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Guidelines for a Renewable Energy Quota System for Indonesia

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About MENTARI

MENTARI Programme, led by the British Embassy Jakarta and its partners, aims to deliver inclusive economic growth and poverty reduction in Indonesia, by supporting the uptake of low carbon energy. The programme has a specific focus on developing the low carbon energy sector to best support disadvantaged communities, and specifically those in eastern Indonesia. MENTARI is a four-year programme, running from 2020-2023.

Guidelines for a Renewable Energy Quota System for Indonesia

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- Edwin Nugraha Putra (PT PLN Persero)
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Acronyms and Abbreviations

Bappenas	Ministry of National Planning (*Badan Pembangunan Nasional*)
BEIS	Department for Business, Energy and Industrial Strategy, United Kingdom
BESS	Battery Energy Storage System
BoD	Board of Directors
BOOT	Build-Own-Operate-Transfer
BPP	Cost of Electricity Generation (*Biaya Pokok Pembangkitan*) – PLN's electricity production cost
BPS	The Central Bureau of Statistics (*Badan Pusat Statistik*)
COD	Commercial Operation Date
DECC	Department of Energy and Climate Change, United Kingdom
DEN	National Energy Council (*Dewan Energi Nasional*)
DfE	Department for the Economy, United Kingdom
DG	Directorate General
DSO	Distribution System Operator
ENS	Energy Not Served
FIT	Feed-In Tariff
GEP	Generation Expansion Planning
GPC	Green Power Certificate
IEA	International Energy Agency
IPP	Independent Power Producer
IRENA	International Renewable Energy Agency
KEK	Special Economic Zones (*Kawasan Ekonomi Khusus*)
KEN	National Energy Policy (*Kebijakan Energi Nasional*)
LDC	Load Duration Curve
LOLE	Loss of Load Expectation
LOLP	Loss of Load Probability
LSS	Large-Scale Solar
MEMR	Ministry of Energy and Mineral Resources
MoF	Ministry of Finance
NEA	National Energy Administration of China
NIAUR	Northern Ireland Authority for Utility Regulation
NIRO	Northern Ireland Renewable Obligation
NREEC	New Renewable Energy and Energy Conservation (*Energi Baru, Terbarukan, dan Konservasi Energi*)
NREL	United States' National Renewable Energy Laboratory
Ofgem	Office of Gas and Electricity Markets, United Kingdom
PLN	State-Owned Electricity Utility Company in Indonesia (PT PLN Persero)
PPA	Power Purchase Agreement

PPP	Public-Private Partnership
PPU	Private Power Utility
RE	Renewable Energy
REPC	Renewable Energy Power Certificate
RO	Renewable Obligation
ROC	Renewable Obligation Certificate
RPJMN	National Medium Term Development Plan (*Rencana Pembangunan Jangka Menengah Nasional*)
RUED	Provincial Energy Master Plan (*Rencana Umum Energi Daerah*)
RUEN	National Energy Master Plan (*Rencana Umum Energi Nasional*)
RUKD	Provincial Electricity Plan (*Rencana Umum Ketenagalistrikan Daerah*)
RUKN	National Electricity Plan (*Rencana Umum Ketenagalistrikan Nasional*)
RUPTL	Electricity Supply Business Plan (*Rencana Usaha Penyediaan Tenaga Listrik*)
SEDA	Sustainable Energy Development Authority of Malaysia
Solar PV	Solar Photovoltaic
TGC	Tradable Green Certificate
TKDN	Local Content Requirement (*Tingkat Komponen Dalam Negeri*)
TSO	Transmission System Operator
UK	United Kingdom
VRE	Variable Renewable Energy
Wilus	Electricity Business Area (*Wilayah Usaha*)

1. INTRODUCTION

In mid-2020, the Ministry of Energy and Mineral Resources (MEMR) anticipated an enactment of the Presidential Decree on Renewable Energy Tariff to accelerate renewable energy development in pursuance of the government's 23% target by 2025. This Presidential Decree will outline a general arrangement for an electricity tariff for renewable energy, covering its technology grouping, period of pricing (based on economic payback time), tariff formulation and scheme. The most recent draft of the decree also appoints MEMR as the institution which will determine the RE quota. In previous policies, PT PLN (Persero) has been in charge through its electricity supply business plan (RUPTL). Of note, it essential that MEMR takes a prudent approach to adopting a methodology which understands the specific issues and constraints from the perspective of the utility. Taking into consideration the utility's concerns about renewable energy will guarantee the relevance and appropriacy of this decree to all actors concerned, making its execution more likely.

As part of the cooperation in developing low-carbon energy in Indonesia between MEMR of the Republic of Indonesia and the British Embassy Jakarta, the MENTARI Programme proposes full technical support to respond to any required subsidiary policies resulting from the presidential decree. The goal of MENTARI's activities is to deliver inclusive economic development and poverty reduction by developing the renewable energy sector in Indonesia in a way designed to best support disadvantaged communities – specifically those in Eastern Indonesia – and to accelerate the deployment of renewable energy projects country-wide. Among MENTARI's activities is one to conduct a study to explore an RE quota system, covering all the requirements needed to set this up, namely, methodology, approach, tool specifications and process framework, up to and including suggestions for ways to mitigate risk to the several challenges that we have identified. This study aims to provide a comprehensive guideline which will assist MEMR and the utilities to set out an RE quota system, incorporating the comprehensive knowledge of the utilities and considerations from their perspective. In other words, the quota set by MEMR will be rational, relevant to and understandable by Indonesia's power utilities.

This study was conducted by means of a thorough review of the existing RUPTL process and its quota determination. The methodology, approach and process it proposes was also informed by consultation with relevant utility experts, policy experts, and PLN as the major utility in Indonesia, through closed focus group discussion at a ministerial event. The goal of the study is to outline a process framework and detailed guideline on how ministries and utilities can determine an RE quota, by considering the following expected outcomes: largest size unit of renewable energy possible in one system, distance between plants (distributive factor), and the maximum variable renewable energy (VRE) penetration that the system can handle.

Against the goal and outcomes, this study is structured in five chapters. Chapter 1 sets out the study's background, goal and outcomes. In Chapter 2, Indonesia's existing policies/regulations on power system planning are revisited to provide us with a legal baseline from which to propose a quota system. This is followed by a comprehensive explanation of how the country's existing power system planning was conducted by PLN. Chapter 3 introduces examples of quota system policy worldwide. Some countries have already implemented a quota system policy and this study examines their unique lessons learnt. The elements and constraints of an RE quota will also be discussed using international references and practices. In Chapter 4, a comprehensive guideline, ranging from scope and assumptions, general frameworks and tool selection, analysis process flow, minimum data requirements, and risks (and risk mitigation) of the RE quota implementation will be outlined as references. Chapter 5 provides a stakeholder map indicating the roles and responsibilities of the actors to be involved in achieving Indonesia's RE quota, as well as recommendations to be suggested to all the relevant stakeholders in the implementation of this policy.

2. RENEWABLE POLICIES AND POWER SYSTEM PLANNING IN INDONESIA

2.1. EXISTING POLICIES AND REGULATION FOR POWER SYSTEM PLANNING

According to Electricity Law No. 30 of 2009, an electricity supply business comprises power generation, transmission and distribution, and transactions to customers. In principle, in Indonesia this electricity supply activity is controlled by the state, specifically by a state-owned corporation. A private entity can take part in the electricity supply business but with limitations, as ultimately the electricity supply must be controlled by the state. Only one authorised company can operate an electricity supply business within a business area.[1]

The Government of Indonesia has provided priority rights to PT PLN (Persero), known as PLN, over the entire country's electricity supply business. However, the business area is also open to private enterprises, cooperatives and self-reliant community institutions involved in the electricity supply business under Ministerial Decree of Ministry of Energy and Mineral Resources (MEMR) No 28 Year 2012.[2] In this case, PLN is the single largest national power utility, with business covering most of areas of Indonesia. PLN manages the entire supply chain – from grid planning, generation, transmission, grid operators/dispatchers, retailers across almost the whole of the country, and settlement/services to customers.

In the electricity market, private entities can be an independent power producer (IPP), a business area owner or a project developer. As an IPP, these entities take an important role in providing generators to the Indonesia electricity market. Any IPP in a determined business area which is able to sell its electricity to supply the local specific demand (such as industries, or to some households) is defined as a business area owner.

Within a business area managed by PLN, private sector participation is allowed. In the electricity generation sector, a private entity can participate through an independent power producer (IPP) agreement or a public-private partnership (PPP) pipeline arrangement. There is also a private power utility (PPU), where a private sector actor generates electricity for their own use rather than for sale to PLN, but with excess capacity allowed to be sold to PLN. Where the PPU sells directly to another user, a business area needs to be granted in compliance with MEMR Decree Year 28 of 2012. The institution must be officially registered under the administration of MEMR Decree 14 of 2012. Only one institution can act as a single off-taker (utility) and operate its business in one business area (*Wilayah Usaha* or Wilus). The business area holder may buy electricity from IPP through a

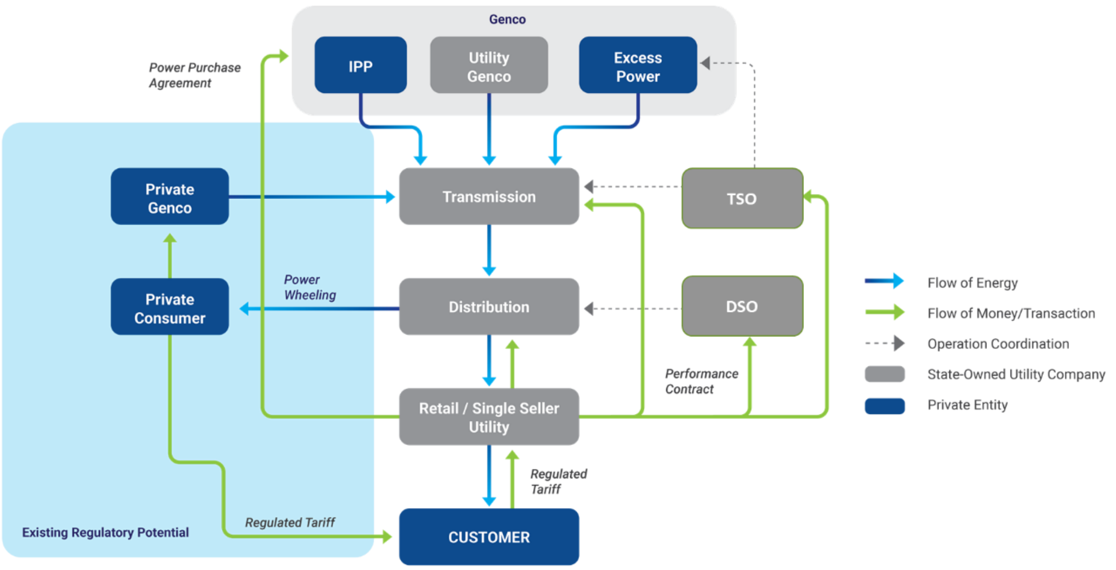
[1] ICEL, 2018. "Mengenal Kebijakan Perencanaan Ketenagalistrikan di Indonesia"
[2] PWC, 2018. "Power in Indonesia – Investment and Taxation Guide – November 2018, 6th ed."

long-term contract or a power purchase agreement (PPA). In addition, a utility may have a non-firm contract, such as one which covers excess power. Whoever the utility is, both PLN and private organisations are responsible for the adequacy of the electricity supply, which they ensure by conducting least-cost development planning and proper operation and maintenance.

In the transmission and distribution sector, the transmission system operator (TSO) and distribution system operator (DSO) are the operation coordinators mainly responsible for ensuring the reliability and security of the system. Both the TSO and DSO are owned by PLN as the state-owned utility. As clarification of MEMR Regulation No. 14 of 2012, MEMR Regulation No. 1 of 2015 allows IPPs and PPUs to utilise PLN's existing transmission and distribution networks through a power wheeling scheme. Power wheeling is the joint use of networks to optimise their value and to speed up the supply of additional generating capacity. However, implementing regulations on the detailed technical procedures and financial charges have yet to be released.[2]

The detail of Indonesia's electricity industry structure is illustrated in Exhibit 2-1.

Exhibit 2-1. Electricity industry structure in Indonesia

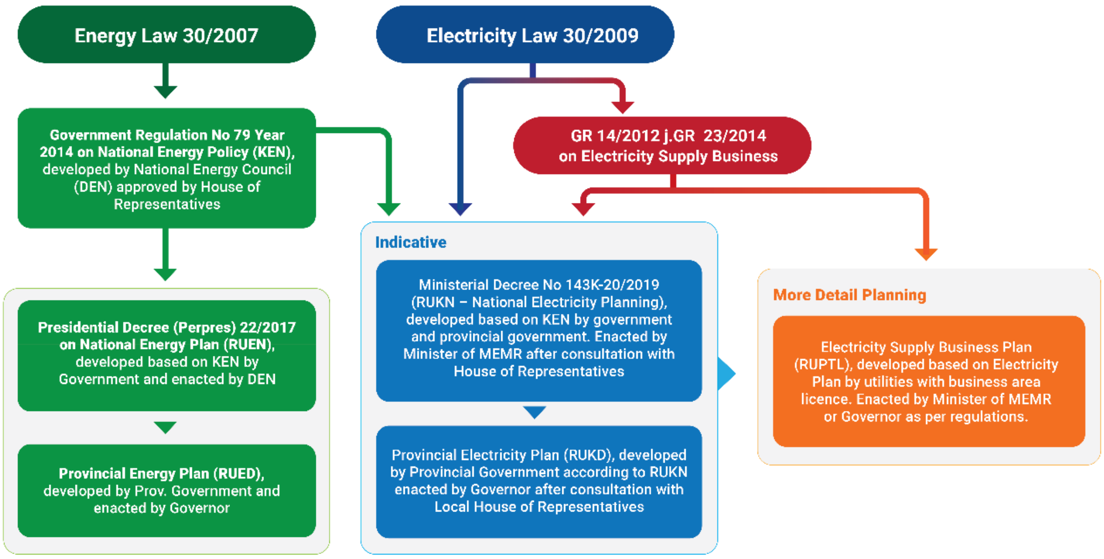


To support the industry structure, power system planning is required as stated in Government Regulation No. 14 of 2002. This stipulates that all business area owners are required to provide a plan for electricity development and an investment plan for a 10-year period. Called RUPTL, this is a comprehensive business plan and comprises a generation, transmission and distribution expansion plan, as well as an electricity purchase projection in its predetermined business area, which can be reviewed annually. The business holder is required to submit the document prior to approval of the business area, as stated under Ministerial Regulation No. 28 Year 2012. As of 2020, Directorate General (DG) of Electricity has granted 40 business areas; meanwhile, 13 business areas remain under the application process.

The business holders' electricity business plan only covers their predetermined area, which is then legalised by a minister or governor, depending on the business area coverage. The method for developing the RUPTL is covered in MEMR Regulation No. 10 Year 2009.

Exhibit 2-2 describes the regulatory framework for the RUPTL. In the case of PLN, the RUPTL is reviewed and released yearly. The document contains generation and transmission planning based on a least-cost plan for the next 10 years. Generation includes IPPs under PLN business areas. The basis for the expansion plan is the demand forecast derived from data in the RPJMN, RUKN, and BPS reports, coupled with PLN demand data.

Exhibit 2-2. Regulatory framework for electricity supply business planning (RUPTL)



The following lists in detail the regulations pertaining to power system planning in Indonesia.

Energy Law No. 30 Year 2007 establishes the legal basis for the National Energy Policy (*Kebijakan Energi Nasional*, KEN) and the National Energy Plan (*Rencana Umum Energi Nasional*, or RUEN). In this Law, KEN is prepared by the National Energy Council (DEN), signed by the Minister, after which the approval process is completed in the House of Representatives. Meanwhile, RUEN is prepared by government and signed by DEN.

Electricity Law No. 30 Year 2009 establishes the legal basis for National Electricity Planning (*Rencana Umum Ketenagalistrikan Nasional*, or RUKN). It also provides a basis for government control to decide power planning at the national level (Article 5). RUKN was developed according to KEN, and evoked by central government in consultation with House of Representatives. Local governments are also involved in discussion of RUKN with central government and the relevant utilities.

Government Regulation No. 79 Year 2014 on National Energy Policy (KEN) emphasises the strategic outcomes for KEN, in which Indonesia set a renewable energy targets of 23% and 31% of the total energy mix by 2025 and 2050, respectively. In electricity planning, it expects to achieve 115 GW and 430 GW of the capacity plan by 2025 and 2050, respectively. This is to meet the target electricity consumption rates of 2,500 kWh per capita in 2025 and 7,000 kWh per capita in 2050.

The term 'minimum quota for renewable energy' was used for the first time in this regulation and is further defined in the next regulation, in which the minimum quota is designed to limit the total renewable energy within the system. This quota is also designated as being under subsidy/incentive, as is required for renewable energy. This proves that minimum quota policy can also be streamlined with tariff regulation (see Chapter 2.2).

Presidential Decree No. 22 Year 2017 on National Energy Plan (RUEN) starts with the issues and problematic chains affecting the energy sector, as the background to the importance of a national energy plan and how importantly renewable energy should be considered by government. The RUEN electricity plan is translated from the KEN definition, where the target of renewable energy is 23% of the total energy mix. RUEN translates this statement into a real amount of capacity addition up to 2025, where Indonesia must achieve renewables of at least 45 GW (out of 135 GW installed capacity).

Ministerial Decree No. 143K-20-MEM 2019 (RUKN – National Electricity Planning). Referring to Article 5 in Electricity Law, one of the government roles is to enact the RUKN, wherein the RUKN sets out a clear direction for Indonesia electricity supply development, accommodates the existing regulatory frameworks in electricity (referring to Electricity Law), and outlines the current status of electricity development and its projection two decades ahead. The power capacity needs outlined in RUKN are indicative, without providing any detailed infrastructure projects. Further, RUKN will allow all electricity stakeholders (e.g. state-owned companies, local government-owned companies, cooperatives, NGOs and private businesses) to participate in the implementation of projects with details conveyed under a specific Regional Power System Plan (*Rencana Umum Ketenagalistrikan Daerah* (RUKD), or RUPTL).

The development of RUKN refers to KEN, where all local governments are involved in a collaborative approach to conform with Article 7 of Electricity Law. However, there is no statement confirming that RUKN is aligned with the translation made by DEN in RUEN, meaning that RUKN may have a different interpretation to the 23% renewable energy target stated in RUEN. RUKN translates as a target of 23% renewable energy in the power generation mix. This misalignment will remain at the ministerial level, as both are correct in term of reference to KEN, but with a different perspective in terms of definition. National Electricity Planning (RUKN) is the main reference of the RUPTL and RUKD drafting process.[3]

Government Regulation No. 14 of 2012 is the principal implementing regulation for Law 30 of 2009 on Electricity concerning both public supply as well as own (captive) supply. The regulation provides for open access, stipulates the procedures and authorities for defining service territories, licensing, tariff setting, land use, technical regulation and supervision, and specifies sanctions.

In the corridors of government official planning, the business flow is streamlined by means of RUKN (prepared under Electricity Law No. 30 Year 2009) and the Electricity Supply Business Plan (RUPTL) (prepared by each business area holder) (PLN and non-PLN entities). RUPTL serves as a guideline for each holder in implementing its business in predetermined areas approved by ministers.

An electricity business permit for the distribution, electricity purchase or any integrated business line in power electricity supply must be completed with (1) a business area permit approved by a minister, and (2) its electricity supply business plan. All electricity supply business plans must refer to the 2012 version of the RUKN draft and permitted by a minister, relevant governor and relevant mayor, depending on where the business area is. In addition, the business area holder must comply with all administrative, technical and environmental-related prerequisites.

Government Regulation 23 of 2014, as the revision of this regulation, states that all public electricity supply must be developed in compliance with RUKN, the RUKD and PLN's RUPTL. In Article 25, an additional statement emphasises the possibility of electricity purchase and/or power wheeling among the business area holders, any of which must be clearly stated in their RUPTL. Electricity purchased through public bidding only works for oil-based generators, while non-oil-based generators (not limited to renewable energy, natural gas, or mine mouth coal power plant) and excess electricity can be implemented through direct selection. Moreover, if any additional capacity is required in the same area, this will be provided directly by one of, or a joint venture with, two business area holders. If the capacity required is built in different areas, the application shall be pipelined through a public selection contest.

Law 23 of 2014 on Local Government reconfigured the authority for the licensing and pricing of supply to unserved areas, which now rests with either the central government (through Ministry ESDM), the provincial government or the regency/municipal government. This clearly distinguishes between the functions and autonomy of local government (at both the provincial and municipal levels) and of central government in cross-sectoral activities. In the power system, provincial government is authorised to release business permits for non-state-owned companies, to release operational permits for facility installations, to set electricity tariffs and the multi-use of communication facility for power system purposes, to set power purchases, wheeling purchases or

[3] For details, see https://jdih.esdm.go.id/storage/document/Kepmen-esdm-143-Thn%202019%20RUKN%202019.pdf.

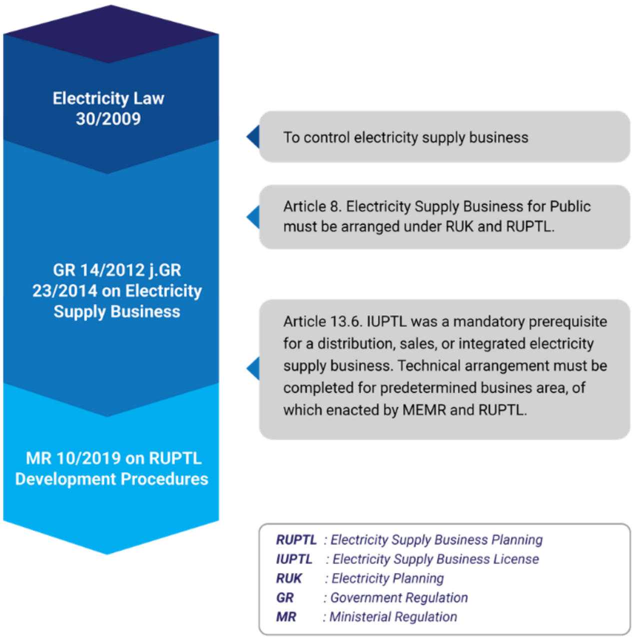
excess power purchases to PLN to grant permits to any supporting entities for power system development, as well as prioritisation of marginal communities or rural electrification. All these authorisations are also applicable for central government as long as they are executed at state cross-border and crossing provincial borders.

Ministry Regulation 10 of 2019 on RUPTL Guidelines. A new enactment of RUKN in Ministerial Decree No. 143K-20-MEM provides a new guideline for all business area holders, business area applicants and business permit applicants. This regulation is to ensure that all business plan updates (by existing holders) or proposal of a business plan (new holders) are in accordance with the results of RUKN and RUKD and based on the current projection of local electricity needs. The detailed guidelines of the RUPTL process are explained by this regulation.

According to Government Regulation 3 of 2005, RUPTL is developed by considering RUKN and RUKD.[1] RUKN and RUKD are a set of indicative electricity planning documents required as per Electricity Law No. 30 of 2007. The law also stated that RUKN is developed considering KEN with RUEN as the reference. KEN is a energy-related planning policy which explains energy availability for national consumption, energy development priorities, national energy utilis ation and national energy reserves, all proposed by DEN.

RUEN provides detailed planning derived from and to reach the targets established in KEN. The relationship between these planning documents is illustrated in Exhibit 2-3.

Exhibit 2-3. Regulatory framework for Indonesia's National Electricity Plan



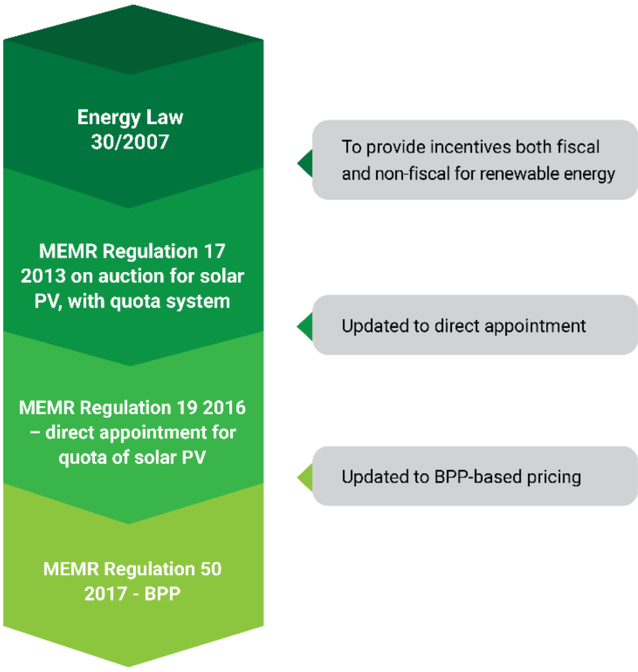
2.2. EXISTING POLICIES AND REGULATION FOR A RENEWABLE ENERGY QUOTA SYSTEM IN INDONESIA

Renewable energy policy in Indonesia was initiated by a promulgation of the National Energy Policy (*Kebijakan Energi Nasional*, KEN) on 25 January 2006 and completed with the establishment of Energy Law No. 30 Year 2007 by incorporating the National Energy Plan (*Rencana Umum Energi Nasional*, or RUEN). A feed-in tariff (FIT) was introduced by MEMR in 2012, specifically for small and medium projects up to 10 MW. FITs provide private investors with a guarantee on fixed returns and consistent revenue from their renewable energy projects. MEMR issued FIT for biomass, biogas, municipal waste and hydro power plants through MEMR Regulation No. 4 of 2012, followed by solar PV through MEMR Regulation No. 17 of 2013, and an update of FIT for hydro power through MEMR regulations No. 12 of 2014, No. 22 of 2014 and No. 19 of 2015. Some updates were also made available for biomass, biogas and municipal waste to attract more investors in 2014–2015. For geothermal power, the New Geothermal Law No. 21 of 2014 was promulgated to accelerate geothermal exploration and utilisation, as well as to begin a new geothermal business regime in Indonesia. In 2016, the solar PV FIT was updated by introducing a provincial capacity quota and new tariff. However, with no impressive development of renewable energy, the FIT era ended and was superseded with a production cost approach as part of a new renewable tariff setting.

A new tariff regime was initiated by a newly appointed minister and stipulation by MEMR Regulation No. 12 of 2017, updated by MEMR Regulation No. 50 of 2017. Through MEMR Regulation No. 9 of 2018, all previous tariffs were abandoned and will be replaced by production cost. Some terms were improved through MEMR Regulation No. 53 of 2018, but the arrangement of cost refers to earlier regulations. To accommodate the enthusiasm of whom who installs rooftop solar panels, an additional regulation covering solar PV electric rooftop panels was prepared under MEMR Regulation nos. 49 of 2018 and 16 of 2019. Based on stakeholder feedback on capacity charge and the Build-Own-Operate-Transfer (BOOT) scheme, a BOOT scheme and lower capacity charge were established under MEMR Regulation No. 4 of 2020.

The following paragraphs provide a more detailed description of historical renewable energy policies relevant to an RE quota system (summarised in Exhibit 2-4).

Exhibit 2-4. Quota-related policies in Indonesia



Energy Law No. 30 Year 2007 established the legal basis for KEN and RUEN, in which new and renewable energy accounted as the agenda. Incentives, both fiscal and non-fiscal, will be further arranged through the regulations mentioned above.

MEMR Regulation No. 17 2013 first introduced a quota system for solar photovoltaics (PV) through auction. In this policy, a quota was defined as the maximum capacity of solar PV plant that can be interconnected to one utility system/subsystem. In this context, utility refers to PT PLN (Persero), or PLN. Article 5 stipulates determination procedures, which state that MEMR will provide a planned quota to PLN and PLN will consider a quota based on the demand characteristic in each system. At the final stage, MEMR will conclude the inputs of a detailed quota system proposed by PLN. Having arrived at a final quota, MEMR will then offer the system to all possible entities to fill it through auction, the mechanism for which is clearly explained in this policy.

MEMR Regulation No. 19 2016 changed the rules of the game from an auction mechanism to direct appointment in order to accelerate solar PV. The maximum quota for each winner is only 20% (for any area with a total quota of 10–100MW) and 20 MW (for any area with a total quota of >100MW). A winner can only bid three times in the same area. If the quota is lower than 10 MW, there is no quota limit for bidders to conform to. This regulation also adds detail about prerequisite documents to be supplied such as registration prerequisites, a feasibility study, and an interconnection study. The quota is set in several phases with the total quota 5,000 MW in stages; stage 1 was started with total 250 MW in 2016 onwards.

MEMR Regulation No. 50 2017 set the electricity tariff based on PLN's production cost (BPP), either local or national. The range is 85%–100% depending on the technology and the tariff refers to PLN's previous year BPP. In 2018, the renewable energy tariff in Indonesia was in the range of 6.9–21 cUSD/kWh. Reflecting on Article 4, any electricity from renewable energy power plants will be purchased by a utility through direct appointment, with a capacity quota bonded and planned by PLN in its RUPTL. In RUPTL, there is an energy balance between each system (Sumatera, Jawa-Bali, Lombok, Timor, West Kalimantan, Kalseltengtimra, Sulbagut, Sulbagsel, Maluku and Papua). RUPTL uses the term 'distributed quota' which is the maximum addition of renewable energy power plant in each system. This distributed quota is used for supporting this regulation. Up to Q1 2021, this regulation still applied, as the enactment of the presidential decree on renewable energy tariff was in progress (there are some updates to some terms made by MEMR Regulation No. 4 of 2020 but these are outside the RE quota context).

In **RUPTL 2019–2028**, RE quotas in each of Indonesia's large systems were identified as the side product of least-cost optimisation (see in Exhibit 2-5)[4]. This is due to RUPTL's main objective, which is to obtain least-cost planning and not to identify the RE quota. In the following section, this guideline examines further the existing RUPTL approach and methodology and suggests an integration of the RE quota scenario (discussed in Chapter 4) into the existing RUPTL process, with some required improvements/recommendations.

Exhibit 2-5. Renewable energy quota in RUPTL 2019–28

Total Quota Capacity per Large System	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Sumatera	-	10	-	75	-	217	720	154	82	10
Jawa-Bali	2	47	62	338	87	11	689	-	-	-
Lombok	20	2	5	-	-	-	-	-	-	-
Timor	-	1	-	10	10	-	-	-	-	-
West Kalimantan	-	17	68	-	-	-	-	-	-	-
Kalseltengtimra	-	33	-	-	-	3.7	-	-	-	-
Sulbagut	-	-	8	10	30	-	40	-	-	35
Sulbagsel	-	-	46	60	80	53	410	-	-	200
Maluku	-	-	-	-	-	-	-	-	-	-
Papua	-	-	-	-	-	-	-	-	-	-

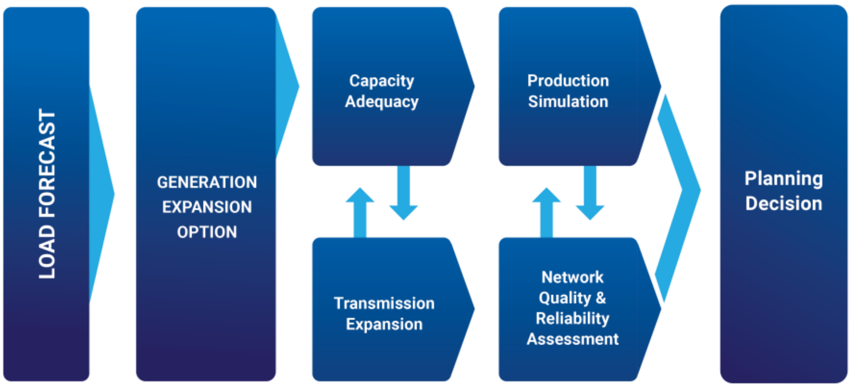
[4] This is only a renewables-based quota. IPP quotas without any "quota distributed" term or non-renewable quota are not considered as part of this table.

2.3. PLN RUPTL PROCESS

As mentioned above, referring to MEMR Regulation No. 10 of 2019, RUPTL is a 10-year electricity business plan document driven by RUKN. As the largest state-owned utility company, PLN's RUPTL covers most of Indonesia's regional development. The RUPTL is developed by PLN HQ together with the regional units and dispatch center unit, with general policy assumption given by the government, and lastly approved by MEMR.

The objective of the RUPTL is to obtain least-cost planning while ensuring demand is met adequately, securely and with a satisfactory quality of electricity supply. As a business entity, PLN needs to balance capital and operational expenditure while providing the required electricity supply in accordance with acceptable criteria, as mentioned earlier. Developing the RUPTL therefore requires modelling to find the least-cost plan. The general least-cost planning process is presented in Exhibit 2-6.

Exhibit 2-6. PLN least-cost power system planning



Demand forecasting

The process begins with an electricity demand forecast. Accuracy in demand forecasting is very important, as over-forecasting would lead to over investment and excessive financial burden, and under-forecasting would lead to a capacity and energy shortage, hindering economic development.

An objective of demand forecasting is to understand the pattern and amount of electricity to be fulfilled adequately and securely, with a satisfied quality of electricity supply. 'Adequately' refers to the condition where power plants are able to supply all demand needs today and in the future; 'securely' refers to the condition whereby the power system is able to supply all demand needs during an unplanned event such as failure of generation or transmission.

