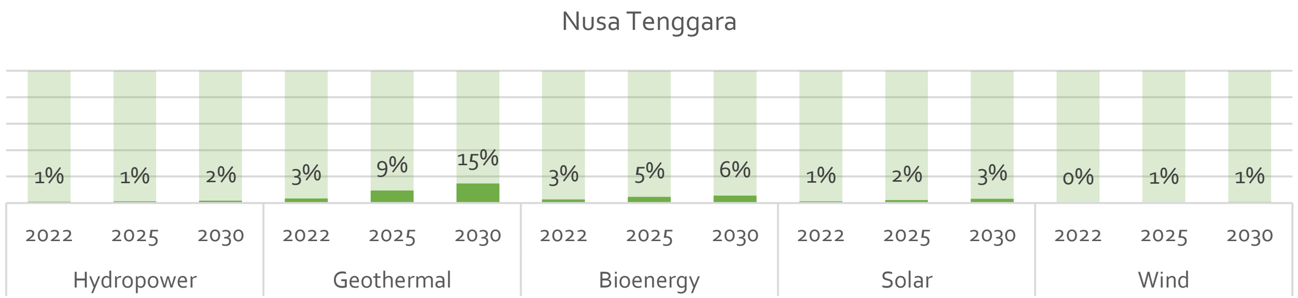
The regional potentials generally follow the national trends with stronger utilization of hydropower, geothermal and in some cases bioenergy. Wind and solar shows the largest unused potentials.

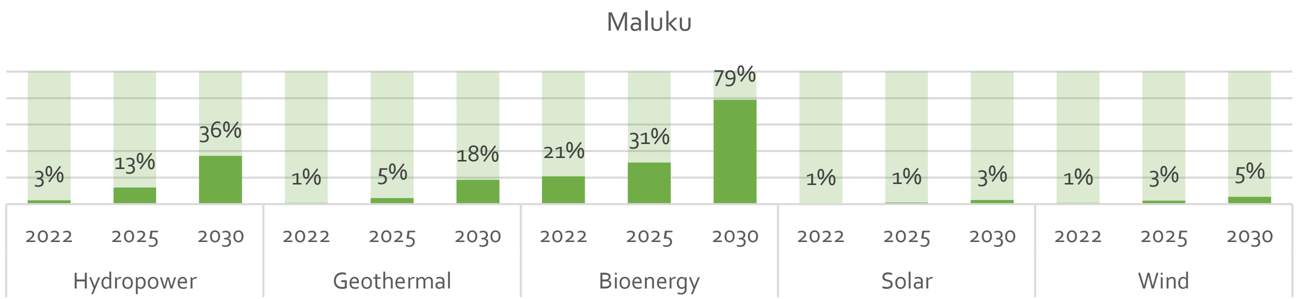


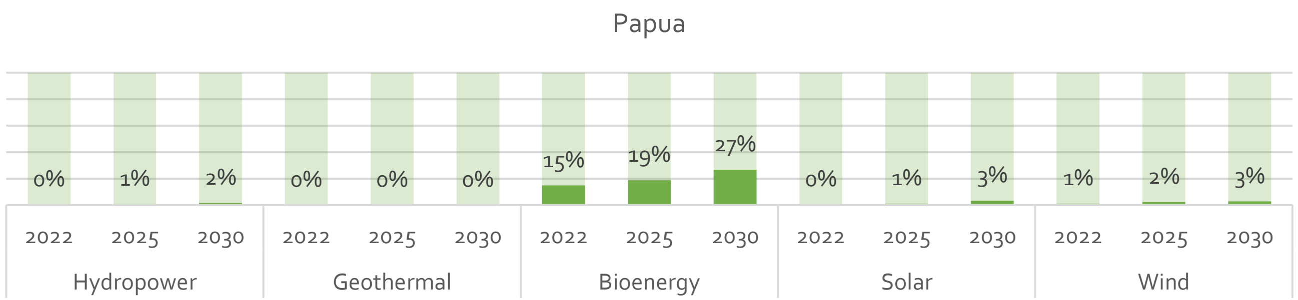







Nusa Tenggara
1%
1%
2%
3%
9%
15%
3%
5%
6%
1%
2%
3%
0%
1%
1%
2022
2025
2030
Hydropower
Geothermal
Bioenergy
Solar
Wind


Maluku
3%
13%
36%
1%
5%
18%
21%
31%
79%
1%
1%
3%
1%
3%
5%
2022
2025
2030
Hydropower
Geothermal
Bioenergy
Solar
Wind


Papua
0%
1%
2%
0%
0%
0%
15%
19%
27%
0%
1%
3%
1%
2%
3%
2022
2025
2030
Hydropower
Geothermal
Bioenergy
Solar
Wind