There are three general methods in demand forecasting: (1) extrapolation, which offers us a time series based on its historical data, (2) correlation with econometric forecast and main affected factors considered, and (3) a mixed approach (that is, a combination of extrapolation and the correlation approach).

The PLN RUPTL uses the econometric model to forecast electricity demand. Correlation between demand and drivers is assessed and then projected over the next 10 years. There are external drivers such as GDP and population, data for which is obtained from the government (from, among others, the RPJMN team, and RUKN, MoF, BPS teams) and internal drivers such as energy sales and number of customers, for which PLN has their own data. Demand is forecasted for each tariff group; these have different characteristics and often include large consumer candidates such as Special Economic Zones (KEK).

Demand forecasting also considers the demand parameters in power system planning, namely peak load growth, energy growth and dynamic load characteristics. These parameters describe how the load would behave and significantly impact the course of the system planning. For example, the load duration curve, which is part of the dynamic load characteristic, informs us how long a certain level of load would be. From this information, the combination of the generation type can be inferred. If the load duration curve is quite steep, then the system would require more peaker units to meet the demand.

Peak load growth is the growth in peak demand in a certain month or year, analysed in terms of the minimum availability of supply to the customer side. Energy growth is the growth of energy needs in a year, supposed to be generated by power generators (including a consideration of system losses). Load characteristics are several parameters on the load itself which can provide us with more detailed information on how the supply of electricity acts and reacts to the demand. Among others, there are three dynamic load characteristics that are very important in power system planning: load factor, load duration curve and chronological curve.

Generation and transmission capacity expansion planning

The next step would be generation expansion planning, the purpose of which is to find, among the generation expansion option comprising existing and candidate plant, the optimal set of options to meet the demand. The result would be able to point out the technology, size, location and timing of the additional candidate plants to be added to obtain a least-cost configuration of generation and to ensure a reliable, secure and satisfactory quality of electricity supply.

To be able to do this, a set of generation expansion options needs to be evaluated with certain parameters to ensure capacity adequacy can be met at all times, including loss of load probability (LOLP), reserve margin, and energy not served (ENS). These are reliability indexes, intended to measure adequacy using the probabilistic method. The reserve margin is somewhat different, as it only reflects the excess capacity of supply to meet the peak demand. Two power systems with similar peak load might require different reserve margins to achieve the same level of reliability.

In semi-parallel, identifying existing and candidate transmission lines has to be done as well. This process is called transmission expansion planning and is important, as transmission enables the energy to be delivered from the selected plant. It provides the planner with sets of generation and transmission options to be optimised in order to obtain the least-cost investment plan.

In a separate process, the regional units within PLN are tasked for distribution expansion planning. Using data derived from demand forecasting and existing load data, decisions regarding distribution expansion can be made by evaluating the decision against the technical constraint. After that, the total cost can be determined. The process is simple and straightforward, but the process involves a lot of detail as there is a large quantity of components within the power system that need to be considered.

Production cost simulation (operational assessment)

When the expansion plan is finished, operational planning is conducted. The objective of system operational planning is to find the optimal operationing costs of power generation within reliability and quality criteria. The optimal cost is the minimal operating cost, which mainly comprises the cost of fuel needed to generate power. The planning period is usually from daily up to annual planning, with hourly resolution. Constraints to be considered include transmission bottlenecks, available reserves and take-or-pay contracts on primary energy. The optimal cost is the short-run marginal cost, which only considers operating costs such as fuel cost and start-up cost.

The first operational planning process is production simulation (which should provide the operating cost of generation).

Production simulation is performed based on the set of existing and candidate plants during the simulated time of planning. Its aim is to find and optimise the operational cost, which will enable an optimal combination of technical and cost considerations. Determining productions costs requires revisiting the expansion planning model; to obtain the best results therefore, this can be iterative with previous steps.

Network quality and reliability assessment

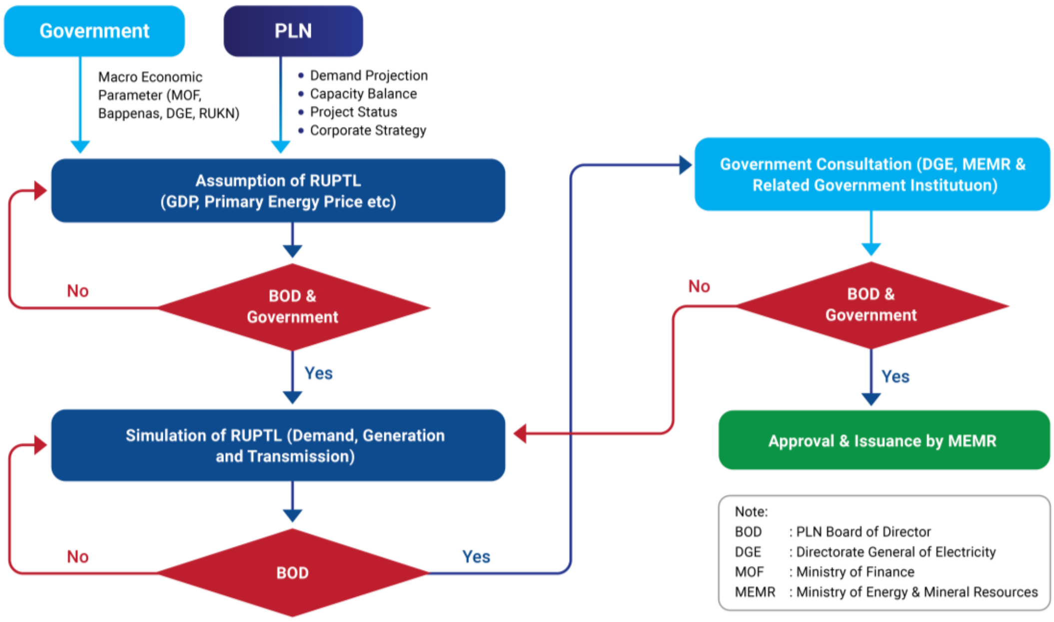
The second operational assessment evaluates network quality and reliability. The optimal system combination resulting from production cost and capacity expansion is evaluated against network quality and reliability assessment to ensure quality of supply. The process of co-optimisation between generation and transmission options is not exactly straightforward, but rather is iterative. Various likely unprecedented scenarios can be considered to ensure the model reflects real-life constraints and to find the optimal combination.

The end product of power system planning is a complete summary of generation, transmission and distribution network development, providing the most optimal cost development and with future demand satisfied, while attaining assured reliability and quality conditions. PLN utilises the following tools in its planning process:

1. Electricity demand forecasting: Simple-E
2. Generation expansion planning: WASP IV & Prosym/Pros
3. Transmission expansion planning and reliability assessment: PSSE/Digsilent

Exhibit 2-7 illustrates this high-level approval process of RUPTL development. In determining assumption, the approval of both the PLN Board of Directors (BoD) and representatives from government is required. For the planning process, only BoD approval is required; however, the planning result must undergo a consultation process with the related government representatives. Once again, the consultation result must be approved by both PLN BoD and government representatives. Only after that can the RUPTL be issued and legalised by MEMR.

Exhibit 2-7. RUPTL approval process



In supporting these processes, Exhibit 2-8 describes the roles of each institution in RUPTL development. As explained, the government is responsible for providing the basic assumption, which can be sourced from RPJMN, RUKN, etc. An involvement of MEMR, Ministry of Finance (MoF), Ministry of National Planning (Bappenas) and RUKN expert members is essential to achieving success in the RUPTL process. Internally within PLN, the detailed tasks are also divided accordingly.

Exhibit 2-8. Roles of institutions in RUPTL development

Role	RUPTL Data Requirement/Process	System Planning in-charge	Data Source/In coordination with
Policy & Data Assumption	Population and GDP	Government	BPS, Kemenkeu
	Economic Forecast		Bappenas, Kemenkeu, Multilateral Lenders Outlook
Demand Forecast	Peak Load & Energy Demand and Capacity Balance	PLN HQ & Regional Unit	PLN Regional Planning, PLN Dispatch Centre
	Peak Load & Energy Demand Growth, Capacity Balance		PLN Regional Unit, Commercial Division
	Energy Demand		RUKN team, RUKD team, DG of Electricity (DJK)
Generation Planning	Primary Energy Price	PLN Power System Planing Division, Regional Unit, Dispatch Center	PLN Oil & Gas Procurement, PLN Coal Procurement
	Primary Energy Price Forecast		Multilateral Lenders Outlook, Crude Petroleum Index, Coal Index, International Energy Price Index etc
	Pre-Feasibility, Feasibility, Project Viablity		PLN Renewable Energy & Engineering
Generation & Transmission Planning	Investment Cost	PLN Power System Planing Division, Regional Unit, Dispatch Center	PLN Procurement, Engineering, Renewable Energy, IPP Procurement
	Financial Model		PLN Power System Planing Division
	Procurement Status		PLN Procurement, PLN IPP Procurement
	Project Status		PLN Project Supervision, & Implementation, IPP Proc., Renewable Energy
	Regional Project Status		PLN Regional Planning
Distribution Planning	All Steps	PLN Regional Unit	
Substation Planning	All Steps	PLN Regional Unit & Dispatch Center	
Model Compilator	All Steps	PLN Power System Planing Division	

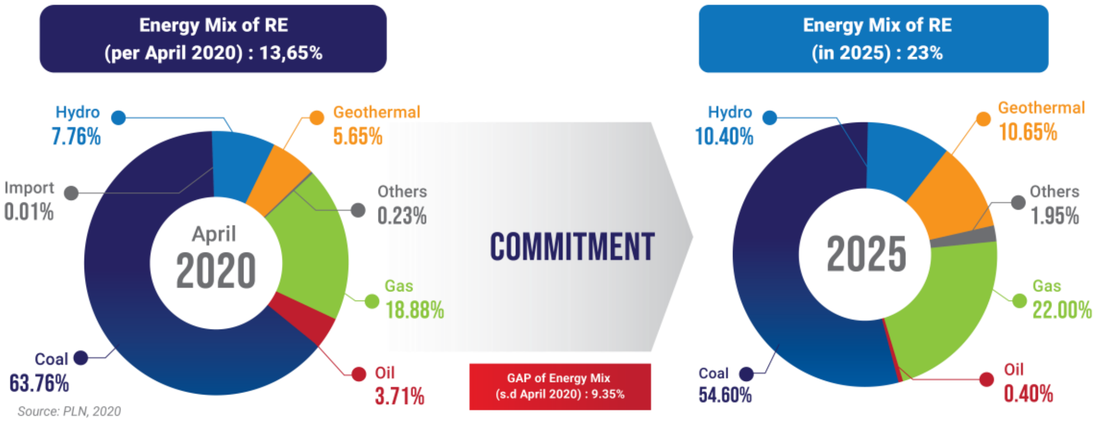
2.4. ISSUES/CHALLENGES IN POWER PLANNING AND POLICIES

Low renewable energy uptake in the power sector

As of 2019, renewable energy uptake in Indonesia's electricity system (both on-grid and off-grid systems) is at only 9.32 GW or 2% of its total renewable energy potential, according to RUEN. More than half of its total renewable installed capacity is represented by hydropower, notably 5.1 GW for large scale hydro and 0.28 GW for small scale hydro (mini and micro). Out of 1.95 GW, renewable installed capacity is represented by geothermal power plants; biodiesel-based generators follow with 1.86 GW. For VRE, wind and solar power plants only have installed capacity of 0.147 and 0.135 GW, respectively.

Exhibit 2-9 shows the amount of renewable energy uptake in April 2020 in comparison with national commitment to the 2025 target. This represents just 13.65% of the total energy mix. Note, however, that this energy mix is based on PLN's perspective, and must be clarified further as the following issues remain.

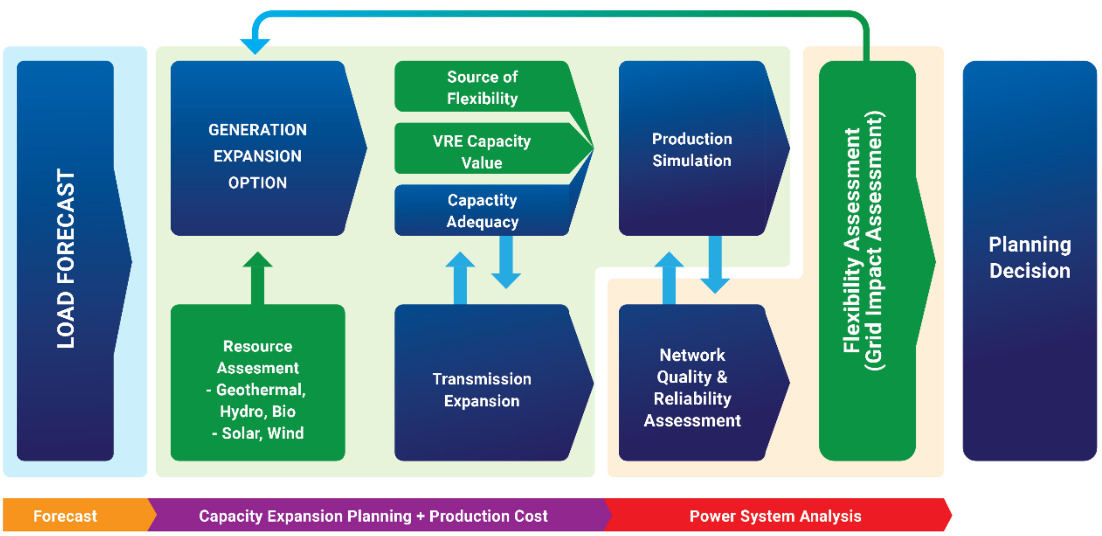
Exhibit 2-9. Indonesia's renewable energy potential vs implementation



Absence of proper and comprehensive VRE planning

RUPTL considers renewable energy an integrated part of the process of power system development. This includes VRE, which is highly dependent on natural characteristics such as wind power and solar power. In addition, VRE has unique characteristics which can influence the security and quality of the power system, namely variability, intermittency, non-synchronous machines, and the fact that it is location-based and non-dispatchable. This means that to achieve a fully comprehensive RUPTL, additional analysisis needed, as Exhibit 2-10 shows.

Exhibit 2-10. Proper renewable energy power planning



Resource assessment of inputs in selected locations is essential to identify the variability of the VRE candidate. This assessment projects the characteristic of each type of VRE over a number of years, taking into consideration its long historical background.

The power planning process needs to anticipate the issues of variability and intermittency; alongside this is the requirement to consider the flexibility of other power plants in the power system. Ramping rate information is also a very important parameter to check to ensure that there will be enough flexibility in the system.

Capacity value is the contribution of a power plant to meeting demand reliably. However, because VRE is non-dispatchable, its capacity value is more complex to determine than conventional power generation. Ascertaining the capacity value of VRE will add system reliability or facilitate the offsetting of conventional power plant capacity.

Considering that intermittency is a natural characteristic of renewable energy, it can be easily anticipated through a comprehensive system flexibility assessment, usually called a grid impact study. This study is carried out using power system analysis, mainly of stability. One of the outputs of this study will be to determine the maximum potential contribution of VRE.

Notably, the current grid impact study is conducted by a third party (that is, a non-PLN body). There is room for this third party to ensure that renewable energy projects are approved or proceeded by PLN. As a consequence, there is a lack of recommendations regarding how to manage the impacts of VRE integration in the larger PLN system. PLN is therefore strongly recommended to conduct a grid impact study for its entire system. This would concurrently assess how third-party results impact upon its grid and will provide concrete step-by-step action for PLN to take within its large system if any integration is made according to its planning. By having such a study, PLN can also manage the terms of its renewable energy projects and their detailed arrangements, as the study will set these out. As a consequence, PLN's readiness to welcome more VRE in the system (discussed later in more detail) would be underpinned and realistically informed by accurate data. It would also avoid any unplanned VRE integration (which is currently causing disruption throughout the entire system).

3. RENEWABLE ENERGY QUOTA SYSTEM: DEFINITION AND BENCHMARKS

Understanding a set of renewable energy policies and power planning procedures will lead to the conclusion that these should be the main components to consider when establishing an RE quota system. As yet however, this document has not provided information on what an RE quota system is. This chapter defines an RE quota system from a generic nomenclature perspective and elaborates in greater detail more of the components required for RE quota determination. The final chapter outlines global practices regarding RE quota systems, as part of the benchmarking process.

3.1. DEFINITION OF A RENEWABLE ENERGY QUOTA SYSTEM

When accelerating the spread of renewable energy, the implementation design of support instruments varies according to whether the instrument principles are based on price or volume control. In volume-based support instruments, there is an implicit cap on policy costs through the target, usually defined in terms of volume. Two well-known examples are the quota system (in terms of quota obligation) and auction/tender schemes. On the other hand, in price-based mechanisms, one important feature of policy cost control is the revision and adaption of the initially set support levels. An example is feed-in systems.[5]

A quota system involves a certain fixed amount or share of renewable-based power (stipulated by the state or zone) and has to be produced, purchased or bought in a given time period by a certain group of actors (suppliers, producers, traders or end customers).[6] It is a generation-based, quantity-driven instrument by which to accelerate a renewable energy portion in pursuing any target set by government. The government defines targets for renewable energy deployment and obliges one or a number of electricity supply-chain entities (such as generators, wholesalers, retailers or consumers) to fulfil them.[7]

According to Indonesia's Ministerial Decrees[8], the Government of Indonesia defines capacity quota (as provided by a quota system) as a maximum power installed capacity cap offered to any entities in one period for a determined electricity purchase price. If the quota is intended for any specific renewable energy technology, those technologies are only permitted to enter a system by complying with its maximum limit. The system itself is defined by a specific geographical boundary (or specifically, a government administrative unit). The detailed boundaries are outlined in PLN's

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[5] Fraunhofer ISI and Ecofys. Design features of support schemes for renewable electricity. 2014.
[6] Mischa Bechberger. Diffusion of renewable feed-in tariffs in the EU-25 – an instrumental contribution for the dissemination of renewable energies. 2005. ECPR Joint Session. Granada Spain.
[7] Gustav Resch, et al. Feed-In Tariffs and Quotas For Renewable Energy In Europe. 2007.
[8] Ministerial Regulation No. 4 Year 2020, No. 50 Year 2017 and No. 12 Year 2017.

RUPTL or electricity supply business plan, and include those defined according to province or by its grid zones.

Returning to worldwide practices, quota systems are normally combined with tradable green certificates (TGCs), mainly to separate the physical power market from the TGC market and to control the compliance of the set quota.[9] All EU countries apply a quota system with tradable renewable energy certificates or TGCs which include penalty payments, although some countries define these as fixed values while others define them as multiples of the current certificate price.[10]

In other cases, a quota system is combined with a price-driven instrument such as feed-in tariffs or auction. Malaysia's large-scale solar (LSS) programme is a successful example of the combining of a quota system (an approach to produce a package of renewable capacity) with an auction system. This LSS programme was first introduced by the Malaysia Energy Commission in 2016 through three rounds of commercial operation date (COD): COD Period 2017–2018 for LSS1, COD Period 2019–2020 for LSS2[11] and COD Period 2021[12] for LSS3. Earlier than this, Indonesia first introduced a combination of an RE quota system with the existing price cap in 2013[13], through MEMR Regulation 17 of 2013. However, this policy has not been well-implemented due to an issue of local content, and as a result a new policy package was introduced through MEMR Regulation 19 of 2016; however, this only existed for a few months before the arrival of new minister. In China, an RE quota system was discussed among the authorities and government in 2014[14], piloted in 2018[15] and finalised in 2019; it was anticipated to take effect at the start of 2020; at the time of writing, no further update was available.[16] Through this RE quota system, China has implemented a certain fraction of renewable energy in its total power generation for each province and grid zone. The quota targets, set as a portion of renewable energy use in the total energy mix, varied in 2019 from 10% in the eastern province of Shandong to as high as 88% in the southwestern province of Sichuan, based on their energy structure.[17,18]

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[9] Mischa Bechberger. Diffusion of renewable feed-in tariffs in the EU-25 – an instrumental contribution for the dissemination of renewable energies. 2005. ECPR Joint Session. Granada Spain.

[10] Fraunhofer ISI and Ecofys. Design features of support schemes for renewable electricity. 2014.

[11] https://www.pv-tech.org/news/malaysia-announces-winners-of-second-lss-solar-auction.

[12] https://www.thestar.com.my/business/business-news/2019/02/14/energy-commission-announces-500mw-large-scale-solar-tender/.

[13] Some institutions may refer to the price for renewables in Indonesia as its feed-in tariff, but it is actually price capping. The different between price capping and a feed-in tariff is that with price capping the price can be lower than stated due to the negotiation/auction process, while the feed-in tariff price is fixed.

[14] Weiming Xiong, et al. Impacts of renewable energy quota system on China's future power sector. 2014.

[15] https://www.chinawaterrisk.org/resources/analysis-reviews/chinas-renewable-energy-quotas/

[16] CRS team. Accelerating Corporate Renewable Energy Engagement in China. November 2019.

[17] https://www.chinawaterrisk.org/resources/analysis-reviews/chinas-renewable-energy-quotas/

[18] https://www.reuters.com/article/us-china-renewables/china-sets-renewable-power-quotas-for-2019-2020-idUSKCN1SL0XA.

These practices show how some countries set a quota system based on two different principles: a quota with an RE certificate (European countries define these quota obligations based on green or renewable energy certificates) and a quota-based zone (by grid/province, as in Indonesia, China, Malaysia and some developing countries).

Coincidently, global practice in RE quota systems shows a relevancy between these principles and the electricity market model. Countries such as China, Indonesia and Malaysia have established a single-buyer market, where an off-taker is fully responsible to the whole electricity supply chain. These countries tend to opt for grid-zone quotas, where quota policy is streamlined with centralised utility planning and the national renewable energy mandate. This is noticeably different to the situation in Europe, an open market region, where its country members decide whether to implement quota certificates or green certificates. Without a monopolistic monarch in their electricity supply chain, more entities are able to participate under the quota certificate system. This provides an end-to-end impact of renewable energy penetration, which at the same time is more effective thanks to its market model. As yet, no comprehensive study exists which examines this relationship. Empirically, these countries implement the quota based on their electricity market model. In principle, understanding the electricity market helps select a suitable quota policy effectively and efficiently.

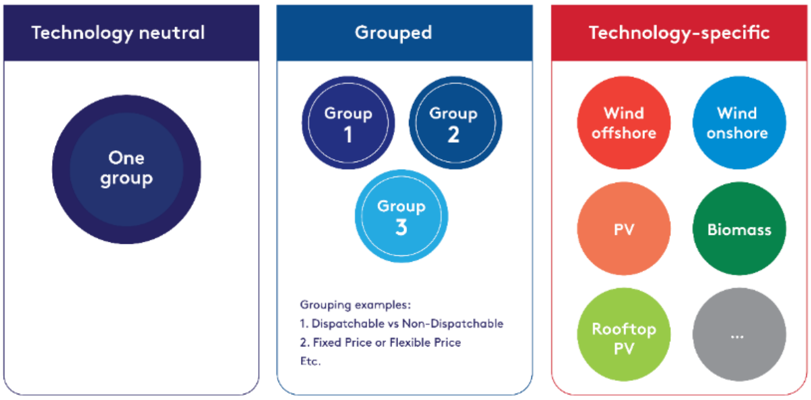
The main characteristics of each quota system as explained above are presented in Exhibit 3-1.

Exhibit 3-1. Characteristics of the RE quota system: quota certificates and quota-based grid zones

Characteristics	Quota Definition	Type	Target	Countries	RE Certificates	Price of electricity for generators
Certificate System	Mandatory target to be achieved (cannot be lower or penalties apply)	Pure Quantity-based Instrument	Generators, wholesalers, customers	• UK • Poland	Required and Tradeable	Unbundled or bundled with certificates
Zonal System	A target to be achieved (can be lower if not achievable)	Can be combined with price-based Instruments	Utilities or provincial government	• Italy • Malaysia • Indonesia	Not necessary	Auction-based or Incentivised price (e.g. FiT, premium prices)

Nevertheless, both principles are best arranged into three general designs, based on the technology: technology neutral, grouped and technology specific. Technology neutrals apply the same terms to all technology (without any special treatment of the specific technology). This crosses the available subsidy from low-cost energy sources to the highest one but does not reflect the real cost of electricity provided by each. A grouped or technology banding approach is taken to set the price based on similar characteristics of renewable energy technology. This is either technology specific (to prioritise an individual technology) or puts the focus on the higher cost of renewable energy (as part of an incentive program).

Exhibit 3-2. Technology-wise arrangement for an RE quota system



Meanwhile, two approaches are applicable for government, regardless of its technology arrangement and the electricity market model: (1) a top-down approach, and (2) an intervention approach.

In a top-down approach, a fully obligatory binding for renewable energy fulfilment is applied to any predetermined subjects/implementors which are responsible. The rule of the game in this approach may vary, from the simplest rules and procedures to the most complicated. The government target is paramount. Utilities and customers are obliged to comply with the target, with no excuse for non-compliance. To ensure policy goals are achieved, a top-down approach tends to provide a strict penalty system. As an assertive approach, no feedback from utilities or customers that challenges the rule and procedure set by government is heeded.

In contrast, an intervention is used to provide a more persuasive approach. Here, the government intercepts any on-going planning process to inject the obligation of an RE quota. With this approach, the RE quota still needs to be fulfilled, but this can be achieved without any penalties or at least with a less stringent penalty system. It can be maintained as such as a testing instrument, where any entity with responsibility to provide electricity is mandated to pursue the government target but incurs a lesser penalty for non-compliance. Any non-compliance will be further evaluated to facilitate policy improvement. The intervention approach is more democratic, but as a consequence its degree of realisation may be lower than the target. Setting a reasonable target is another way to achieve a realistic target.

Both approaches are able to support the grid zone quota, while a quota certificate is considered mainly by the intervention approach. However, an examination of several other countries' practices indicates that this categorisation might not be strictly accurate. Basically, everything depends on individual country preference and the arrangement of its rules and procedures.

Advantages and disadvantages of the renewable energy quota system

Whether effected via a quota certificate or zonal approach, the advantages of an RE quota system are clear and are as follows[19]:

1. A quota system provides many implementation options, from its combination options (with TGC, FIT or auction) to the technology arrangement shown in Exhibit 3-2.
2. In term of effectiveness, a quota obligation is theoretically well-suited to meet the renewable energy target exactly; however, empirical evidence shows that over- fulfillment (as in the case of Texas) and a target shortfall are likely.
3. The application of quota certificates will benefit a high compatibility with market principles.
4. If the auction method is applied, competitive price determination is possible, as in the case of Malaysia. This is also applicable to quota certificates.
5. Levying fines for target non-compliance will be more beneficial for encouraging the participation of utilities/wholesalers/customers; however, fines which are too high or low might at the same time be discouraging for utilities/generators/customers.
6. A quota obligation can be designed in a technology-neutral way, supporting only the most cost-effective technologies and leading theoretically to a high static efficiency.
7. A technology-neutral approach will also result in low dynamic cost efficiencies, as with this the most cost-intensive technologies do not receive sufficient support. On the contrary, technology banding will lead to the avoidance of overcompensating cheaper technology and the reflection of explicit technology innovation and diversification goals.[20]
8. An RE quota system will provide an insight to utilities into renewable energy grid integration and contribute to an inclusive transition in the power system.[21]

It is also important to consider some disadvantages of RE quota implementation[22]:

1. As a minimum, any penalties have to exceed the costs of the marginal technology required to meet the target. Levying low fines for non-compliance might lead to a preference among utilities for paying a penalty rather than having a marginal cost in their system.
2. With renewable certificates or FIT, high risk premiums result from the uncertain development of the price of electricity/certificates and typically increase policy costs.
3. However, a quota obligation which features a cap and floor price and technology differentiation is hardly distinguishable from the FIT and auction options.
4. An auction-based quota system requires mature market establishment at a highly competitive level. If only a few players sign up, it will discourage a competitive price. A sunk cost for bidders needs to be considered. Moreover, the risk of underbidding is also possible.[23]

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[19] Fraunhofer ISI and Ecofys. Design features of support schemes for renewable electricity. 2014.
[20] European Commission guidance for the design of renewables support schemes. 2013.
[21] IRENA. Global Trends in Competitive Procurement Global Trends and Key Takeaways. Nov 2019.
[22] Fraunhofer ISI and Ecofys. Design features of support schemes for renewable electricity. 2014.
[23] Sarah Lawson. Asia EDGE Regional Competitive Procurement Dialogue. Nov 2019.

3.2. MINIMUM COMPONENTS OF A RENEWABLE ENERGY QUOTA SYSTEM

As a policy instrument, an RE quota system has various designs, constraints and components. This sub-chapter elaborates all of these; however, a common understanding of Indonesia's erstwhile RE quota system is important to begin with.

Referring to MEMR Regulations No. 17 of 2013 and No. 19 of 2016 (revoked in 2018), the RE quota system was designed as a technology-specific quota system, covering only solar PV. In 2017, MEMR Regulation No. 50 of 2017 replaced this with a quota system capturing all types of renewable technology (wind, solar, biomass, hydropower, etc.). The following components were considered to support a renewable quota system in Indonesia.

1. **Price setting:** a price cap with 25 cUSD/kWh (2013), shifting to regional-based pricing, ranging from 15–25 cUSD/kWh (2016). The prevailing mechanism allows for a price based on BPP (2017–now)
2. **Local content (TKDN):** this is not obligatory (2013) but since 2016, due to challenges from local industries, has been a must-comply-with term. TKDN is 40% (2017–now); there is a delay in increasing this to 60%.
3. **RE quota system determination:** the DG of New Renewable Energy and Energy Conservation (DG NREEC) and PLN together set the RE quota (2013); MEMR determined the total quota in 2016; MEMR will follow the distributed quota numbers in RUPTL (2017).
4. **Mechanism for applications:** an auction system was applied (2013) and then replaced with direct appointment for the MEMR quota (2016) and direct appointment for the RUPTL quota (2017–now)
5. **Staging phases:** this is only available through No. 19 of 2016.
6. **Quota rules and regulations:** the winner can only obtain 20% of the quota (for <100MW) and a total quota of 20 MW (for >100MW) in only three sites (2016).
7. **Penalties:** if there is no COD 1-year extension period after the agreed date, a penalty will be applied (unpublished formula) (2013–2016). There is no extension to build the plant, with penalties applied in the contract (2017–now).

Alongside these, the Government of Indonesia could also consider other designs and components as part of enacting a new quota system, with a view to further improving the effectiveness and efficiency of its policy.

3.2.1 Level of effort in designing a renewable energy quota

The earlier sub-chapter discussed the combination of a quota system and other policy components: certificates, FITs, auctions and other pricing-based instruments. However, this guideline does not limited itself to this, but also presents a conceptual design in the belief that this will assist with determining the quota system in the optimum manner possible. There are five approaches to this:

Level 1: Demand-based quota system

This quota is defined according to the local demand situation. The main considerations are the load characteristics and load pattern, which are the only parameters. As no deep analysis is possible, a hypothetical quota calculation is distributed proportional to demand. The regulator determines the quota as a percentage of peak local demand; its advantage is that it prioritises renewable development in the demand centre. However, this methodology is too simple and does not consider renewable energy source availability or cost analysis. For instance, the RE quota is equal to 10% of peak demand (based on the unproven rule of thumb method). This approach is considered as Level 1.

Level 2: Price-based quota system

A quota system can also be determined through a price set-up in a country. Commonly, a regulator or utility has already analysed the local system price, including production cost, marginal price and other incorporated/intangible costs. The utility also identifies the average national cost as a benchmark. Geographical areas (provinces, cities, states) where the total cost is higher than the national average have a greater RE quota, resulting in low cost electricity. Increasing the RE quota helps the system lower its cost. Geographical areas with a lower than national cost might not need an RE quota to lower its cost down. This approach is mostly related to the incentives/subsidies given to the amount of renewable energy installed later. Lower cost areas do not need more subsidy/incentives and can be reallocated the potential to the higher cost areas. The advantage of this approach is that it establishes a price equally across whole regions in a country; however, this will not faciliate increased quotas for renewable energy development if the system cost is already cheaper because of a huge dependency on coal. The true cost of a system, including externalities and other costs, should therefore be carefully considered in order to avoid any misuse of the RE quota system. The government requires all the cost information in entire region, which also takes time for the government to decide upon. This might be more complicated than the demand-based quota system. Possible low renewable energy integration ensures this as Level 2.

Level 3: Renewable energy source-based quota system

To determine a quota in a system can also be conducted by assessing domestic renewable energy sources. This assessment will require sets of reliable data measured by satellite (for wind, solar and hydro), weather monitoring system (for wind and solar), local measurements for exploration prior to geothermal exploration, for head, water sources/inflows, and dam in hydropower and the supply chain for bioenergy sources), or other acceptable resource assessment authorized by government/institutes. The geospatial analysis may also be an option in particular for solar PV and winds.

Whatever the assessment methodology, those will lead to the decisions regarding the location, power plant size, technical arrangement, distance to the demand or existing grids and add-on infrastructure (transmission, roads, supply chain, etc.). As the results, government could identify which region has greater renewable energy potential, how far with the demand, and what infrastructure is required. The more sources are identified in that system, the more quota will be set for that system. Nevertheless, this approach is highly dependent to technology. Solar and wind can be done in single weather dataset, however, it requires more efforts if the quota will be set for other technologies. The assessment is technology-wise, therefore all the technology under quota must be well assessed. Some may refer to solar or wind with this approach, because it will take more time, effort for collecting substantial databases. The process can be simplified by using public tool provided by many prominent institutions but its use is limited to solar and wind assessment. Due to the efforts, this quota design is at Level 3.

Level 3: Technology-based quota system[24]

As with source-based renewable energy, a quota system can be also determined for a specific technology, with a different quota given for each renewable energy technology. In a quota system with green certificates, this design is generally known as technology banding. The quota system is limited only to certain technologies; others are not limited by a quota as long as the potential is available. The government commonly establishes quotas for a specific technology, while others are set a lower quota according to the political, economic or technical factors at play. Under this method, each province/region only has a certain technology, with other regions having a different quota with a different technology. The disadvantage of this method is that the technology penetration and resource assessment need to be carefully studied. The levelised cost of each technology is also significant, with the price of the technology being the main criteria. This approach provides the government with more options to look at cheaper technology: abundant sources are available. Notably, implementation of this design can also be driven by a political agenda. This advanced determination considers this design as Level 3.

Level 4: Target set-based quota system

A more advanced way is to make the quota target-based, with a national target clearly translated into a target for every zone/province, or when every zone/province has the autonomy to set the target itself, independently. The aim is how well a quota system is distributed each year by each province/zone in order to achieve a certain goal within the quota system policy. The advantage of this quota system is that it can ensure a clear pathway by which a country's efforts can achieve its target. One consideration here is that this way, the target is to be achieved at all costs, meaning that this is not necessarily the country's least-cost option. This type of quota system needs data

[24] Mischa Bechberger. Diffusion of renewable feed-in tariffs in the EU-25 – an instrumental contribution for the dissemination of renewable energies. 2005. ECPR Joint Session. Granada Spain.

information such as demand and renewable energy sources, without any system price or alternative technology options: as long as cumulative quotas achieve the national target, there is no cost issue. In some countries, a quota system represents a portion of the national target, thus deeming it a target-set based quota. This design is at level 4.

Level 5: Least-cost optimisation-based quota system

As part of the optimisation process, the regulators consider all the above approaches, with demand, resource assessment, price, technology availability and cost or country target all considered to be inputs. This approach determines which technology will fulfill the demand and the target, with the lowest cost of technology and the lowest operational system cost/marginal cost, and by taking into careful consideration the availability of local resources. It is a more advanced approach to determining a quota system for renewables in the utility grid, its advantage being that it provides the 'best of the best' quota for each province by considering all parameters in one calculation. This analysis can involve huge efforts, has comprehensive data requirements and requires expensive tools; its results will, however, save billions of dollars in investment. The design of this quota system is at the highest level, Level 5.

Indeed, this guideline will propose the most suitable efforts to employ to determine a quota system for Indonesia (see Section 3.4).

3.2.2 General constraints impacting on renewable energy quota design

Of note is that regulators should understand that they will encounter limits when calculating or determining the RE quota for any area. These constraints are:

Financial capability

For renewable energy to succeed, it requires support in the form of incentives/subsidies, and to guarantee this, government requires a reservoir of cash. The amount that a government is willing to provide will indeed limit the total quota, and have a greater effect than any results suggested possible by powerful tools. This is reflected in certain countries (such as Italy and Indonesia) where the quota is combined with feed-in tariffs or price capping (in both countries, the government must recheck their cash account before stating the specific size of quota that it is able to incentivise).

Renewable energy resource availability

Different RE technology is assessed through distinct approaches (tool selection, methodology options, source of data, the comprehensiveness of data requirements, the constraints or layers taken into account, considerable assumptions and degree of geospatial information data). Each institution may have different results, based on the techniques, tools and assumptions/constraints they defined. Different results might emerge from various renewable energy resource assessment studies. As long as these are well-communicated and acceptable by government or from a utility's perspective, any of these results can be used.

Transmission constraints

Grid adequacy is an issue for countries which experience RE expansion in a short period of time, that is, a renewable energy boom. In such cases, the large amount of local generation renders inadequate the grid capacity to evacuate on-grid renewable energy. The time required to develop a transmission system ranges from 3–5 years, while several gigawatts from renewable energy plants take six months, a mismatched development that leads to an issue of transmission. This guideline proposes a solution to this, namely, that renewable energy is developed not at utility scale but rather at small scale.

Competition level

Market competition level is another constraint. Regulators proposing the quota system should first consider the market size in their country, to what degree local/foreign players are technically and financially viable to conduct the entire RE quota system, how the existing project is regarded by local/foreign players, how the system will be established to protect local players and industries, how local industries/players can ensure the quality of their products/services in comparison to foreign/global partners, and how fair the competition will be.

Emission constraint

Where there is an emissions target, the quota calculation can be re-adjusted. However, this constraint also has implications in terms of how the government provides more incentives for more quotas.

Political constraint

The political will of a country may also limit the space for an RE quota to be determined, such as a government pursuing an acceleration in a certain technology or showing its tendency towards fossil fuels as its economic backbone. Even though many studies show that more renewable energy is required to achieve the least-cost option, the utilities tend to emphasise an alternative point of view, justifying their maintaining a dependency on coal/oil. An evidence-based policymaking process can be introduced to a government or policymaker champion to counteract this. This is the most difficult constraint to enabling a greater RE quota in a country, unless government is in full support of renewable energy.

Other policy constraints

Other policy may also drive some concerns of policy constraints to the RE quota. For example, to protect local players/industries, there is an application of local content (TKDN). To date, the capacity of domestic production for solar PV is only at 500 MW per annum (APAMSI, 2021). These domestic manufacturers meet the requirement of local content. If solar PV quota in national level is higher than domestic manufacturing capacity who meets the requirements, this mean the quota is not doable by government. Local content will limit whatever the quota is, this will be the key barrier for renewable energy penetration. The quota will never be achieved, unless it is outside the quota set government. Let say, private companies installed their rooftops with imported solar PV. The quota of government can be achieved, but not through the government/state-owned utility's procurement.

3.2.3 Elements in designing an RE quota

This guideline identifies a number of other elements which government or the regulator must consider before applying a quota system.

Proper renewable power planning

A power planning process and procedure (detailed in Chapter 2.4) is a fundamental element of an RE quota system. Without this, the quota system design process cannot be implemented except by using a expert guess to determine the system's future peak demand (see Level 1). Power planning also has granularity in terms of time and methodology, making proper RE planning essential.

Notably, conventional power system planning is inadequate to accommodate renewable energy, as discussed earlier in Chapter 2.4, a proper study of which needs to take into account some additional assessments. Without these, an ambiguity of judgement will arise on the part of the utility, resulting in a lack of evidence-based process for RE quota determination.

Quota formula

The most crucial element in RE quota design is its quota formula. This formula ranges from a simple calculation (e.g. a certain percentage of peak demand) to the most complicated way possible (that is, least-cost optimisation). A formula can also be improved in response to any learning curve of assumption updates. To be well-sustained, a predetermined formula must dwell among the regulators and utilities through the establishment of a specific taskforce (which should be multi-institutional) or an institution that is fully in charge of quota design. The taskforce should preserve the knowledge acquired and manage it well, thereby ensuring a continuation of the quota system formula. All countries can derive a formula for their quota; however, each individual formula is confidential and so no public information about it is available.

Clear pricing system for renewable energy

There are five general pricing systems applicable to an RE quota: pay-as-bid, uniform price, price capping, premium price and price with negotiation. Pay-as-bid allows the system to determine a price in any selected bid. Uniform price is a price set equally for the entire country, without any consideration of geographic, system condition or economic differences. Price capping ensures that the price does not go over a certain limit set by the regulator. Any incentivised price is defined as a premium price: feed-in tariffs, net metering and others are in this group. Price with negotiation is an opaque pricing system, which really depends on negotiation between the electricity seller and the off-taker in any country.

Continuity rules

- **Timeline staging process**
  A quota is laid out to pursue a pre-determined target, and a timeline is therefore desirable to measure progress towards meeting this target. For example, Italy consistently sets a three-year period target for its quota system; Malaysia elaborates each phase in its large scale solar auction; the UK evaluates progress and sets the upcoming target annually.

- **Penalties**
  A penalty is a necessary tool as part of the quota system policy, where it can control and supervise the progress of project implementation to achieve the quota. If a quota is not complete or is delayed, a penalty will be applied to any of the institutions responsible. There are two types of penalty: financial penalties (which can be a deduction in price due to delay), or direct payment to government/utilities and non-financial penalties (e.g. exclusion from future auction rounds, or off-taker bonds guarantee stops). From a financial perspective, a minimum quota must be equal to any marginal cost applied in a system, to guarantee utility concern with achieving compliance. However, setting a high penalty will also discourage implementors. A set of penalties should therefore be considered and correlated with a feedback-loop rule set by the regulators. Utilities or government can therefore benefit from the rules, with minimum risk in each manner of noncompliance. Most European countries apply penalties, except Portugal.[25]

Information platform

A transparent, integrated information platform is a supporting tool by which to accommodate all data and knowledge used to adequately inform all quota stakeholders about the progress of the quota system. In addition, any quota with an auction system will provide detailed bidding information and status. It is not necessary to build an advanced information system for a quota system; a dedicated website for quota progress with monthly update of progress is the lowest hanging fruit by which to start this information system off. Minimum information can include status and timeline of quota system process, rule and procedures for any off-taker (or the implementors) and any developers (or the participants), bidding status (if bidding is employed) and a quota database for each participant/off-taker, following the predefined quotas. As a good example, Malaysia provides a dedicated online page for its quota system progress monitoring.

Market size

Market size informs a government as to what level of expected competition is considered sufficient. Each quota system defined in each year can be considered as the market size; however, the competition level to reach these quotas must be assessed and valued according to what the

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[25] Dr. Corinna Klessmann, Ecofys. Overview of design elements of RES-E auctions. 26 September 2016, Brussels.

government expects. In sizing the market, government should thoroughly assess the price level at which utilities can purchase from the developers; the market price should reflect the amount of market players and competition level. All of this information provides a good indication by which to determine the market size needed to fill a set of quotas. In addition, the time of energy production and source of energy can also influence market size. For example, solar PV has a limited window for energy production. Indeed, this market may be influenced if no back-up system is put in place to guarantee it in terms of system dispatch.

Qualification requirements

- **Administrative requirements**
  These are needed to fulfill any administrative arrangement during candidate or quota determination. Local content issues or other procurement regulations are discussed under this element.

- **Technical and financial requirements**
  Technical documents must be collected by the quota implementor (that is, the utilities/provincial government) or quota participants (developers) based on each necessity. A complete technical document (grid impact study and feasibility study, or other study for renewable energy on-grid) must be completed upon the request of existing procedures. In addition, the financial viability or bankability of the projects will be another of a utility's concerns in ensuring projects are implemented on time without any financial issues. A proper selection requires a financial background assessment, or bond or guarantee letters from government.

- **Level of achievement and winner criteria**
  Last but not least, the regulator is to provoke a standardised level on how any utility/local government will be considered to have achieved the quota target based on a quality and quantity perspective. This will help a monitoring and evaluation system (discussed later). A transparent winner assessment with detailed criteria and its weighting process are an essential element of any RE quota system. Various criteria can be used to obtain a winner assessment, including lowest bid for electricity, lowest bid for electricity subject to optimisation of the power system (model run by regulator), lowest capacity payment, highest price and non-price weighted score or territorial/zonal based determination.

3.3. BENCHMARKING FOR RE QUOTA AND SUMMARY

As a policy package, RE quota systems have been efficiently implemented globally. Various combinations of quota system with other incentive policies (such as green certification, auctions, feed-in tariffs and a premium pricing system) exist, with different details and procedures set by each government. This subchapter is benchmarked against only selected best practices from quota-based certificate models (UK and Poland) and to the quota-based grid zone approach (Italy, Malaysia and China). Three case samples are adequate for providing a benchmark for this study, with selection based on their special characteristic arrangements, level of detail, and availability of reliable information.

Quota-based certificates

United Kingdom: quota obligation system

In the UK, an RE quota system has been introduced as a renewable obligation (RO), where it places an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources. This came into effect in 2002 in England, Wales and Scotland, followed by Northern Ireland in 2005. The RO requires there to be a specified number of renewable obligation certificates (ROCs) per MWh of electricity supplied. It is also to provide incentives for the deployment of large-scale renewable electricity in the UK.[26] Incentives are provided through trade activities conducted by electricity suppliers/operators with other parties, or by making a payment to Ofgem (for Scottish consumers), a body which administers the ROs on behalf of Scottish ministers. Through section 121 of the Energy Act 2004, the Gas and Electricity Markets Authority and the Northern Ireland Authority for Utility Regulation (NIAUR) can enter into an arrangement for the Authority to act on behalf of NIAUR in respect of the Northern Ireland renewable obligation (NIRO). Ofgem carries out the functions (monitoring and administering compliance, calculating buyout and mutualisation ceiling, receiving and distributing buy-out and late payments) for NIRO on behalf of NIAUR.

According to this arrangement, the RO is set annually by the Secretary of State for Business, Energy and Industrial Strategy, Scottish ministers, and the Department for the Economy (DfE), and is zonal- and technology band-specific. The obligation period runs from 1 April (in its current year) to 31 March (in the next year). The detailed Renewable Energy Certificate price per MWh for England is defined as listed in Exhibit 3-3.

[26] https://www.gov.uk/government/publications/2010-to-2015-government-policy-low-carbon-technologies/2010-to-2015-government-policy-low-carbon-technologies#appendix-5-the-renewables-obligation-ro.

Exhibit 3-3. An example of selected technology bands for ROCs for England 2013–17

Unit: (ROC/MWh)

Technology Band	13/14 support	14/15 support	15/16 support	16/17 support
Onshore wind	0.9	0.9	0.9	0.9
Offshore wind	2	2	1.9	1.8
Hydro	0.7	0.7	0.7	0.7
Geothermal	2	2	1.9	1.8
Building mounted solar PV	1.7	1.6	1.5	1.4
Ground mounted solar PV	1.6	1.4	1.3	1.2
Gasification/pyrolysis	2	2	1.9	1.8
Tidal stream	5	5	5	5
Wave	5	5	5	5
Landfill gas - closed sites	0.2	0.2	0.2	0.2

The scheme allows suppliers to meet their annual obligation by presenting ROCs, making a payment into a buy-out fund, or a combination of the two. Where no electricity has been supplied from a renewable energy source during an obligation period, a zero sales declaration must be made instead. The buy-out price per ROC is then applied, adjusted annually with the Retail Prices Index. For a cyclical process, the scheme administration costs are recovered from the buy-out fund (non-compliance actions). The remaining buy-out fund together with any interest accrued is then redistributed to suppliers in proportion to the number of ROCs each supplier in the process, stimulating demand for renewable electricity.

A supplier obligation (the ROCs) is a total relevant electricity times (MWh) with obligation level (ROCs/MWh), where 'relevant electricity' refers to supplier-relevant volume (G) which follows this formula:

$$G = (B + C + D) - F$$

The bracketed information (B+C+D) represents the total supply to customers in distribution (B+C) and transmission level (D); total supply to energy intensive industries (F) is considered an exemption of any RO scheme.

According to the calculation guideline 2020/2021[27], to arrive at the obligation level requires two calculations:

1. **Fixed target:** the Department Business, Energy and Industrial Strategy (BEIS) is required to estimate the total amount of electricity (MWh) expected to be supplied to customers during the current obligation period, for both Great Britain and Northern Ireland. The overall obligation

[27] https://www.gov.uk/government/publications/renewables-obligation-level-calculations-2021-to-2022.

(in ROCs) is then obtained by multiplying these figures by the fixed targets specified in the Renewable Obligation Order 2015. These are 0.154 ROCs per MWh for Great Britain and 0.063 ROCs per MWh for Northern Ireland.

2. **Headroom**: that is, the number of ROCs to be issued to stations expected to be operational during the certain obligation period, for both existing and forthcoming stations, and then uplifted by 10 per cent. For each installation, generation is estimated by multiplying the capacity by the number of hours in the year, and the expected load factor. The expected ROCs are then calculated by applying the banding level for that technology to the generation. The list of existing sites was taken from Ofgem's RO accredited stations database[28] and only those expected to generate in a predetermined obligation period have been included. A list of these new stations was sourced from internal information obtained from Ofgem and only those predicted to generate in the same predetermined obligation period have been included. In terms of load factor, BEIS earlier considered splitting this into two categories: one for existing stations and one for new build. In the 2020/2021 calculation, BEIS only apply one load factor for both existing and new build. The load factors presented below are net of availability, expressed on a total installed capacity basis. For the year 2020/2021 calculation, BEIS used monthly generation and capacity data (on an unchanged configuration basis) based on ROCs issued from April 2010 up to 31 March 2020, as published by Ofgem. Unchanged configuration load factors express the average hourly quantity of electricity generated by stations operational the entire year (in the same configuration) as a percentage of capacity operational the entire year (from the same stations). As such, this removes bias from changes in capacity during the year (e.g. because of sites beginning operation at the beginning or end of the year).

The total obligation, which is then used to determine the level of the obligation, is set as one of these calculations, determined as:

1. **Fixed target**: if the fixed target (Calculation A) is equal to or greater than headroom (Calculation B); or
2. **Headroom**: if headroom (Calculation B) is greater than the fixed target (Calculation A).

In calculating these, BEIS coordinates with Ofgem and with the Department of Energy and Climate Change (DECC) to ensure coordination with other DECC financial incentive schemes. Considering these values, the updates of development and achievements for ROC in England, Wales and Scotland since 2002 are tabulated in Exhibit 3-4.[29]

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[28] Ofgem's accredited stations database is available at: https://www.renewablesandchp.ofgem.gov.uk/Public/ReportViewer.aspx?ReportPath=/Renewables/Accreditation/AccreditedStationsExternalPublic&ReportVisibility=1&ReportCategory=1.

[29] ROC/MWh and buyout price are well taken from document Renewables Obligation: Guidance for Suppliers. For achievements, they are calculated based on the ratio of ROC buy-out to total ROC (presented plus buyout). The data was taken from https://www.gov.uk/government/statistics/regional-renewable-statistics.

Exhibit 3-4. ROCs/MWh in England, Wales and Scotland

Period	Target (BOC/MWh)	Achievement	Target (million ROCs)	ROC presented (million ROCs)	ROC Buyout (million ROCs)
2002/2003	0.03	58.9%	9.26	5.45	3.81
2003/2004	0.043	55.8%	13.63	7.61	6.02
2004/2005	0.049	68.9%	15.77	10.86	4.91
2005/2006	0.055	76.0%	18.03	13.7	4.33
2006/2007	0.067	67.5%	21.63	14.61	7.02
2007/2008	0.079	64.5%	25.55	16.47	9.08
2008/2009	0.091	65.4%	28.98	18.95	10.03
2009/2010	0.097	70.9%	30.1	21.34	8.76
2010/2011	0.111	71.9%	34.75	24.97	9.78
2011/2012	0.124	91.3%	37.67	34.4	3.27
2012/2013	0.158	91.5%	48.91	44.77	4.14
2013/2014	0.206	98.2%	61.86	60.76	1.1
2014/2015	0.244	99.1%	71.93	71.28	0.65
2015/2016	0.29	99.9%	84.43	84.38	0.05
2016/2017	0.348	89.5%	100.74	90.21	10.53
2017/2018	0.409	87.6%	117.84	103.22	14.62
2018/2019	0.468	84.3%	127.62	107.64	19.98

A lesson learnt: Poland's Green Certificates

The 2005 Polish Energy Law Act was amended in order to implement the decisions of EU Directive 2001/77/EC. A quota system obligation for electricity derived from renewable energy sources was introduced in the form of a "Green Certificate" system which came into force on 1 October 2005. Energy companies selling electricity to end users are obliged to obtain and submit to the President of the Energy Regulatory Office (ERO) a certificate of origin of their product – the Green Certificate. The 2006 regulation replaced the quotas with a higher amount.

A subsequent Decree (14 August 2008) provides details on the RE quota obligation and certificates system, outlining how the scheme will be implemented. It specifies that all technologies are eligible under the scheme, with some conditions for biomass co-firing (a specified percentage of biomass must be used for facilities over 5MW) and origin of biomass (for facilities over 20MW). During the first four years the quota was adjusted three times.

All energy companies that sell electricity to final consumers and are connected to the Polish grid must comply with the quota requirements. The Decree establishes the quota amounts to be met, expressed as a percentage of the amount of energy sold by the company. The quota amount can be met using any technology or combination of technologies. From 2005 to the latest order (Order of 5/5/2014), the quota obligation system at national level basis was set as shown in Exhibit 3-5.

Exhibit 3-5. Quota obligation system in Poland, based on MWh generation

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013
Quota	3.1%	3.6%	5.1%	7.0%	8.7%	10.4%	10.4%	10.4%	12%
Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**NA**
Quota	13%	14%	15.0%	16.0%	17.0%	18.0%	19.0%	20.0%	NA

In the period 2005–2015, the achievement of green certificates is represented as oversupply of green certificates (normal) and shortage of green certificates (red font). The numbers increased but were stagnant in 2010–2012 to recover the shortage of green certificates. An issue of electricity oversupply in 2012 was then managed by this recovery period.

Exhibit 3-6. Quota vs. achievement in Poland

	Quota (%)	Subtitution fee (MWh)	Oversupply/shortage of green certificates (MWh)	RES energy produced (MWh of certificates issued)	Obligation quota (MWh)
2005	3.1	2.400	392.089	3.760.301	3.368.212
2006	3.6	357.501	19,854	4.221.547	4.241.401
2007	5.1	1.169.741	685,137	5.229.525	5.914.662
2008	7.0	1.865.325	1,989,541	6.493.066	8.482.607
2009	8.7	1.698.163	1,526,713	8.605.161	10.131.874
2010	10.4	2.216.235	1,627,179	10.987.832	12.615.011
2011	10.4	1.256.956	317.524	12.976.992	12.658.655
2012	10.4	25.971	3.433.855	16.095.366	12.661.511
2013	12.0	24.688	2.172.318	16.781.754	14.609.436
2014	13.0	N/A	3.487.385	19.347.385	15.860.000
2015	14.0	N.A	6.635.900	22.599.900	16.164.000

The disadvantages of the Poland quota system are that it has no transparent information scheme or clear government communication system by which to announce regulatory intentions pertaining to the RES support scheme, and no analysis scheme to monitor the development of the RES sector and the functioning of the support scheme on a current basis. There is also no structure of pricing or on how to determine the quota.

Quota-based grid zone

Italy: zonal-based renewable quota system (with auction and FIT)

In line with the European Directives for the liberalisation of energy markets, Legislative Decree 79/99 (enacted in 1999) addressed the restructuring and gradual liberalisation of the Italian electricity market.[30] Under the quota obligation, in 2001 the decree also introduced a tradable green certificate system, following EU Directive 2001/77/EC. This green certificate mechanism required power producers and importers to produce a certain percentage of electricity from renewable sources, starting from 2% and increasing by 0.35% a year to 2.35% in 2005, 2.70% in 2006 and 3.05% in 2007.[31]

Green certificates were to be used to fulfil this obligation, but producers and importers could also fulfil their RE quota obligation by purchasing certificates from third parties. Moreover, since 2008 until the end of the Italian quota system they have also been allowed to feed imported renewable-generated electricity into the Italian grid, but this energy must be certified by a Guarantee of Origin.[32] The certificates were traded in a parallel market independent of the electricity market; in 2005, the price of a green certificate stood at €109/MWh (USD 172.7/MWh).[33] Green certificates are advantageous for renewable generators because of the duration of the support (12 years for all technologies and 8 years for biomass) and the high annual reference. In addition, some first elements of technology banding in Italy were introduced in 2006 by differentiating the validity horizon of certificates for different technologies.

In general, the performance of the Italian quota obligation was characterised by high certificate prices (with average values ranged from €74/MWh to €85/MWh between 2009 and 2012) and low effectiveness for most of the technologies, in particular in the earlier phases of the quota obligation.[34] A problem observed in the Italian system was the less favourable technology banding issue, along with the non-existence of clear and explicit non-compliance penalties. Although sanctions in the case of non-fulfilment exist in theory, there are only vague rules for monitoring compliance.[35]

As of 2013, green certificates were replaced by a quota-based tender scheme for large-scale power plants, while smaller scale applications receive feed-in tariffs. This tender scheme was continued up to the most recent renewable policy, FER (*Fonti Energie Rinnovabili*) 2019, which entered into force on 10 August 2019.

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[30] IRENA-GWEC: 30 Years of Policies for Wind Energy.
[31] IEA. Innovative Electricity Markets to Incorporate Variable Production to IEA – Renewable Energy Technology Deployment. May 2008.
[32] Ibid.
[33] IRENA-GWEC: 30 Years of Policies for Wind Energy.
[34] Steinhilber et al. 2011
[35] Fraunhofer ISI and Ecofys. Design features of support schemes for renewable electricity. 27 January 2014.

FER 2019 provides for new incentives that can be granted, upon specific award procedures, to renewable energy source plants. Most renewable energy source plants are eligible, including solar plants (except for ground-mounted solar plants located in agricultural areas) that in the past benefited from a separate incentive scheme, and the incentives also apply to construction, revamping and repowering (except for solar plants, which are not eligible for repowering/ revamping).[36]

Based on indicative yearly costs equal to €5.8 billion per year, the incentive system ends once the incentives granted have reached the indicative cost. FER 2019 provides two ways to benefit from the incentives:

1. via enrolment in special registers (for plants with a power capacity lower than 1 MW); and
2. via auctions (for plants with a power capacity equal to or higher than 1 MW, including aggregates of plants that have an overall capacity equal to or exceeding 1 MW and individual capacities of between 20 kW and 500 kW).

In order to benefit from the incentive, a rankings system for plants is applied, according to the power quotas set for each renewable source. The plant must already have been authorised at the time of the subsidy application, thus:

- It must have all necessary permits.
- The connection proposal by the grid operator must have been accepted.
- The incentives will be available to plants where construction works are due to start after the plant has been included in the rankings (except for plants that were not successfully included in the rankings of the previous FER Decree 2016 Ministerial Decree 23 June 2016 or those having direct access to the incentive pursuant to the same decree, i.e. without either enrolment in a register or auction).

For power plants of less than 1 MW, delivery of a bid bond must be equal to 1% of the capital expenditure (capex) (with a final performance bond equal to 2% of the capex to be delivered upon award of the incentive). When the above eligibility requirements have been met, bidders are ranked based on certain priorities, set under government regulations and lowest value of tariff due in absolute terms.

For power plants of more than 1 MW, the following conditions of eligibility are applied:

1. delivery of a bid bond equal to 5% of the capex (final performance bond equal to 10% of the capex to be delivered upon award of the incentive);
2. evidence of financial capacity (by means of a bank statement which may be in the form of a commitment to finance the works); and

[36] Elena G. and Carloandrea M. from Ashurst. Available in this link (accessed 20 Oct 2020): https://www.ashurst.com/en/news-and-insights/insights/new-italian-incentives-for-renewables-fer-2019/.

3. capitalisation (paid-up share capital and/or payments for future share capital) in the following percentages:
   - 10% on the capex up to €100 million
   - 5% on the capex between €100 million and €200 million
   - 2% on the capex exceeding €200 million.

When the above eligibility requirements are met, bidders for plants >1 MW are ranked based on certain priority criteria, namely, the highest percentage of reduction of the base tariff offered by the bidder (the reduction of the base tariff cannot be lower than 2% nor higher than 70%).

In its quota determination, there is no detailed information on how the Italian government should calculate/analyse the quota. It provides seven tender procedures to obtain incentives, which will be launched over a three-year period, each with different (and increasing) power quota for each group of plant, as follows:

- Group A: includes wind plants and solar plants;
- Group A-2 (only for plant with power capacity lower than 1 MW and registered in special records); this includes rooftop solar plants replacing roofs of buildings and rural buildings, and with full removal of Eternit or asbestos (such plants may accrue, in addition to the incentive, a bonus of €12 per MWh);
- Group B: includes hydroelectric plants and sewage treatment gas plants; and
- Group C: includes wind plants and B-Group plants in ongoing entire or partial refurbishment.

Exhibit 3-7. Quota system groups: in < 1MW power plants (left) and in >1 MW power plants (right)

Procedure No.	Group A-2 *(MW)*	Group A-2 *(MW)*	Group B *(MW)*	Group C *(MW)*
1	45	100	10	10
2	45	100	10	10
3	100	100	10	10
4	100	100	10	10
5	120	100	10	20
6	120	100	10	20
7	240	200	20	40
Total	770	800	80	120

Procedure No.	Group A *(MW)*	Group B *(MW)*	Group C *(MW)*
1	500	5	60
2	500	5	60
3	700	10	60
4	700	15	60
5	700	15	80
6	800	20	100
7	1.600	40	200
Total	5.500	110	620

Based on the seven tender procedures, the launch dates started in 30 Sept 2019. The GSE[37] published the rankings within 90 days of the tender closure, in which a deadline to submit applications is 30 days from the launch date. In total, a procedure requires 120 days. The next tender is 120 days after

[37] Gestore Servizi Energetici, the Italian public authority in charge of the incentives.

the previous one. For example, tender 1 was on 30 September 2019, thus tender 2 was on 31 Jan 2020 (the end of the month) and so on.

Most of the working life of the plant is 20 years from the commercial operation date, as set by FER 2019 based on type of electricity source. The incentive is equal to the tariff offered by the bidder, minus the hourly zonal price of the area where the energy produced by the plant is fed into the grid. In cases where the zonal price is higher than the tariff, the negative difference is adjusted by the GSE through a clawback mechanism. The base tariff by type of plant and working life during which the tariff will be paid are presented in Exhibit 3-8.[38]

Exhibit 3-8. Base tariff and working life of plants established by Italian incentives

Renewable Energy Soource	Type	Wattage KW	Working life of the plants	Base tariff £/MWh
Wind Power	Onshore	1≤100	20	150
		100≤1000	20	90
		P≥1000	20	70
Hydro Power	Flowing water (aquaduct plants included)	1≤400	20	155
		400≤1000	25	110
		P≥1000	30	80
	Hydroelectric reservoir basin or tank	1≤1000	25	90
		P≥1000	30	80
Sewage treatment gas		1≤100	20	110
		100≤1000	20	100
		P≥1000	30	80
Photovoltatic Solar Power		20≤100	20	105
		100≤1000	20	90
		P≥1000	20	70

From January 2021, the base tariff reduced by 2% for Group B plants and by 5% for Group A plants. Additional tariff reductions are provided depending on the date of entry into operation of the plant.

Malaysia: zonal-based renewable quota system (with auction)

In 2011, Malaysia introduced a feed-in tariff for renewables. Because of the lower price of solar PV, Malaysia decreased FIT rates for solar PV by 15%–20% annually, instead of the planned 8%. This reduced pressure on the RE Fund, enabling more capacity to be released for renewables in same year. By the end of 2015 therefore, Malaysia had achieved 240 MW solar PV installed capacity, instead of its target of 65 MW. All the other technologies achieved only a small fraction of the

[38] Elena G. and Carloandrea M. from Ashurst. Available here: https://www.ashurst.com/en/news-and-insights/insights/new-italian-incentives-for-renewables-fer-2019/ (accessed 20 October, 2020).

target. Solar PV, biomass, biogas, small hydro and waste-to-energy only achieved a total of 350 MW, instead of the target of 985 MW.

Continuing the FIT approach, the large scale solar (LSS) programme as a new instrument of combination between a quota system (package capacity) and an auction system, was first introduced by the Malaysia Energy Commission in 2016, to be executed in three rounds of COD: COD Period 2017–2018 (LSS1), COD Period 2019–2020 (LSS2)[39] and COD Period 2021[40] (LSS3). Whereas the Italian government applies a quota system based on technology grouping, the Malaysian LSS is specifically only for solar PV and utilises the quota system on a zonal basis and in certain plant size-based packages (see Exhibit 3-9).

This zonal-based quota system was calculated using Malaysia Generation Development Planning, which took into consideration the government target of achieving 20% renewable energy capacity in 2025. Through generation capacity expansion planning, the 20% renewable energy target translated into year-by-year solar PV forecasted capacity in Malaysia's system. These forecasted capacities were then distributed into three different policies: (1) LSS, (2) net energy metering, and (3) off-grid[41]. The decision was made by the Sustainable Energy Development Authority (SEDA) and the Suruhanjaya Tenaga (Energy Commission) to devise an administrative and bidding mechanism.[42]

Exhibit 3-9. Quota-based large scale solar programme in Malaysia

Peninsular

LSS Bidding Cycle 2017 - 2018			
Catergory	1 MWac - 5 MWac	6 MWac - 29 MWac	30 MWac - 50 MWac
Maximum Quota	[10 MWac (5%)]	[100 MWac (50%)]	[90 MWac (45%)]

LSS Bidding Cycle 2019 - 2020			
Catergory	1 MWac - 5.99 MWac	6 MWac - 9.99 MWac	10 MWac - 30.00 MWac
Maximum Quota	[36 MWac (10%)]	[144 MWac (40%)]	[180 MWac (50%)]

Sabah/Labuan

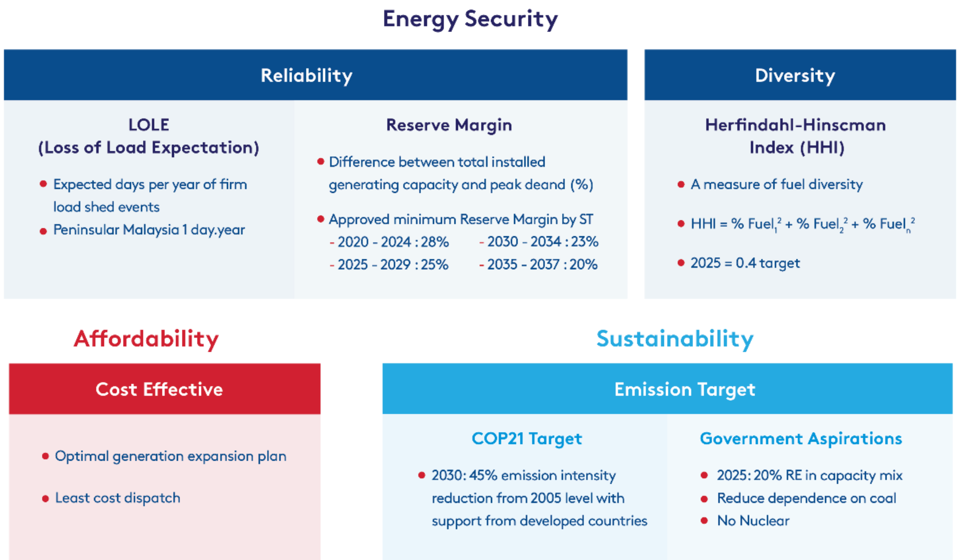
LSS Bidding Cycle 2017 - 2018		
Catergory	1 MWac - 5 MWac	6 MWac - 10 MWac
Maximum Quota	10 MWac (20%)	40 MWac (80%)

LSS Bidding Cycle 2019 - 2020		
Catergory	1 MWac - 5.99 MWac	6 MWac - 10.00 MWac
Maximum Quota	[20 MWac (20%)]	80 MWac (80%)

Under LSS1, the export capacity for COD in 2017–18 was 250 MWac in Peninsular Malaysia and 50 MWac in Sabah/Labuan. The solar quota was calculated through a trilemma concept integrated into the capacity expansion planning model. The Government of Malaysia has established several policies and planning criteria, as Exhibit 3-10 shows.

[39] https://www.pv-tech.org/news/malaysia-announces-winners-of-second-lss-solar-auction.
[40] https://www.thestar.com.my/business/business-news/2019/02/14/energy-commission-announces-500mw-large-scale-solar-tender/.
[41] For solar, eed-in tariff is no longer applied.
[42] Based on an unofficial interview/discussion with a ST colleague.

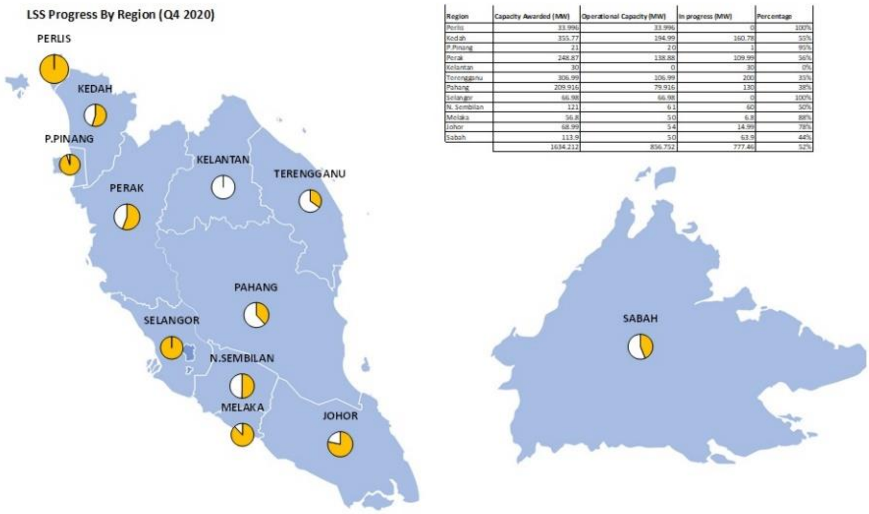
Exhibit 3-10. Malaysia's generation development plan: planning criteria



The LSS program is unique, in that it combines a quota with the auction scheme. The goal of the programme is not only to attract investment in renewable energy but also (and more importantly) to promote transfer of technology, knowledge and skills. This is seen in the difference between the LSS1 and LSS2 programs and the LSS3 program. In LSS1 and LSS2, there were no foreign ownership restrictions to the engineering, procurement and construction contractors. In contrast, in the LSS3 programme, foreign shareholding of no more than 49% was permitted in the project company and there were also restrictions to foreign shareholding for the contractors. However, in practice, the LSS was only ever open to 100% local solar companies, in order to guarantee the involvement of domestic industries. This is also an advantage of Malaysia's process, whose solar PV industry (scale production of GW) is far ahead of Indonesia (which is only at 300 MW production). The third LSS programme has been successful enough to demonstrate that the Malaysian market has matured and that local players are fully capable of developing and constructing large-scale solar projects.

Another advantage of the Malaysia quota system is its transparency and effective scheme process. LSS1 took only six months to award bidders (through the auction process). This is longer than Italy, but for an auction scheme is appropriate for a developing country. The system for awarding auction winners and reporting on LSS progress (see Exhibit 3-11) was transparent and publicly available on the Energy Commission website. The guidelines, presentations and all the materials relevant to the application were clear. The SEDA and Energy Commission's websites also informed the applicant candidates clearly by means of a thorough step-by-step process, constituting a very user-friendly window for developers/investors to enter into the bidding.

Exhibit 3-11. LSS progress by region (Q4-2020)[43]



Region	Capacity Awarded (MW)	Operational Capacity (MW)	In progress (MW)	Percentage
Perlis	33.996	33.996	0	100%
Kedah	355.77	194.99	160.78	55%
P.Pinang	21	20	1	95%
Perak	248.87	138.88	109.99	56%
Kelantan	30	0	30	0%
Terengganu	306.99	106.99	200	35%
Pahang	209.916	79.916	130	38%
Selangor	66.98	66.98	0	100%
N. Sembilan	121	61	60	50%
Melaka	56.8	50	6.8	88%
Johor	68.99	54	14.99	78%
Sabah	113.9	50	63.9	44%
	1634.212	856.752	777.46	52%

China: zonal-based renewable quota system (with no incentive)

The National Energy Administration (NEA) of China sets renewable energy targets in its Five-Year Plans. In its most recent, 13th Five-Year Plan, its 2020 targets for wind and solar implied steadier growth, which it declined to update as the market outpaced them. This is in contrast to the 12th Five-Year Plan which set ambitious targets for wind and solar, supported by subsidised feed-in tariffs, which policymakers often revised upward when the market overshot them.

Through its 13th Five-Year Plan, NEA increased its focus on the consumption of renewable energy. Starting with a mandate of full purchase for renewable energy and establishing a minimum operating hours purchase rule for provinces, the policy came into effect in 2016.[44]

In 2017, China piloted a green power certificate (GPC) as an alternative to the heavily burdened renewable energy subsidy system (including FIT). Interest was low, with only 20,000 out of eight million available GPCs sold during the first four months of implementation. Six per cent of these were to state-owned enterprises, while the rest were to private sector actors. The lack of promotion and incentive policies were the main reasons for such low take-up. However, China went on to improve the GPC system, introducing a quota system by province.[45]

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[43] For details, see https://www.st.gov.my/en/web/industry/details/2/17.

[44] Management Measures for the Full Guaranteed Acquisition of Renewable Energy Generation, National Development and Reform Commission, 31 March 2016.

[45] Original analysis is available in Chinese here: https://www.jiemian.com/article/1737776.html; an English translation is available here: https://www.chinawaterrisk.org/resources/analysis-reviews/chinas-renewable-energy-quotas/.

To trigger more liquidity and attract more consumption of renewable energy, in 2018 the Chinese government introduced a quota for the provinces and grid companies to steadily reduce wind and solar curtailment. This sets annual province-specific renewable energy requirements and designates the grid companies, retailers and power purchasers contracting on the wholesale market, and captive power plant owners as the parties obligated to purchase a certain percentage of their electricity from renewable energy sources. Beside improving interest in GPC, the quota system sets a goal of curtailment below 5% in all provinces for both wind and solar, to "basically resolve" renewable energy integration issues.[46] Within the quota, bidding on curtailed renewable energy in neighboring provinces' power markets, as well as new transmission lines, is also feasible.[47]

The quota system in China was designed by its provinces, according to total local renewable energy consumption, and is uniquely split into hydro and non-hydro targets. It specifies consumption targets for just three years (including the current year), rather than setting targets for the provinces or the market to aim for over the long-term. Indeed, the provincial quota for 2020 was adjusted in June 2020 to reflect output more closely. Figures for the 2018–20 quota for three provinces are presented in Exhibit 3-12.[48]

Exhibit 3-12. China's 2018–20 renewable obligation and electricity statistics

	Total Generation (TWh)	Total Consumption (TWh)	Generation from wind (TWh)	Generation from solar (TWh)	Generation from hydro (TWh)	Current share of RE	Renewable Obligation in 2020	Non-hydro Renewable Obligation in 2020
Henan Province	292	342	8.8 (3%)	12.8 (4.4%)	14.1 (4.8%)	12.2%	17.5%	17.5%
Hunan Province	142	175	7.5 (5.3%)	2.6 (1.8%)	52.8 (37.2%)	44.3%	40%	40%
Shanxi Province	304	216	22.4 (7.4%)	10.2 (3.4%)	5.6 (1.8%)	23.2%	17%	17%

The detailed non-hydro quota is mapped in Exhibit 3-13.[49] To help provinces meet their quotas, an upgraded GPC was introduced. This is the Renewable Energy Power Certificate (REPC) scheme, which can assess the production, consumption and trade of every MWh of renewable power that has been proposed. Enterprises can either self-generate renewable energy or purchase it using REPCs from other renewable energy enterprises. With a wider scope of renewable energy with more marketised prices, the REPC system allows enterprises to both sell REPCs and to obtain subsidies, thus providing more income to renewable energy enterprises. GPCs have no effects on subsidies.

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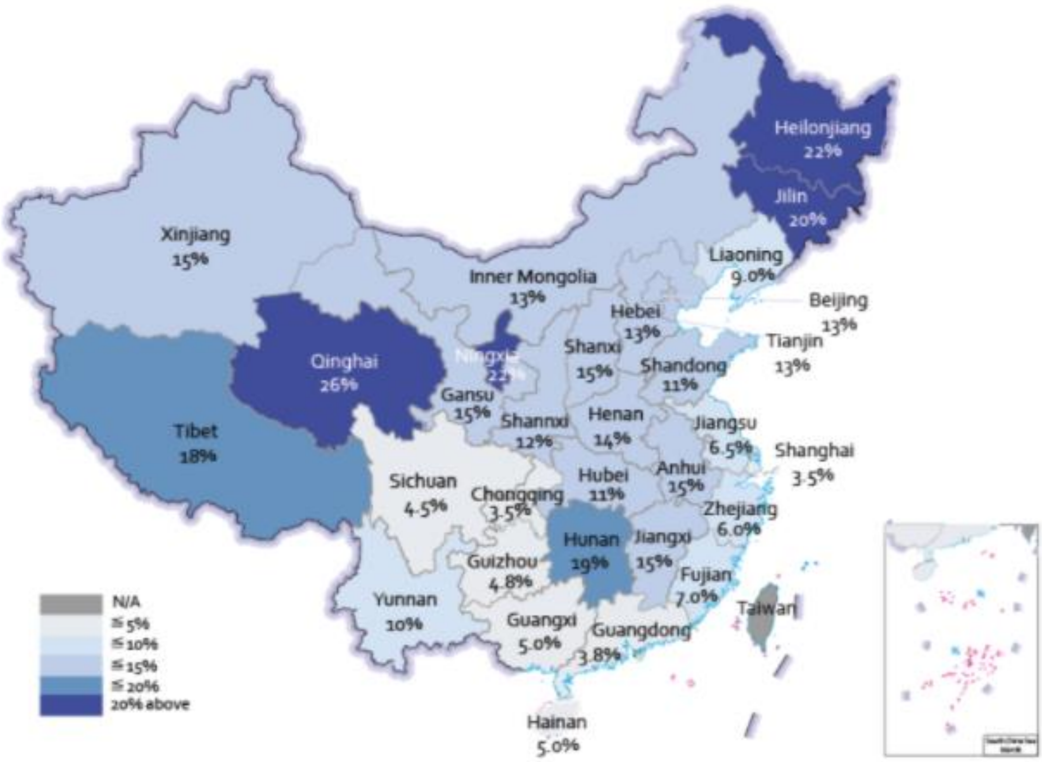
[46] Clean energy consumption action plan [2018-2020], National Energy Administration, 4 December 2018.
[47] Oxford Institute for Energy Studies, Current direction for renewable energy in China. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and Oxford Institute for Energy Studies. June 2020.
[48] Ibid.
[49] Anders Hove. GIZ 2018, based on National Energy Administration data. Available via this link.

An article addressing how the Chinese government assesses the grid and determines the quota is no longer accessible in the public domain. However, a 2014 paper stated that the Chinese government determines the quota by capacity expansion planning. Using The Balmorel[50], a least-cost generation and transmission capacity expansion plan for China's future power sector based on a recursive linear optimisation approach, was undertaken. The optimisation takes account of electricity imports and exports for each province in each time slice, taking into consideration transmission constraints, natural resource endowment and emission constraints.

Exhibit 3-13. Non-hydro renewable energy obligation for whole provinces in China



Non-quota policies, but unique lessons learnt for Indonesia's RE quota

In developing an RE quota, Indonesia can also learn more from countries which have no quota system obligation and which might provide a better example of how renewable energy development can be more easily developed with the quota system.

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[50] The Balmorel model is designed as a partial equilibrium model, with assumption of perfect competition to analysis relevant energy policy questions in the power sector. The model finds minimised-cost solutions for generation capacity expansion as well as transmission capacity in different regions, which includes the investment cost and operation cost meeting load of electricity, transmission constraint, technical maximum restrict among other policy-relevant targets

Germany

In 2018, Germany reached 37.8% of gross electricity consumption through renewable energy. In 2019, the total installed capacity for its wind-generated power was 59.0 GW (including 6.4 GW offshore), with solar PV and biomass at 45.3 GW and 8 GW, respectively. Minimum demand in Germany is no higher than 32 GW[51]. Germany transformed its electricity from a lack of renewable energy (18.9 TWh in 1990) predominantly provided by hydro, into being the giant of European renewable energy production in 2018, with half of its production of 225.7 TWh coming from wind energy.[52] In its fuel mix, 40.6% of Germany's electricity supply was generated by renewable energy in 2018.[53] Germany has set a target of 80% minimum share in gross electricity consumption by 2050.

Exhibit 3-14. Map of distributed renewable energy in Germany: 2000, 2006 and 2016.

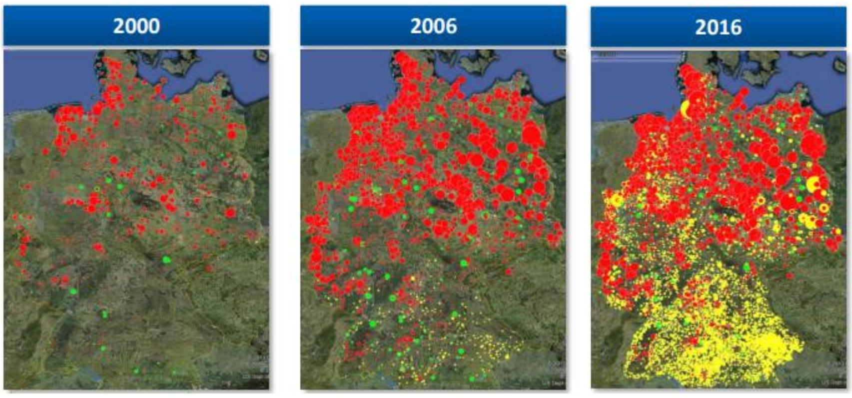

Exhibit 3-14 shows the distribution of renewable energy throughout Germany and how this increased between 2000 and 2016. It also notes the typical distribution for renewable energy, which is well-distributed throughout the entire country. Wind farms (indicated in red) are mostly distributed in northern Germany, with solar PV plants (yellow) mostly distributed in southern Germany. Green indicates biomass RE. Electricity in eastern and western Germany is generated equally by wind and solar. The equal geographical distribution from solar PV and wind greatly helps to alleviate system stiffness and stability caused by the variability and the intermittence characteristics of renewable energy.

Germany provides the world with another lesson learnt, by distributing renewable energy at various voltage levels in their transmission and distribution. In 2017, only 7.5% of renewable energy capacity was installed in its ultra-high voltage grid. Almost a third and a quarter of renewable

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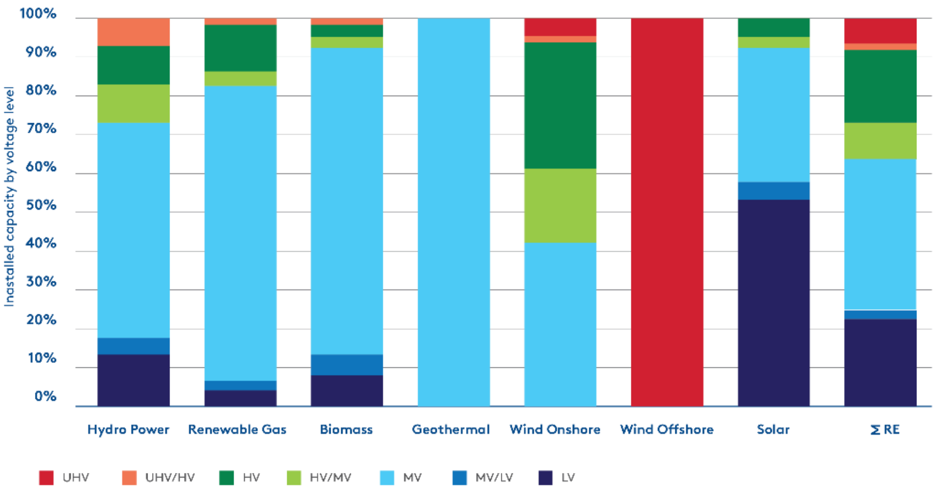
[51] Source: 50Hertz, Amprion, TenneT, Transnet BW, Google Earth, BMWi.
[52] Source: Development of Renewable Energy Sources in Germany 2018, BMWi, February 2019.
[53] Source : https ://www.energy-charts.de/energy_pie.htm?year=2018.

energy capacity was integrated into the high level voltage and low voltage grid, respectively. Solar PV and wind are predominantly integrated into the medium voltage level at 45.1%. Some plants connect to more than one voltage level.

Exhibit 3-15 provides detailed distribution information for each technology and definition of each voltage level.

Exhibit 3-15. Renewable energy based on voltage level in Germany's transmission (originally from Bundesnetzagentur, EEG in Zahlen 2017, cited by Energynautics)

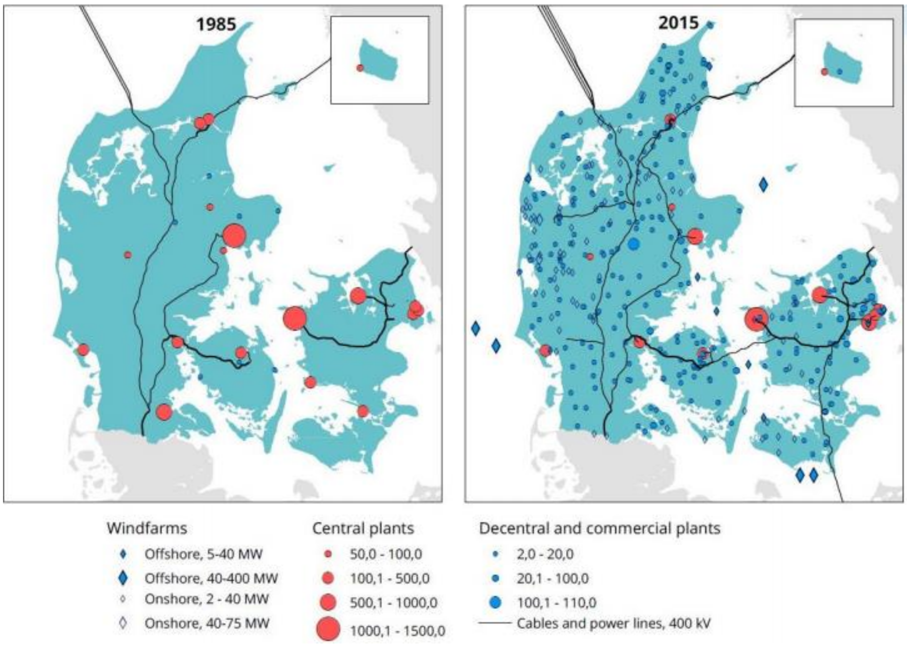


Denmark

Generating 30.5 TWh of electricity per year, Denmark produces more renewable-based electricity than fossil fuel. Wind power delivers 41.9%, while biofuels, waste and solar PV respectively produce 13.3%, 5.1% and 2.4%. Coal represents 29%, while gas only generates 7.1%. The remainder is generated from oil and hydro (<1%).

Denmark's renewable energy development is almost identical to Germany. Small to huge MW plants are evenly distributed acorss the country. The experience of Denmark and Germany shows that more distributed renewable energy helps planners and central dispatch to manage the system easily. When the wind stops blowing in one area, other areas with normal wind speed can cover it. The distribution of wind power plants in Denmark is shown in Exhibit 3-16. Due to strong interconnectors and a well-functioning international market for electricity with its neighbouring countries, wind also helps Denmark to understand when the country needs to import and to export electricity, as Exhibit 3-16 shows. It actually depends on how many farms are in production to fulfill the exact time of demand. Denmark's peak load is 6.1 GW, while total capacity of generation is 14.4 GW.

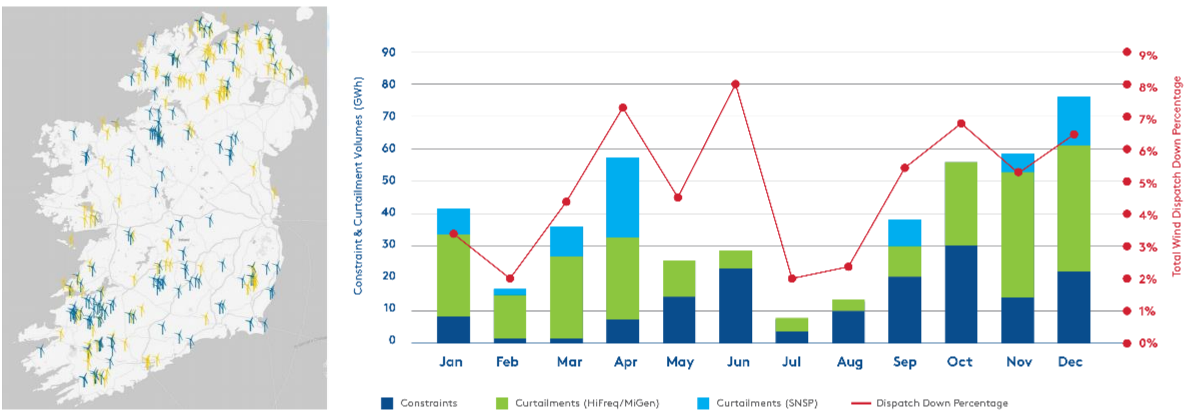
Exhibit 3-16. Distribution map of wind farms in Denmark, 1985 (left) and 2015 (right)



Ireland

As a good example of an international case, Ireland has installed nearly 5 GW of wind farms on the island. On 12 December 2018, all-island wind generation reached a record 4 GW, equivalent to 70% of demand, with the highest record of percentage (85% of demand) in September of that year. In 2018, half of Ireland's fuel mix was generated by natural gas, followed by renewables, which represented a third. The rest came from imported and non-renewable energy sources. The highest contribution to renewable energy was from wind (29.3%). Similar to Germany and Denmark, Ireland also utilises an equal distribution in Northern Ireland and the Republic of Ireland (Eire), reducing the risk of variability and intermittency of wind in whole system.

Exhibit 3-17. Wind distribution in Ireland (all-island) (left) and its monthly constraint curtailment in 2018 (right).



In the power planning practice, studies of Ireland indicate that it currently limits the grid to 55% instantaneous non-synchronous penetration. The island's power demand is at 6.5 GW peak. This is to set the basis of optimal control of Ireland's wind turbines. Moreover, the dispatch and constraints are also set every time. Exhibit 3-17 presents the monthly graph of detailed curtailment and constraint for 2018. This curtailment can be considered a best practice for Indonesia to learn from.

In conclusion, these countries' RE quota systems are summarised in Exhibit 3-18.

Exhibit 3-18. Summary of RE quota systems in other countries

Certificate System	Certificate System	Zonal System	Zonal System	Zonal System
Renewable Obligation/ROC (2002-2021)	Green Certificate (2008-2021)	Incentives FER 2019 (2019-2021)	Provincial Quota (2017-2021)	Large Scale Solar (2017-2021)
Either by Fixed Supply Target or Headroom	Fixed Supply Target	Budget Constraint: € 4.8 Billion	Capacity Expansion and Grid Study	Capacity Expansion and Grid Study
£51.8-55.5/ROC in 2020 (Fixed Tariff)	€21.95/MWh in 2019 (Market Price)	Base Tariff €70 -155/MWh (Feed in Tariff)	No information on tariff (Normal Tariff)	Price under Lowest Bidding (Auction)
Target ROC 2018 (127.64 million) 2020 (124.1 million)	Target MWh 2015 (16 million)	Total Target 2021: 1860 MW for <1 MW 6230 MW for >1MW	Target by Provinces	Total Target 2021: 1634 MW
ROC Achievement 2018 (90.21 million)	Achievement 2015 (22.6 million)	No Achievement reported	No Achievement reported	Operational in 2020: 690 MW
Specialty: Buyout price system	Specialty: Nothing	Specialty: Quota by Group of Technology	Specialty: 1) Combining Grid Zone and Certificate, 2) Quota Target for RE and RE non hydro. 3) No incentives	Specialty: Auctioned Solar Quota

Source: OFGEM Website and Database. UK Gov Website. ICIS publication 2020, 2019. IRENA GWEC. IEA 2008. Steinhilber et al 2011. Fraunhofer ISI and Ecofys 2014. Ashurst 2020. Gestore Servizi Energetici. Several news and online ppts about Solar Auction in Malaysia. Informal Discussion with Suruhanjaya Tenaga Representative. Malaysia Power Development Plan. Suruhanjaya Tenaga Website on LSS.

3.4. PREFERENCE OF RENEWABLE ENERGY QUOTA DEFINITION AND DESIGN

The wide application of RE quotas in worldwide practice leads us to conclude that this constitutes an integrated policy, used to promote renewable energy with a certain limit as a target, and which adheres to a selected incentive (feed-in tariff, certificates market, auction or others). It defines not only the level of renewable energy penetration (in MWh, MW or relative to any parameter) but also identifies some constraints, and elements required to ensure its execution. This study therefore suggests the following definition and components (see Exhibit 4-1)

The definition of a renewable energy quota system is therefore proposed thus:

An instrument by which to evaluate the maximum penetration in a power system, by considering renewable energy sources (including VRE), technical constraints and the natural characteristics of VRE, system adequacy, stability and reliability, and the least-cost option for VRE integration.

This definition makes it clear that this is a way for utilities (either PLN or non-PLN) to achieve maximum penetration in the least-cost manner. Both might be capable of managing greater renewable energy penetration; however, adopting a quota system means that the responsibility for the consequences of spending a huge amount of capital to ensure flexibility, and of embracing the risks of VRE, rest with the government. The least-cost definition is selected, as this means the Indonesian government regulates the tariff. This provides the way for utilities to address renewable energy penetration with their system remaining safe and secure, no financial burden, and able to deliver affordable energy to their customers.

Exhibit 3-19. Preferences regarding renewable energy quota system components in Indonesia

Components	Preference for Indonesia	Reasons
Design	Zonal System	Integration with RUPTL PLN and PPUs
Incentive Design	Feed-in Tariff, Lowest Bid Price, Celling Tariff, Negotiated Price	Following Perpres RE Tariff 2020
Level of Efforts	Least cost optimization with renewable energy preference	To improve current power system planning with renewable energy preference
Key Constraints /Enablers	• Financial Capability • Transmission Constraint • RE resource constraint • Market competitiveness	Those significantly risks the pursuance of renewable energy target in this quota system determination

Design: zonal system

In Indonesia's previous quota policies, the quota was allocated to each province. This study proposes a similar way of quota allocation; however, the suggestion is to allow the allocation in one system, rather than on a provincial basis. RUPTL identifies several systems for MEMR to reference and then to discuss system determination with PLN.

The other systems owned by the PPU will be allocated as per the PPU's area, as designated in business area license. We therefore suggest a zonal system as an RE quota design.

Incentive design

Anticipating the enactment of the Presidential Decree on Renewable Energy Tariff, this guideline will comply with whatever incentive designs are set within the decree. The design consists comprehensively of an arrangement of tariff, contract, period and technology grouping. The information is not however presented here in order to respect the on-going Presidential Decree process.

Level of effort

The RE quota will be devised using least-cost optimisation with renewable energy preferences, with a methodology called 'renewable energy grid integration'. This chapter also contains guidance to the policymakers and utilities regarding the correct way to analyse the RE quota.

As Exhibit 2-10 shows, this proposed methodology will consider the additional processes required for RE quota determination. The current power system planning performed by PLN does not take renewable grid integration into account yet. The proposed method is therefore intended for PLN to aid in developing the RUPTL, but it can also be adopted by other business area permit holders in Indonesia as the approach is quite similar (only the scale might be different).

Key constraints/enablers

Chapter 3 identifies some constraints (or put another way, enablers) which may impact the quota determination. In Indonesia, the following enablers/constraints are fundamental to the development of the RE quota:

1. Constraint/enabler: financial capability of government to provide incentives to grant the RE quota more possibility to implement the quota policy set by MEMR. Understanding MoF's decision regarding how much the money will be allocated is a key constraint to ensuring that the tariffs set by the modelling are implementable. The amount of renewable energy offered can be as high as government financial capability and vice versa. This is also highly dependent on the tariff set under the upcoming Presidential Decree. A higher tariff will provide a smaller quota with the same level of financial capability.
2. A constraint: transmission line development sometimes lags behind that of solar PV or wind farm development (an estimated 3–5 year, compared with solar PV or a wind farm which takes just six months to 1 year). Capacity to evacuate the power during specific events is also very critical to ensure system adequacy, stability and reliability.
3. A constraint: renewable energy resource constraint is based on the land use and availability area for commercial sites as well as the distance of each power plant determined through a grid study.
4. A constraint: in another policy, local content challenges the investor to provide affordable electricity for the users. This is due to the small production scale and incomplete production line process of local manufacturers. The absence of massive scale production indeed means that investors will incur higher costs in purchasing any renewable energy technology. This is set against the degree of willingness of utilities/government which only purchase renewable energy

at a certain level of competitiveness, in line with fossil-based electricity. Most solar PV production, battery or wind turbine line processes do not start with the bulk materials. Higher local content arrangements will hinder investors from proposing a least-cost price to government/PLN, while local manufacturers are not improving their production scale and machine technology to compete with the cheap and higher quality of imported technology.

5. An enabler: political commitment to renewable energy would actually assist the government to allow higher penetration while conversely, political commitment to coal or other fossil fuels would surely slow down achievement of the RE quota. A 35,000 MW programme such as this can be re-addressed to not only be installed by the large scale of fossil power plants but can be modified into a 35,000 MW renewable energy programme. This turn-around in political commitment will enable multiplier effects in the development of the policy and business environment in Indonesia.
6. An enabler: market competitiveness is a key parameter to demonstrate the maturity of the renewable energy business environment. This can be shown by the emergence of a group of players involved in a series of large-scale renewable energy projects and friendly financing institutions which facilitate all the national renewable energy projects with a deep understanding of its risks. Sometimes it is also valued by its relationship with manufacturers. This of course guarantees responses to the RE quota, soon after the quota regulation is launched.

4. PROPOSED METHODOLOGY FOR DEVISING AN RE QUOTA SYSTEM

4.1. OBJECTIVES, SCOPE AND EXPECTED OUTCOMES

Chapter 3.4 suggests the quota system as a way to achieve maximum VRE penetration without risk to or destabilising the system. It also concludes that the most suitable option for this purpose is a least-cost optimisation-based quota system, in which technical and resource constraints are considered to see how the system can contribute to the greatest extent possible towards Indonesia's renewable energy target. This approach is somewhat in line with the RUPTL (electricity business plan) process followed by PLN as the largest utility in Indonesia; however, it can be also adopted by the private power utilities (PPUs) which establish their own RUPTL (although currently, PPUs struggle to comply with the standardised process of least-cost planning). This proposed methodology will indeed fundamentally restructure the business plan analysis and process.

The existing RUPTL development (owned by PLN and most of PPUs) has followed just one scenario (least cost) working towards the target of 23% renewable energy in 2025. This guideline suggests the amendment of RUPTL approach by having two scenarios, in order to identify how much to investment needs and how policy intervention planned to achieve the government's renewable energy target over the least-cost option. We advise that the Indonesia's government and its utilities consider these proposed alternative scenarios further. They are:

1. **Least cost scenario**

   This scenario demonstrates the least-cost way for PLN or other utilities to plan their power system management independently of influence from any political aim or driver. This is the ideal scenario, providing an overview of how the utilities could select their future power plant to achieve a minimum cost goal without any governmental target or interruption. It acts as an underlying projection of how PLN/other utilities (that is, a state-owned enterprise or business entity) could run their business at the minimum possible cost. The modelling tool can select either renewable or fossil plants, based on actual price and operation.

2. **Renewable energy quota scenario (from the perspective of DG NREEC)**

   The renewable energy target scenario is an inherited scenario of least cost to optimally achieve the 23% target by 2025. This is not to force the model to add massive additional capacity by 2024 and 2025, as in the earlier RUPTL. However, it will explain the trajectory from the current position towards the 23% target, taking a 'make-sense' approach. The model identifies the most reliable and optimal renewable energy integration by which to achieve the 23% target, taking the time of writing as the start point, and may differ from the previous RUPTL. It also includes a proper system analysis that meets system stability and flexibility requirement. It outlines the full mitigation actions needed to ensure the 23% target, with a clear plan from the first year of modelling (or RE quota implementation) (this might constitute the key difference between the current RUPTL and the scenario that this study presents). MEMR will aso take responsibility for the transition cost, in order to provide a clear pathway for pursuing Indonesia's national renewable energy target.

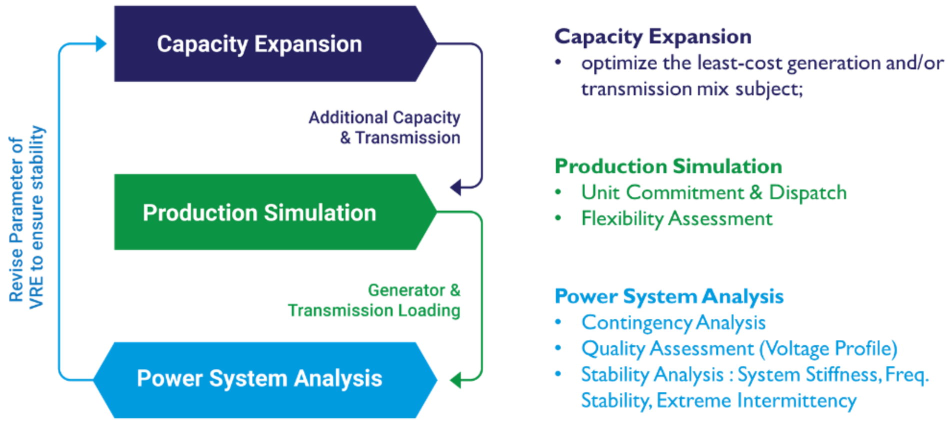
In 2012, MEMR received a number of quotas from PLN, derived from generation candidates in RUPTL. Until now, RUPTL's intention is not to calculate the RE quota, due to its limitation in the current process of renewable energy analysis. However, the upcoming presidential decree on the renewable energy tariff has tasked MEMR with determining the RE quota; MEMR appears to find it difficult to initiate this quota from point zero and will need a long process to train in the basics of renewable energy power planning from the utility's perspective. Without this perspective, planning is unlikely to be implementable.

This guideline suggests an improved methodology in PLN power planning aimed at meeting the standards needs while correctly determining the RE quota. Combining the longstanding planning knowledge owned by PLN, and the source of the RE database resting with MEMR will provide the least cost, most effective and simplest option for MEMR to determine the quota. This guideline shows that integration is possible, with a clear-step-by-step process presented later, where the constraints and enablers are also considered carefully during the planning process. It also discusses the risk provided by higher VRE penetration, together with the mitigation actions recommended to ensure smooth renewable integration into the system.

In general, the planning process can be divided into three steps: demand forecast, capacity expansion and production simulation, and power system analysis. It is iterative rather than straightforward, as shown in Exhibit 4-1. The end goal is to find the least-cost option which meets all the planning criteria, which it will achieve by:

- identifying the future generation and transmission portfolios needed to achieve RE targets at least cost while maintaining reliability objectives;
- simulating the operation of the power system under different future RE penetration scenarios and at different time scales;
- identifying reliability constraints associated with different RE scenarios; and/or
- determining the relative cost of actions needed to integrate high levels of variable RE.

Exhibit 4-1. Grid integration study



A grid integration study is designed to identify the following problems to be overcome in each system:

- congestion
- voltage violation
- low voltage ride-through
- frequency drop due to variability
- frequency stability during a disturbance (e.g. inverter fault/biggest unit trip)

As this study has been prepared to reconfirm and enhance the government renewable energy target to provide a detailed renewable energy allocation, and to define the strategy needed to maximise and reach the target, the scope of modelling will only cover:

1. **Technical analysis.** This includes an examination of the technical information and results from the capacity expansion planning, production cost simulation, flexibility analysis, capacity value assessment, network quality and reliability assessment with higher VRE integration (through load flow, short circuit and contingencies analysis, transient stability analysis and higher VRE penetration).
2. **Economic analysis.** This captures a general overview of power plant costing, a macroeconomic view of data collection, net present value analysis and employs other non-detailed approaches to economic analysis. Any detailed technical information will be welcomed and utlised, as this will help to satisfy the results of economic analysis.
3. **Verification of standards and planning criteria**, that is, an evaluation of the standards and planning criteria set by MEMR. Satisfying all the existing criteria is mandatory; if unmet standards are identified, action will be required by PLN, PPU or IPP to ensure compliance is achieved.

4.2. DEMAND FORECASTING

Demand forecasting is the first step of planning and the result is very important, as this drives the rest of the planning process. System adequacy (an important planning criterion in the next step) revolves around the idea of how existing and planned generation can meet the forecasted demand. It is essential to obtain the proper forecast result, as an under-forecast will result in unmet energy demand (which will hinder economy growth) and an over-forecast will cause excessive investment and financial burden.

The process is illustrated in Exhibit 4-2. The scope of demand forecasting emerges from the time period, factors, special factors and demand parameters. The goal is to predict load and future energy consumption. For load forecasting, peak load growth and load characteristic are observed. Peak load is the maximum load that needs to be met, and growth is forecasted in a given timeframe. The load characteristic describes the behaviour of the load in a given duration, usually occurring in cycles (e.g. daily); it can be described chronologically in a certain time step (e.g. hourly), presented with a proper time sequence. The curve shows the variation of demand load and the cycles of the variation occurrence. From this load curve, the load duration curve (LDC) can be formed, as Exhibit 4-3 shows. The LDC is plotted in order of decreasing magnitude and shows the duration that the system experiences a certain level of load in a given timeframe, for example annually. This model disregards the time stamp and only focuses on the duration. (it discusses why using a chronological load curve is more appropriate for planning when considering VRE compared to using LDC). Energy forecasting can be derived from the load forecasting result. This describes the total amount of energy required in a given timeframe and is used to optimise the allocation of production simulation in the next step.

Exhibit 4-2. Demand forecast process

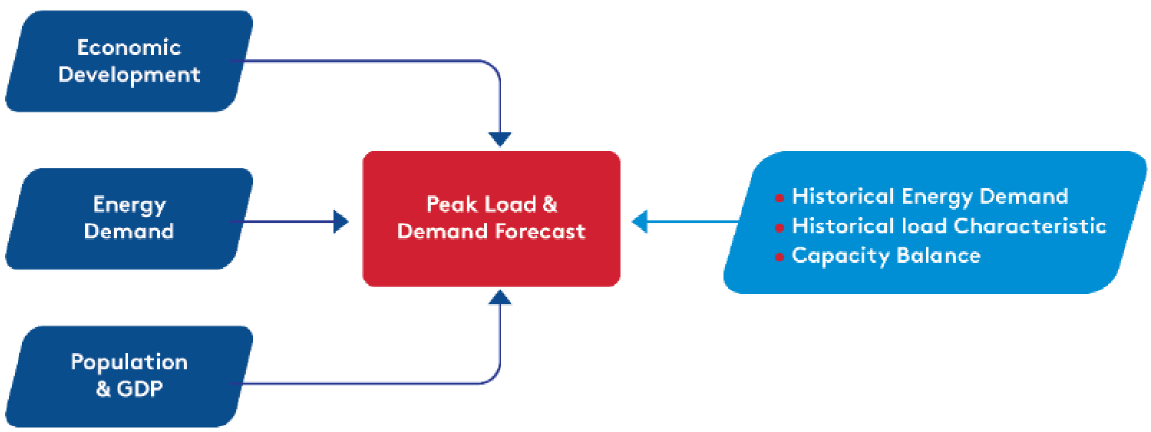
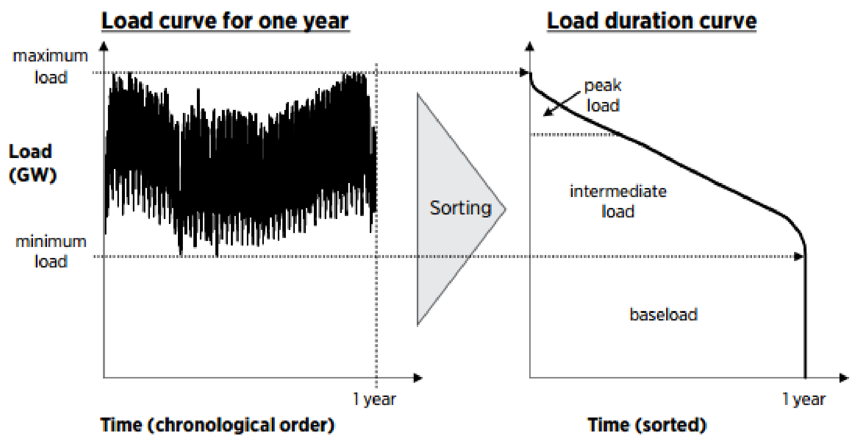
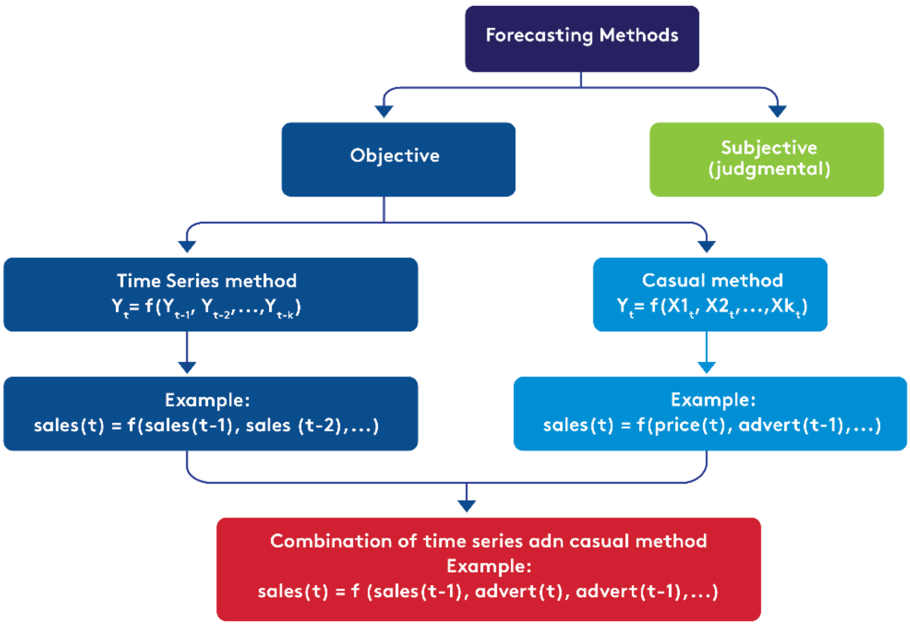


Exhibit 4-3. Chronological load curve and load duration curve (source: IRENA, 2015)



In general, there are two demand forecasting methods: judgmental or objective. In the objective method, three approaches are possible: time series, causal method and a combination of both. Indonesia uses the combined method, using Simple E[54] or a similar tool. This utilises a statistical model based upon historical data and demand drivers (a variable which has a strong correlation with demand) such as economic development and population. Specific future development requiring a considerable amount of energy such as the development of a business and industrial area or an electricity access acceleration programme need also to be taken into account.

Exhibit 4-4. Demand forecasting methodology



[54] Simple E (Simple Econometric Simulation System) is a Microsoft Excel-based tool developed by The Institute of Energy Economics Japan (IEEJ) which utilises an econometric method for demand forecasting.

In the case of PLN's RUPTL, PLN currently uses Simple-E. Level of detail plays an important role in determining the accuracy of the forecasting, and in PLN's RUPTL, demand forecasting is conducted for every province and PLN's area of service (*wilayah*), Meaning that data is required at the provincial level: national level data is not enough.

Exhibit 4-5 lists the data used in demand forecast lists the data used for demand forecasting, along with a list of stakeholders responsible for providing it.

Exhibit 4-5. Data used in demand forecasting

Catergory	Description	Data Provider Example
Demand Drivers	Economic Development	RPJMN, Multilateral Lender Outlook
	GDP Growth for Each Sector	Bappenas
	Population and Population Growth	BPS
	Additional Parameter with Strong Correlation	Etc.
Historical Data	Energy Consumption Data	PLN
	Load Characteristic with Hourly Resolution	PLN
	Specific Day Load Characteristic	PLN
Future Deveopment	Energy Demand	RUEN, RUKN
	Industrial & Busines Development	Government of Indonesia
	Specific Economic Zone	Government of Indonesia
	Acceleration of Electricity Access	MEMR
	Behavioural Change in Electricity Usage	PLN

In this case, the current demand forecasting process is still relevant to VRE planning. Of note, however, is the importance of having chronological demand data instead of just a duration curve, as the next step requires chronological modelling to simulate the VRE characteristic.

4.3. RENEWABLE ENERGY ASSESSMENT

Identifying candidates for renewable energy power plants is more complex than for fossil power plants. Renewable energy is ubiquitous and able to be utilised domestically, making resource assessment essential to ensure that the sites are capable of producing enough electricity in the future with minimum risk.

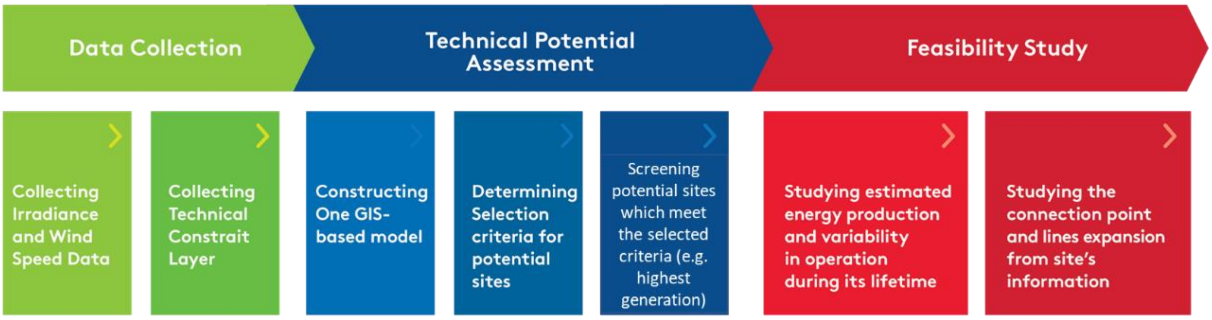
In current power planning, resource assessment is only represented generally by irradiance mapping for solar PV, wind speed potential mapping and a feasibility study of selected or proposed sites. However, PLN or MEMR does not have enough comprehensive geospatial-based resource database and potential site information for VRE power plants. This means that MEMR has no basis to determine how much resource potential is available for penetration into the system. This lack of information on resource potential will discourage the market intention to fill the quota determined by MEMR, and if the quota is higher than the resource availability, this will be considered to have failed. A quota should never be higher than the technical potential available in one predetermined area. Moreover, conducting capacity expansion without proper renewable energy resource assessment will miss out the verification process of any proposed site, even if the sites proposed by developers produce higher generation and are geographically easy to tap with existing or planned lines for renewable energy development. The identified sites based on MEMR criteria will effectively pursue the national target by prioritising sites with the highest generation and commercially viability. However, the MEMR remains welcoming to any other sites proposed by developers as long as the developers have strong justifications to support the pursuance of 23% target.

In conducting a proper resource assessment for the whole country, MEMR through the DG NREEC must map the renewable energy resource potential. This represents the theoretical availability of a renewable energy resource (including wind speed, solar irradiance, hydro flow or geothermal heat) in a defined region.[55] However, for capacity expansion planning, a map of resource potential is not enough for commercial projects, and must therefore be followed up by documenting historical natural characteristics (at least the last 30 years of irradiance or wind speed information), a technical potential assessment and financial feasibility study.

The DG NREEC can assist with further analysis of which sites have potential and are promising in terms of development of a renewable energy power plant. The DG NREEC should therefore identify potential sites early on, including in this a technical assessment. The technical potential analysis estimates the capacity of an RE technology (e.g. solar PV, wind) available for development after accounting for topographic limitations, land-use constraints and system performance. The assessment can utilise a geospatial-based information system (GIS) by filtering out areas that are not technically feasible for development (due to geographical contours, urban development, or financial, market or other considerations). When all the feasible land areas have been identified, technology-specific system modeling calculates the maximum potential electric power generation based on resources, available land and various system assumptions. Next, the sites that the DG NREEC have identified can be proposed to potential developers/investors. The developers then analyse the connection point further and verify the historical potential of the previous 30 years (by examining chronological wind speed and solar irradiation) to well forecast future generation and to model their variability in delivering power and determining plant operation. The result of the resource assessment will help in determining the net capacity and capacity value, which define the ability of VRE power plants to meet demand reliably. Exhibit 4-6 presents the step-by-step process for renewable energy assessment in Indonesia.

[55] NREL.

Exhibit 4-6. Renewable energy assessment to identify potential sites in Indonesia



A geospatial approach will be used to assess resource potential, taking into consideration technical constraints such as protected areas, urbanised areas, water bodies, terrain features and other relevant features (see Exhibit 4-7 and Exhibit 4-8). MEMR can collect this information from other ministries to compile into one GIS database in One-Map. For instance, wind speed can be measured in each harbor, meteorological post or disaster mitigation post, or compiled from the relevant ministries. Together with constraint layers such as the urban layer, forest layer and water bodies, the wind speed map and irradiance map can be combined into a single GIS-based model for Indonesia. In order to produce a detailed analysis, a detailed technical constraint such as a slope/contour, and a certain distance (technical offset) from highways, main roads, railroads, buildings or others must be determined. This information can be obtained and compiled from the relevant authorities, or possibly by using practical international standard offset. Criteria of best site selection should also be determined, to provide the best high irradiance/wind speed sites possible for renewable-based development, and should be technically feasible and economically viable. Criteria for wind and solar are listed as follows:

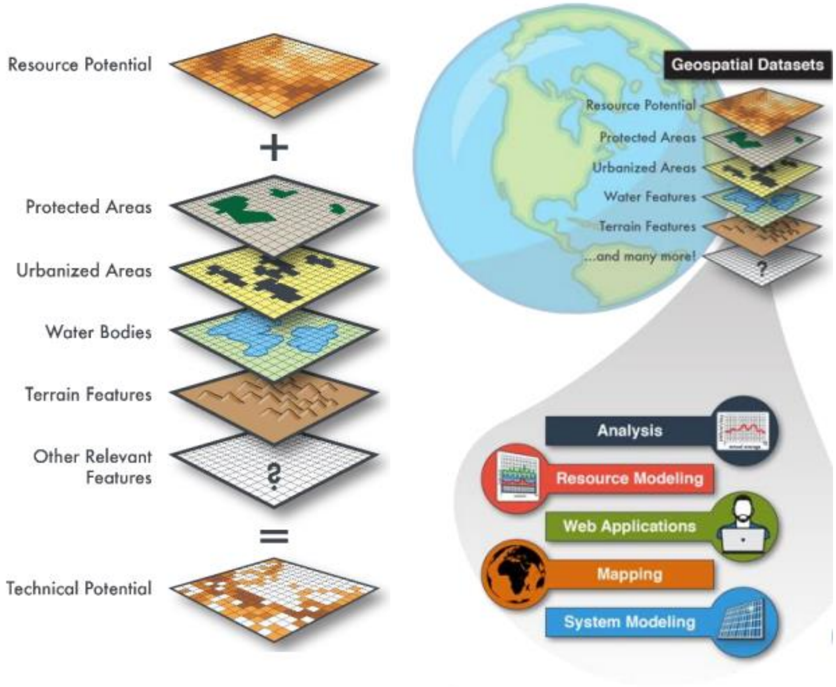
Exhibit 4-7. Site selection criteria (source: NREL)

Parameter	Solar	Wind
GIS Resolution	1 km x 1 km	2.5 km x 2.5 km
Wind height	None	100 m
Minimum and Maximum Resource	Minimum: 4.5 kWh/m2/day Maximum: 10 kWh/m2/day	Minimum: 5 m/s Maximum: 20 m/s
Power Density	45 MW/km2	6 MW/km^2
Terrain Slope	Maximum 10% grade	<17%

Furthermore, the package of layers for technical analysis must also be determined, to ensure which layers are restricted for solar PV and wind development. Other considerations to be arranged by MEMR during technical potential analysis are:

1. To include the solar PV rooftop option into the quota system, urban areas will not be an exclusion layer during technical analysis. However, the possibility of including solar PV rooftops for residential use is small and not relevant to the utility-level quota.
2. To consider floating solar PV, MEMR must include a regulation from the Ministry of Public Works and Housing (MPWH) stating that only 5% of waterbody surface can be installed with floating solar PV. As consequence, total potential area in waterbodies must be multiplied by factor of 0.1. Please make sure that MEMR also adds the waterbody layer in the geospatial database.
3. This study excludes off-shore wind but is still applicable to on-shore wind or off-shore wind, 5km from shorelines.

Exhibit 4-8. Technical potential analysis for RE resource assessment (source: NREL)



Along those processes, there might be more considerations for offshore wind or floating solar PV, by assessing exclusive economic zones, global accepted seawater borders, the navy areas, transportation line, dam/lake/river utilisations or other maritime activities/needs.

The aforementioned process is great to be executed with the official data or GIS data from relevant government/authorities. If there is lack of data/information, solar PV and wind assessments can be alternatively conducted with following free or commercial public tool for solar PV and wind assessment:

- Solar PV and Wind:
  - Southeast Asia RE Data Explorer: https://www.re-explorer.org/
  - Renewable ninja: https://www.renewables.ninja/
- Specific:
  - Global Solar Atlas (https://globalsolaratlas.info/map)

  - Global Wind Atlas (https://globalwindatlas.info/)
- Other specific tools (commercial).

In some areas, PLN and MEMR might have already conducted a feasibility study, in which case the results (see Exhibit 4-9) can be compiled, analysed and input into a resource assessment database in MEMR. For any undiscovered area, MEMR can task third party actors to identify the best sites in unoccupied areas. The results derive from how many MWs are not yet occupied by developers and could be utilised to achieve the quota target.

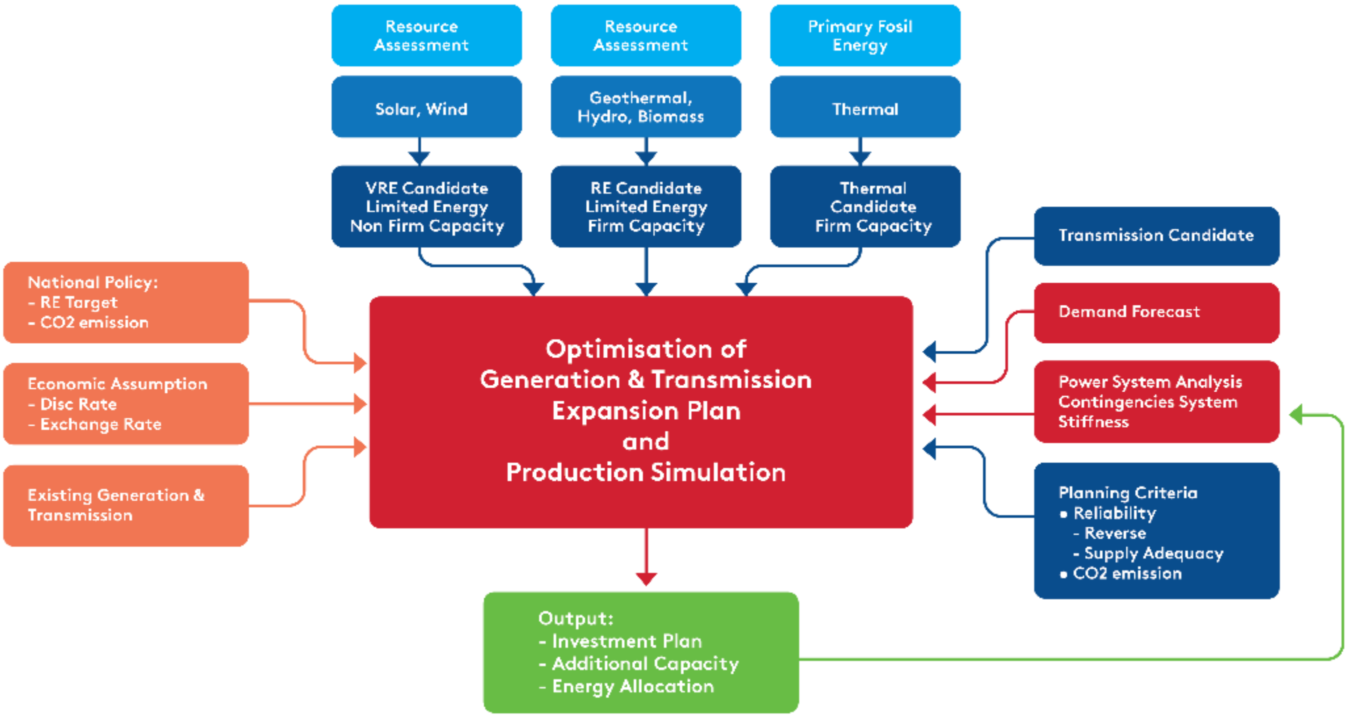
Exhibit 4-9. Existing resource assessment for renewable energy sources implemented by developers

Category	Type	Resource Assessment
Dispatchable Renewable Energy	Geothermal	Feasibility study to determine proven resources
	Hydro	Feasibility study to determine hydrology condition
	Biomass	Feasibility study to determine biomass source availability
Variable Renewable Energy	Solar	Chronological solar irradiation characteristic
	Wind	Chronological wind speed characteristic

4.4. GENERATION EXPANSION AND PRODUCTION SIMULATION

Generation expansion and production simulation are techno-economic assessments for sets of generation and to enable transmission candidates to formulate the least-cost plan capable of meeting the demand forecasted in the previous stage while satisfying the required planning criteria. In this stage, generation candidates are identified based on the resource assessment result; by evaluating the power evacuation between generation and load, the transmission candidate is identified as well. Coupled with existing generation and transmission, candidates are assessed on their capability to meet the forecasted demand. The techno-economic assessment takes into consideration economic assumptions such as discount rate and exchange rate, while ensuring the set of chosen candidates is able to meet the national policy target and at the same time achieve the planning criteria imposed by the utility in the form of reliability indices. The output is a set of candidate plants, in which investment and an operation plan can be formulated from the least-cost plan. The least-cost plan is evaluated in the next step (power system analysis) and the iterative process continues until all the planning criteria are satisfied. This process is depicted in Exhibit 4-10. The power system analysis part is discussed in the section 4.5.

Exhibit 4-10. Generation expansion and production simulation process



4.4.1 Identifying the candidates

At this stage, the first step is identifying the generation candidates. Fossil thermal power plants are easier to identify as they have firm capacity. With fossil thermal energy sources such as coal, oil and natural gas, in the planning process it is assumed that there is no limitation on fuel availability and that the plants have firm capacity which is always available when needed. This is due to the nature of these plants, which always have a fuel source ready at their disposal. Information on the cost projection of the fuel at the generation plant is also very important, as this will affect the viability of fossil thermal power plant competitiveness (compared to renewable energy power plant, for example).

On the other hand, identifying candidates for renewable energy power plant is more complex. Dispatchable renewable power plants are still considered as having firm capacity, that is, the capacity is always available when needed, or is easily predictable. Geothermal, hydro, and biomass power plants are included in this category. Nevertheless, as discussed earlier, a resource assessment is still necessary to ensure their availability and viability. This should be performed by means of a feasibility study which covers an assessment of resource status and availability, as well as an assessment of preliminary project viability and cost. The situation differs when it comes to VRE power plant, which is considered to have non-firm capacity. Additional information on resource characteristics such as chronological wind speed and solar irradiation is needed to model their variability in delivering power and to determine the plant operation. The result of the resource assessment will help in determining capacity value which defines the ability of a VRE power plant to meet demand reliably. For each generation candidate, parameters that describe the characteristic of the power plant candidate is required. Exhibit 4-11 lists sample parameters for generation candidates. For a non-renewable/fossil fuel power plant candidate, information on fossil fuel price projection during the study timeframe is required. Additional information such as a take-or-pay clause in a natural gas contract should also be considered, as this will create inflexibility in operation which would impact upon the calculation. For a renewable energy candidate, as mentioned above, a resource assessment must be carried out first, providing information on energy yield and capacity availability. This is incredibly important especially for VRE power plants. For example, solar irradiation characteristics in a one-year period with hourly resolution is required for solar PV, information which can only be obtained from resource assessment. A generation forecast also requires collecting records going back over 20-30 years to discover any incidence of historical irradiation in the area to accurately obtain the projected energy yield in future.

Identifying a transmission candidate is quite straightforward, as this depends on the power evacuation needed between generation and load. As the transmission candidate relies heavily on the generation candidate, when running the model, co-optimisation between generation and transmission can be performed, as long as the tools are capable of modelling the transmission line, in which the model is usually referred to as a 'multi region model'. The parameter sample for transmission candidates is presented in Exhibit 4-12. Data such as cost of build per km, capacity and connection points is also required.

Least-cost planning evaluates and opts for the optimal power plant that fits with demand. Information on cost structure and the technical capability of every generation candidate is a very important input to ensure optimal least-cost planning. Cost structure includes capital cost and operating cost (see Exhibit 4-13). Capital cost is the total upfront cost of building power plants, and includes investment cost and its related cost in its financing. Operating cost is the cost of operating the power plant, which includes overhead cost for maintenance and other administration costs, and variable cost which is mostly for fuel and consumables that correlate with the production of energy, such as lubrication.

Exhibit 4-11. Generation candidate parameter sample

Parameters for Per Unit Generation	Unit	Thermal Plants			VRE	Hydro		Energy Storage	
		Fossil-based	Geo-thermal	Bio-based	Solar/ Wind	Small	Large	Pump Storage	Battery
Capacity	MW	v	v	v	v	v	v	v	v
Installation Date	Date	v	v	v	v	v	v	v	v
Retirement Date/Economic Lifetime	Date or years	v	v	v	v	v	v	v	v
Scheduled Outage Rate	Number of Days/%	v	v	v	v	v	v	N/A	N/A
Forced Outage Rate	%	v	v	v	v	v	v	N/A	N/A
Min Operating Point (Min Stable Loading)	MW	v	v	v	N/A	N/A	N/A	N/A	N/A
Ramping Rate	MW/Minute	v	v	v	N/A	v	v	v	N/A
Min Up/Down Time	Hour	v	v	v	N/A	v	v	v	N/A
Heat Rate	BTU/kWh	v	N/A	v	N/A	N/A	N/A	N/A	N/A
Plant Efficiency/Battery Roundtrip Efficiency	%	v	v	v	v	v	v	v	v
Installation Cost	$/MW	v	v	v	v	v	v	v	v
Variable O&M Cost	$/MWh	v	v	v	v	v	v	v	v
Fixed O&M Cost	$/kW/Year	v	v	v	v	v	v	N/A	N/A
Plant emission rates	kg/MMBTU or kg/MWh	v	N/A	v	N/A	N/A	N/A	N/A	N/A
Hourly generation profile for Wind and Solar or Monthly Generation for Hydro	MWh	N/A	N/A	N/A	v	v	v	v	N/A
Minimum Capacity	MW	N/A	N/A	N/A	N/A	v	v	v	v
Maximum Capacity	MW	N/A	N/A	N/A	N/A	v	v	v	N/A
Power Curve for PV and Wind	N/A	N/A	N/A	N/A	v	N/A	N/A	N/A	N/A
Future Unit Plant Size	MW	v	v	v	v	v	v	v	v
Maximum Unit Built for Fossils (Future)	MW	v	N/A	N/A	v	N/A	N/A	N/A	N/A

Exhibit 4-12. Transmission candidate parameter sample

Parameters for Per Unit Transmission	Unit
Capacity/Rate	MW or MVA
Voltage level	kV
Installation Date	Date
Line Current	HVAC or HVDC
Installation	Overhead lines or Underground
Types	Example: ACSR 4x Zebra
R, X, B information	pu
Length	Km
Total Power Losses (Due to heat, etc.)	%
Minimum Capacity	MW
Maximum Capacity	MW

Exhibit 4-13. Cost data requirement for capacity expansion planning

Parameters for Per Unit Generation and Transmission Lines	Unit	Thermal Plants			VRE	Hydro		Energy Storage	
		Fossil-based	Geo-thermal	Bio-based	Solar/ Wind	Small	Large	Pump Storage	Battery
Plant Installation Cost	$/MW	v	v	v	v	v	v	v	v
Installation Cost Trend	Decline or Flat	v	v	v	v	v	v	v	v
Variable O&M Cost	$/MWh	v	v	v	v	v	v	v	v
Fixed O&M Cost	$/kW/Year	v	v	v	v	v	v	N/A	N/A
HVAC Installation Cost	$/kV/km	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HVDC Installation Cost	$/kV/km	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

For production cost simulations, per power plant units shall possess these following costs and technical parameters.

- Minimal load
- Minimum Up & Down time: minimum hours the plants need to be idle and minimum hours the plant needs to operate
- Outage rate, either forced or planned
- Curtailment
- Plant Factor
- No load cost
- Startup cost (with heat rate and its incremental if any)
- Efficiency
- Ramping rate (% installed capacity per hour)
- Plant contribution for spinning reserves
- Line loading (for transmission data)

4.4.2 Economic assumption, national policy and planning criteria

As this planning process relies heavily on economic assessment for multi-year generation expansion, assumption on economic parameters is required to run the model. These assumptions play an important role in determining the set of options to be included in the least-cost plan. Exhibit 4-14 lists some of these parameters, including fuel price and discount rate.

Exhibit 4-14. Economic assumption sample

Parameters	Unit
Fuel Price	$/ton, $/mmbtu, $/litre, etc.
WACC	%
Inflation Rate	%
Discount Rate	%

Both national policy and planning criteria define the constraints that the model must meet while ensuring the planning results entail the least cost. Those constraints that arise from national policy define the government agenda regarding electricity supply. Examples include the target of renewable energy share in the energy mix and the emission reduction target. It is not uncommon to create modelling scenarios during the planning process to see how the target would impact the planning result. On the other hand, constraints formed from planning criteria define the capacity adequacy. Usually, reliability indices are used as planning criteria, as listed in Exhibit 4-15.

Exhibit 4-15. Planning criteria sample

Parameters	Unit
Loss of Load Probability (LOLP)	%
Loss of Load Expectation (LOLE)	%
Expected Energy not Served (EENS)	MWh/GWh
Reserve Margin	MW/GW

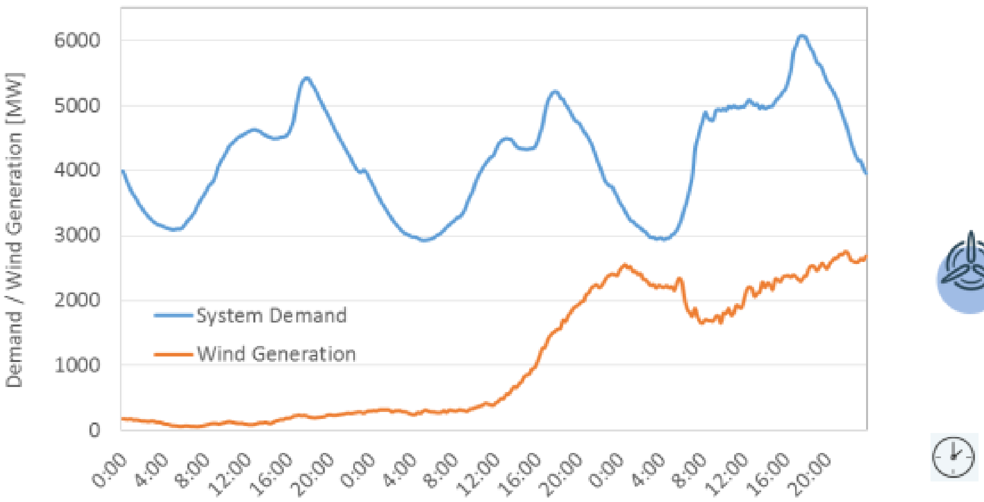
For PLN's RUTPL, reliability is measured with loss of load expectation (LOLE) and reserve margin[56]. LOLE measures the number of days in one year when daily peak load is expected to exceed available capacity. For planning the Java-Bali system, the LOLE used is one day per year, with a higher number used for systems outside Java-Bali. LOLE and loss of load probability (LOLP) are quite

[56] PLN's RUPTL 2019–2028.

similar and interchangeable. LOLE on one day per year means LOLP of 1/365, or equal to 0.274%. With a lower LOLP number, reliability is higher but the cost of electricity provision is higher as well. The reserve margin states the excess capacity of supply compared to peak demand. For planning purposes, PLN maintains the reserve margin within 25%–35%, a number which varies for each system. It is important to note that the reserve margin does not fully reflect the reliability situation. For example, two systems with a similar peak load might require different levels of reserve margin to reach the same LOLP, depending on factors such as the load duration curve and quantity and unit size of unit.

For VRE, defining the capacity able to contribute to the capacity adequacy and reserve margin calculation is a complex issue, as the variability does not allow the plant to contribute its full capacity. As mentioned in section 4.4.1, VRE is considered to have a non-firm capacity. Output depends on the energy source variability and it is not dispatchable, creating a mismatch between generation variability and demand variability, as described in Exhibit 4-16. One megawatt of VRE power plant is valued at less than one megawatt of conventional thermal power plant in terms of its ability to meet demand reliably.

Exhibit 4-16. Illustration of VRE variability: mismatch between generation and demand[57]



To tackle this issue, capacity value can be formulated. This defines the fraction of VRE capacity that can be relied upon as firm VRE capacity, and acts as an indicator to measure how well VRE generation matches demand. There have been several approaches in formulating capacity credit, including[57]:

- using reliability indices, by calculating how many conventional generations can be replaced by VRE while maintaining a reliability indicator, such as LOLP;
- using time-period-based approximation, by considering the capacity factor during peak hours;

[57] IRENA, 2017.

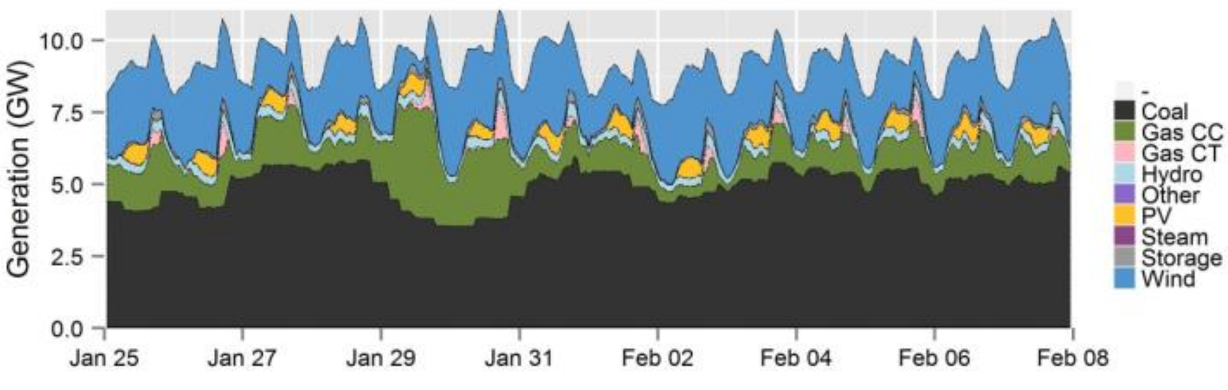
- using the difference between peak load and the peak of the residual load (load minus VRE supply at a given time), divided by VRE capacity. This difference is interpreted as the generation capacity that is not required due to the existence of VRE capacity, that is, this VRE capacity is considered "firm"; and
- using a rule-of-thumb approach, such as fixed percentage (0%, 5%, 7%, 20%) as available generation.

4.4.3 Running the model

With the model built, the result can finally be observed. The generation expansion result shows the investment plan, as in when and which candidate needs to be built as part of the least-cost plan that can meet the planning criteria. Energy allocation from the modelling can be observed as well. Generation expansion generally covers a wide timeframe, from 10 years to up to 50 years, with yearly time steps. As previously mentioned, co-optimisation with transmission candidates can also be performed, resulting in both a generation and transmission investment plan.

From this result, production simulation is performed. Compared with generation expansion, production simulation has a shorter timeframe, usually ranging from a weekly to a yearly time horizon with hourly or even smaller time steps. At this stage, the dispatch per time step from each generation that would meet the load can be observed, as illustrated in Exhibit 4-17. Production simulation results in a more detailed operation plan to identify how the dispatch is configured from each source, as a part of the least-cost plan.

Exhibit 4-17. Production simulation result[58]



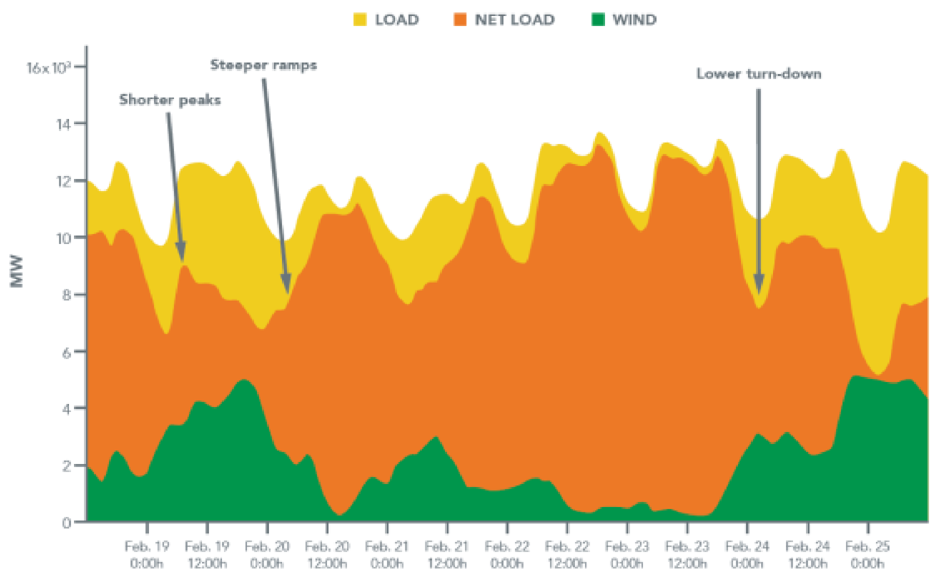
In power system operation, it is important to balance supply and demand to ensure the system is secure and reliable. Should there be a mismatch, generation must adjust its output to meet the supply, or else load shedding will happen to balance the system. The ability to adjust generation output is often referred to as 'flexibility'. As well as the demand variability that always happens,

[58] NREL, 2014.

additional variability now also arises from the high penetration of VREs, such as that which occurs from a decreasing output from solar PV in the afternoon or rising wind speed. These characteristics make it more challenging to balance the system, meaning that sufficient flexibility is required to tackle this issue, which planning must take into account.

Exhibit 4-18 illustrates how higher VRE penetration leads to a greater need for flexibility. Steeper ramps require a higher ramp rate from dispatchable generation and lower turn-down requires dispatchable generators to decrease output but remain available to ramp again quickly.

Exhibit 4-18. High VRE penetration and the need for flexibility[59]



Production simulation can help in assessing flexibility for an hourly or sub-hourly timeframe. Identifying flexibility sources can be achieved by observing dispatchable power plants with fast ramping capability from the generation expansion result. Typically, plant that falls into this category are hydropower and gas power plants. Other forms of flexibility can also come from the usage of storage and demand side management. To be able to assess flexibility properly, it is important to use chronological demand data from the demand forecast and chronological VRE generation data from the resource assessment. Both sets of data must have sufficient time-step or resolution, such as hourly or sub-hourly resolution, and the tool must also be capable of computation with such a time-step. Smaller resolution would be better, but for this the data resolution and computational power requirement would be more significant.

To perform both generation expansion and production simulation, several tool options are available in the market, such as Plexos from Energy Exemplar, PROMOD from ABB, WASP from IAEA, Balmorel, and many more. Exhibit 4-19 provides a brief overview of some of the options, including

[59] NREL, 2015.

pro and cons for each tool. The tools are not limited by this list; more similar tools exist which support MEMR's options, and the pros and cons listed are subjective to the MENTARI team. Upcoming updates on tools might not be listed or may create inaccuracy in this pros and cons analysis.

Exhibit 4-19. Tools for generation expansion planning (GEP) and production cost simulation (PS) with VRE integration.

Total Option	Developer	Pros	Cons	GEP	TEP	PC	VRE
Plexos	Energy Exemplar	Comprehensive capabilities including chronological sampling, generation/ transmission co-optimization, stochastic optimization, cascade and pumped storage hydro modelling, etc.	Cost (USD 40,000 per year for single user) and steep learning curve	√	√	√	√
PROPHET	IES	Handles transmission, hydro and dispatchable loads.	Two linked models (system simulation and system planning). They use a common database but unclear how smooth the integration is. Does not appear to accommodate stochastic analysis	√	√		√
Balmoral		Open-source (it is free). This handles generation and transmission capacity expansion planning. The hourly dispatch is also considered.	Coding and abbreviations are required.	√	√		√
EGEAS		Handle generation co-optimisation, but through adjustments to load duration curves (LDCs). It is modular package with algorithm generalized benders decomposition and dynamic programming	No consideration of transmission, no stochastic analysis.	√			

WASP (Wien Automatic System Planner)	International Atomic Energy Agency	Large user base, reasonable cost, probabilistic analysis	Uses load duration curves, so representation of demand-side resources and variable renewable energy (VRE) supply is difficult. No consideration of transmission.	√	√		
Strategist	ABB	Considers demand side and renewable resources, but through adjustments to load duration curves (LDCs)	Limited representation of generation (e.g. no ramp rates), no consideration of transmission, no stochastic analysis. Price unknown	√			
PowerSimm Planner	Ascend Analytics	Considers transmission, handles chronological dispatch and stochastic analysis, demand side resources	Price and ease of use unknown		√		
Resource Planning Model	National Renewable Energy Laboratory, NREL	Public domain model, most likely reasonably priced. Co-optimizes transmission, utilizes chronological dispatch (designed for assessment of VREs).	Does not appear to offer stochastic analysis, cascading hydro or pumped storage. Optimizes for discrete one year periods that must be combined for long-term studies. Does not appear to calculate reliability metrics, but rather uses reliability criteria as constraints.		√		√
SWITCH	University of Hawaii	Open source (it's free). Handles transmission and stochastic analysis. Designed to assess renewable integration into power grids.	Limited support. Need to download as Python script. Not user friendly; "primitive" user interface and model compilation, though the core analytical engine appears very robust		√		√
ProMod	ABB	Integrated model with hourly chronological load. Covered both economic and reliability. All costs, market operation and unit commitments are well covered for production cost simulation.	Difficult user-interface,			√	

Prosym		Integrated model with hourly chronological load. All costs, market operation and unit commitments are well covered for production cost simulation.	No reliability consideration.			√	
GEMaps	General Electric (GE)	Transmission based production cost model based on standard least marginal cost operating practice. Commitments and dispatched are considered.	Exclusive to GE clients (difficult to access and learn). Untransparent process and assumptions limited to GE products.			√	√

4.5. POWER SYSTEM ANALYSIS

The last step is power system analysis, which assesses the technical aspect of the grid with the least-cost plan derived from the previous step. In general, the study performs three steps as a part of power system analysis: load flow study, short circuit study, and stability study. The result of the analysis will serve as feedback for generation expansion planning, for example regarding unit size option to maintain the stability of the power system. In terms of planning considering VRE, the stability study is the most important as it is affected by VRE uncertainty and variability. The load flow and short circuit studies are lightly affected in comparison.

As power system analysis constitutes basic knowledge for every electrical engineer, a lot of software is available on the market to assist with these studies. On a utility scale, some of the most popular software for power system analysis is DigSilent Power Factory, PSSE for transmission level, PSS Sincal for distribution level, and ETAP which is more popular for industrial application.

4.5.1. Load flow study and Contingency Analysis

A load flow study is a steady state analysis of a power system network; its aim is to identify the operating state of the system for a given load. It provides a picture of how the power will be transferred if the grid is operational, while at the same time informing the loading percentage of each component, in order to check the possibility of bottlenecks which may occur when evacuating power. A load flow study also provides an estimation of voltage levels at each node, ensuring that this meets the criteria stipulated in the grid code. Exhibit 4-20 lists the observed criteria for a load flow study and some of the data required to perform the study.

Exhibit 4-20. Load flow study: observed criteria and data requirements

Criteria	Unit
Voltage	V
Current	A
Active, Reactive, Apparent Power	W, VAR, VA
Component Loading	%

Parameter	Unit
Nominal component voltage	V
Capacity for each component	W, VAR, VA
Impedance for each component (resistance, reactance, capacitance)	Ω, L, C
Voltage regulator setting	

Contingency analysis (or N-1 analysis) is a further study utilising load flow study as its basis. The idea is simple: the system must be able to maintain operation even if one component such as a generator or transmission line is out of operation or missing. The analysis therefore defines and then simulates scenarios of outage. Similar criteria are observed and any violations investigated. One of the remedial actions based on the result of contingency analysis is reconfiguration of generation dispatch.

4.5.2. Quasi-dynamic load flow

As the output of VRE varies depending on its source, load flow analysis can no longer be carried out by assuming a single state. To address this issue, a quasi-dynamic simulation can be utilised, performing multiple load flow calculations with defined time step size. Using the varying output data, the simulation is repeated for several states to observe the impact of the variability. For example, if the energy production data from VRE is available in the form of hourly data, then 24 states of the system can be observed within a day to see whether any limit is violated during each state. A mitigation plan can then be formulated for a particular hour.

4.5.3 Short circuit study

A short-circuit study determines the magnitude of the current flowing during an electrical fault occurrence. Its result is used to determine the equipment ratings to ensure that the equipment can handle such a large amount of current. This is the first step in ensuring that the power system is safely protected. The data required to perform the study is similar to the load flow data requirement, with the addition of sequential impedance from the generators. This study continues with a protection coordination study in the further stage of planning (detailed engineering design or operation planning stage) to determine the appropriate protection settings that ensure the system is still in operation even after a fault occurs. In terms of planning with VRE, as with the load flow study, it is advisable to consider additional scenarios able to take into account VRE variability.

4.5.4 Energy not served/supplied (ENS)

Unlike other study in steady-state condition, the energy not served is not able to be metered or measured by the utilities or power plant owners. This must be analysed through significant events, significant incidents, data historian, SCADA system analysis, or any handwritten logs of any supply were offered back to a customers.[60] ENS is a metric for estimating the energy that would have been served had the event not occurred made it available. This is valued in MWh unit, which consists of duration of the event (hour) and the total demand lost during the event (MW). The analysis is through probabilistic and represents the reliability index for the system.

4.5.5 Stability study

A power system stability study covers the dynamics of the system in the event of disturbance. Events such as loss of the largest unit of power plant and loss of transmission lines are simulated to assess the impact to the system. Criteria related to stability are observed, such as frequency stability, voltage stability and rotor angle stability. This study covers a very short timeframe, around seconds or milliseconds. System stability itself implies its ability to return to normal or stable operation after having been subjected to some form of disturbance. Power system instability can be caused by loss of synchronism (i.e. some synchronous machines going out of step) when the system is subjected to a particular disturbance.

The data requirement for this study is quite extensive, as it needs to model the control part of the power plant. Most of the data currently recorded/available is for transient behaviour; however a stability study requires Data is needed pertaining to, among other matters, inertia, impedance during transient conditions, excitation equipment parameters, power system stabiliser parameters and governor parameters. This data requirement is listed on the grid code for the respective region.

The variability of VRE and its uncertainty characteristic require additional stability analysis on top of the current stability study, which does not take these into account. For example, cases have occurred involving cloud covering the PV farm and wind speed rising rapidly above the wind turbine cut-out speed, causing the turbine to shut down to avoid damage. The impact can be likened to a partial power plant outage within a specific duration of time. A flexibility assessment using this short timeframe is required to assess whether the system can withstand VRE variability and uncertainty, as illustrated in Exhibit 4-21.

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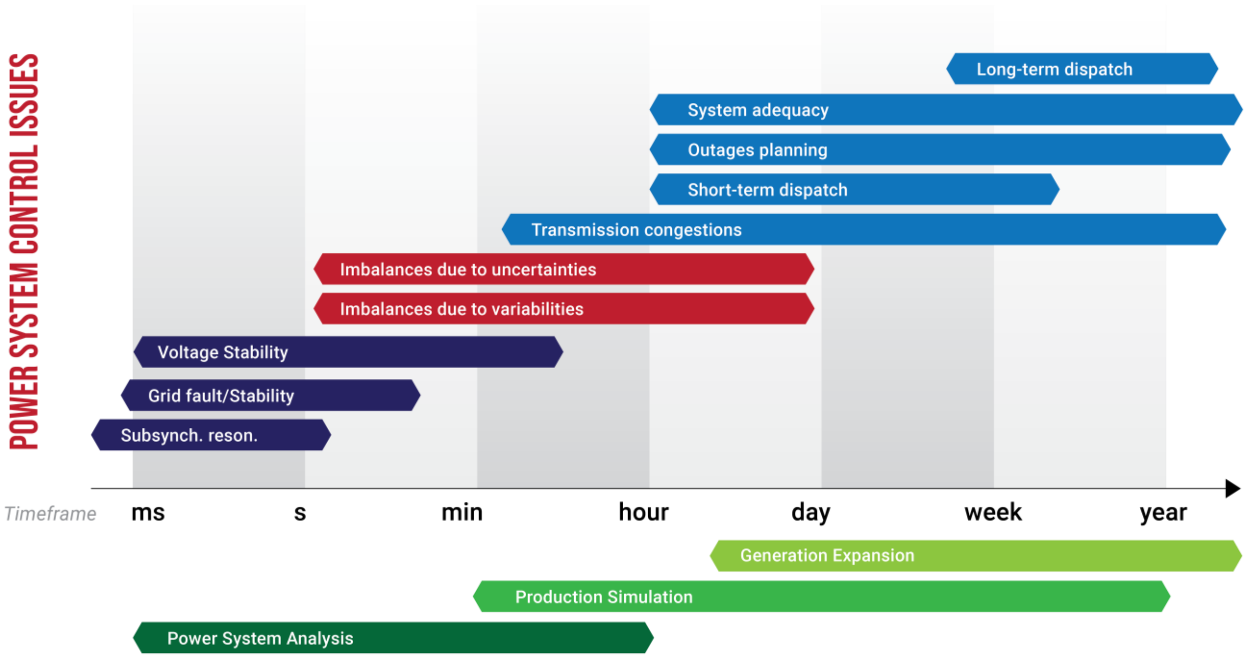
[60] The detail can be seen in how Ofgem measures ENS and provide incentives: https://www.ofgem.gov.uk/sites/default/files/docs/2016/05/joint_to_methodology_for_estimating_energy_not_supplied_issue_3_september_2015.pdf

Exhibit 4-21. Timeframe for power system control issues



Current practice dictates that the owner/developer of the VRE must perform a connection study (which includes a stability study) to assess the technical feasibility and conformance to connection code and grid code. The result must be presented to PLN. However, this study is commissioned by the developer which has a stake in the VRE development, and whose interest only revolves around that particular VRE project.

Taken altogether, these reasons provide the reason why current practice is deemed insufficient to capture the impact to the system of high VRE penetration, and why we therefore propose the implementation of a grid impact study performed by a system planner. The grid impact study shall take into account the aggregate effect of the entire VRE on the power system, not just that of one individual VRE, and develop scenarios which take into consideration the characteristics of VRE, as described in Exhibit 4-22. As this study would be conducted solely by PLN, it should be better able to capture and identify any concern of PLN regarding any risk that might arise from high VRE penetration. The study will also formulate mitigation measures for de-risking. Its results will empower the system planner and increase their confidence in formulating and implementing an action plan to achieve higher VRE penetration.

Exhibit 4-22. Scenarios for consideration in a VRE stability study

Scenario Aspect	Description
Variability & Uncertainty	Full cloud coverage on Solar Park
	Rising wind speed until above the cut-off speed on Wind Park
Disturbance	Fault on Inverter side
	Biggest unit forced outage
Time of Simulation	Light Load
	Peak Load
	Seasonal

4.6. RENEWABLE ENERGY QUOTA FORMULATION, RISK AND MITIGATION

As described in the previous section, GEP will produce a list of the additional power plant needed to supply demand during the period of study, and a production simulation will allocate energy production of each power plant and mode of operation, taking into consideration the economic and flexibility behaviour of each power plant. The power system analysis will then verify VRE behaviour under different scenarios that might occur, based on the dispatching result of the production simulation.

The major part of the grid impact study is the power system analysis, which presents different possible scenarios designed to verify system stability during the most extreme intermittence that can occur. Exhibit 4-23 presents some scenarios for consideration. Verification of the scenarios will be achieved through analysis of contingency, quality and stability, including issues such as a fault on the VRE inverter.

Exhibit 4-23. Scenarios for consideration in a VRE grid impact study

No	Wind generation	Solar generation	System demand	Local demand
1	Peak wind season	Maximum	Maximum system demand during peak wind season	Corresponding local load
2	Peak wind season	Minimum	Minimum system demand during peak wind season	Corresponding local load
3	Peak wind season	Maximum	Maximum system demand during peak wind season	Local sub-station light load in peak wind generation
4	Peak wind season	Minimum	Minimum system demand during peak wind season	Local sub-station light load in peak wind generation
5	Off-peak wind season	Maximum	Maximum system demand during off-peak wind season	Corresponding local load
6	Off-peak wind season	No Solar	Minimum system demand during off-peak wind season	Corresponding local load

If there is no wind, low load high solar PV or low solar PV high load can be considered.

The idea of having this quota is to also minimise as possible the disturbances occurred in the system. The disturbance can be reduced by setting the largest unit size of solar PV or wind in system and set the minimum distance of largest unit in system. This might be something new for utility, but it can be simulated through the penetration of largest unit and trial and errors in above analysis. Sometimes the largest unit can bring the unwilling disturbances that utility does not want, therefore, the unwilling local disturbances must be identified by trial and error of some largest unit sizes proposed by the utility. Therefore, utility can understand how those size the local disturbance. Then, the distance between largest unit can be also simulated in same system, by overseeing the impacts of some parameters, such frequency, voltage, or other parameters that might be impacted due to the close distance of largest units. Trial and errors must be conducted to see which distance is preferable with the most minimum impact to the grid.

By having a grid integration study completed, the least-cost optimisation and grid assessments, but limited to:

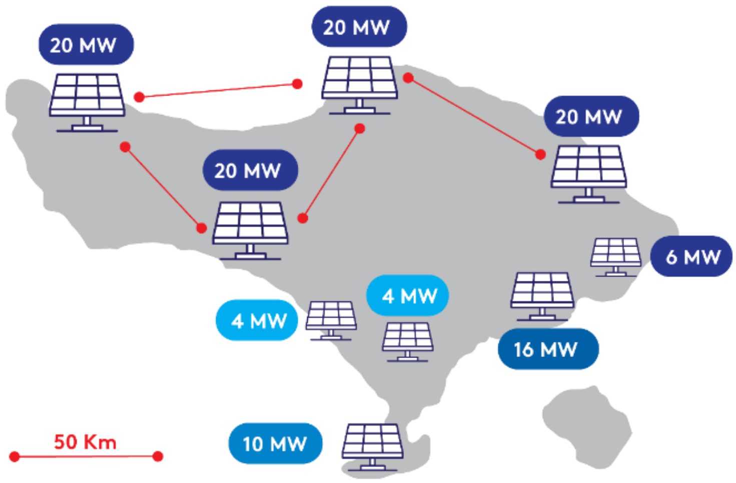
1. **Largest plant size**
   This is to effectively manage the system and to avoid unprecedented events (e.g. a sudden drop in wind from maximum wind speed to 0) in the power system.

2. **Minimum distances between largest plant size (related to system stiffness)**
   Learning from Germany, Denmark and Ireland, this guideline proposes a geographic distribution of the variable power plants. The distance between the two closest large power plants must be arranged to encourage an equal distribution in the entire selected system.

3. **Maximum penetration (quota allocation)**
   There is a maximum penetration of VRE that the system can handle without any the need for expensive mitigation plans. The MEMR's goal is to assess whether the quota system can be streamlined or not to achieve the 23% target. It would also like to identify a list of mitigation actions required if the quota meets the target; it also identifies the transition cost of these mitigations.

As an example, this methodology was applied for Bali island. The expected results were not solely dependent on the size of the quota allocation, but also the minimum distance and largest plant size as indicative information for the developers. Exhibit 4-24 represents the RE quota in Bali.

Exhibit 4-24. Expected results from RE quota: Bali (Dummy)



Zone	Technology	Quota (MW)	Largest Plant (MW)	Distance between Largest Plant (km)
Zone A	Solar PV	500 MW	50 MW	50 km
	Wind	200 MW	100 MW	100 km
Zone B	Solar PV	1000 MW	75 MW	25 km
	Wind	250 MW	75 MW	50 km

4.6.1 Renewable energy risks

The highest risk in renewable energy is the investment risk. This is because the biggest part of the renewable energy total cost is the investment cost, as most renewable energy has low or almost zero fuel cost. Certainty in resource adequacy assessment is highly important in mitigating this risk. Of course there are other risks affecting the appetite of renewable energy development including financing risk, regulatory risk and operational risk.

Resource assessment is highly important in order to derisk, and will at the same time reduce other risks such as financing and market risk. Hydro, wind and biomass sources of energy need on-site assessment for a period of at least one year: even these face uncertainty in the operation phase. Solar power has less risk, as it provides less uncertainty in terms of irradiation in certain regions; there is also a great deal of database information available for resource assessment in regard to solar power. Geothermal projects have a specific risk in the exploration phase, where drilling involves a high cost with an uncertain result in terms of resources.

This chapter mainly describes the risk in power system operation which make utilities think twice about increasing the contribution of renewable energy. The differences in power system characteristics between VRE and fossil fuel create a 'new' risk for the system operator which have been traditionally managed mostly by dispatchable power plants.

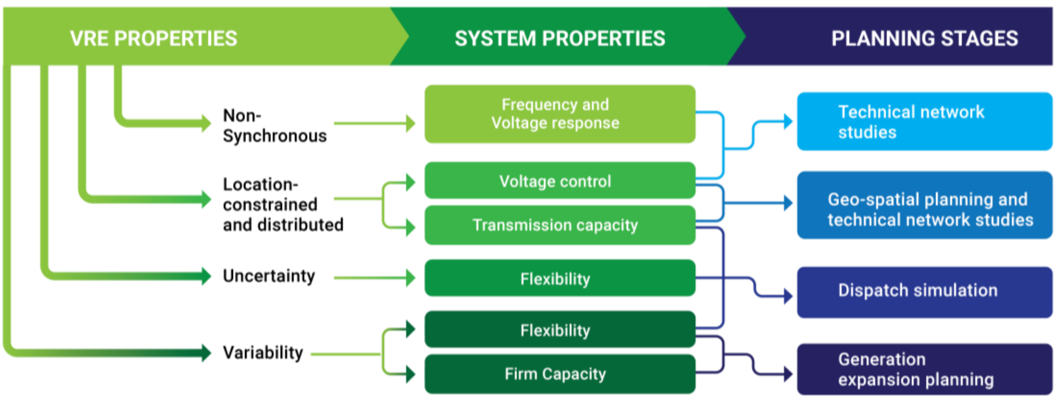
4.6.2 Risk and characteristics of variable renewable energy

The main characteristic of VRE is its variability. This means that the conventional system operator has to be aware that while most power plants in the power system have firm capacity and are dispatchable, variability means an increase in uncertainty and loss of flexibility. The more specific characteristics of VRE which differ from a fossil thermal power plant are:

- VRE is non-dispatchable – it is weather-dependent and its output is based on resource input.
- To some extent, VRE can be forecasted, but some uncertainty remains.
- VRE is location constrained – resources must be utilised locally and cannot be transported.
- VRE comprises nonsynchronous power sources, interfacing with the grid by means of a power electronic device (inverter)
- VRE is often installed on the distribution side rather than the transmission side.

These characteristics affect power system planning to ensure power system operation will not be adversely affected. Effects on the power system include a consideration of firm capacity, flexibility, transmission/distribution network capacity, voltage and frequency response and control. Exhibit 4-25 presents the links between VRE properties and the power system, which must be considered at the power system planning stages.

Exhibit 4-25. The links between VRE properties and the power system



1. VRE is non-synchronous

VRE design incorporates a power electronic interface with the grid, known as an inverter. This is different to a synchronous generator, in that it does not have inertia to stabilise frequency when there is a change in balancing load and generation. This rotating inertia[61] helps synchronous generators maintain frequency deviations in the grid caused by abnormal operations such as when a fault occurs.

During a system disturbance, generation and demand become unbalanced, resulting in a change of system frequency. Stored kinetic energy in the rotating generators is then released, slowing the drop in frequency to allow other generators time to restore balance. This is an example of rotating inertia. Having more VRE in a system is contradictory to the current power system. As more synchronous generators in a power system are replaced by inverter-based VRE, the less inertia that power system will have. This affects the power system, which has less capability to respond the frequency changes.

2. Location constraints

Unlike fossil fuel thermal power plants, solar and wind resources are location specific, and not transportable. This creates a need in the network to evacuate power from the plant to the load centre. If this power has a long distance to travel, voltage support is needed so that quality (and any losses) will still be within reasonable limits.

3. Resource uncertainty

The availability of VRE resources is variate in every second, which makes the output of the VRE plant variate in every second as well. To maintain power system frequency, other power plants in the system must respond to this variation in real time.

Although the variability of VRE resources can be forecasted, there is always a chance of forecast error. Short-term variability or intermittency will depend on intermittent variations in cloud movement, temperature and change in atmospheric pressure. This intermittency adds uncertainty to the output of a VRE plant, which is essential to anticipate in order to maintain power system stability.

4. Non-firm capacity

Variability and dependency on resources makes it difficult for VRE to provide firm capacity in a power system. Firm capacity is the amount of power generation that can be guaranteed to meet demand at any given time, which VRE cannot provide due to temporal mismatch. Only a part of the capacity, called capacity credit, can be considered firm capacity.

[61] Inertia is the resistance of an object to a change in its motion, as stated on the first Newton law of motion. In the electric grid, the motion is the rotating mass of a generator spinning at a rate synchronised with the system frequency. Inertia is stored rotating energy in the system.

4.6.3 Mitigation of VRE characteristic

Power system development that incorporates a high share of VRE must consider the distinct characteristic of VRE and its impact on the power system. This is essential in order to maintain a reliable supply of electricity.

1. Non-synchronous

Power system stability is one of the important conditions needing to be maintained during operation. The lower the total inertia in the system, the lower the power system stiffness. Power system stiffness refers to its capability to maintain the frequency and voltage at a stable level. As VRE becoming increasingly bigger, inertia will be less, resulting in less grid stiffness.

Grid stiffness can be measured through stability analysis, which identifies probable disturbance or variability that may disturb voltage and frequency. Bases on this analysis, mitigation action can be defined to create a stable voltage and frequency.

The absence of inertia in VRE and its variability needs to be considered in the planning stage, as this will make for a less stable power system if no mitigation action is taken. The mitigation approach can be taken from two sides: increasing the inertia or reducing the variability.

An inverter-based solution can synthesise inertia. This is analogically similar to pumping the brakes on a moving train, an action which creates additional inertia that is not real inertia, and so is called synthetic or virtual inertia. Synthetic inertia works instantaneously by increasing output to counter frequency drops via swift control of power electronics.

A battery energy storage system (BESS) also can provide additional inertia. BESSs can be used to mimic the inertial response of synchronous generators; controlled BESS converters reproduce synchronous generator dynamics. The storage is needed to provide the energy necessary to control the active power output. Various forms of control are possible and have differing impact on the grid.

A large, old, retired thermal power plant station can be retained and used as a synchronous condenser, which can provide additional inertia. As the turbine of this machine will have been taken away, the inertia will be reduced but is still present. This machine may also contribute voltage control and short circuit currents.

On the other hand, mitigation action regarding the source of variability can be effected by reducing the variability. This is achieved by maintaining the unit size of the VRE so that variability at one location will not affect the voltage and frequency stability. The more distributed the VRE, the less the variability of the total VRE.

2. Location constraints

The availability of VRE resources depends on their location, and new capacity may need to be planned to transmit power from VRE resources that are far from centres of demand. Long-distance transmission lines also may need enhanced ways of controlling voltage. With VRE that needs a long transmission line, consideration of voltage control capability is important.

Mitigation of these matters takes place during the planning stage. Analysis of resource potential for VRE and having in place a strong and extensive transmission grid allows a system to benefit from the smoothing out of VRE variability from geographically dispersed VRE sites.

Identification of a compensator that helps facilitate voltage control between the VRE and the connection point is important before the VRE connection to the grid. The compensator can be a capacitor, FLEX or synchronous condenser.

3. Resource uncertainty

One of the characteristics that makes VRE integration a challenge is the uncertainty associated with output; at the same time, in order to keep a power system secure and reliable, demand and supply must be balanced at all times. To deal with the variability of VRE, the system must have the ability to adjust other portions of generated power to meet the load. The capability of power system generation to anticipate variability is called flexibility (the presence of a balancing process in the power system is not actually new, as demand has always been variable to some extent).

The higher the VRE portion of a power system, the more important is the system's flexibility. Planning the deployment of VRE can mitigate the challenge of balancing supply and demand by additional flexible generation and reduce uncertainty regarding variability and intermittency. On the other hand, failing to deliver this could lead to the extreme curtailment of VRE and the cost efficiency that this implies.

On the generation expansion stage, flexibility is usually achievable by means of, among other things, a dispatchable generator, storage, demand response, and cross border interconnection. Combined with variability of demand and VRE, models can optimise generation expansion in terms of flexibility and meet the system requirement as an additional constraint to conventional generation expansion planning. Flexibility accuracy is dependent on the time resolution of the simulation model: the higher the resolution, the better the accuracy. Generation expansion planning with lower resolution that assumes the generator has enough flexibility and ignores the cost of cycling tends to produce sub-optimal results.

Dispatchable power plant flexibility contribution can be identified by its parameters – ramping rate, start-up time, minimum up/down time and minimum stable level – which must be considered as part of the generation expansion planning model. Dispatchable power plants are usually categorised as base loaders, load followers and peakers. The base loader is usually a big power plant with low operational cost but low flexibility; it operates continuously and the load is almost flat. An example is the coal steam power plant. The load follower has medium flexibility capability, usually serving the variability of demand during off-peak times; the load will be variable during the day. An example of this type of power plant is the combined cycle power plant. A peaker, as its name suggests, operates only during peak hours and encounters daily start-stops with high flexibility. A gas turbine is a peaker generator.

Electricity storage can be used for a variety of functions including regulation, load following, and energy shifting, to add or absorb energy from a power system. Electricity storage systems are used primarily to shift the timing of electricity supply and demand, by storing and then dispatching energy. Storage can help VRE to produce a smoother output by balancing its intermittency. Hydro pump storage is very common; batteries are increasingly popular for smaller and faster balancing, as they have a quick start and fast ramping rate.

Demand response can be used to compensate variability. Demand response is load that can be managed in response to an on-purpose trigger, or changes in electric usage by end-use customers from their normal consumption patterns to avoid system instability.

Demand response helps system flexibility during the decreasing of VRE resource by decreasing the demand. Along with storage, demand response can help to increase penetration of VRE, as both have a very fast response in terms of flexibility.

Cross-border interconnection will facilitate both systems to share reserve and flexibility. Interconnection also improves the grids in terms of balancing capabilities, reliability and stability. Interconnectors allow the flexibilities of power systems to be shared by enabling the transfer of power from a surplus to a deficit area. The benefits are greater when areas with different generation and load characteristics are connected.

4. Non-firm capacity

One of the key factors that long-term models must consider is whether there is sufficient capacity to maintain system reliability. Resource adequacy refers to the need to have enough available resources to meet anticipated demand while accounting for a reasonable number of contingencies. Adequacy capacity is the total available firm capacity that each power plant can provide at any time it is needed to supply the demand.

Only a fraction of VRE capacity can be considered to be firm capacity, and this must be considered in generation expansion planning. Other power plants must cover the demand when low amounts of VRE are available.

4.7. TRANSITION (INTEGRATION) COST

In the prevailing modelling approach, power system planning only identifies the cost of total investment, and operation of generation and transmission during the planning time horizon. The original planning objectives are designed to obtain the least-cost scenario for additional generation and transmission capacity at a certain level of reliability. This least-cost scenario is known as the base case.

Keeping in mind the 2025 target, additional efforts will be needed to determine the RE quota, due to huge gap to date, and the VRE contribution within the power system. Indeed, these extra efforts will also cost more for the utility. The additional cost needed to guarantee that the power system acts reliably and securely even though a higher amount of VRE has penetrated the system will be acknowledged as a transition cost.

An analysis of this cost shows that it is not only based on the optimum penetration of RE but also on the requirement to capture the needs of more alternative resources and facilities without any consequence to power system reliability. Transition cost can be represented by:

1. Different cost for generation capacity and transmission line capacity addition between two scenarios
2. Reallocating existing spinning reserve for flexible sources
3. additional cost for back-up capacity, such as that provided by a battery system;
4. cost to shut down some non-flexible power plants;
5. curtailment cost; and
6. cost of other options required to increase the flexibility and stability of the power system.

The VRE contribution to the power system can only be facilitated by accommodating its characteristics of variability, uncertainty, location-specific and low inertia. These characteristics make up the additional facility of the grid, which needs to be more flexible in order to adopt them, and reliable in so doing. The cost involved in this case is usually defined as the 'grid integration cost'.

A scenario which meets the RE quota must be devised to identify the transition cost, which is government's responsibility to fund. The identification of this cost will help the government to define the lowest hanging fruit strategy by which to accelerate the increase in renewable energy. In power system planning, the process can to be set to identify the cost of energy transition to fulfil the 23% target by comparing the base case scenario (least cost) with the renewable energy target scenario. It is essential that the mechanism of transition cost funding is defined clearly, in order to facilitate a clear road map which will enable the RE quota to be met in due time. In Chapter 5, this guideline outlines the stakeholder mapping process, where the Ministry of Finance and the Ministry of Energy and Mineral Resources have significant roles in establishing the source of funds for this transition cost. Before that, this chapter presents a detailed guideline identifying how PLN/other utilities can analyse the RE quota properly.

4.8. RENEWABLE ENERGY PLANNING FOR ISOLATED SYSTEMS

Indonesia is an archipelagic country of over 17,000 islands and it is not surprising therefore that interconnection between islands is not always available. In fact, almost all of the islands lack connection. It is estimated that Indonesia has more than 600 power systems, with peak load ranging from less than 1 MW up to more than 25,000 MW. Power system planning methods are principally the same for all power systems, and the bigger the system, the more complex the model.

A small power system that does not have a high voltage transmission system is usually defined as an isolated system, with no synchronous connection to the main transmission systems, and the highest voltage used being above 1 kV.

Power system planning methods apply to both interconnected and isolated systems. An isolated system usually has a bigger ratio of power plant unit size compared to demand, and higher flexibility, but a less synchronous power plant. Grid integration analysis is important to determine frequency stability; a scenario must be built to consider the most representative states of the system, to enable detailed static and dynamic analyses.

Power system planning in small islands is very challenging as the following indicates[62]:

- Expansion planning identifies limited primary resources available in place for new generating units, environmental constraints for network expansion, high uncertainty in terms of electricity demand growth, etc.; and
- Power system analysis shows small system inertia, high sensitivity of network voltages and system frequency with respect to small variations in the load and renewable energy generation, system reliability, etc.

Tools for conducting a grid integration study of an isolated system may be less complex. The popular tool for generation expansion and production simulation is HOMER or other equivalent tools (either free or commercial), which cannot be used on a large interconnected system. Power system analysis is usually conducted at the distribution level; quite popular software is ETAP or other equivalent tools (either free or commercial).

The specific requirement that should be given attention in an isolated system is the need for frequency control, black start facility in the synchronous power plant, and battery support. As there are not many power plants in an isolated system, the dominant power plant should have a facility capable of full frequency control, and a black start system. Energy storage may be required for smoothing or load shifting from VRE generators in island power systems, where the area is small and distributed VRE locations are limited.

Indonesia's most isolated system, with a peak load of less than 10 MW, is supplied by a diesel power plant, which is the easiest practical way to provide electricity in an isolated remote area. This

[62] IRENA, Transforming Small Island Power System, 2018.

makes the system extremely dependent on expensive fossil fuels, producing a great amount of carbon emissions which are not environmentally friendly. Used to power conventional power plants, these fuels are usually transported to the islands by tanker, creating an unsustainable service mode. The carbon footprints of the tankers/diesel-powered boats are in themselves another issue, particularly in light of the ratification by Indonesia of the legally binding Paris Agreement. Renewable energy technology makes the power system supply more sustainable by using locally available renewable energy resources, such as solar, wind, hydro and biomass.

The development of the power electronics industry makes 100% renewable energy supply possible, eradicating the dependence on expensive fossil fuel supply. The integration of a battery-photovoltaic power plant in the islands creates the required conditions for operating the system without synchronous unit scenarios, with a system dominated by power electronics. The possibility of operating the system under these conditions is assured by grid-forming inverters connected to battery energy storage systems.[63]

A grid-forming inverter is an inverter system that participates actively in forming the grid voltage, as it is a voltage source inverter. It has the capability of a black start facility and must be equipped with battery energy storage. The cost of a grid-forming inverter is several times that of a grid-tie inverter.

The renewable contribution in an isolated system is expected to have a larger potential, because of:

- current high costs of producing electricity due to the widespread use of diesel generators which run on imported fuels;
- local availability of renewable energy resources including solar, wind, geothermal and hydroelectric resources;
- environmental and social benefits of renewable energy use (including reductions in greenhouse gas emissions, job creation and strengthening of local communities); and
- political support for the development of sustainable energy supply strategies.

[63] Beires, PP et al, Grid-forming inverters replacing Diesel generators in small-scale islanded power systems, 2019, Power Tech 2019.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS FROM THE GUIDELINE

The following salient points are summarised from the discussion presented above:

- Having an RE quota is an increasingly common global practice by which to achieve a country's renewable energy target. Countries including the UK, Poland, Italy, China and Malaysia have already implemented a quota system, of which there is at least two types: a certificate and a zonal system. The design of an RE quota can be quite specific, with several components to ensure its effective implementation. It is important that constraints and enablers such as financial capability, market competitiveness and transmission capacity are examined by government and utilities, ensuring that implementation encounters fewer issues.

- This study suggests that the design of an RE quota in Indonesia is conducted through a renewable energy grid study with a VRE preference incorporated into its least-cost planning option. The quota will be integrated in the RUPTL process, in line with strengthening power system planning for renewable energy by PLN/utilities.

- An RE quota is required as part of the roadmap to reaching a renewable energy target share of 23% by 2025, as stipulated by the Government of Indonesia. Its purpose is not to limit the amount of renewable installation, but rather to provide a clearer picture of how to achieve the target by distributing installation using the result of a rigorous planning process and considering the technical capabilities of the system.

- An RE quota would help PLN in mapping the risk of renewable installation, especially from the point of view of VRE source characteristics, and in formulating a mitigation plan accordingly. A mitigation plan can be incorporated into system design, system operation or PLN's internal working process, or take the form of an additional project designed to help with the integration.

- By mapping the associated risk clearly and formulating a mitigation plan, economic assessment can be done to identify the cost required to achieve the target. This would be a very positive input for PLN and the Government of Indonesia (as the sole owner of PLN), facilitating the formulation of a more detailed plan in terms of financial planning.

- This study proposes the formulation of an RE quota using a techno-economic planning process, the foundation of which has been laid by PLN's RUPTL planning. The proposed planning process, or grid integration study, tweaks this process to help incorporate renewable energy characteristics, especially from VRE sources.

- The planning process can be differentiated into three steps: demand forecast, generation expansion and production simulation, and power system analysis. Demand forecast should consider not only the government target, but also the views of experts on economic development.

- In terms of generation expansion and production simulation, an optimum value of additional capacity is needed to meet demand within the constraints of reliability and government policy such as the RE quota. Resource assessment of renewable resources becomes crucial to analysing the amount of energy and capacity that can be produced by renewable energy. Flexibility assessment is also conducted here to anticipate VRE plant variability.

- Power system analysis is able to deal with a shorter timeframe, as it simulates the system in milliseconds, seconds or minutes. This is to ensure security to cope with unexpected events such as extreme intermittency and system disturbance. Several scenarios of simulations are developed to reflect variability, VRE uncertainty and system disturbances, to see how the system performs. Problems such as congestion, voltage violation, low voltage ride through, frequency drop due to variability, and frequency stability during disturbance are assessed here.

- The expected outcome from the above planning process revolves around determining the optimum additional capacity of generation and transmission within the constraint of reliability and the RE quota. The maximum penetration of VRE will be determined by the largest plant size in a system, the minimum distance between largest plants, the maximum penetration of VRE in a system, and system flexibility. These serve as the basis for the RE quota and as feedback for the planning process.

- To ensure proper planning output is acquired, it is recommended to open a part of the planning process for public review and consultation. Inputs from experts or concern from the public regarding the planning should be incorporated during the consultation to help steer planning in a favourable direction.

5.2. RECOMMENDATIONS

This guideline also outlines two types of recommendations: (1) policy recommendations and (2) stakeholder mapping recommendations. The lowest hanging fruit action to be executed next is to do a pilot study in a small system, as a demonstration sample of proving this RE quota methodology is applicable and identifying challenges along the process.

5.2.1 Policy recommendations

Special roadmap for VRE phase development

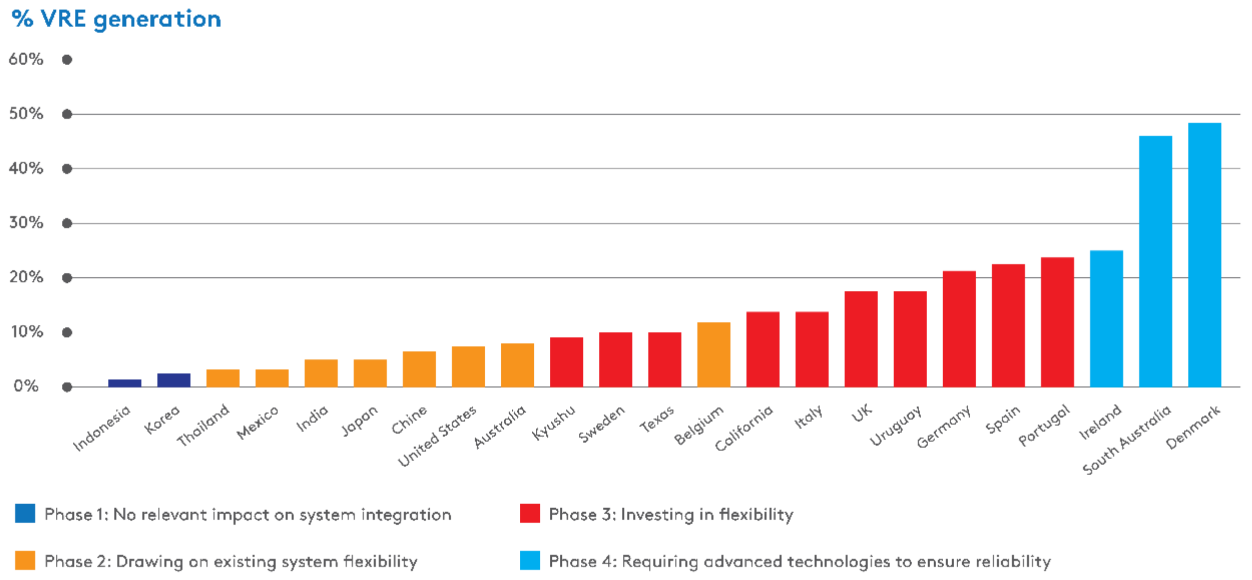
The RE quota was determined using a least-cost optimisation approach, or so-called renewable energy grid integration study. To conduct this study, policymakers should at least understand the

VRE integration level experienced globally. According to the International Energy Agency (IEA) there are at least six levels of renewable integration in the power system, as follows:

1. VRE has no noticeable impact on the system. This causes no system flexibility issues (in almost all Indonesia's systems, except Sulbagsel).
2. VRE capacity becomes noticeable to the system operator. In this stage, it has a minor to moderate impact on system operation. VRE variability and intermittency are not significant but may change operating patterns. Nevertheless, they are manageable (e.g. Sulbagsel system, Indonesia).
3. VRE generation determines the operation pattern of the system. Flexibility becomes more relevant with greater swings in the supply/demand balance. VRE has changed the baseload power plant profile and may cause periodic shutdown.
4. The system experiences VRE supplying almost all of the load. Stability becomes relevant. VRE output can cover most of the demand at certain times. Almost all power plants adjust their output to compensate for VRE.
5. There is a growing amount of surplus VRE. Electrification of other sectors (sector coupling) becomes relevant, which can also anticipate flexibility issues. Longer periods of surplus or deficit of energy.
6. Seasonal or inter-annual surplus/deficit of VRE supply. Seasonal storage use of hydrogen or synthetic fuels.

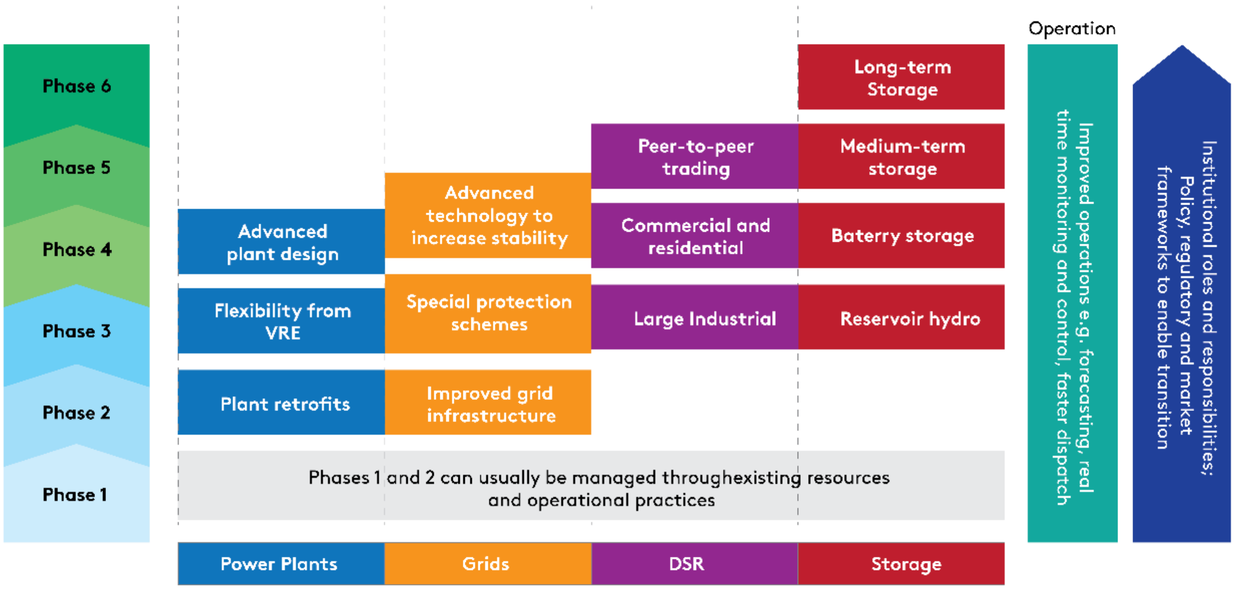
In comparison with other countries (see Exhibit 5-1), Indonesia's renewable energy is small in terms of percentage of total installed capacity in its power system. However, a focus is needed on each of the country's power systems to decide accurately the real situation of its power system operation. Jawa-Bali, Sumatera and Kalimantan, for example, have no noticeable VRE yet (Phase 1). In contrast, Sulbagsel has a higher contribution of VRE due to the large wind farms integrated within the system. System operation is at a different level where significant efforts were considered to anticipate VRE variability and intermittency from the two largest wind farms in Indonesia (Phase 2). In another of MENTARI's activities, PLN is planning to replace its diesel power plants with renewables. Most diesel power plants were installed in small islands which have low demand. If the replacement happens, transition will have moved from Phase 1 directly to Phase 3. To achieve the 23% renewable energy target, Indonesia's power system must be ready as a minimum to level up to Phase 2 and Phase 3.

Exhibit 5-1. Percentage of VRE generation and its IEA categorisation: a comparison between Indonesia and other countries



To pursue its target, Indonesia is strongly suggested to have a clear roadmap on their power system planning and operation to tackle all the natural challenges from VRE discussed in section 4.6. As a minimum, this roadmap should cover the step-by-step actions for utilities, dispatch centres and regulators to anticipate the next level requirements needed to serve a higher amount of VRE. On the flexibility issue, there are at least four flexible resources, namely power plants (fossil or renewable-based), grids, demand responses and storage. These must be addressed in at least PLN RUPTL or any midterm planning of PLN. The utilities are acutely aware of these options; however, it will require significant changes in operational basis, system management and if needed, any structural arrangement. The utility must deal with these as well as the flexibility options or these changes. At some point, the options might cost them more than expected. This is called a transition cost or VRE integration cost. Government must provide any necessary assistance to cover the cost to prevent it from being passed directly through to the customer, who will incur a higher electricity tariff as a consequence.

Exhibit 5-2. Sample of actions for a roadmap for higher VRE in Indonesia



Key flexible resource examples to enable transition

Therefore, policymakers such as MEMR (DG of Electricity or DG of New Renewable Energy and Energy Conservation) do not to worry about the needs of battery or smarter technology. The impacts of renewable energy can be minimised through a planning stage, and cheapest flexibility sources, as long as utility shrewd on this matter and no more than 10% of penetration. Such Java-Bali with 30s GW supply, can actually being installed with 3 GW of solar PV without the problem if the planning is correct, flexible sources from gas/hydro as spinning reserve are well utilised, advance design of solar PV, or retrofitting fossil plants to be flexible. The needs of battery or storage will only be necessary if the solar PV penetration is up to 30% above. The case of Germany and Denmark as mentioned in Chapter 2, were showing that these countries do not require huge installation of energy storage for greater renewable energy penetration.

Transition cost requirement

Any VRE integration into the system will be followed by its shadow cost. This is a cost to facilitate higher renewable energy integration without any significant disturbance events to the system by carrying out mitigation steps as discussed in section 4.6.2. It is also called a transition or integration cost.

The need for a transition cost must be considered by utilities and government. At the time of writing, the transition cost will not be affordable if the utility prefers to select a back-up capacity unit as their mitigation options. Many alternative options can be outlined, from the cheapest (co-optimisation of power system, dispatch interval, intraday market arrangement, ancillary services and improved VRE forecasting methodology) to the most expensive (utility scale storage and sector coupling such as electric vehicle system).[64] A transition cost is inevitable, and must be allocated by government who owns the target of 23% renewable energy. The establishment of a friendly financing environment (e.g. fiscal or non-fiscal incentives) or a new advanced market (peer-to-peer, or ancillary market) might reduce the use of the state's own budget and avoid the customer incurring higher electricity bills.

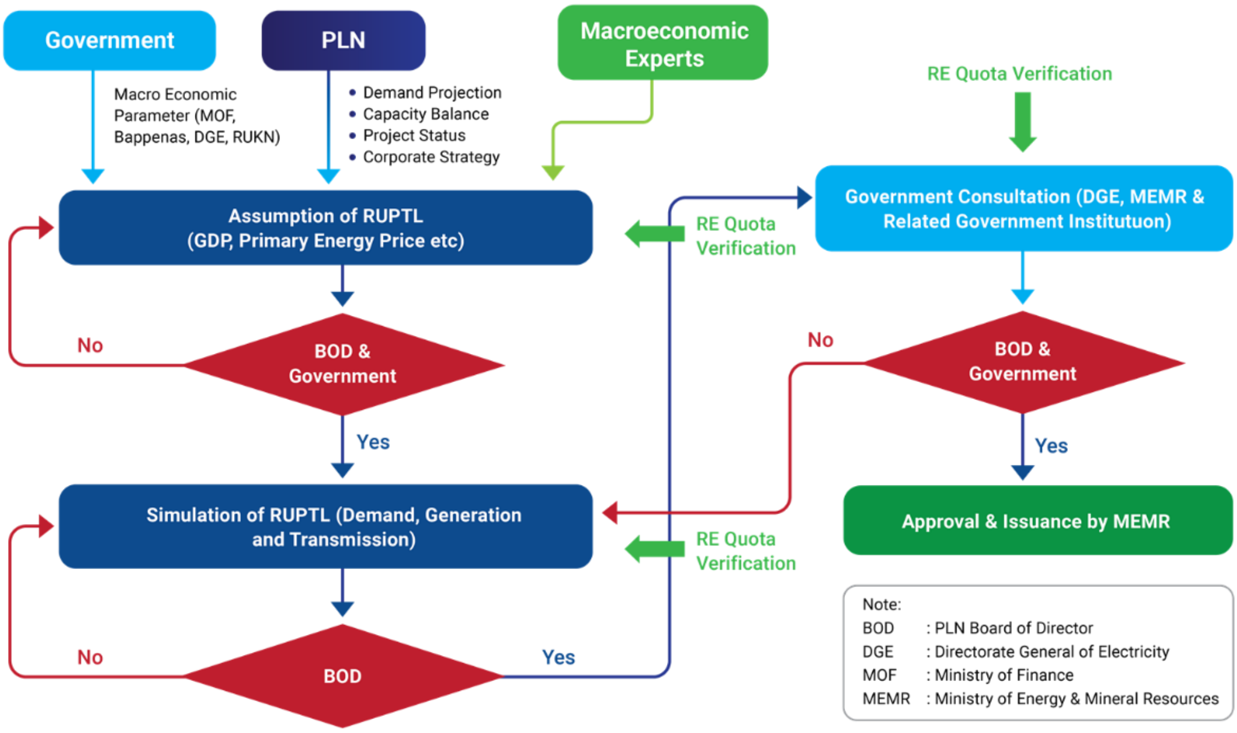
Improvements to the power system planning process

The current RUPTL acknowledges Indonesia's renewable energy target and least-cost optimisation; however, detailed renewable energy planning (discussed in section 2.4 and Chapter 4) is still missing and includes no intention to determine an RE quota. An RE quota is produced as the side product of power optimisation arranged in the RUPTL model. Indeed, some improvements are suggested. For instance, compliance with this guideline is mandatory for the power system and generation planning process. The proper process and methodology explained in Chapter 4 must be carefully carried out by the utility in coordination with MEMR. Even if MEMR conducts this, the technical modelling and analysis must nevertheless rest with the utility, which is the expert, unless there is an independent authority (either government or the utilities) which will plan a national power system. This is known as the system planner, which some countries whose electricity market is advanced have already established. However, an improvement to the methodology, tools and human capacity in each utility's power system planning unit is more than enough to determine an RE quota, without any additional action needed to establish a new institution, which would be more complicated than necessary and unreliable for any short-term action.

Furthermore, public participation (through public hearings) is critically important to the RUPTL modelling process. This will collect positive feedback from various institutions/bodies, which will further improve the quality of RUPTL itself. This transparent process engaged in by the public will also provide another perspective for planning. Currently, the RUPTL process is only published and disseminated when it is finished. Public participation is currently close to zero, even though the public owns PLN, which is a state-owned enterprise. Public hearings have been implemented as part of power system planning in many countries such as the Philippines and and Vietnam. Public contribution to the RUPTL process can be conducted in particular during the consultation process (see Exhibit 5-3). In addition, several experts could be invited to review and assist PLN in conducting the simulation and assumption determination. Indeed, an RE quota will also help these steps to be verified with the intention of RE quota calculation which has not yet been considered. An additional macroeconomic expert is also necessary to help

[64] IRENA, 2017

Exhibit 5-3. RUPTL approval process incorporating MENTARI's suggestions



Supporting policies: power purchase agreements and the pricing system

One of the most important factors in accelerating VRE development is the PPA. This outlines the risk-sharing and responsibility of each party, addressing any uncertainty in the operation and revenue of the project. The PPA also influences the bankability of the VRE.

The VRE cost structure mostly involves capital cost and has a very small variable cost, making the capital cost the riskiest. The developer needs certainty on the return of their investment, and the riskier this is, the higher the price offer will be.

Currently, the price structure of most VRE PPAs in Indonesia uses a single tariff with a take-or-pay contract. This is accepted by the developer as long as the transaction pertaining to deemed dispatch is calculated correctly. Quite often, deemed dispatch becomes a disputed matter, which creates some degree of risk in terms of revenue certainty.

A better price structure is one which splits the fixed charge and variable charge. The fixed charge comprises capital return, fixed operation, maintenance cost and profit, while the variable charge is for variable operation and maintenance. This price structure is the same as the PPA for other coal power plants, but with a different method for measuring availability.

The fixed charge is based on the VRE performance ratio, which is the ratio of energy available for export to the grid after deduction of energy loss and energy consumption used for operation and the theoretical output. Theoretical output is the energy produced by the VRE at 100% availability ('100% availability' can be defined as power produced by a reference cell with the same irradiance variability during the same period). The reference cell usually uses a standard pyranometer for solar power or an anemometer for wind power. The variable charge is minimal in the VRE PPA, usually to compensate for variable operation and maintenance cost, which varies with VRE production.

With a fixed charge, there is a clear risk allocation for developers and utility. The developer is responsible for the availability of VRE, while the utility takes the power generated by the VRE. The risk of the demand is borne by the utility, and the risk of VRE performance is borne by the developer. The utility decides the VRE need that can be absorbed by the power system.

The fund provider sees less risk with this price scheme as it only depends on developer performance; this might bring the cost of finance down. Any dispute about energy that will be absorbed by the power system, or about the event of curtailment is not a dispute, as the variable charge will be very low, providing VRE with a high competitive dispatch (the marginal cost will also be very low).

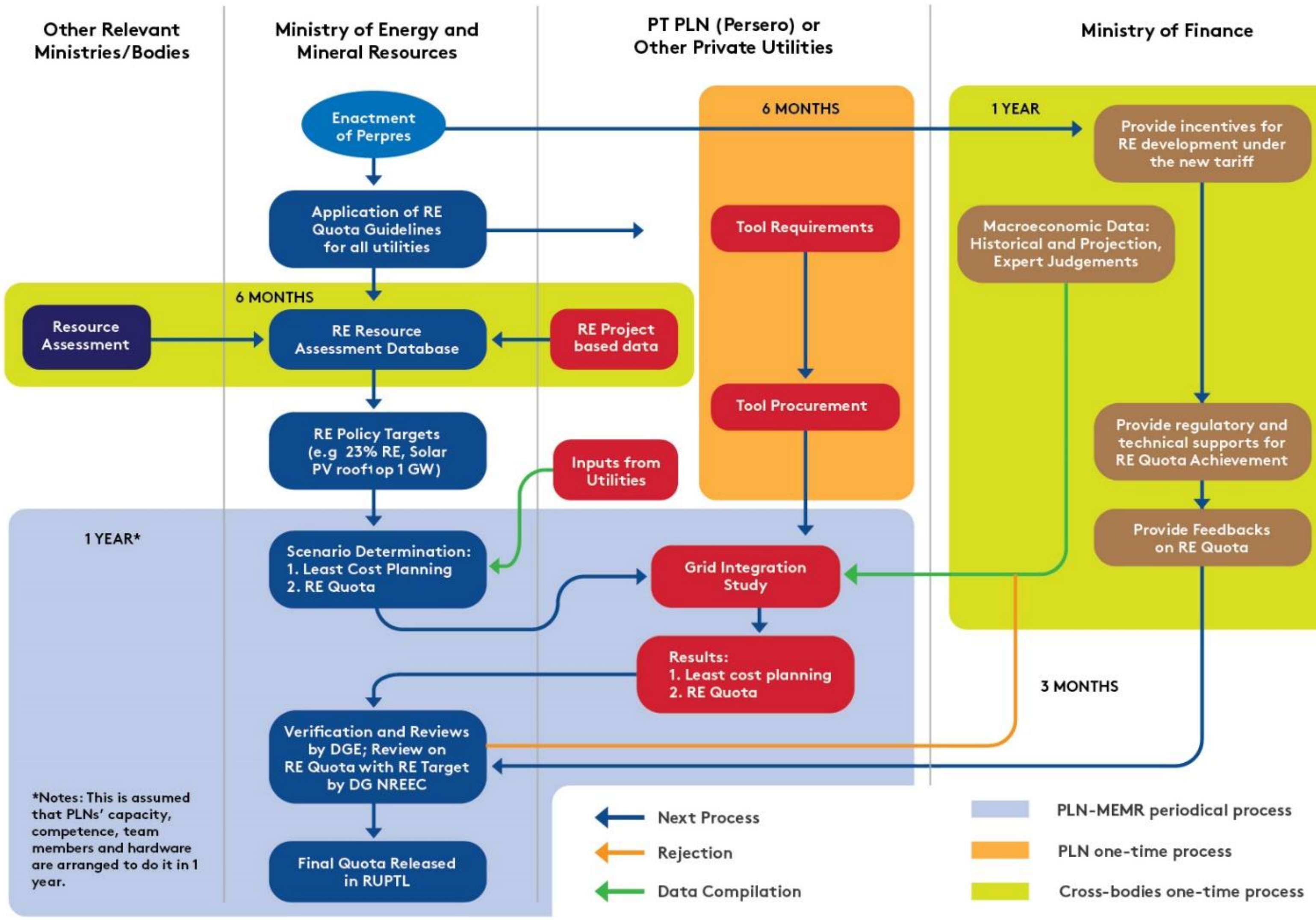
5.2.2 Recommendations to stakeholders

From the stakeholder point of view, this guideline encourages other relevant bodies and ministries to support MEMR in the RE quota implementation process. Formulating an RE quota policy will not be a single body task or responsibility, but rather a national collaborative effort. Many stakeholders will have a part to play in RE quota implementation, but this guideline is limited to defining the roles and expected outcomes from each institution involved during the RE quota determination process (see Exhibit 5-4). Further activities and results can be translated into a process diagram outlining the quota determination process, as presented in Exhibit 5-5.

Exhibit 5-4. Responsibilities and expected results from each institution in RE quota determination

Institution	Activities	Results
MEMR	Dissemination for RE Quota Guidelines to All Utilities: PLN and PPUs	Understanding on Methodology for RE Quota Allocation
	Develop RE Resource Assessment Databases.	List of Potential Sites and RE Resource Database
	Determine the RE Target Policies (Including Solar PV Rooftop) that must be achieved in RE grid integration study.	RE Target policies used in model
	Lead the discussion with other relevant ministries and utilities in selecting the model scenarios. At least, there are two scenarios: 1) Least cost scenario 2) RE Quota scenario	Selected Scenarios
	Verify and Review the RUPTL results by DG of Electricity – as mandated.	Approval or Rejection on RUPTL results
	Review the RE Quota resulted from RUPTL by DG New Renewable Energy and Energy Conservation	Approval or Rejection on Quota results
PLN/Utilities agreement	Study the guideline and check the tools requirement set under guideline	Selected tools for RE Grid Integration Study
	Procure the selected tool	Ready-to-use tools
	Construct the comprehensive model of each system and conduct the RE grid integration study	Results from RE Grid Integration Study: 1. Maximum Penetration 2. Minimum Distance among RE Plants 3. Maximum RE Plant Size. 4. VRE Mitigation Options
	Provide all the FS and resource assessment data from existing plants and on-going plants.	List of information and RE resource assessment data, to be submitted to MEMR
	Provide the feedbacks and inputs on scenario determination	PLN/Utilities agreement on scenarios
	Revise and Adjust the Grid Integration Models if an necessary inputs from MEMR	Revised model
	Collect the relevant macroeconomic data required from Ministry of Finance	List of information to be used in models
Other Relevant Ministries	Support and Provide Relevant Renewable Energy Assessment Data required by MEMR	Data t hat will be used by consultant
Ministry of Finance	Provide incentives for RE development under the new tariff	Incentive packages
	Provide regulatory and technical supports for RE Quota Achievement	Regulatory package (MoF Regulation or PMK) and financing assistances (guidelines or mechanism) to PLN/MEMR
	Discuss with MEMR by providing feedbacks and inputs to RE Quota results	MoF's Agreement to support RE Quota

Exhibit 5-5. Process diagram for RE quota determination



6. REFERENCES

Anindarini, G., & Quina, M. (2018). Mengenal Kebijakan Perencanaan Ketenagalistrikan di Indonesia. Jakarta: Indonesian Center for Environmental Law.

Ashrust. (2020, February 10). *New Italian Incentives for Renewables FER 2019*. Retrieved October 21, 2020, from ashrust: https://www.ashurst.com/en/news-and-insights/insights/new-italian-incentives-for-renewables-fer-2019/

Bechberger, M. (2005). Diffusion of renewable feed-in tariffs in the EU-25 – an instrumental contribution for the dissemination of renewable energies. . Granada : ECPR Joint Session.

Beires, P. e. (2019). *Grid-forming inverters replacing Diesel generators in small-scale islanded power systems*. Power Tech 2019.

BMWi. (2019). *Development of Renewable Energy Sources in Germany 2018*. BMWi.

Boyd, E. (n.d.). Power Sector Modeling 101. *Presentation*. Department of Energy.

Chaerudin, B., & Sugiyanto, A. (2017, August). Materi Training Perencanaan Sistem Pembangkit WASP IV. *Presentation*. Jakarta: PT PLN (Persero).

Chernyakhovskiy, I., & Katz, J. (2020). *Variable Renewable Energy Grid Integration Studies: A Guidebook For Practitioners*. NREL.

Cochran, J. (2018). Grid Integration and Power System Flexibility: Challenges and Trends. *Presentation*. Manila, Philippines: Asian Clean Energy Forum 2018.

Cretu, G. (2018, March 22). Draft Policy Guidelines on Competitive Selection and Support for Renewable Energy. *Presentation 5th RECG Meeting*. Vienna: Energy Community Secretariat.

Department for Business, Energy & Industrial Strategy. (2020). *Renewables obligation level calculations: 2021 to 2022*. Department for Business, Energy & Industrial Strategy. Retrieved October 21, 2020, from https://www.gov.uk/government/publications/renewables-obligation-level-calculations-2021-to-2022

Department for Business, Energy and Industrial Strategy. (2019). *THE RENEWABLES OBLIGATION FOR 2020-21: Calculating the level of the Renewables Obligation for 2020/21*. Department for Business, Energy and Industrial Strategy.

Department of Energy and Climate Change. (2015, May 8). *2010 to 2015 government policy: low carbon technologies*. Retrieved from Department of Energy and Climate Change: https://www.gov.uk/government/publications/2010-to-2015-government-policy-low-carbon-technologies/2010-to-2015-government-policy-low-carbon-technologies#appendix-5-the-renewables-obligation-ro

EDF. (2013). *Grid Impact Analysis and Assessment for Increased Penetration of Renewable Energy into the Jamaican Electricity Grid*. The Ministry of Science, Technology, Energy, and Mining (MSTEM).

EDF, Hinicio. (2013). *Grid Impact Analysis and Assessment for Increased Penetration of Renewable Energy into the Jamaican Electricity Grid*. The Ministry of Science, Technology, Energy, and Mining (MSTEM) Jamaica.

European Commission. (2013). *European Commission guidance for the design of renewables support schemes* . Brussels: European Commission.

Fraunhofer ISI and Ecofys. (2014). *Design features of support schemes for renewable electricity*. Utrecht: ECOFYS Netherlands B.V.

GE Energy Consulting. (2012). *Hawaii Solar Integration Study*.

Hove, A., & Wetzel, D. (2018, April 23). *China is planning provincial quotas for clean energy*. Retrieved October 21, 2020, from China Dialogue: https://chinadialogue.net/en/energy/10574-china-is-planning-provincial-quotas-for-clean-energy/#:~:text=In%20March%2C%20China%20issued%20a,non-hydro%20renewable%20electricity%20consumption.&text=There%20will%20be%20separate%20renewable,wind%2C%20solar%2C%

IEA. (2019). *Status of Power System Transformation 2019: Power system flexibility*. IEA.

International Renewable Energy Agency. (2018). *Power System Flexibility for the Energy Transition*. International Renewable Energy Agency (IRENA) .

IPA Energy + Water Economics . (2008). *Innovative Electricity Markets to Incorporate Variable Production to IEA – Renewable Energy Technology Deploymen*. Edinburgh: IPA Energy + Water Economics .

IRENA. (2013). *30 Years of Policies for Wind Energy: Lessons from 12 Wind Energy Markets*. IRENA.

IRENA. (2018). *Transforming Small Island Power System*. IRENA.

IRENA. (2019). *Global Trends in Competitive Procurement Global Trends and Key Takeaways*. IRENA.

IRENA, OECD/IEA and REN21. (2018). *Renewable Energy Policies in a Time of Transition*.

Kenning, T. (2017, December 8). *Malaysia awards 563MW of solar in second LSS auction*.

Klessmann, C. (2016). *Overview of design elements of RES-E auctions*. Brussels: Ecofys.

Lannoye, E., Tuohy, A., Daly, P., Flynn , D., & O'Malley, M. (2015). Assessing Power System Flexibility for Variable Renewable Integration: A Flexibility Metric for Long-Term System Planning. *CIGRE Science & Engineering, vol. 3*, 26–39.

Lawson, S. (2019). *Asia EDGE Regional Competitive Procurement Dialogue*. USAID.

Lee, N., & Roberts, B. (2018). *Technical Potential Assessment for the Renewable Energy Zone (REZ) Process: A GIS-based Approach*. National Renewable Energy Laboratory.

Leisch, J., & Cochran, J. (2015). *Grid Integration Studies: Data Requirement*. NREL.

Leisch, J., & Cochran, J. (2015). *USING WIND AND SOLAR TO RELIABLY MEET ELECTRICITY DEMAND*. NREL.

Lim, M., Lim, S., & Razak, F. (2020). *Competitive Bidding for the Development of Large Scale Solar Photovoltaic Plants in Malaysia Under the Malaysia Electricity Industry to Attract RE Investment Programme (LSS@MEnTARI Programme)*. Kuala Lumpur: Wong & Partners.

Malaysian Photovoltaic Industry Association. (n.d.). Market Report Malaysia. *Presentation*. Malaysian Photovoltaic Industry Association.

Midwest ISO. (n.d.). Production Cost Model Fundamentals. Midwest ISO.

Miketa, A. (2019, April 21). Key long-term planning considerations with a higher share of VRE. *Presentation*. IRENA.

Mohamad, A. S. (2016, September 21). Overview of Malaysia's Renewable Energy Initatives. *Presentation*. SHER Engineering and Consultancy.

Mohanan , M., & Go, Y. (2020). *Optimized Power System Management Scheme for LSS PV Grid Integration in Malaysia Using Reactive Power Compensation Technique*. Weinheim: Global Challenges.

Moustafa, M. (n.d.). Incorporating VRE into Long-term Power System Planning of Egypt. Ministry of Electricity & Renewable Energies.

Muras, Z. (2011). *Polish support schemes for renewable and cogeneration sources*. Polish Energy Regulatory Office.

National Energy Administration. (2018). *Clean energy consumption action plan [2018-2020]*. National Energy Administration.

Patel, C. (2021, March 8). *UK ROC prices and recycle rates fall on Weaker Demand*. Retrieved from Independent Commodity Intelligence Services: https://www.icis.com/explore/resources/news/2020/07/06/10526965/uk-roc-prices-and-recycle-rates-fall-on-weaker-demand

Pranadi, A. D. (2019, June 18). Mapping Opportunities for Utility-Scale Renewables: The Southeast Asia Renewable Energy Data Explorer. *Presentation Asia Clean Energy Forum 2019*. Manila, Philippines: ACE.

PWC. (2018). *Power in Indonesia – Investment and Taxation Guide – November 2018, 6th ed.* Jakarta: PWC.

Ravn, H. (2001). *The Balmorel Model: Theoretical Background.*

Ravn, H. (2016). *The Balmorel Model Structure.*

Reliability Panel AEMC. (2019). *Definition of Unserved Energy.* Reliability Panel AEMC.

Resch, G., Ragwitz, M., Held, A., Faber, T., & Haas, R. (2007). *Feed-In Tariffs and Quotas For Renewable Energy In Europe.* CESifo DICE Report.

Reuters. (2019, May 15). *China sets renewable power quotas for 2019, 2020.* Retrieved December 31, 2020, from https://www.reuters.com/article/us-china-renewables/china-sets-renewable-power-quotas-for-2019-2020-idUSKCN1SL0XA

Reuters. (2019, May 15). *China sets renewable power quotas for 2019, 2020.* Retrieved from Reuters: https://www.reuters.com/article/us-china-renewables/china-sets-renewable-power-quotas-for-2019-2020-idUSKCN1SL0XA

Schierhorn, P.-P., & Hülsmann, L. (2019). *International Examples:Power System Planning with VRE.* Energynautics GmbH.

SEDA Malaysia. (2020). *ACEF 2019 Presentations.* Retrieved from Asia Clean Energy Forum: https://www.asiacleanenergyforum.org/presentations/

Shinha, A. (n.d.). Overcoming Barriers to Flexibility in the Generation Fleet. *Presentation.* NTPC India.

Skarżyński, G. (2016, March). The Green Certificates market in Poland – Origin, evolution, outlook. *Presentation.* PSEW.

Suruhanjaya Tenaga Energy Commission. (2016, May 26). Briefing Session on the RFP for LSS PV Plants 2017-2018. *Presentation.* Suruhanjaya Tenaga Energy Commission.

Suruhanjaya Tenaga Energy Commission. (2021, March 8). *Large Scale Solar Photovoltaic Plant.* Retrieved from Suruhanjaya Tenaga Energy Commission: https://www.st.gov.my/en/web/industry/details/2/3

Suruhanjaya Tenaga Energy Commission. (2021). *LSS Progress By Region (Q4 2020).* Retrieved from Suruhanjaya Tenaga Energy Commission: https://www.st.gov.my/en/web/industry/details/2/17

Suruhanjaya Tenaga Energy Commission. (2021). *LSSPV Bidding Cycle 1.* Retrieved from Suruhanjaya Tenaga Energy Commission: https://www.st.gov.my/en/web/industry/details/2/12

Suruhanjaya Tenaga Energy Commission. (2021). *LSSPV Bidding Cycle 2*. Retrieved from Suruhanjaya Tenaga Energy Commission: https://www.st.gov.my/en/web/industry/details/2/13

Suruhanjaya Tenaga Energy Commission. (2021). *LSSPV Bidding Cycle 3*. Retrieved from Suruhanjaya Tenaga Energy Commission: https://www.st.gov.my/en/web/industry/details/2/14

Suruhanjaya Tenaga Energy Commission. (2021). *LSSPV Bidding Cycle 4 (LSS@MEnTARI)*. Retrieved from Suruhanjaya Tenaga Energy Commission: https://www.st.gov.my/en/web/industry/details/2/15

Sustainability Roundtable, Inc. (2012). *International Markets for Renewable Energy Certificates (RECs)*. Sustainability Roundtable, Inc.

Terada, R., Cook, O., & Leschke, M. (2019). *Accelerating Corporate Renewable Energy Engagement in China*. San Francisco: Center for Resource Solutions, (CRS).

Terada, R., Cook, O., & Leschke, M. (2019). *Accelerating Corporate Renewable Energy Engagement in China*. Center for Resource Solutions.

The EirGrid Group. (n.d.). *The DS3 Programme*. The EirGrid Group.

The Energy-Charts. (2021). *Welcome to the Energy-Charts*. Retrieved from The Energy-Charts: https://energy-charts.info/?l=en&c=DE

The Oxford Institute for Energy Studies & Internationale Zusammenarbeit (GIZ) GmbH. (2020). *Current direction for renewable energy in China*. The Oxford Institute for Energy Studies.

The Star. (2019, Feb 14). *Energy Commission announces 500MW large scale solar tender*. Retrieved from The Star: https://www.thestar.com.my/business/business-news/2019/02/14/energy-commission-announces-500mw-large-scale-solar-tender/

The World Bank. (2009). *Energy Demand Models for Policy Formulation*. The World Bank.

UK Department of Energy and Climate Change. (2012). *Government response to the consultation on proposals for the levels of banded support under the Renewables Obligation for the period 2013-17 and the Renewables Obligation Order 2012*. London: UK Department of Energy and Climate Change.

UK Government. (2020, September 24). *National Statistic: Regional Renewable Statistic*. Retrieved from UK Government Regional Renewable Statistic: https://www.gov.uk/government/statistics/regional-renewable-statistics

UK Ofgem. (2020). *Renewables Obligation: Guidance for Suppliers*. UK Ofgem.

UK Ofgem. (n.d.). *RO Data UK Ofgem*. Retrieved from RO Data UK Ofgem: https://www.renewablesandchp.ofgem.gov.uk/Public/ReportViewer.aspx?ReportPath=/Re newables/Accreditation/AccreditedStationsExternalPublic&ReportVisibility=1&ReportCategory=1

University of Hawaii. (2011). *Oahu Wind Integration Study* . United States Department of Energy.

Vithayasrichareon, P. (2017, June 6). Creating and enabling environment for Power Plant Flexibility. *Presentation Asia Clean Energy Forum 2017*. Manila, Philippines: IEA.

Vithayasrichareon, P. (2018, November 15). Grid Planning and Operation for High VRE Penetration. *Presentation of Indonesia Energy Transition Dialogue Forum 2018*. Jakarta: IEA.

World Bank. (2019). *Vietnam Solar Competitive Bidding Strategy and Framework*. Washington, DC: World Bank.

Xiong, W., Zhang, D., Mischke, P., & Zhang, X. (2014). Impacts of renewable energy quota system on China's future power sector. *The 6th International Conference on Applied Energy – ICAE2014* . Science Direct.

Xu, Y. (2018, August 16). *China's Renewable Energy Quotas*. Retrieved December 31, 2020, from https://www.chinawaterrisk.org/resources/analysis-reviews/chinas-renewable-energy-quotas/

APPENDIX A: SAMPLE LIST OF MINIMUM DATA REQUIREMENTS FOR STABILITY ANALYSIS

Tabulasi 1 - Data Desain Unit Pembangkit

Pemilik/Owner	Sentral	Lokasi/Location	Unit	Jenis/Type

Data		Satuan/Unit	Nilai/Value
Item	**Deskripsi/Description**		
1.1	**Data Teknis Umum**		
1.1.1	MVA *rated*	MVA	
1.1.2	Kapasitas *rated*	MW	
1.1.3	*Rated gross* MW	MW	
1.1.4	Tegangan terminal	KV	
1.1.5	Beban *auxiliary* pada kapasitas *rated*	MW	
1.1.6	Daya *reactif (output) rated*	MVAR	
1.1.7	Beban minimum	MW	
1.1.8	Konstanta-inertia turbo generator *rated*	MW-sec	
1.1.9	Ratio Hubung singkat		
1.1.10	Arus stator *(rated)*	Amps	
1.1.11	Arus kotor pada rated MVA dan faktor-daya, *rated* tegangan-terminal dan rpm	Amps	
1.2	**Tahanan/Resistance**		
1.2.1	Tahanan *stator* Rs	Per Unit	
1.2.2	Tahanan *negative sequence* R2	Per Unit	
1.2.3	Tahanan *zero sequence* Ro	Per Unit	
1.2.4	Tahanan pentanahan Re	Per Unit	
1.3	**Reaktansi/*Reactances (unsaturated)***		
1.3.1	*Reaktansi direct axis synchronous Xd*	Per Unit	
1.3.2	*Reaktansi direct axis transient Xd'*	Per Unit	
1.3.3	*Reaktansi direct axis sub-transient Xd''*	Per Unit	
1.3.4	*Reaktansi quad axis synchronous Xd*	Per Unit	
1.3.5	*Reaktansi quad axis transient Xd'*	Per Unit	
1.3.6	*Reaktansi quad axis sub-transient Xd''*	Per Unit	
1.3.7	*Reaktansi kebocoran stator*	Per Unit	
1.3.8	*Reaktansi urutan nol X0*	Per Unit	
1.3.9	*Reaktansi urutan negatif X2*	Per Unit	
1.3.10	*Reaktansi Potier xpot*	Per Unit	
1.3.11	*Reaktansi* pentanahan Xe	Per Unit	

Tabulasi 1 - Data Desain Unit Pembangkit

Pemilik/Owner	Sentral	Lokasi/Location	Unit	Jenis/Type

Data		Satuan/Unit	Nilai/Value
Item	**Deskripsi/Description**		
1.4	**Reaktansi/*Reactance (Saturated)***		
1.4.1	*Reaktansi direct axis sinkron Xdsat*	Per Unit	
1.4.2	*Reaktansi direct axis sub-transient Xsd"sat*	Per Unit	
1.5	**Daya *Bruto (Rated)* MW**		
1.5.1	1.0 PU saturation parameter	Per Unit	
1.5.2	1.2 PU saturation parameter	Per Unit	
1.6	**Konstanta Waktu *(unsaturated)***		
1.6.1	*Direct axis short circuit transient Td'*	sec	
1.6.2	*Direct axis short circuit sub-transient Td'*	sec	
1.6.3	*Quad axis short circuit transient Tq'*	sec	
1.6.4	*Quad axis short circuit transient Tq'*	sec	
1.7	**Trafo-Generator *(Step-Up)***		
1.7.1	Jumlah belitan		
1.7.2	*Rated* MVA setiap belitan	MVA	
1.7.3	Tegangan utama tap rated	kV	
1.7.4	Tahanan setiap belitan	Per Unit	
1.7.5	*Reaktansi* urutan positif setiap belitan	Per Unit	
1.7.6	*Reaktansi* urutan negatif setiap belitan	Per Unit	
1.7.7	*Reaktansi* urutan nol setiap belitan	Per Unit	
1.7.8	Tegangan minimum tap	kV	
1.7.9	Tegangan maximum tap	kV	
1.7.10	Jenis *tap change (on-load/off-load)*		
1.7.11	*Tap changer cycle time*	Sec	
1.8	**Kemampuan Reaktif (pada terminal)**		
1.8.1	Daya reaktif *lagging* pada kapasitas rated	MVAR	
1.8.2	Daya reaktif *lagging* pada pembangkit minimum	MVAR	
1.8.3	Daya reaktif *lagging*,sesaat	MVAR	

Tabulasi 1 - Data Desain Unit Pembangkit

Pemilik/Owner	Sentral	Lokasi/Location	Unit	Jenis/Type

Data		Satuan/Unit	Nilai/Value
Item	**Deskripsi/Description**		
1.9	**Karaktersitik Peralatan Eksitasi**		
1.9.1	Tegangan medan pada rated MVA dan faktor-daya, rated tegangan terminal dan rpm	Per Unit	
1.9.2	Tegangan medan maksimum, Efdmx	Per Unit	
1.9.3	Tegangan medan minimum, Efdmx	PU	
1.9.4	Maksimum kecepatan kenaikan tegangan medan	V/sec	
1.9.5	Maksimum kecepatan penurunan tegangan medan	V/sec	
1.9.6	Arus eksitasi maksimum, Curmx	amps	
1.9.7	Arus eksitasi minimum, Curmn	amps	
1.9.8	DC *gain of excitation control loop Vspp*	PU	
1.9.9	*Regulator input filter time constant Tvm*	sec	
1.9.10	*Regulator integration time constant P3Bi*	sec	
1.9.11	*Regulator amplifier time constant Tvs*	sec	
1.9.12	*Maximum internal voltage regulator signal Urma*	PU	
1.9.13	Minimum *internal voltage regulator signal* Urmin	PU	
1.9.14	*Regulator stabilizing Gain Vss*	PU	
1.9.15	*Regulator stabilizing circuit time-constant Tst 1*	sec	
1.9.16	*Regulator stabilizing circuit time-constant Tst 2*	sec	
1.9.17	*Excitation constant Kerr*	PU	
1.9.18	*Excitation time constant Terr*	sec	
1.9.19	*Excitation saturation constant 1 Aerr*	PU	
1.9.20	*Excitation saturation constant 2 Berr*	PU	
1.9.21	*Regulator time constant Ta*	sec	
1.9.22	*Coefficient of ceiling regulator voltage to terminal voltage Kc*	PU	
1.9.23	*Voltage Gain from shunt self excitation Kp*	PU	

Tabulasi 1 - Data Desain Unit Pembangkit

Pemilik/Owner	Sentral	Lokasi/Location	Unit	Jenis/Type

Data		Satuan/Unit	Nilai/Value
Item	Deskripsi/Description		
1.10	***Power System Stabilizer***		
1.10.1	*PSS gain for mech. Speed input signal kaom*	Per Unit	
1.10.2	*Time constant for mech. Speed, measurement Taom*	sec	
1.10.3	*PSS gain for elect. Freq. measurement Kafe*		
1.10.4	*Time constant for elect. Freq. measurement Tafe*	sec	
1.10.5	*PSS gain for elect. power input signal Kape*	Per Unit	
1.10.6	*Time constant for elect. Power measurement Kape*	sec	
1.10.7	*PSS gain for terminal voltage input signal*	Per Unit	
1.10.8	*Time constant for term. Voltage measurement Taui*	sec	
1.10.9	*Steady sate PSS gain Kpss*	Per Unit	
1.10.10	*PSS gain for turbine torque input signal Ktrg*	Per Unit	
1.10.11	*PSS gain for valve position input signal Kayt*	Per Unit	
1.10.12	*Time constant for valve pos. Measurement Tayt*	Sec	
1.10.13	*Stabilizing time constant*	Tss	
1.10.14	*Water hammer filter time constant Tw*	Tw	
1.10.15	*Output signal magnitude limit Upsmx*	Per Unit	

Tabulasi 1 - Data Desain Unit Pembangkit

Pemilik/Owner	Sentral	Lokasi/Location	Unit	Jenis/Type

Data		Satuan/Unit	Nilai/Value
Item	Deskripsi/Description		
1.11	**Unit governor**		
1.11.1	*Time constant for elect. Power transducer Tp*	Sec	
1.11.2	*Freq. shifted power controller static droop bpf*	%	
1.11.3	*Freq. shifted power controller transient droop bpf*	%	
1.11.4	*Time constant Tdf*	Sec	
1.11.5	*Power controller gain Kf*	Per Unit	
1.11.6	*Power controller integration time constan Tip*	Sec	
1.11.7	*Speed controller static drop bp*	%	
1.11.8	*Speed controller transient drop bp*	%	
1.11.9	*Regulator time-constant (Pilot value) tr*	Sec	
1.11.10	*Main servo dead band Dband*	Per Unit	
1.11.11	*Main servo time-constant Ty*	Sec	
1.11.12	*Main servo max. opening time Tyo*	Sec	
1.11.13	*Main servo max. closing time Tyc*	Sec	
1.11.14	*Max. Main servo position Ytmax*	Per Unit	
1.11.15	*Valve characteristic Yyt*	%	
1.11.16	*Elect. freq./speed input signal switch ippco*		
1.11.17	*Power setpoint integration time grdpu*	sec	
1.11.18	*SCO- participation factor bpace*	Per Unit	
1.11.19	*Pilot value opening time (Hidro) Tro*	sec	
1.11.20	*Pilot value closing time (Hidro) Trc*	sec	
1.11.21	*Speed-controller input filter time constant Tm*	sec	
1.11.22	*Power-controller input filter time constant Tp*	sec	
1.11.23	*Temperature-speed dependency alft*		
1.11.24	*Temperature input filter time constant Tvr*	sec	
1.11.25	*Temperature-controller amplification gain Kt*	Per Unit	
1.11.26	*Temperature contr. Integration time constant Tit.*	sec	
1.11.27	*Speed-power controller amplification gain Vr*	Per Unit	
1.11.28	*Speed-power controller time constant Tn*	sec	

Tabulasi 1 - Data Desain Unit Pembangkit

Pemilik/Owner	Sentral	Lokasi/Location	Unit	Jenis/Type

Data		Satuan/Unit	Nilai/Value
Item	**Deskripsi/Description**		
1.12	**Unit governor**		
1.12.1	*Sustained response to frequency change*	MW	
1.12.2	*Non-sustained response to frequency change*	MW	
1.12.3	*Load rejection capability*	MW	
1.13	*Primer Mover*		
1.13.1	*High pressure turbine time constant (GT) Thp*	Sec	
1.13.2	*First reheater time constant Tip*	Sec	
1.13.3	*Second reheater time Constant Tlp*	Sec	
1.13.4	*High pressure turbine ratio alfhp*	Per Unit	
1.13.5	*Low pressure turbine ratio alfhp*	Per Unit	
1.13.6	*Boiler capacity time constant P3Bi*	Sec	
1.13.7	*Heat transfer time constant Tkes*	Sec	
1.13.8	*Fuel controller amplification Kmbr*	Per Unit	
1.13.9	*Fuel controller integration time constant Kmbr*	Sec	
1.13.10	*Water starting time constant (Hydro) TW*	Sec	
1.13.11	*Half reflexion time of pressure tube (Hydro) TI*	Sec	
1.13.12	*Allievi-constant Zw (Hydro) Zw*		
1.13.13	*Initial water pressure (Hydro) Ho*	Per Unit	
1.13.14	*Turbine water-flow dependency to mech speed komwp*	Per Unit	
1.13.15	*Dynamic pressure losses (Hydro) rbdyn*	Per Unit	
1.13.16	*Static pressure losses (Hydro) rbsta*	Per Unit	
1.13.17	*Water flow for point wip (min) (Hydro) wqmin*	Per Unit	
1.13.18	*Water flow for point wip 5 (max) (Hydro) wqmax*	Per Unit	
1.13.19	*Turbine efficiency (Hydro) wip*	%	

Tabulasi 1 - Data Desain Unit Pembangkit

Pemilik/Owner	Sentral	Lokasi/Location	Unit	Jenis/Type

Data		Satuan/Unit	Nilai/Value
Item	Deskripsi/Description		
1.14	**Charts**		
1.14.1	*Capability chart*	Graphical data	
1.14.2	*Open circuit characteristic*	Graphical data	
1.14.3	*Short circuit characteristic*	Graphical data	
1.14.4	*Zero Power factor curve*	Graphical data	
1.15	Trafo *Generator*		
1.15.1	*Tapped winding*	text, diagram	
1.15.2	*Vector group*	Diagram	
1.15.3	*Earthing arrangement*	text, diagram	
1.16	*Reactive Capability* (di terminal generator)		
1.16.1	*Overload at rated capacity*	Diagram as a function of time	
1.17	**Eksitasi (Excitation)**		
1.17.1	*Generator and exciter saturation characteristic*	Diagram 50-120% teg. Rated	
1.17.2	*Dynamic characteristics of over-excitation limiter*	Text, block diagram	
1.17.3	*Dynamic characteristics of under-excitation limiter*	Text, block diagram	
1.18	***Power plant technical data***		
1.18.1	Tegangan pada titik sambungan	kV	
1.18.2	Kapasitas Maksimum Total Sentral	MW	
1.18.3	Injeksi arus maximum hubung singkat simetris tiga fasa	kA	
1.18.4	Injeksi arus maksimum hubung singkat tak-simetris tiga (3) fasa	kA	
1.18.5	Impedansi Minimum Urutan Nol Generator	Per Unit	
1.18.6	Impedansi Minimum Urutan Negatif Generator	Per Unit	

Tabulasi 4 - Data Instalasi Pemakai Jaringan

Pemakai Jaringan	Titik sambungan	Lokasi/Location

Data Pusat Pembangkit sebagai berikut harus disampaikan:

Data		Satuan/Unit	Nilai/Value
Item	**Deskripsi/Description**		
4.1	**Rating Tegangan**		
4.1.1	Tegangan Nominal	kV	
4.1.2	Tegangan Tertinggi	kV	
4.2	**Koordinasi Isolasi**		
4.2.1	*Rated lightning impulse withstand voltage*	kV	
4.2.2	*Rated short duration power frequency withstand voltage*	kV	
4.3	**Rated short time withstand current**	**kA**	
4.4	**Rated Current**		
	Circuit maximum current	amps	
4.5	**Pentanahan**		
	Earth Grid rated thermal current		
4.6	**Insulation pollution performance**		
4.6.1	*Minimum total creepage*	milimeter	
4.6.2	*Pollution level as per IEC 815*		
4.7	**Short circuit infeed to the system**		
4.7.1	*Maximum 3-phase short circuit symmetrical infeed, including infeed from embedded power plants directly connected to the User's system*	kA	
4.7.2	*Total infeed st the instand of fault taking into consideration induction motors contribution*	kA	
4.7.3	*Minimum zero sequence impedance of user's system at connection point (base : 100 MVA)*	PU	
4.7.4	*Minimum zero sequence impedance of user's system at connection point (base : 100 MVA)*	PU	